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# National Range and Pasture Handbook

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| Definition of Affiliations | |
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| ACES | Agriculture Conservation Experienced Services program for retirees |
| ARS | USDA-Agricultural Research Service |
| CEAP | Conservation Effects Assessment Project |
| CNTSC | NRCS-Central National Technical Support Center, Fort Worth, TX |
| ENTSC | NRCS-East National Technical Support Center, Greensboro, NC |
| GEO | USDA Farm Production and Conservation, Geospatial Enterprise Operations Branch (GEO) |
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| NPDT | National Plant Data Team |
| NRCS | USDA Natural Resources Conservation Service |
| SPSD | NRCS-Soil and Plant Science Division |
| USFS | US Forest Service |
| WNTSC | NRCS-West National Technical Support Center, Portland, OR |

### Previous version of the handbook

While many specialists worked on this revision, the former authors listed below are thanked for the foundation they built, the expertise and leadership they shared, and their continued involvement of moving the grazing discipline forward.

This National Range and Pasture Handbook was originally produced by the Natural Resources Conservation Service's Grazing Lands Technology Institute (GLTI), Fort Worth, Texas, Rhett H. Johnson, director. Larry D. Butler, Ph.D., rangeland management specialist, was the primary technical editor and day-to-day project coordinator.

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## 645.0002 Preface

A. The National Range and Pasture Handbook (NRPH) provides the Natural Resources Conservation Service (NRCS) with technical information, methodologies, and procedures for assisting land managers, farmers, ranchers, organizations, governmental units, and soil and water conservation districts in planning and applying conservation on non-Federal grazing lands across the United States. This handbook was prepared primarily for NRCS, but other users will find the information informative.

B. The NRPH was developed by NRCS grazing lands specialists using their experience, “thunder books,” libraries, literature reviews, land grant university publications, interagency technical notes, current analyses of resource data, partnering agencies’ manuals, and many other scientific publications as a source for technical information. Collaboration among partners include the USDA-Agriculture Research Service, USDI-Bureau of Land Management, U.S. Forest Service, Xerces Society for Invertebrate Conservation, land grant universities, State agencies, consultants, researchers, and many others who help provide the advancement of technology on grazing lands and the grazing discipline. A list of the authors, contributors, and reviewers of this handbook are in section 645.001. The previous authors are thanked for the foundation they built, the expertise and leadership they shared, and their continued involvement in moving the grazing discipline forward. The authors would also like to thank Jerry Bernard, editor, ACES – National Experience Workforce Solutions, for all his work, expertise, and professionalism in editing and formatting this version of this handbook.

C. The purpose of this NRPH is to provide technical updates to concepts, terminology, practices and procedures, ecological principles, and conservation management applications. It replaces the previous NRPH editions (2003, 1997, 1987, 1976, 1942, 1938), which were written predominantly to be applicable only on rangelands and other native grazing lands. In addition to providing guidance for rangelands, this handbook includes more information and guidance on pasturelands, haylands, grazed forests, grazed croplands, and naturalized pastures.

D. Changes to this revision include using scientific citations in the text. A list of references is provided at the end of each subpart, showing the cited literature. This improves transparency on sources of information, credits, and attributes original authors and creators. The references also increase accessibility of finding additional information, document the advancement of research, and build integrity and trust in the information provided in this handbook as a national document for NRCS staff working on grazing lands. This document is available as a free download from the NRCS‘s eDirectives Electronic Directives System. Updates to the individual subparts:

(1) Combine authority, mission, and policy in this Preface.
(2) Greatly expand and revise many sections, including new subparts on Resource Concerns and Trends on non-Federal Grazing Lands: National Resource Inventory (NRI) Analyses and Implications for Conservation Planning (Subpart C); Prescribed Burning (Subpart J); An Ecosystem View of Range and Pasture Soil Health (Subpart K); and Pollinator Habitat Considerations for Range and Pasturelands (Subpart M).

(3) Include information on Ecological Sites, Ecological Site Descriptions: Ecological Classification as a Concept and Use in Conservation Planning and Resource Monitoring (Subpart B)
(4) The concept of forage suitability groups has been replaced with pasture states with specific pasture interpretations as depicted in the ecological site state-and-transition model.
(5) Add new tools to Grazing Land Economics (Subpart L)
(6) Add new protocols and methodologies to the Inventory, Assessment, and Monitoring of Grazing Lands (Subpart E)
(7) Expand the Inventory section in the Wildlife Management on Grazing Lands (Subpart I) to include Wildlife Habitat Evaluation Guide information.

E. This handbook contains information to assist the NRCS conservationist in providing technical assistance to cooperators in all phases of the conservation planning process. Other sources of information and guidance include the National Range and Pasture Manual, the National Planning Procedures Handbook, General Manual, National Instructions, Technical Notes, and other appropriate NRCS technical and policy guidance documents and handbooks.

F. Specifically, this handbook covers the study, inventory, analysis, treatment, and management of grazing lands resources, while the 2021 National Range and Pasture Manual sets forth the NRCS policy for conservation planning on grazing lands at https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=46772. The purpose of this new NRPH handbook is to provide guidance to NRCS planners when assisting clients with development of grazing management plans on grazing lands including pasture, rangeland, grazed forest, hayland, and grazed cropland.

G. The appendices in this handbook are to be considered an official part of the handbook. This handbook is found on eDirectives Electronic Directives System in Handbooks, Title 190 – Ecological Sciences at https://directives.sc.egov.usda.gov.

## 645.0003 Authority

A. The Soil Conservation Act, passed by Congress, and signed into law in 1935 by President Franklin D. Roosevelt, declared that “the wastage of soil and moisture resources on farm, grazing, and forest lands…is a menace to the national welfare,” and directed the Secretary of Agriculture to establish the Soil Conservation Service (which became the Natural Resources Conservation Service in 1994) as a permanent agency to extend conservation assistance and technology to landowners.

B. The authority to assist in applying sound conservation on private lands is provided through the authorities charged to the Secretary of Agriculture and delegated to the Under Secretary for Farm Productions and Conservation (as defined in 7 CFR Section 2.16), who in turn, has provided that authority to the NRCS Chief through 7 CFR Section 2.43.

C. The Conservation Technical Assistance Program (CTAP) is the foundation of the Nation’s Federal conservation efforts on private lands, which is implemented in cooperation with NRCS’s partners. CTAP is delivered to decision makers, Tribes, units of governments, and nongovernmental organizations in all 50 States, the District of Columbia, Puerto Rico, U.S. Virgin Islands, Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, the Republic of Palau, and the Marshall Islands. NRCS, through CTAP, provides conservation technical assistance to individuals, communities, and units of government to improve the long-term sustainability of the natural resource base on cropland, forestland, grazing lands, coastal lands, and developed or developing lands. Conservation technical assistance on Federal lands involving a significant amount of NRCS resources can be provided only through formal agreements (Title 440, Conservation Programs Manual, Part 525, Subpart A, Section 525.1E).

D. The specific authority to provide grazing lands conservation assistance is found in 7 CFR Section 2.16a3 (xiii)(I). Conservation of Private Grazing Lands is authorized by section 1240M of the Food Security Act (16U.S.C. 3839bb). That specific code states: “It is the purpose of this section to authorize the Secretary to provide a coordinated technical, educational, and related assistance program to conserve and enhance private grazing land resources and provide related benefits to all citizens of the United States by–

(1) establishing a coordinated and cooperative Federal, State, and local grazing conservation program for management of private grazing lands;
(2) strengthening technical, educational, and related assistance programs that provide assistance to owners and managers of private grazing lands;
(3) conserving and improving wildlife habitat on private grazing lands;
(4) conserving and improving fish habitat and aquatic systems through grazing land conservation treatment;
(5) protecting and improving water quality;
(6) improving the dependability and consistency of water supplies;
(7) identifying and managing weed, noxious weed, and brush encroachment problems on private grazing lands; and
(8) integrating conservation planning and management decisions by owners and managers of private grazing lands on a voluntary basis.”

## 645.0004 Mission

The mission of NRCS is to improve the health of the Nation’s natural resources, while sustaining and enhancing the productivity of American agriculture. NRCS achieves this by providing voluntary assistance through strong partnerships with private landowners, managers, and communities to conserve, protect, restore, and enhance the lands and waters upon which people and the environment depend. NRCS has specific responsibility to assist owners and operators of grazing lands in planning and applying conservation programs on the privately controlled land in their operating units (Amendment 4, Title 9, Administrative Regulations, May 17, 1954; and Comptroller General’s Opinion B-115665 of October 1, 1953, 33CG:133) (Title 190, National Range and Pasture Handbook, 190-NRPH).

## 645.0005 Goal

A. There are approximately 600 million acres of non-Federal (privately owned, State and local publicly owned, and tribally owned) grazing lands in the United States. Non-Federal grazing lands occur in every State. These rangelands, pasturelands, haylands, grazed forest lands, grazed croplands, and naturalized pastures constitute about half of the total lands on which the NRCS provides technical assistance.

B. The goal of NRCS grazing lands activities is to provide the management, enhancement, and, where necessary, restoration of privately owned grazing lands throughout the United States through a voluntary technical assistance program that results in multiple environmental, social, and economic benefits. The broad public benefits that will result from well managed grazing lands include:

(1) Conservation of grazing lands ecosystems
(2) Prevention of soil erosion
(3) Maintenance or enhancement of soil health
(4) Sustained forage and livestock production
(5) Improved water yield and quality
(6) Maintaining diverse wildlife habitat

(7) Maintaining and enhancing species diversity
(8) Aesthetics and open space
(9) Quality recreational opportunities

## 645.0006 Policies

NRCS policy is to maintain high standards of technical quality in all activities related to grazing lands. The National Range and Pasture Manual provides guidance to NRCS planners when assisting clients with developing grazing management plans on grazing lands, including pastureland, rangeland, grazed forestland, hayland, and grazed cropland. The manual describes the policy for technical assistance on grazing lands while this supporting handbook provides the technical information, methodologies, and procedures for conservation planners to carry out policy on grazing lands. See Subpart D, Conservation Planning on Grazing Lands, for additional information. The manual can be downloaded at https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=46772.

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# Part 645 – National Range and Pasture Handbook

## Subpart A – Grazing Land Resources

### 645.0101 General Information

A. Extent

(1) The two major global terrestrial land types are rangeland and forestland. Rangeland includes natural grasslands, savannas, shrublands, many deserts, tundra, alpine communities, marshes, and meadows. About 35 percent of the land area in the world is grasslands and woodlands, 21 percent sparse and barren lands, 28 percent forest and woodlands, and 12 percent farmland (see table A-1). Estimates of rangeland throughout the world vary. Summaries by Lund (2007) show a rangeland as 18–80 percent of the landscape. The differences are based on land surface, ice-free land surface, ground surveys and inventories, remote sensing, and soil maps. Heitschmidt and Stuth (1991) estimate that rangelands occupy 47 percent of the world's land area; Mannetje (2002) estimates 50 percent.

**Table A-1.** Global extent of land use categories (Food and Agriculture Organization (FAO) 2011). Global land area = (32.6 billion acres; 13.2 billion hectares)

| Terrestrial Land Cover Types | Acres billion (hectares) | % of Land Area |
|---|---|---|
| Grasslands and Woodlands | 11.4 (4.6) | 35 |
| Forest | 9.1 (3.7) | 28 |
| Sparsely Vegetated (Barren Lands) | 6.9 (2.8) | 21 |
| Cultivated lands | 4 (1.6) | 12 |
| Settlement and Infrastructure | 0.37 (0.15) | 1.2 |
| Inland Water | 0.59 (0.24) | 2 |

(2) Land use and land cover are often related, but they have different contexts among land management agencies. The Economic Research Service states that "Land use involves an element of human activity and reflects human decisions about how land will be used. Land cover refers to the vegetative characteristics or manmade constructions on the land's surface. Land use is generally determined by surveys based on field observations or enumeration, while land cover is generally determined using remote sensing techniques or interpretation of aerial photography" (ERS 2019). Figure A-1 shows the distribution of the world's rangelands based on land cover. Table A-2 summarizes land use and cover data for Federal and non-Federal land in the United States.

(3) Federal lands managed by federal agencies such as the Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), National Wildlife Refuge System managed by the U.S. Fish and Wildlife Service (FWS), Army Corp of Engineers, and U.S. military bases amount to about 26.0 percent (about one-quarter) of U.S. lands (Figure A-2). Almost half (48.6 percent) of the 13 Western States are Federal lands.

**Figure A-1.** Rangeland (land cover) of the world. Information & Education (I&E) and Remote Sensing & GIS committees of the Society for Range Management (SRM).
**https://www.webpages.uidaho.edu/what-is-range/rangelands_map.htm**

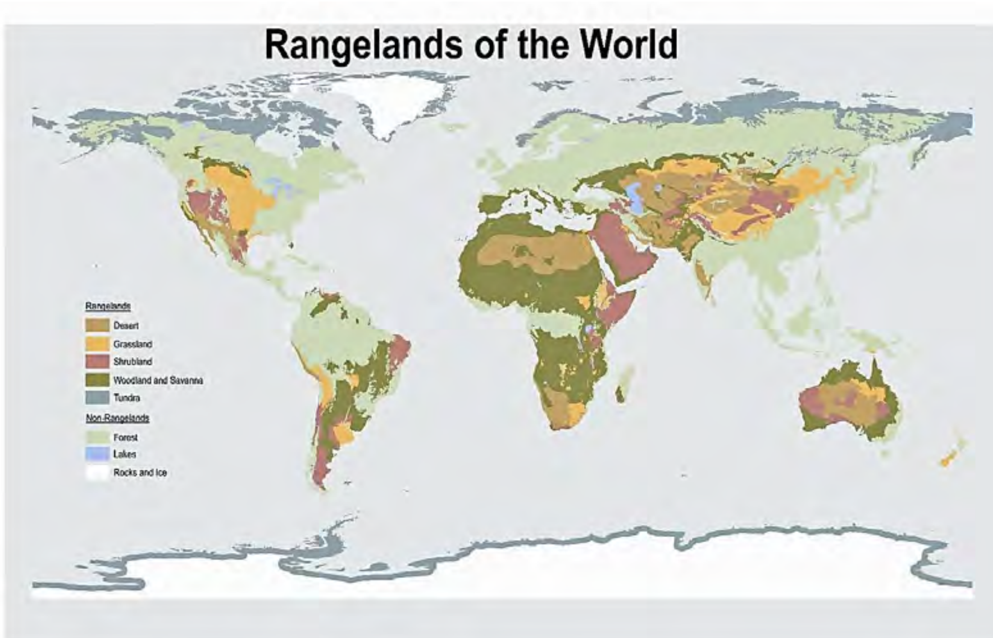



**Figure A-2.** Federal lands in the United States.

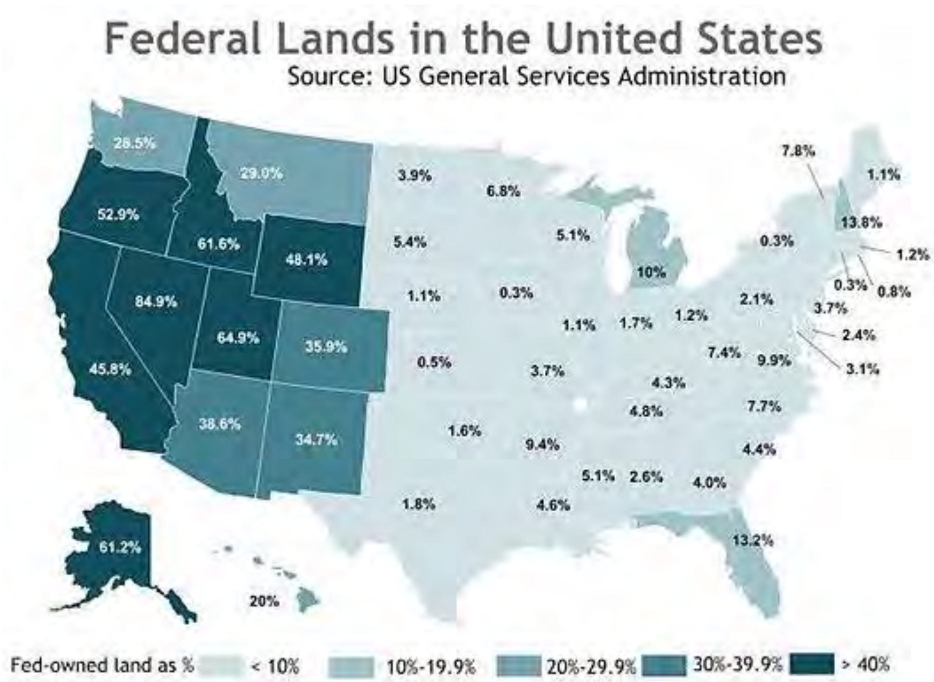


**Table A-2.** Land use and land cover estimates for the United States, by source (millions of acres) (ERS 2019).

| Land Use Categories | USFS[1] (all forest land) | BLM[1] (area managed by BLM) | NASS[1] (land in farms) | Census Bureau[1] (urban areas) | ERS[1] (all land uses) | NRCS[2] (all non-Federal land) | USGS[3] (all land and water cover) | BLM[3] (area managed by BLM) |
|---|---|---|---|---|---|---|---|---|
| Forest/woodland | 751 | 11 | 75 | -- | 671 | 409 | 600 | 69 |
| —Forest in timber use | N/A | 11 | 46 | -- | 544 | N/A | N/A | N/A |
| —Forest in grazed uses | N/A | N/A | 29 | -- | 127 | N/A | N/A | N/A |
| Permanent pasture/range | -- | 158 | 409 | -- | 614 | 529 | 995 | 174 |
| Range | -- | -- | -- | -- | -- | 406 | -- | -- |
| Pasture | -- | -- | -- | -- | -- | 121 | -- | -- |
| Cropland | -- | -- | 406 | -- | 408 | 390 | 311 | -- |
| Urban areas | -- | -- | -- | 68 | 61 | 112* | 102 | -- |
| Rural parks, wilderness areas | -- | 2 | -- | -- | 252 | -- | -- | -- |
| Rural transportation | -- | -- | -- | -- | 26 | * | -- | -- |
| Other | -- | 85 | 32 | -- | 232 | 504 | 373 | 13 |
| Total area included in estimates | 751 | 256 | 922 | 68 | 2,264 | 1,944 | 2,381 | 256 |
| Total U.S. land area: 2,264 million acres (source: Census Bureau) | | | | | | | | |
| Total U.S. land and water area: 2,381 million acres (source: USGS) | | | | | | | | |
| Year estimates were derived | 2007 | 2007 | 2007 | 2010 | 2007 | 2007 | 2006** | 2007 |
| Number of U.S. States included | 50 | 26# | 50 | 50 | 50 | 49* | 50 | 26# |

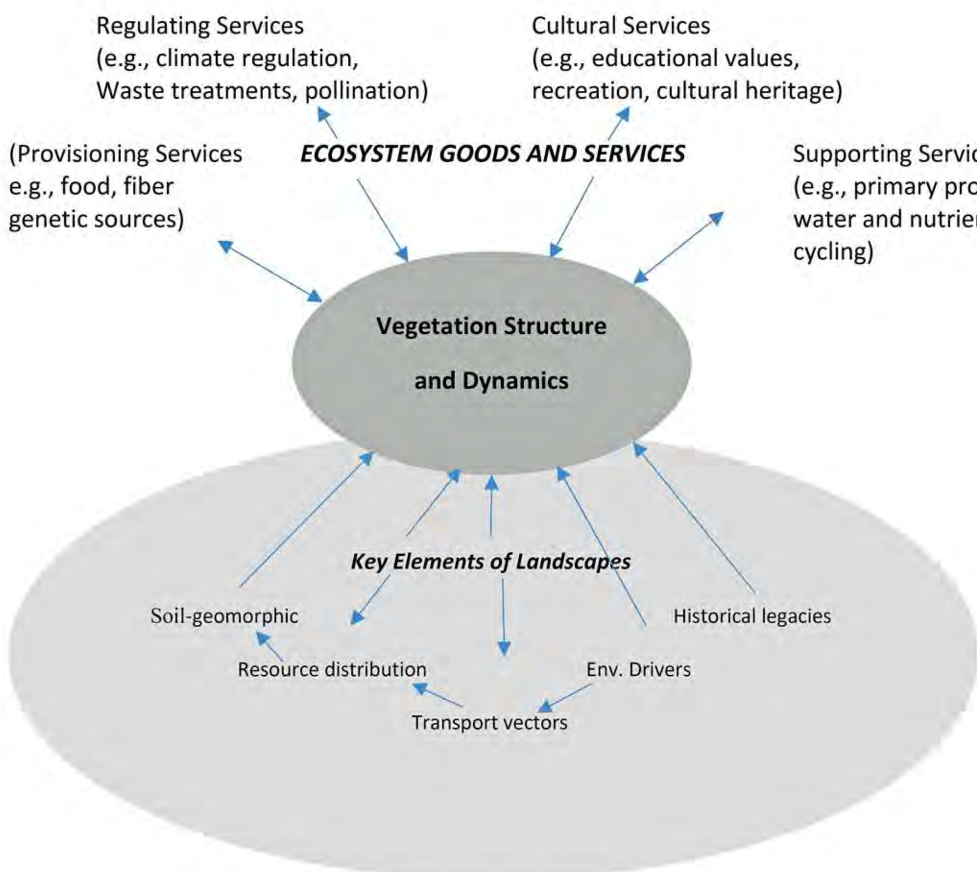
[1] Land use.
[2] Hybrid land use/land cover.
[3] Land cover.
* NRCS combines Urban areas and Rural Transportation into a Developed Land category. NRCS estimates exclude AK.
** USGS data are from 2006, except AK and HI estimates are from 2001.
N/A = Not Applicable.
# = BLM estimates exclude States that do not contain surface acres managed by BLM.

B. Rangeland Uses and Benefits

(1) Rangelands throughout the world are and will continue to be affected by increasing world population (projected to increase by 40 percent by 2050), especially for food and fiber production and other ecosystem services (Holechek 2013). The outcomes and future issues in the years ahead for rangeland managers will include geopolitical stresses, increasing pressure to produce food and fiber, financial pressures (higher interest rates, higher production costs), and biological and environmental risks (impacts of climate variability). Survivability mechanisms for rangeland producers include low risk approaches to livestock production that involves conservative stocking, use of highly adapted livestock, and application of behavioral knowledge of livestock to efficiently use forage resources (Holechek 2013).

(2) Rangelands provide many goods and services, and USDA is committed to providing conservation technical assistance to private land users and others in addressing the various ecosystem goods and services (EGS) that may be available (figure A-3).

**Figure A-3**. Interacting elements of rangeland landscapes that determine vegetation structure and dynamics with resulting effects on ecosystem goods and services: (1) historical legacies of past climate, disturbances, and human activities, (2) environmental drivers, (3) transport vectors, such as the run-on and runoff of water associated with site hydrologic dynamics, (4) redistribution of resources, such as soil, nutrients, and seeds, and (5) the soil-geomorphic template (after Alcamo et al. 2003; Peters et al. 2006; Havstad et al. 2007).




Rangeland plant communities are multivariate in nature. They are unique because of plants, soils, hydrology, climate, and management response mechanisms. Rangeland plant communities produce a unique set of benefits and services. Basic categorical EGS uses are:

(i) Rangeland watersheds and their supply of freshwater for domestic, municipal, industrial, and commercial uses
(ii) Origin and maintenance of soils and their buffering capacity
(iii) Livestock products
(iv) Wildlife habitat
(v) Pollen source
(vi) Flood protection
(vii) Scenery
(viii) Recreation and tourism
(ix) Wood products
(x) Industrial products
(xi) Minerals

(xii) Ecological continuity
(xiii) Plant diversity and genetics
(xiv) Aesthetic, cultural and spiritual renewal

(3) In summary, public and private rangeland resources provide a wide variety of EGS. Additionally, spiritual values are vital to the well-being of ranching operations, surrounding communities, and the nation as a whole. Society is placing multiple demands on the nation’s natural resources, and it is extremely important that NRCS be able to provide resource data and technical assistance at local and national levels.

(4) Rangelands are in constant jeopardy, either from misuse or conversion to other uses. Holechek et al. (2004) and Holechek (2013) states that in the next 100 years, up to 40 percent of U.S. rangelands could be converted and lost to other uses. Land-use shifts from grazing use to urbanization will be much greater in areas of more rapid population increases and associated appreciating land values. Projections supporting forage demand suggest that changes in land use will decrease the amount of land available for grazing to a greater extent in the Pacific Coast and Rocky Mountains, compared to the North or South Assessment Regions (Mitchell 2000).

(5) As society attempts to satisfy multiple demands with limited resources, many ranching and farming operations seek to expand operations for multiple goods and services beyond traditional cattle production. Some diversified enterprises may include the following:

(i) Management to enhance wildlife abundance and diversity for fishing, hunting and non-hunting activities
(ii) Maintaining habitat for rare plants
(iii) Accommodating nature enthusiasts, bird watchers, and amateur botanists.

(6) Planning, evaluation, and communication are necessary steps (consult conservation planning steps) prior to initiating any new rangeland EGS-based enterprises.

## 645.0102 Grazing Land Definitions

A. Rangeland

(1) Rangeland is a land cover or use composed of grasses, grass-like plants, forbs, shrubs, and trees that is typically unsuited to cultivation because of physical limitations such as low and erratic precipitation, rough topography, poor drainage, or cold temperatures. Rangeland can include the following:

(i) natural lands that have not been cultivated and consist of a historic complement of adapted plant species; and
(ii) natural (go-back lands, old-field) or converted revegetated lands that are managed like native vegetation. Note: The USDA-NRCS rangeland Natural Resources Inventory (NRI) includes this designation in their definition of rangeland. In assessing rangeland conditions and health, keeping these designations separate would provide for more detailed information about rangeland trends and health.

(2) Converted rangelands can include lands seeded to native species, and/or introduced hardy and persistent plant species (grasses, grass-like plants, forbs, shrubs, and trees). However, previously cultivated rangelands that have been reseeded to native or introduced adapted species do not truly represent both soil and plant dynamics of the historic native plant community. The ecological state may be classified as “converted” in ecological site state-and-transition models. Natural grasslands, prairies, savannas, chaparral, shrublands, pinyon-juniper (depending on tree stature and canopy closure, see forestland definition below), steppes, many deserts, tundra, alpine communities, marshes and meadows are classified as rangeland. Rangelands provide numerous products and services (see above)

and are a primary source of forage for livestock and for wildlife. Rangelands may be harvested by haying equipment and for seed production.

(3) Rangeland comprises over two-thirds of the Nation's watershed area (FAO 1990) and provides a significant part of its water supply. The increasing importance of water has added a new dimension in range management strategies. In the Southwestern and Western United States, rangeland watersheds are the source of most surface water flow and aquifer recharge. Management on these lands can have a positive or negative effect on plant cover and compositional change, which ultimately influences water quality and quantity.

(4) Rangelands have diverse physical characteristics due to climate, soil, topography, and physiography. Physical properties determine types and amounts of vegetation, productivity, and types and carrying capacity of livestock and wildlife.

(i) Rangelands are also important pools of soil organic carbon stored in soil and vegetation (figure A-4). On a global basis, 9.1 billion ac (3.7 billion ha) of rangeland stores about 20–25 percent of the total global terrestrial carbon (306–330 Petagrams of organic carbon and 470–550 Petagrams of inorganic carbon) (A petagram (Pg) is a unit of mass equal to $10^{15}$ grams) (Batjes 1996; Kimble et al. 2001). On rangelands, carbon sequestration dynamics are quite complex, and estimation of rates and amounts are systematically more difficult than cultivated croplands (Schuman et al. 2002). This is because rangelands have more heterogeneous soil characteristics, wide daily temperature fluctuations, intermittent precipitation, and diverse vegetation life and growth forms (productivity, root-shoot ratios, herbivore use, and imposed disturbance and management practices).

(ii) Globally, forests (1.2–1.4 Pg Carbon $yr^{-1}$) and cropland (0.4–1.2 Pg Carbon $yr^{-1}$) have the largest potentials for sequestering carbon, although grazing lands (range and pasturelands) can contribute up to 10 percent of the overall terrestrial sink capacity. On a global perspective, rangelands occupy about half of the world's land area, 10 percent of the terrestrial biomass, and 10–30 percent of the soil organic carbon (Schlesinger 1997). An average estimate of globally sequestered soil carbon on rangelands is 0.5 Pg Carbon $yr^{-1}$ (Schlesinger 1997; Scurlock and Hall 1998). Table A-3 shows global and U.S. potential carbon storage for varied terrestrial biomes.

**Figure A-4.** Average soil organic matter content for selected soil orders on rangeland. (Spaeth 2020).

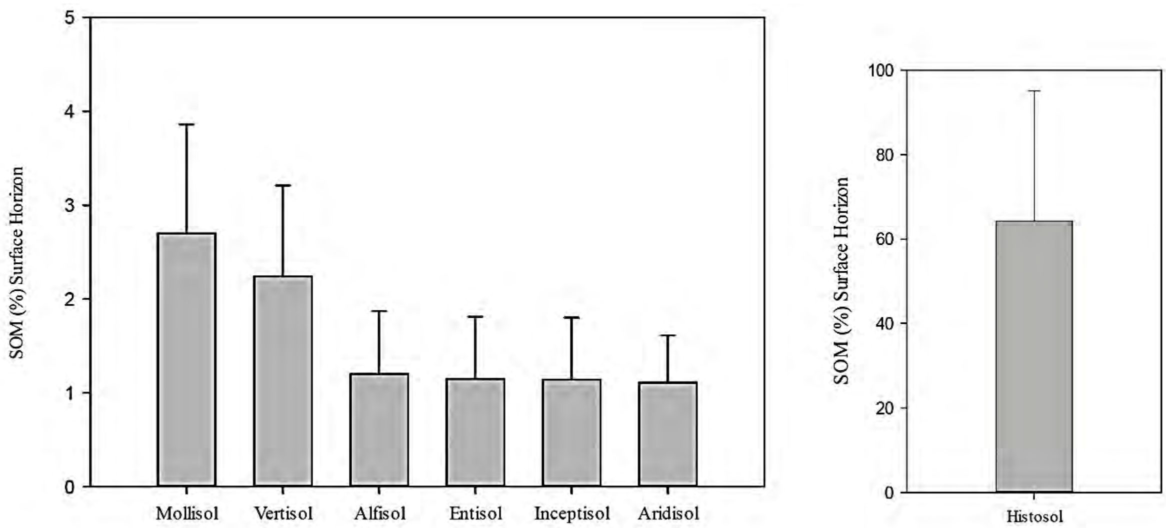



**Table A-3.** Yearly potential carbon storage in terrestrial biomes (United States and globally) (Spaeth, 2020). A petagram (Pg) is a unit of mass equal to $10^{15}$ grams.

| Land Use Activities | United States (Pg $yr^{-1}$) | Globally (Pg $yr^{-1}$) |
|---|---|---|
| Afforestation, agroforestry, natural forest succession, peatlands | | 1.2–1.4 |
| Natural forest plantings (plantations)<br>Improved forest management<br>USFS National Forest System | <br><br>0.0317–0.0500 | 0.2–0.5<br><br>0.08 |
| Rangelands improved management | 0.0054–0.0160 | |
| Pastureland grazing management<br>Pastureland fertility management<br>Pastureland manure management<br>Pastureland improved species | 0.0046–0.0190<br>0.0015–0.0031<br>0.0036–0.0090<br>0.0008–0.0023 | |
| Total grazing land intensification and improvement | 0.0160–0.0504 (avg. 0.033) | 0.3–0.5 |
| Desertification control | | 0.2–0.7 |
| Management of salic soils | | 0.3–0.7 |
| Cropland conservation and cultural practices | 0.1440–0.4320 (avg. 0.2880) | 0.4–1.85 |
| Total potential | 0.2000–0.4800 | 2.55–4.96 (avg. 3.8) |

B. Pastureland

Pastureland, often called improved pasture or tame pasture, is a land use where introduced or domesticated (tame) and/or native forage species mixtures are established through seeding, sprigging, etc. that can be grazed and/or intermittently hayed or deferred for environmental purposes. Various degrees of management inputs may be applied, such as fertilization, liming, overseeding with grasses and legumes, mowing, remedial tillage, and irrigation. Pasture vegetation can consist of grasses, legumes, other forbs, shrubs, trees, or mixtures of plant life forms. Croplands seeded to temporary cover crops that are grazed are not typically classified as pasture. Holding pens, corrals, and loafing lots in or near barns, dairy facilities, etc. are not classified as pasture. Pasturelands can provide benefits other than forage for livestock such as wildlife habitat and use, watershed sources, zones for reducing runoff and erosion control, recreational, and aesthetic purposes.

C. Other Grazing Lands

Most grazing lands are considered either range or pasture, but grazing lands also include grazed forest lands, grazed croplands, and haylands. These other land use types make up an additional 106 million acres of privately-owned grazing lands, or about 17 percent of the total U.S. grazing lands.

(i) Naturalized pasture is cleared, converted, past cultivation, and "old-field" or "go-back land." It is forestland and cropland that primarily contain introduced species that are largely adapted and have become established without agronomic and cultural inputs, persist under the current conditions of the local environment, and are stable over long time periods. Naturalized pasture is different from rangeland in that rangeland includes the following:

- Natural lands that have not been cultivated and consist of a historic complement of adapted plant species.
- Natural (go-back lands, old-field) or converted revegetated lands that are managed like native vegetation. Naturalized pasture, some rangelands that have been disturbed, and old-field or go-back lands have overlapping concepts and grey areas. A guideline to differentiate naturalized pasture from rangeland (as defined from part 2 of the rangeland definition above) can be based on the type of plants that currently occupy the site (e.g., early seral species, tropical plant species, or predominantly cool season forage grasses that have become naturalized without seeding or other establishment methods).
- Some forest lands may persist as naturalized pasture after disturbance; however, over time, they naturally revert back to a forest-dominated plant community unless practices are applied to keep it in a herbaceous state. If the forest site has not been cultivated in the past, the retrogression could eventually resemble the forest reference state. If the forestland has had a history of cultivation, then the reverted site would be described in a converted forest state.

(ii) Cultural hayland: A land use subcategory of cropland managed for the production of forage crops that are culturally established and typically machine-harvested. These crops may be grasses, legumes, or a mixture of both. Croplands seeded to annual forage species that are harvested by grazing, are hayed, or are ensiled are not classified as hayland. Some uncultivated native stands of grasses and forbs are hayed and are classified as rangeland.

(iii) Forestland: "For the purpose of developing ecological site descriptions, a spatially defined site where the historic climax plant community was dominated by a 25 percent overstory canopy of trees, as determined by crown perimeter-vertical projection (USDA NRCS 2010)."

Forestland, grazed: A land use category that includes forest land that is grazed and managed, using range or pasture management principles and practices that maintain soil and surface stability, hydrologic function, and biotic integrity.

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# Part 645 – National Range and Pasture Handbook

## Subpart B – Ecological Sites, Ecological Site Descriptions: Ecological Classification as a Concept and Use in Conservation Planning and Resource Monitoring

### 645.0201 General Information

A. Purpose

Ecological Site Descriptions (ESDs) serve as a classification concept, which are integral to grazing land planning, monitoring, and assessment. The purpose of this subpart is to provide an explanation and understanding of ecological site descriptions as a decision-support tool for conservation planning and management on grazing lands. Ecological site descriptions also describe other inherent land uses such as pasture, agroforestry, and cropland. The objective of this subpart is to also augment sections of the National Ecological Site Handbook and provide additional dialogue on the importance of ecological sites in NRCS conservation activities.

B. Introduction

The Ecological Site is an essential ecological concept used in conservation planning, monitoring, evaluation, and adaptation of management for all land types and uses. Ecological Site Descriptions serve as references and are the working document for the following uses:

(i) Describe unique ecological parameters based on properties inherent to specific landscape features.
(ii) Use quantitative environmental factors and qualitative information based on field-observable features.
(iii) Provide an ecological reference and historical document that serves as a basis for land management activities related to the site.
(iv) Provide reference information for monitoring and assessment activities.

C. Ecological Site Reference Material

(1) The Natural Resources Conservation Service (NRCS) utilizes three handbooks that serve as technical and procedural references to support policies and responsibilities for the development of ecological site concepts and ecological site descriptions.

(i) Title 190, Interagency Ecological Site Handbook for Rangelands (190-IESHR): The 190-IESH for Rangelands was developed to implement the policy outlined in the Title 190, Rangeland Interagency Ecological Site Manual (RIESM). This policy provides direction to the Bureau of Land Management (BLM), U.S. Forest Service (USFS), and the NRCS to cooperatively identify and describe rangeland ecological sites for use in inventory, monitoring, evaluation, and management of the Nation's rangelands. This is a response, in part, to direction from Congress in the Department of the Interior and Related Agencies Appropriations Act of 2002. This interagency handbook includes ecological sites as the component of ecological classification at local management levels and provides a standardized method to be used by the BLM, USFS, and NRCS to define, delineate, and describe terrestrial ecological sites on rangelands.

(ii) Title 190, National Ecological Site Handbook (190-NESH): Provides standards, guidelines, and definitions to support policies and indicates the responsibilities and procedures for conducting the collaborative process for development of ES concepts and ESD information. Responsibilities for ES activity are shared among disciplines, including soil science, range science, forestry, agronomy, wildlife biology, hydrology, and ecology.

The 190-NESH is specific to NRCS, but it adheres to the guidelines established in the Title 190, Interagency Ecological Site Handbook for Rangelands. The standards set in the NESH are specific for policy, development, and use by NRCS.

(iii) Title 190, National Range and Pasture Handbook, Part 645 (NRPH): 190-NRPH-645 reviews NRCS policies and procedures for assisting farmers, ranchers, groups, organizations, units of government, and others working through conservation districts in planning and applying resource conservation on non-Federal grazing lands throughout the United States. This handbook also serves as a general reference for grazing lands resource information and was developed by NRCS grazing lands specialists, using current technical references including textbooks, scientific publications, manuals, and expert knowledge.

(2) Other handbooks such as the National Soil Survey Handbook, Soil Survey Manual, National Forestry Handbook, National Forestry Manual, and National Biology Manual provide additional supporting information for ecological site development.[1] .Responsibilities for ES activities are shared among disciplines, including soil science, range science, forestry, agronomy, animal science, wildlife biology, hydrology, and ecology.

(3) The Ecosystem Dynamics Interpretative Tool (EDIT), a Web-based database, has replaced the Ecological Site Information System (ESIS) as the official repository of ESDs for the NRCS.

## 645.0202 Ecological Site Concept

A. Historical background

(1) Two underlying themes (or hypotheses) of plant ecology which categorize vegetation patterns across landscapes have emerged since the early 1900s: the community unit theory and the individualistic-continuum concept.

(i) The debate regarding the nature of community organization has been discussed for almost a century (Whittaker 1962; Shipley and Keddy 1987; Austin and Smith 1990; McIntosh 1995; Callaway 1997; Reinhart 2012) and started with a basic question: "are plant communities an organized system of co-occurring species, or an assemblage of a random collection of individualistic species arriving on a site that varies continuously with environmental change across the landscape?" Frederick E. Clements (1874–1945), an American plant ecologist who presented the view of organismic concept of communities – also called the community-unit concept – proposed that plant communities were holistic and interdependent (Clements, 1916). Plant communities were likened to a facsimile of an individual organism (growth, maturation, and death), visualized as natural units of coevolved species populations forming homogeneous, discrete, and recognizable vegetation units.

(ii) In contrast, Henry Allan Gleason (1882–1975), an American botanist, advocated the individualistic continuum concept or individualistic concept of community organization, where communities are a collection of species that have commonality with respect to adaptations to the abiotic environment (Gleason 1926, 1939). The transition to the individualistic viewpoint gained momentum when Whittaker (1967) used sophisticated gradient analyses, which showed patterns of species replacements along a gradient representing the continuum. Ecologists now recognize that species dynamics (existence, composition, fitness, distribution), are not wholly dependent on abiotic conditions and

[1] These handbooks and manuals may not reflect the most recent ESD guidelines and procedures. The purpose of Subpart B of the NRPH is to highlight and maintain current policy and technology changes regarding ESDs.

competition, but are highly affected by complex interactions within the plant community, mutualists, and consumers (Callaway 1997).

(2) In reality, vegetation and species populations in plant communities continuously intergrade along environmental gradients, or the continuum. However, plant communities with similar species assemblages are also repetitive and recognizable on the landscape. As Whittaker (1975) later stated: "…classifications of communities are often needed. There is no real conflict between the principle that communities are generally (but not universally) continuous with one another, and the practice of classifying these communities as a means of communication about them" (Whittaker 1975). Land managers recognize the fact that a continuum cannot be effectively managed. Ecologists recognize that plant species are distributed in space and respond according to unique genetic, physiological, life-cycle characteristics; and physical and environmental factors.

(3) Community-units are characterized as homogenous discrete community units organized in a hierarchical structure (e.g., plant communities, cover types, habitat types, and ecological sites). Although vegetation occurs along a continuum, ecological understanding and land management are facilitated by forming homogeneous recognizable groups such as the ecological site.

B. Ecological Site Definition

An ecological site is a conceptual classification of the landscape. It is a distinctive land unit based on a recurring landform with distinct soils (chemical, physical, and biological attributes), kinds and amounts of vegetation, hydrology, geology, climatic characteristics, inherent ecological resistance and resiliency, unique successional dynamics and pathways, natural disturbance regimes, geologic and evolutionary history including herbivore and other animal impacts, and response to management actions and natural disturbances. These discrete characteristics separate one ecological site from another.

C. Classifying Ecological Sites

(1) NRCS classifies rangeland and forestland into ecological sites for scientific study, evaluation, monitoring, planning activities, and management. Alternative land uses such as pasture and crop can be represented in the ecological site state-and-transition model.

(2) Ecological sites are classified and correlated with soil map units and components. When landscapes are categorized into ESs, unique ecological processes and abiotic factors allow for more specific, targeted management goals and objectives, monitoring plans, and assessments of management actions. The adoption of ESs as fundamental land units subdivides the landscape into groups representing discrete responses to environmental conditions and subsequent disturbances, which helps to identify appropriate management and restoration targets (Monaco et al. 2015). Ecological sites integrate ecological concepts (figure B-1), including plant and soil interactions, hydrologic dynamics, successional pathways, equilibrium and nonequilibrium concepts pertinent to the discrete aspects of community structure, ecological gradients, and spatial and temporal heterogeneity (Moseley et al. 2010) (figure B-2).

**Figure B-1.** Environmental and Ecological Factors associated with Ecological Sites.

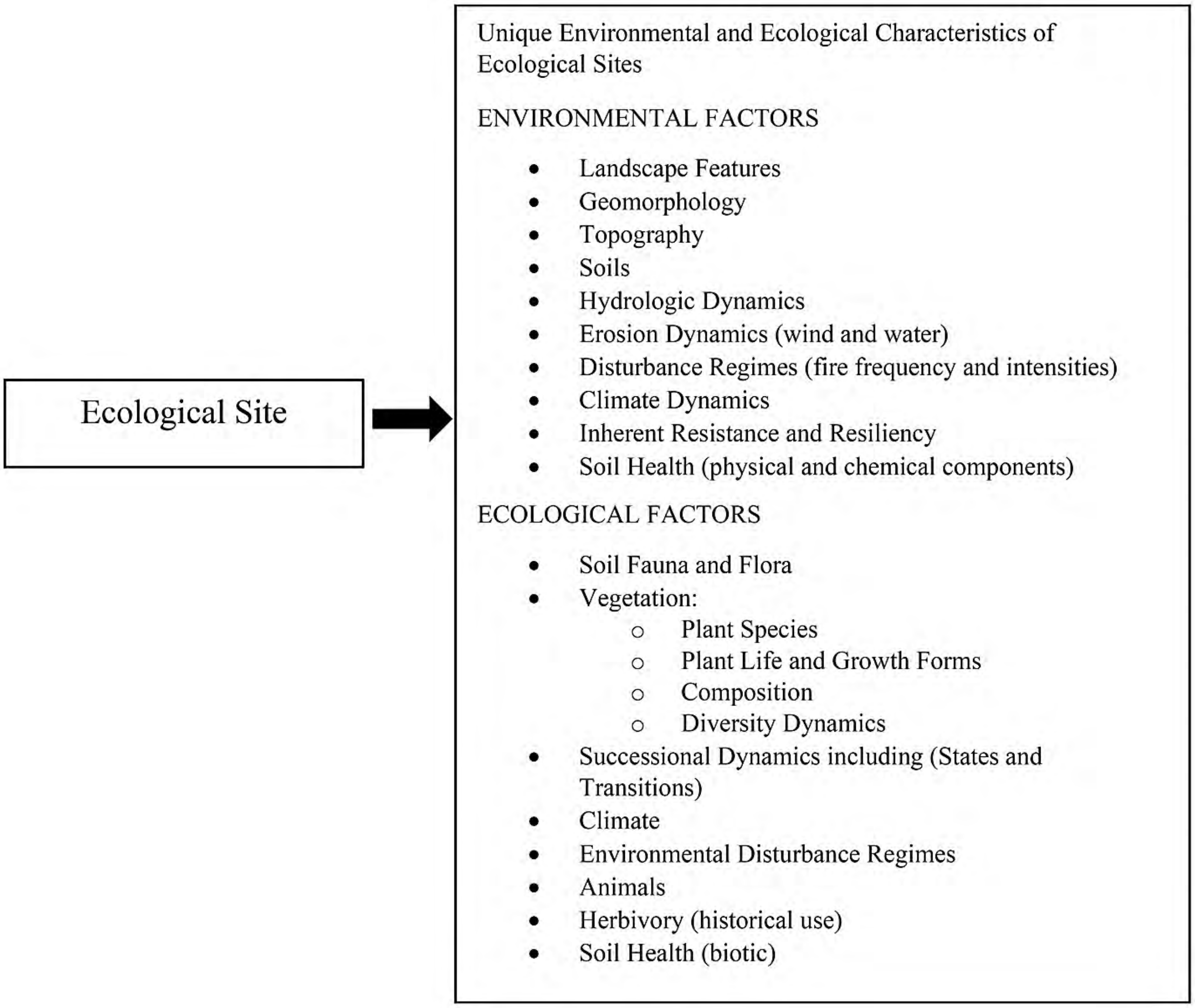
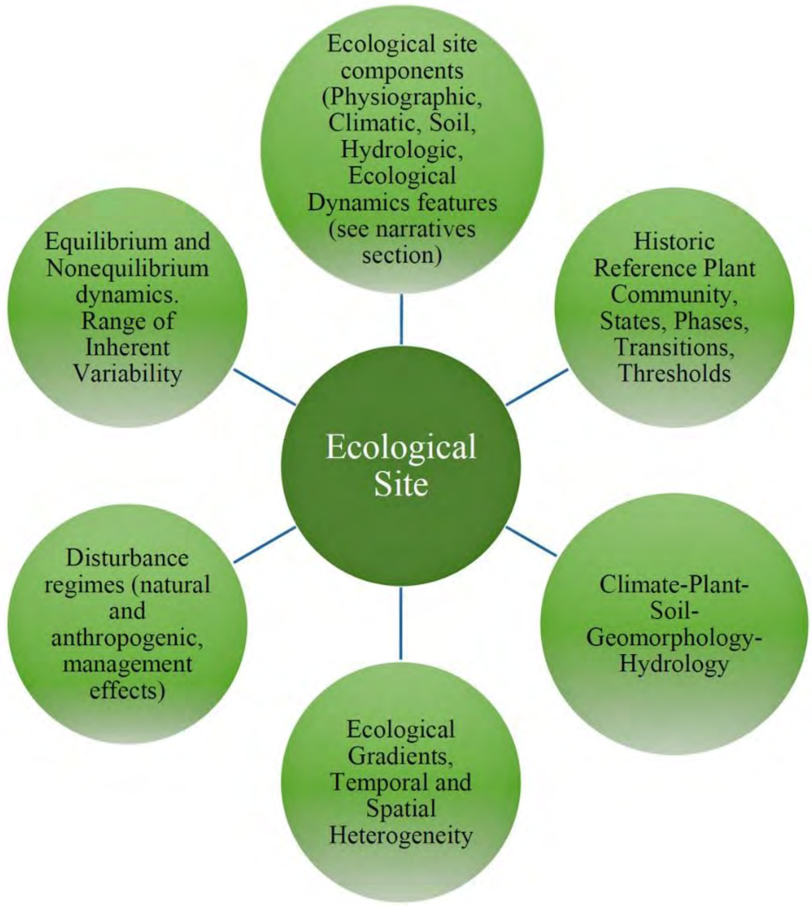


**Figure B-2.** Interacting ecological components and ecological factors relating to Ecological Sites.




## 645.0203 Developing Ecological Site Descriptions

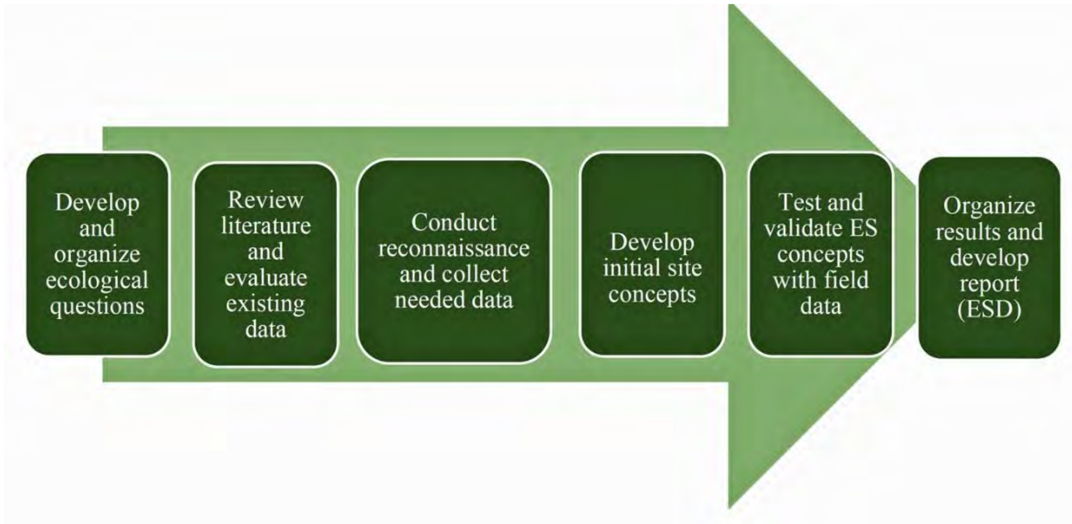
A. Ecological sites are described using the modal concept approach with typifies a representative example of plant community composition and associated environmental factors. The ESD contains information about the representative site concept rather than including detailed information about outlier aspects of the site. However, variability may be unusually high (e.g., mound-intermound; dune-interdune settings) in some ecological sites because of environmental factors; therefore, these dynamics need to be discussed.

B. Within NRCS, the ESD development effort is a collaborative effort between Soil Science and Resource Assessment, Science and Technology, Conservation Planning and Program Delivery Deputy Areas as well as State Technical and Field Office personnel.

(1) At the local level, NRCS Soil Survey Offices lead technical teams comprised of NRCS technical specialists, personnel from partnering state and federal agencies, universities, and non-government organizations, as well as landowners/managers and/or other stakeholders. Diverse technical teams ensure ESDs are reliable and credible.

(2) Figure B.3 illustrates the general steps in the ES development process. For specific standards, procedures, and guidance for developing ESDs please refer to Title 190, National Ecological Site Handbook (190-NESH).

**Figure B-3.** General steps in the ES development process.




## 645.0204 Contents of an Ecological Site Description

A. This section provides a summary of the contents of an ecological site description. For more detailed information, especially on how to develop these sections, see NESH 2017. The official repository of ESDs is the Ecosystem Dynamics Interpretative Tool (EDIT).

B. General Information – Status

(1) Draft: An established ESD in EDIT that has not undergone quality control and quality assurance and is not available to the public.
(2) Provisional: A provisional ESD has undergone quality control and quality assurance review and is viewable to the public. It contains a working state-and-transition model and sufficient information to identify the ecological site.
(3) Approved: An approved ESD has undergone quality control and quality assurance review. It must contain a defined set of criteria. In general, approved ESDs are a more comprehensive and complete document than a provisional ESD.
  (i) <u>Site ID</u>: Alphabetic and numeric characters that represent the Land Resource Region (LRR), Major Land Resource Area (MLRA), Land Resource Area (if applicable), and the ecological site ID number.
  (ii) <u>Legacy ID</u>: If applicable, the code that was used in the first generation of ESDs.
  (iii) <u>Ecological Site Name</u>: A descriptive abiotic common name and a biotic plant community name. The biotic name includes both the scientific and common plant species names.

C. Hierarchical Classification

(1) MLRA Notes: A description of residing MLRA and LRU (if applicable) (see Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin Handbook 296).
(2) Classification Relationship: A comparison of other ecological classifications (e.g., USDA Forest Service, US Environmental Protection Agency) to NRCS's classification (LRR, MLRA, LRU). If applicable stream and wetland classifications may be included.
(3) Ecological Site Concept: A summary of characteristic abiotic and biotic indicators, including ecological dynamics, that differentiate the site from others. This may include information on climate, topography, hydrology, geomorphology, vegetation, and soil characteristics.

(4) State Correlation: States where the ecological site has been identified.
(5) Associated Sites: Other ESs commonly located adjacent to or associated with the ES. A diagram is often used to denote landscape position in relation to other sites.
(6) Similar Sites: ESs that resemble the site.

D. Physiographic Features

A description of the physiographic features of the ES such as landscape position, landform, geology (lithology and stratigraphy), aspect, site elevation, slope, water table, flooding, ponding, and runoff potential.

E. Climate Features

A description of the climatic features that typify the ES and relate to its potential, and characterize the dynamics of the ES, such as storm intensity, frequency of catastrophic storm events, and drought and/or temperature cycles. Climatic features also include frost-free period, freeze-free period, mean annual precipitation, monthly moisture and temperature distribution, and location of climate stations used to evaluate and determine means and averages. Many ecological sites occur in areas for which appropriate climate station data are not available. Climate data included in an ESD may be extrapolated from climate models (e.g., PRISM). A listing of climate stations used is also included in the ESD.

F. Influencing Water Features

Description of water features or adjacent wetland or riparian water regimes that influence the vegetation or management of the site and make the site distinctive from other ESs. Information can include subsurface waterflow, seasonal groundwater levels, overland flow, streams, springs, wetland, and depressions. Use terminology associated with Wetland Classification (Cowardin 1979), Rosgen Stream Classification (Rosgen and Silvey 1996), or another established water or hydrology-related classification system.

G. Soil Features

(1) Representative soil features include soil physical and chemical attributes such as parent material, surface and subsurface texture, surface and subsurface fragments, drainage class, hydrologic conductivity (permeability class), depth to diagnostic horizons, soil depth, electrical conductivity, sodium adsorption ratio, calcium carbonate equivalent, soil reaction (pH), and available water capacity. The representative soil features narrative presents the inherent range that corresponds with the ecological site concept, while also describing expected variability associated with the ecological site.
(2) A new feature related to soil dynamics is soil health and quality. Discussion and information relative to these topics can be described for the reference state and succeeding alternative states. Soil carbon/Organic carbon dynamics can be discussed with baseline information to provide a reference for steady-state levels and potential losses attributed to various disturbances.

H. Hydrology Features

(1) This section contains information about site hydrology: run-on and runoff characteristics on the landscape, infiltration dynamics with respect to plant life/growth form and species, potential water holding capacity, drainage, and erosion dynamics and potential risks based on long-term average precipitation and from design storm frequencies (e.g., 2, 5, 10, 25, 50, 75, 100-year storms) (see subpart G). Eco-hydrologic topics including water flow patterns, overland flow, subsurface flows, evaporative rates, and discussion on their influence on plant compositional changes and corresponding hydrologic changes should also be included. The NOAA Atlas 14-point precipitation frequency estimates data can be included to provide

valuable information for discussions of rainfall intensity and frequency for the representative climate station associated with the ecological site.

(2) On rangelands, the Rangeland Hydrology and Erosion Model (RHEM) can be used to compare runoff and erosion risks and changes, with corresponding changes in the state-and-transition model (Williams et al. 2016). The RHEM model can also be used to evaluate pastureland sites[2]. The rangeland hydrology and erosion model evaluates runoff and erosion dynamics based on long term averages and for high intensity storm frequencies (2 to100-yr storm intensities) (see subpart G).

(3) The hydrologic features narrative should discuss the inherent range of variability that corresponds with the ecological site concept, while also explaining any allowable and typical variation across the ecological site (See subpart G for example on hydrology writeup with RHEM model information and interpretations). See Appendices A and B as example of a state and transition diagram with hydrology and erosion estimates associated with various states and phases.

I. Ecological Dynamics

The ecological dynamics section provides historical context and describes how the ecological processes and plant communities of the site are impacted by and react to the natural variability of weather, fire, native herbivory, and other natural disturbances (see appendix B-B). Site resistance and resiliency to anthropogenic disturbances should also be addressed such as livestock grazing and dominant plant physiological response to grazing. Other general information regarding the dynamics of the site should be described, such as human management impacts. Use citations from the scientific literature and if expert knowledge is used, list in the "Other References" section of the ESD. References to climate, soil, hydrologic features are common to support discussion of ecological dynamics.

J. State and Transition Diagram

(1) A state-and-transition model (STM) describes the temporal dynamics of an ES. STMs display and describe the historic plant community or reference state, and multiple states and community phases (unique combinations of biotic and abiotic attributes), and the transitions between states (driving forces, processes, and thresholds). An STM provides a general graphical overview of ecological states and transitions, and the accompanying narrative describes these in detail (figure B-4). Although STMs graphically display specific successional trajectories or pathways, they do not explicitly explain or propose theories regarding plant successional dynamics that may be unique among plant community types (figures B-4, B-5. Also see Appendices B-A, B-B, B-C). The use and benefits of using STMs in conservation planning are to provide a framework for discussion with clients to address the ecological dynamics associated with current conditions and help assess and predict future changes – a roadmap of possibilities and can help predict the results of management actions.

[2] USDA NRCS and ARS are currently evaluating RHEM on pasturelands and this subpart will be updated with more examples when that effort is completed.

**Figure B-4.** Detailed example of rangeland state-and-transition model with community pathways (Loamy Calcareous Green River Basin R34AB126WY).

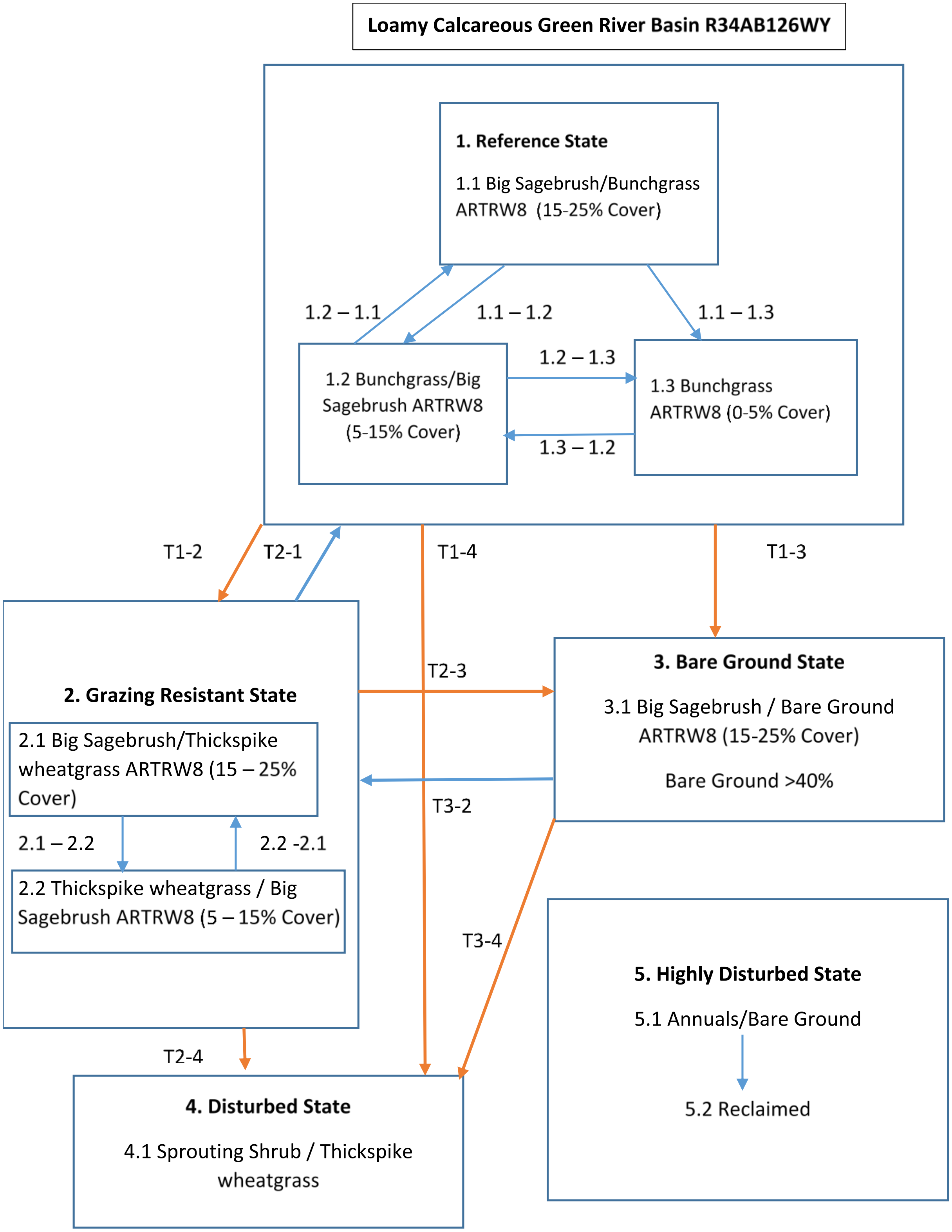
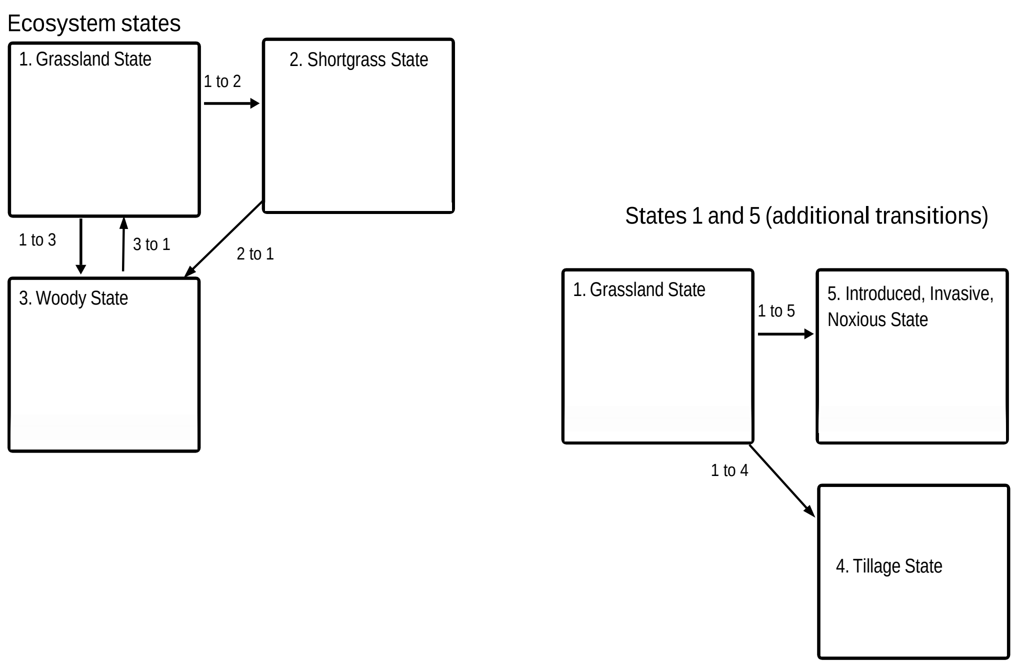


**Table B-1.** Pathways.

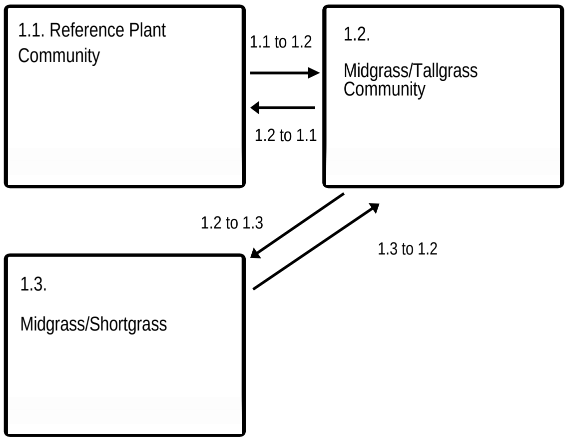
| | | |
|---|---|---|
| **Community Pathways** | 1.1–1.2 | Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed) |
| | 1.1–1.3 | Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed) |
| | 1.2–1.1 | Natural selection |
| | 1.2–1.3 | Drought, insects and disease, mechanical, biological and chemical treatment, fire (wild and prescribed) |
| | 2.1–2.2 | No disturbance |
| | 2.2–2.1 | Lack of sagebrush killing disturbances |
| **State Transitions** | T1–2 | Continuous spring grazing |
| | T2–1 | Mechanical, chemical treatments, fire, grazing, rest and deferment, and season of use change |
| | T1–3 | Continuous high intensity early season grazing |
| | T1–4 | Increased frequency of disturbance cycle (i.e., grazing, drought, fire, mechanical, biological, chemical treatments) |
| | T2–3 | Continuous high intensity early season grazing |
| | T3–2 | Changing grazing season of use and/or mechanical, chemical, and biological treatments |
| | T2–3 | Increased frequency of disturbance cycle (i.e., grazing, drought, fire, mechanical, biological, chemical treatments) |
| | T3–4 | Fire (wild and prescribed), drought, insects and disease, mechanical, biological, chemical treatments |

**Figure B-5.** Ecosystem states, Loamy Hills HX076XY115.




**1 to 2**–Long-term, heavy, continuous overgrazing, no rest and recovery
**1 to 3**–Lack of fire and brush control
**1 to 4**–Tillage by machinery
**1 to 5**–Introduction of non-native species
**3 to 1**–Prescribed grazing, brush management, and prescribed burning

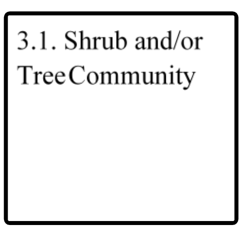
**State 1 submodel, plant communities**




**1.1 to 1.2**–Heavy, continuous grazing without adequate rest and recovery
**1.1 to 1.1**–Prescribed grazing that incorporates periods of deferment during the growing season
**1.2 to 1.3**–Long-term (>20 years) continuous grazing with no rest and no recovery
**1.2to 1.2**–Prescribed grazing with adequate rest and recovery period during the growing season

**State 2 submodel, plant communities**


**State 3 submodel, plant communities**



**State 4 submodel, plant communities**


**State 5 submodel, plant communities**

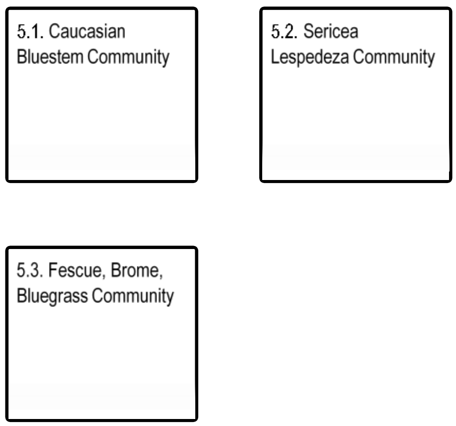


**Figure B-6.** Example of STM identifying several land uses within an ecological site.

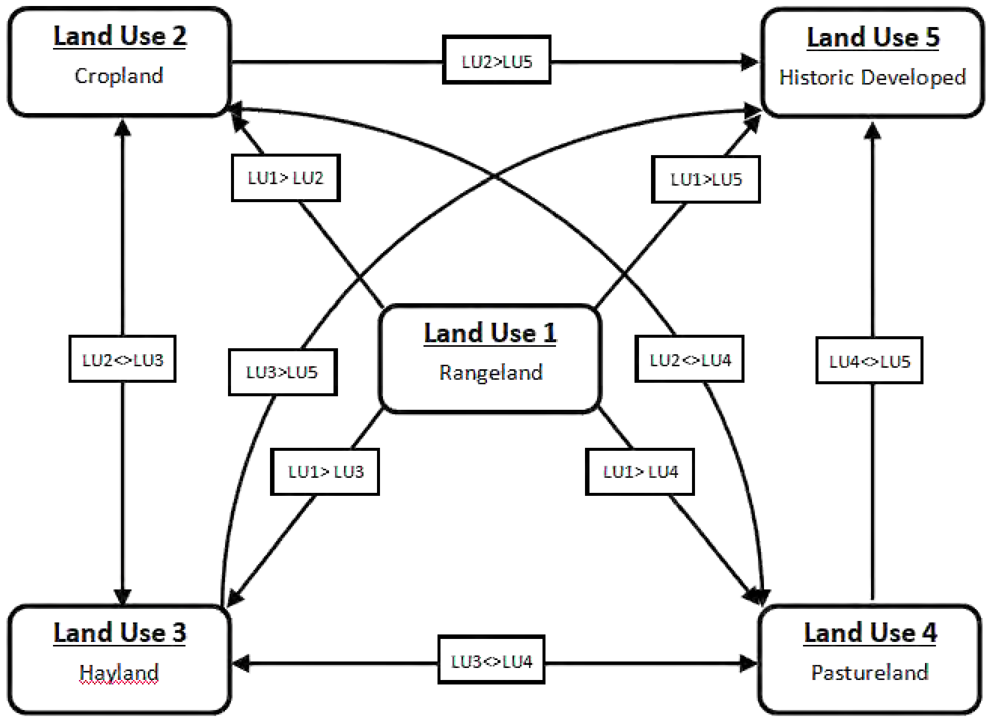
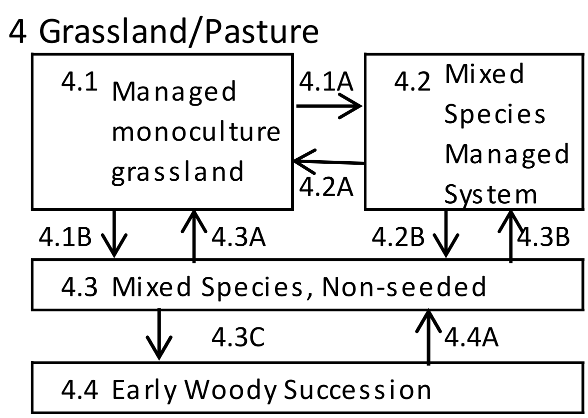



**Figure B-7.** An example of pastureland sub-state-within state-and-transition model.



(2) States

(i) An ecological state is a suite of temporally related plant community phases and associated dynamic soil properties that produce persistent characteristic structural and functional ecosystem attributes (Bestelmeyer 2009). States generally exhibit vegetation composition and structure, and ecological processes that are in equilibrium to self-sustain (negative feedback mechanisms) ecological resilience of the respective state and produce the largest array of potential ecosystem services (Bestelmeyer et al. 2009). Thus, states are often distinguished and described by differences in ecological processes, such as hydrology, nutrient cycling, or energy capture.

(ii) Ecological resilience is an indication of the amount of alteration required to shift an ecosystem from one stable state of reinforcing structure-function feedback mechanisms to a new stable state sustained by different structure-function feedback mechanisms (Briske et al. 2008). At-risk community phases exhibit conditions near structural or functional thresholds, beyond which shifts in ecological processes (positive feedback mechanisms) facilitate state transition. Structural thresholds are identified (structural indicators) based on changes in vegetation (composition, growth form, and distribution) and bare ground connectivity; whereas functional thresholds are identified (functional indicators) by shifts in processes (e.g., water infiltration and runoff, soil retention and erosion, nutrient cycling and distribution, solar energy capture and use) that promote ecological function and resilience of an alternative state. A STM typically includes an accompanying table with text descriptions of the plant community composition, community pathway and transition dynamics, and key structural and functional indicators (Williams et al. 2016).

(iii) The ES reference state and plant community phases generally exhibit vegetation composition and structure, and ecological processes that are in relative equilibrium to self-sustain (negative feedback mechanisms) ecological resilience of the respective state and produce the largest array of potential ecosystem services (Bestelmeyer et al. 2009).

(iv) The NESH states: "In all cases, the desired 'interpretive plant community' will be the reference state. If there is no data available for the reference state, describe the naturalized plant communities that occupy the site. The naturalized plant community that is most similar to the reference state becomes the interpretive plant community". As NESH instructs, in situations where the interpretive plant community cannot be identified, is not known, or no longer exists on the landscape, a surrogate reference state may be developed and described (see comments in paragraph below). Often times the interpretive plant community is based on the historic plant community. Debate often arises as to what the historic plant community was. If relict sites can be found, they can provide a basis for constructing the historic plant community; however, if there is doubt about historic conditions because of major plant community change and transformation in relation to introduced species, the default as NESH describes is the naturalized plant community. In the manual, interpreting indicators of rangeland health, Pellant et al. (2020) provide the following statement about historic plant communities as reference states: "Historical baseline: The inherent complexities of vegetation dynamics (e.g., how vegetation originated in an area and how it might change in the future) require an understanding of historic disturbance regimes, climatic variability (including climate change), and current vegetation. Although long-term trends in historic vegetation can be displayed over time periods spanning thousands of years using pollen analysis and other palaeoecological techniques, the relevance of ecological data to current state-and-transition models diminishes further back in time due to increasing differences in climate, disturbance regimes, and species distributions. In western North America, a 500-year or shorter period immediately preceding European settlement is a reasonable time period for describing the reference state (Winthers et al. 2005)."

(v) Deciding on what the historic plant community or the naturalized plant community is or was, is not a clear-cut endeavor. Some recommendations include, plant community composition based on pre-European man >200 years ago, finding relict sites, evaluating inherent native plant composition associated with the soil component, and compiling and evaluating historic literature and documents. Where introduced species such as cheatgrass, yellowstar thistle, knapweeds, leafy spurge etc., have naturalized and have transitioned as the dominant species, it may be difficult to identify a reference state. When all else, fails, document the situation and provide an honest assessment.

(3) Transitions

Transitions are simply the mechanisms by which state shifts occur and are commonly initiated by a trigger (e.g., wildfire, drought, long-term flooding, invasive plants, grazing) (Briske et al. 2006, 2008). A transition from one state to another is associated with "crossing a threshold" (Pellant et al. 2020). Ecological site transitions among states are often caused by a combination of factors and feedback mechanisms that alter plant community dynamics (e.g., Schlesinger et al. 1990) and that contribute directly to a loss of state resilience (Caudle et al. 2013). Transitions to alternate states may often be irreversible, especially where considerable plant compositional changes have occurred, accelerated runoff, and soil loss (sheet erosion, rill erosion, and/or gully erosion). Transitions (T) in state-and-transition models are used to designate downward and upward trends.

(4) Community phases

One or more plant community phases may exist in each state (see figure B-4, there are three community phases in State 1). The described disturbance regime (for each state) cause shifts between identified community phases. Shifts between phases are described using arrows and narrative. Descriptions of plant community phases include information such as species composition, annual primary production by species (lbs/ac), percent foliar and ground cover, canopy structure: height above ground (ft), and growth curves. Plant species are often grouped with similar species based on their structure and ecological function.

(5) Alternate Land Use State-and-Transition Models

(i) Ecological site descriptions may contain one or several interconnected STMs depending on land use (range, forest, pasture, crop). Figures B-5, 7, and 8 contain examples of STMs which incorporate various land uses. Each land use will have its own subset STM.

(ii) Pasture states are now a formal part of state-and-transition models and replace many of the components of Forage Suitability Groups (FSGs). The concept of FSGs was to group soils with similar landform and agronomic properties such as available water-holding capacities, pH, slope, drainage class, frequency and duration of flooding, depth to restrictive layers, surface soil texture, cation exchange capacity, sodium adsorption rations, salt contents, permeability classes, natural potassium and phosphorous reserves, and organic matter levels etc. with the ability to sustain a suite of forage species. Forage suitability groups contained similar information as ESDs (climate, physiographic features, soil features, water features, plant growth curves, etc.), which are now included in the ESD, thus eliminating duplicity. Appendix B-C shows some key attributes of example descriptions for a pastureland state.

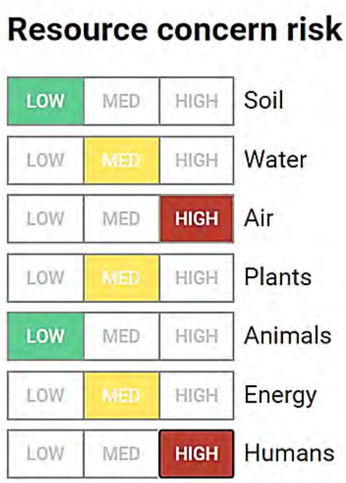
(6) Resource Concerns Risk Assessment in STMs

(i) NRCS resource concerns are organized by the following categories: soil, water, air, plants, animals, energy, and human considerations (SWAPA+H). A resource concern is the resource condition that does not meet minimum acceptable condition levels as established by resource planning criteria.

(ii) Planning criteria are established for all NRCS resource concerns and may be assessed using tools specific to land use or through client input and planner observation. The information contained in the ecological site description may be adequate to determine the likely outcome of an assessment tool and the probability of a resource concern.

(iii) Environmental and management drivers between states are often associated with resource concerns that have and/or are occurring. For example, a historic grassland site that is moving toward a woody invaded state is associated with several resource concerns such as invasive plants and other pests, productivity, soil health concerns, changes in plant structure and composition, and erosion (water and wind). By associating these resource concerns that alter the plant community, STMs can be used to display the three levels of risk or probability that a resource concern's presence within that state or plant community. This level of risk can be displayed as either Low, Medium, or High within a color-coded risk assessment table (figure B-8). Green values imply no resource concern exists, yellow indicates a moderate probability of a resource concern, and red indicates a high probability that a resource concern exists. A yellow value would require additional field assessment to determine whether a resource concern is present or not. Note: only one resource concern in a SWAPA+H category need be present or be represented on the table. The resource concern(s) considered are indicated in the resource concerns check list in EDIT.

**Figure B-8.** Resource Concern Risk Assessment Table from EDIT. Risk concerns can be designated by color code.




(7) Management Interpretations

(i) Management implications inherent to a community phase or state are described. Management interpretations include topics such as grazing management (suitability/limitations), fire behavior, brush management or pest management techniques, range and pasture seeding, wildlife considerations, pasture management (soil fertility and/or amendments, equipment limitations, etc.), and other interpretations.

(ii) Other aspects of management interpretations can be considered and/or included in EDIT as tables and narrative. They include: 1) grazing accessibility, 2) grazing forage palatability, 3) annual forage, 4) wood products, 5) pastureland management, 6) agronomic management, 7) recreational uses, 8) wildlife habitat suitability, 9) wildlife plants, 10) fire occurrence and characteristics, 11) fuel models and fire fuel characteristics, 12) fire behavior site characteristics, and 13) other products.

(8) Supporting Information

Supporting information includes, but is not limited to, type location, references, author/coauthor, and reviewers, etc.

(9) Rangeland Health Information

Rangeland health analysis is tied to the ecological site and the information contained within the ESD. Rangeland health reference information for the 17 indicators used to determine the preponderance of evidence for soil and surface stability, hydrologic function, and biotic integrity can be found in EDIT.

K. Other Ecological Site Components (See NESH)

(1) Animal community
(2) Recreational uses
(3) Wood products
(4) Other products
(5) Other information
(6) Inventory data references
(7) References
(8) Other references
(9) Contributors
(10) Approval
(11) Acknowledgments

L. Rangeland health reference sheet

(1) The rangeland health reference sheet provides documentation for expected conditions of the 17 indicators relative to the reference state (appendix B-D). The rangeland health reference sheet is integral to evaluating the 17 indicators of the rangeland health matrix. The reference sheet and corresponding ecological site matrix (appendix B-E) describes the range of expected spatial and temporal variability of each indicator within the natural disturbance regime based on each ecological site (or equivalent unit).
(2) Coinciding with the ecological site reference sheet (appendix B-D), an ecological site-specific evaluation matrix (appendix B-E) is a valuable tool to evaluate each rangeland health indictor based on general descriptions of key characteristics for each degree of departure (none to slight . . . extreme). Pellant et al. (2020), interpreting indicators of rangeland health contains a generic evaluation matrix; however, it is strongly recommended that an ecological site-specific matrix be developed that can be used to evaluate a suite of ecological sites (see matrix example, appendix B-E).
(3) Pellant et al. (2020) recommends that a cadre of knowledgeable individuals work in tandem to develop reference sheets and coinciding matrices as the 17 indicators are associated with various environmental factors (plants, soils, and hydrology).
(4) A reference sheet cannot be created without a complete ecological site description; however, if the respective ecological site description and/or soil survey does not exist, a protocol called "Describing Indicators of Rangeland Health" (DIRH) may be used to evaluate the 17 indicators and derive a preponderance of evidence for the three attributes. A guide for DIRH (Pellant et al. 2020) is as follows:

**Table B-2.** Guide for Implementing Describing Indicators of Rangeland Health (DIRH).

| Soil Survey Status | Ecological Site Description Status | Identify Soil Map Unit Component? | Identify Ecological Site? | Complete IIRH? |
|---|---|---|---|---|
| A soil survey exists. | Ecological site description exists.[1] | Yes | Yes | Yes[2] |
| No soil survey exists, but soils are comparable to soils described in another soil survey within the major land resource area. | Ecological sites are described for the major land resource area, including the precipitation zone. | Yes | Yes | Yes |
| No relevant soil information exists. | Ecological sites are not described for the major land resource area. | No, follow DIRH instructions. | No | No, follow DIRH instructions. |

[1] If a soil survey exists, it should include soils/ecological site correlations.
[2] Refer to appendix B-D to develop a reference sheet if one does not exist.

M. Identifying Ecological Sites

(1) Identifying the correct corresponding ecological site with the soil component is imperative in planning and monitoring/assessment activities. Several tools require identification of the ecological site:
(i) Calculating Similarity Index
(ii) Interpreting Indicators of Rangeland Health
(iii) Assessing Apparent Rangeland Trend
(iv) Monitoring plant species composition (e.g., foliar cover, production by species)
(v) Assessing potential forage species for rangeland seedings
(vi) Assessing status of forage production by species
(vii) Evaluating other ecological information in discussions with landowners

(2) Appendices F and G provide detailed instructions for identifying soil map units, soil components, and correlated ecological sites.

N. Approval Process

(1) Responsibilities for ES activity are shared among disciplines, including soil science, range science, forestry, agronomy, wildlife biology, hydrology, and ecology. The steps needed to collect, analyze and synthesize information on-site attributes, site correlation and classification, site dynamics, and site interpretations are all separate, but they must be coordinated so that all ES activity can be efficient (NESH 2017).

(2) NRCS state offices: 1) provide ecological site technical services and assistance within the state as needed; 2) ensure existing ES information is evaluated by knowledgeable personnel; 3) provide technical input during the development of ES information; and 4) ensure it meets the state's needs for conservation planning, implementation, monitoring, and assessment. The state office also works with area and field offices to assist in field data collection and investigations for ES development.

(3) The state office also develops local ecological site interpretations as needed and leads Rangeland Health reference sheet development. State staff have the ability to enter this data into the EDIT (Ecosystem Dynamics Interpretive Tool) with login permissions from the National Ecological Site Team (NEST). Upon login, EDIT provides instructions where field

data can be stored for review, as well as provides Reference Sheet templates for Reference Sheet data input. For a full list of Ecological Site Development Roles and Responsibilities, see the National Ecological Site Handbook (NESH) part 630.3.

## 645.0204 Application of Ecological Sites

Ecological Sites (ESs) and their descriptions (ESDs) are concepts that are used to describe and communicate ecological information at a discrete site level. They are an important tool for providing the ecological basis for evaluating ecosystem health, both in the National Resource Inventory (NRI), and during monitoring and assessment activities. In conservation planning, they are important in developing land management objectives, selecting conservation practices, and communicating ecosystem responses to management (Williams et al. 2016; USDA 2013).

(1) Ecological Applications
- (i) Provide ecological site information to NRCS customers at a finite scale of land classification – the Ecological Site
- (ii) Document and archive information about the ecological dynamics of a site
- (iii) Provide baseline ecological information for hydrologic models, such as Rangeland Hydrology and Erosion Model (RHEM)
- (iv) Provide ecological foundation for soil and plant health
- (v) Plant community baseline data for scientific research and experimental studies
- (vi) Provide baseline ecological information for land health assessments and evaluations
- (vii) Document and archive information about livestock and wildlife grazing and management approaches
- (viii) On-site and watershed scale modeling
- (ix) Use in GIS level modeling tools
- (x) Model and compare management scenarios with vegetation change
- (xi) Management interpretations for wildlife habitat
- (xii) Provides classification for NRI data collection and analyses

(2) Conservation Planning Applications:
- (i) Provide the best available information to assist with resource inventories, identifying resource concern probabilities, setting objectives, and selecting and implementing conservation practices to achieve goals
- (ii) Provide reference conditions for numerous resource management tools (e.g. Interpreting Indicators of Rangeland Health, Rangeland Hydrology and Erosion Model, Determining Indicators of Pastureland Health, Pasture Condition Scoring, Soil Health Assessments, etc.)
- (iii) Selecting suitable native species for restoration projects
- (iv) Selecting suitable forage species for planting on grazed lands
- (v) Risk analysis and assessment of alternatives
- (vi) Performance criteria for ecological outcomes assessment
- (vii) Provide a basis for recommending adaptive changes to management decisions to achieve desired goals and objectives
- (viii) Help prioritize conservation planning and management decisions
- (ix) Provide a basis for interpreting observed resource concerns
- (x) Incorporate climate change and management responses at the individual field and property level

## 645.0205 Accessing Ecological Site Descriptions

Ecological Site Descriptions can be accessed through Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

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## 645.0207 Appendices

### Appendix B-A. – State-and-transition models

**Figure B-A-1.** Example of a rangeland state-and-transition model (Williams et al. 2016) showing fundamental components for hydrologic data (Stringham et al. 2003; Briske et al. 2005, 2006, 2008; Bestelmeyer et al. 2009, 2010).

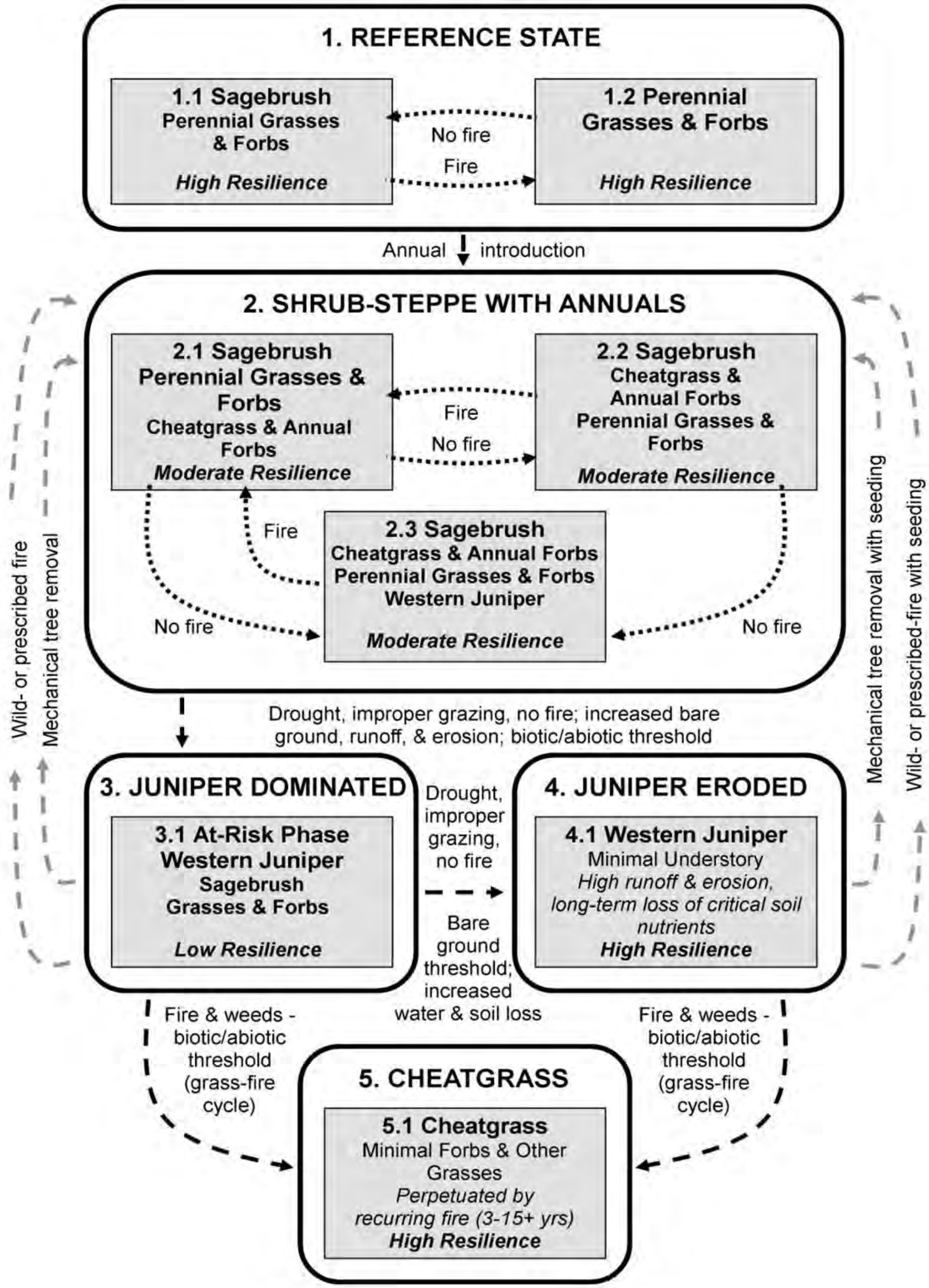
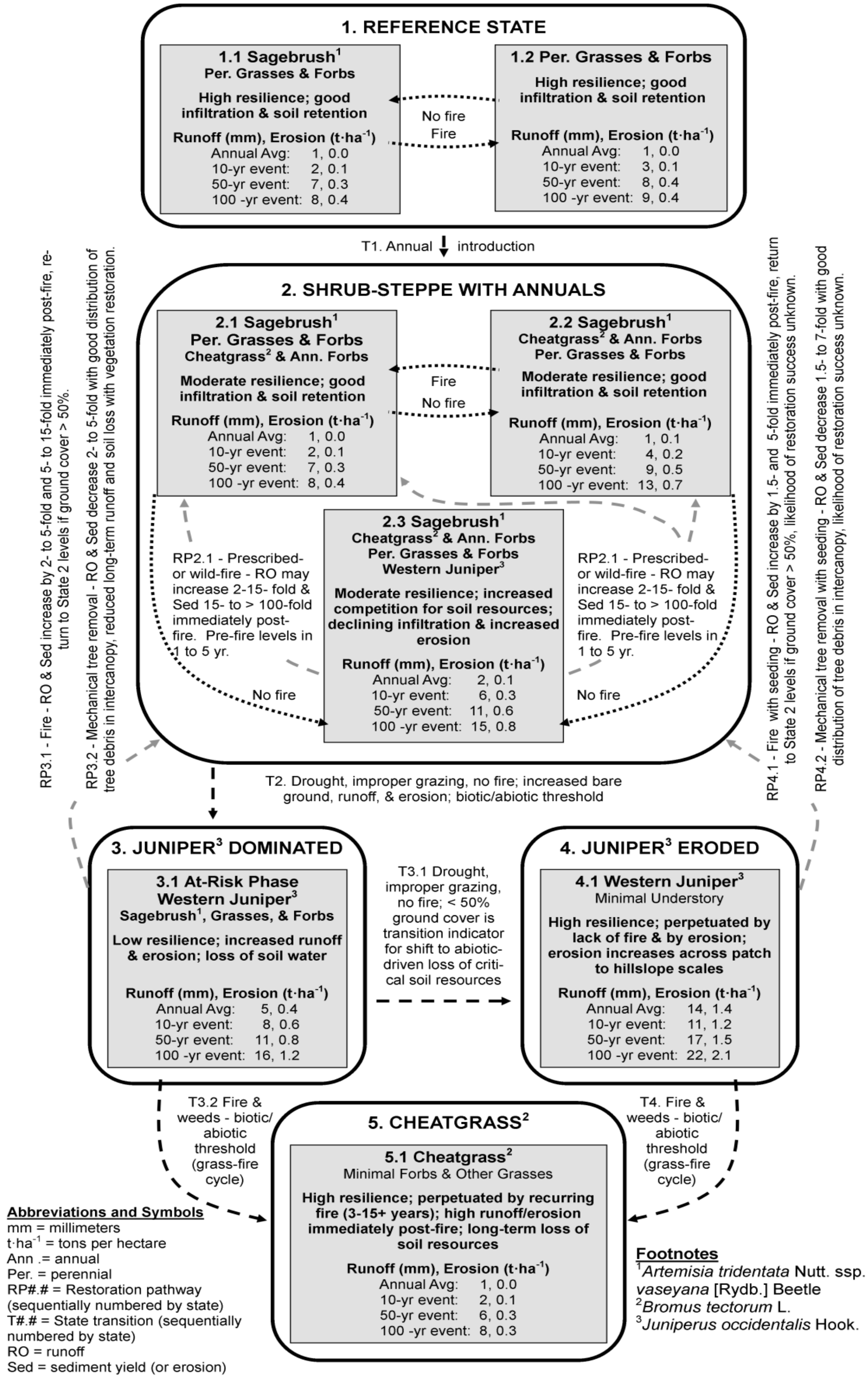


**Figure B-A-2.** State and Transition with hydrology and erosion estimates using RHEM.



## Appendix B-B. – Rangeland Ecological Site Narrative with Emphasis on Hydrology and Erosion (Hydrologic Function)

The tall forb community type extends from the southern Wasatch range in Utah northward into Montana, east and west slopes of the Teton Range on the Idaho-Wyoming border, eastward into the Big Horn Mountains, along the southern border of the Jarbridge Mountains in Idaho-Nevada, the Ruby Mountains of Nevada, and the Uinta Mountains in Utah (Winward 1994). Tall forb communities are not unique to the United States, they also occur worldwide in high elevations throughout Europe, middle Asia, and Eurasia (Seffer et al, 1989; Ermakov 2003; Michl et al. 2010; Nowak et al. 2020). The community type is found on all aspects and slope gradients on deeper soils (>0.5m) and where soil moisture is adequate for nearly season-long plant growth. Representative sites are typically dominated by mixed forbs 16-48 inches (40-122 cm) in height with graminoid species occurring in minor amounts. On the average, perennial forb species comprise about 70-80 percent of the species composition, 20-30 percent grasses and grass-likes, and shrubs (0-2) percent. Average, total annual production is 2,200 lbs/ac (1980 kg ha) in a normal year. Production in a favorable year is 2,800 lbs/ac (2520 kg/ha). Production in an unfavorable year is 1,300 lbs/ac (1,170 kg ha). Tall forb communities occur at elevations between 6,300–10,000 ft (1,920–3,048 m); habitats include small openings in forest, and in larger open parklands within Douglas-fir (*Pseudotsuga menziesii*) and spruce-fir (*Picea engelmannii*-*Abies lasiocarpa*) stands. Tall forb vegetation is commonly associated as an understory layer in mountain big sagebrush *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle (mountain big sagebrush), *Artemisia tridentata* ssp. *spiciformis* (subalpine big sagebrush), *Populus tremuloides* (aspen), and open Douglas-fir and spruce-fir sites when contiguous to tall forbs communities.

Tall forb plant communities have evolved in a montane climate characterized by cool, dry summers and cold, wet winters. Average annual precipitation of this site typically ranges from 22 inches or more. About three-quarters of the moisture is received during the plant dormant winter period (October–May). Frost heaving is common in tall forb communities (Goodrich, 2009). Average frost-free period is from 60–80 days. About half of the total site precipitation occurs as snow and usually remains in place during the winter with some drifting. Annual snowfall averages 150 to 200 inches (381–508 cm) per year.

Temperatures vary significantly between summer and winter and between daily maximums and minimums and is primarily due to high elevation and dry air, which permits rapid incoming and outgoing radiation. Mean annual air temperature is 33.3°F (16.0°F Avg. Min. to 50.6°F Avg. Max.). Prominent forb species found within the tall forb community type include: *Geranium viscosissimum* (Sticky geranium), *Potentilla glandulosa*, *P. groenlandica*, *Geranium richardsonii* (Richardson's geranium), *Balsamorhiza macrophylla* Nutt. (cutleaf balsamroot), *Ligusticum filicinum* (fernleaf licorice-root), *Aconitum columbianum* (Columbia monkshood), *Agastache urticifolia* (nettleleaf), *Osmorhiza occidentalis* (western sweetroot), *Thalictrum fendleri* (meadowrue), *Delphinium* (larkspur spp.), *Hackelia floribunda* (stickseed), *Polygonum douglasii* (knotweed), *Henium hoopesii* (sneezeweed), *Oxalis dichondrifolia* (peonyleaf woodsorrel) (Winward 1994; USDA-NRCS 2009). Major grass species found within the type include *Elymus trachycaulus* (slender wheatgrass), *Bromus carinatus* (mountain bromegrass), *Melica spectabilis* (purple oniongrass), *Achnatherum nelsonii* (Columbia needlegrass), *Phleum alpinum* (alpine timothy), *Poa reflexa* (nodding bluegrass), *Carex raynoldsii* (Raynolds' sedge), and *Carex microptera* (smallwing sedge) (USDA-NRCS 2009).

Herbivory has historically occurred in this community type; herbivores include mule deer, Rocky Mountain elk, and small rodents, especially pocket gophers. Livestock also utilize tall forb plant communities and in general, prolonged heavy grazing by cattle results in forb dominated communities, while heavy sheep use results in grass dominated communities (Ellison 1954; Winward

1994). State and transition changes concomitant with soil loss due to improper management caused by intensive livestock grazing causes a shift from mesic to xeric plant species. When this shift has occurred and state and transition thresholds are crossed (figure B-B-2), species like *Geranium viscosissimum* (sticky purple geranium), *Achillea millefolium* (western yarrow), *Taraxacum officinale* (dandelion), annual invasive mountain tarweed (*Madia glomerata*), and *Lomatium* spp. (biscuitroot) increase and become dominant. Tarweed contains allelopathic substances that inhibit growth of seedlings (Carnahan and Hull 1962). Continual overgrazing and repeated disturbance also result in vegetation shifts to *Wyethia amplexicaulis* (mule-ears), *Veratrum californicum* (California falsehellebore), *Lathyrus lanzwertii* (aspen peavine), and *Rudbeckia* spp. (coneflower) (Winward 1994). There are examples of dominant mules-ear stands in the Bridger-Teton National Forest (figure 1). The species is a highly competitive and aggressive—it monopolizes soil moisture and light and excludes other more desirable species and persists when grazing pressure is reduced or eliminated (Mueggler et al. 1951; Gregory 1983; Matthews 1993). Mule-ears reproduces by seed and resprouts from underground rootstalks or from the plant crown (Mueggler et al. 1951; Young et al. 1979). Another invasive species, *Taraxacum officinale* (common dandelion) is an indicator of livestock driven plant community dynamics, while decreases in dandelion are often associated with pocket gopher activity (USDA-NRCS 2009). Pocket gophers appear to be forb dependent (Goodrich and Cameron 2010), prefer forbs (oniongrass is an exception) and areas with high snow cover, and can enhance infiltration capacity and create open niches for seedling establishment. Soils with pocket gophers and no livestock grazing tend to be looser and more friable with higher total porosity and lower bulk density (USDA-NRCS 2009).

**Figure B-B-1a.** *Wyethia amplexicaulis* (mule-ears), postgrazing.

**Figure B-B-1b.**


b) Midseason, Mule-ears/forb community. Typical dieback of forbs associated with fall has occurred. In addition, light snow has fallen over the area and started to knock over vegetation. The effect of snowfall knocking overvegetation is very similar to that of sheep moving through an area in late summer/early fall at other forb sites observed this grazing season. Livestock have been removed from the area in preparation of winter conditions.

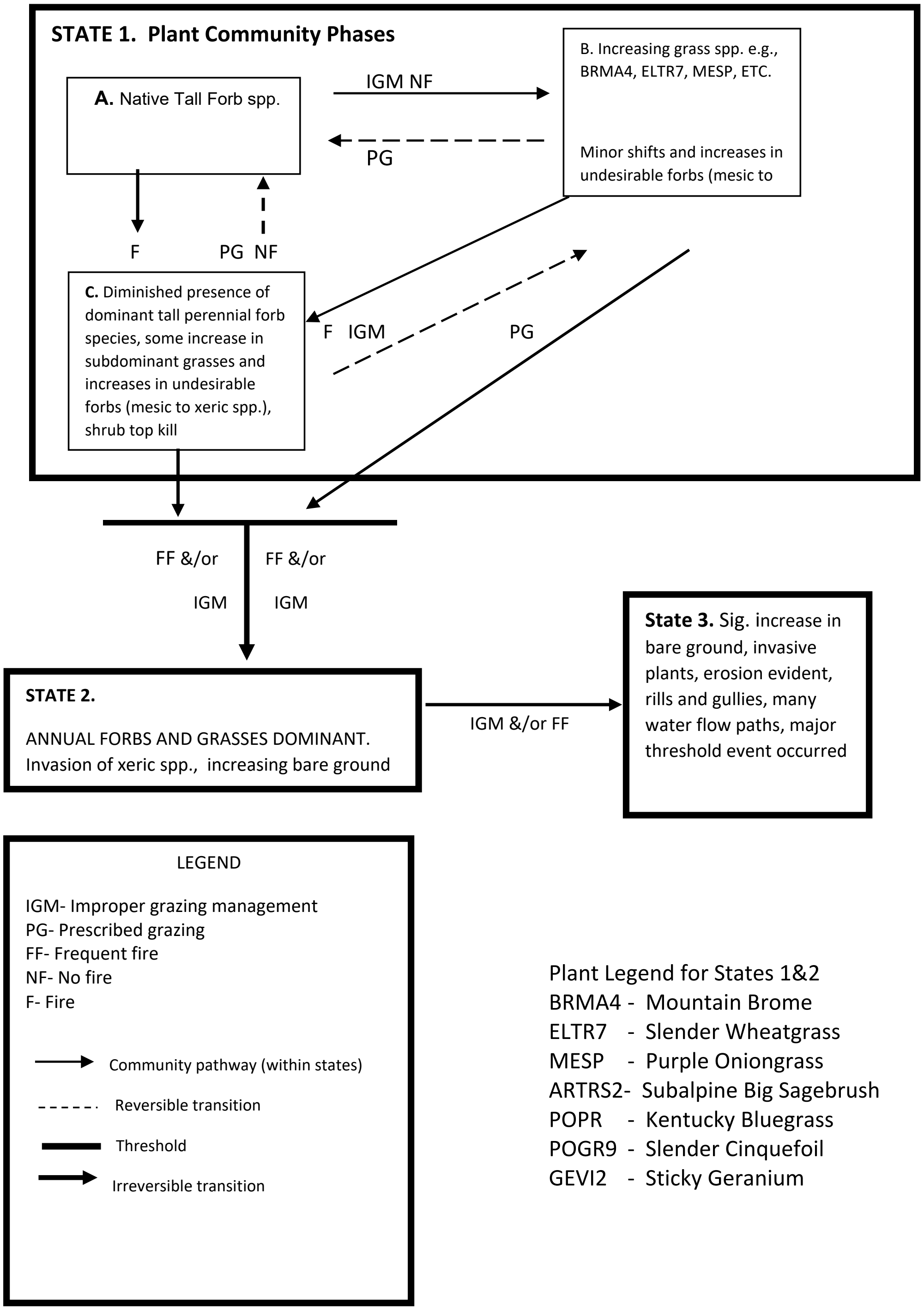
The effects of livestock grazing on soil surface stability and hydrologic function (resistance/resilience) are associated with the degree to which soil surface physical conditions and spatial and temporal changes in plant foliar and ground cover and species composition are altered. Since tall forb communities are prone to increasing bare ground with heavy livestock/wildlife use, the risk of accelerated runoff and soil loss can be significant. This change often accelerates increased water runoff and soil erosion. As with any rangeland plant community, crossing ecological thresholds where soil loss occurs is usually irrevocable (Weltz and Spaeth 2012).

Fire has historically occurred on the site at intervals of 20–50 years. Occasional and frequent fire is a dynamic that affects State 1 and 2 in the Ecological Site state-and-transition model (figure B-B-2). The Historic Plant Community (HPC) is the Reference State (State 1), and movement from State 1A to B and C occurs depending on the natural and anthropogenic disturbances that impact plant community composition and productivity (figure B-B-2).

Maintaining biotic integrity of tall forb plant communities is a key issue, and information about soil and surface stability and hydrologic function are needed to assess risks associated with various management scenarios including grazing by livestock (USFS Preliminary Science Summary June 2020). Tall forb species do not provide significant foliar and ground cover protection against erosion until late spring and early summer, and depauperate conditions advance again in late summer and fall when the leaves senesce (figure B-B-3). Vegetative cover and biomass have a major effect on hydrology and soil loss as indicated by numerous field studies (figure B-B-3) (Tromble et al. 1974; Wood and Blackburn 1981; Gifford 1985; Blackburn et al. 1986; Thurow et al. 1986; Wilcox et al. 1988; Abrahams et al. 1995; Spaeth et al. 1996a,b; Weltz et al. 1998; Williams et al. 2014; Nouwakpo et al. 2018; Zobell et al. 2020; Spaeth 2021). In addition, rainfall simulation experiments have shown that plant life form and individual species (taxa) also can have a profound influence on hydrology and erosion (Dee et al. 1966, Spaeth et al. 1996a, b; Pierson et al. 2002a, b; USDA-NRCS 2020; Spaeth 2021). Levels of foliar cover necessary for site protection against accelerated soil erosion on rangelands vary from 20% in Kenya to 100% for some Australian conditions. Most studies indicate that cover of 50 to 75% is probably sufficient to prevent degradation from accelerated soil erosion processes. However, every soil-plant complex is unique with respect to plant composition and hydrologic dynamics (Gifford 1985). The tall forb plant community type is especially unique with respect to resistance and residency ecological dynamics; therefore, patent management practices associated with rangeland management (prescribed grazing, deferment, prescribed fire, brush and/or herbaceous weed management) may not be remedial in the context of the state-and-transition model or produce desired results in the short-term, or often long-term as well.

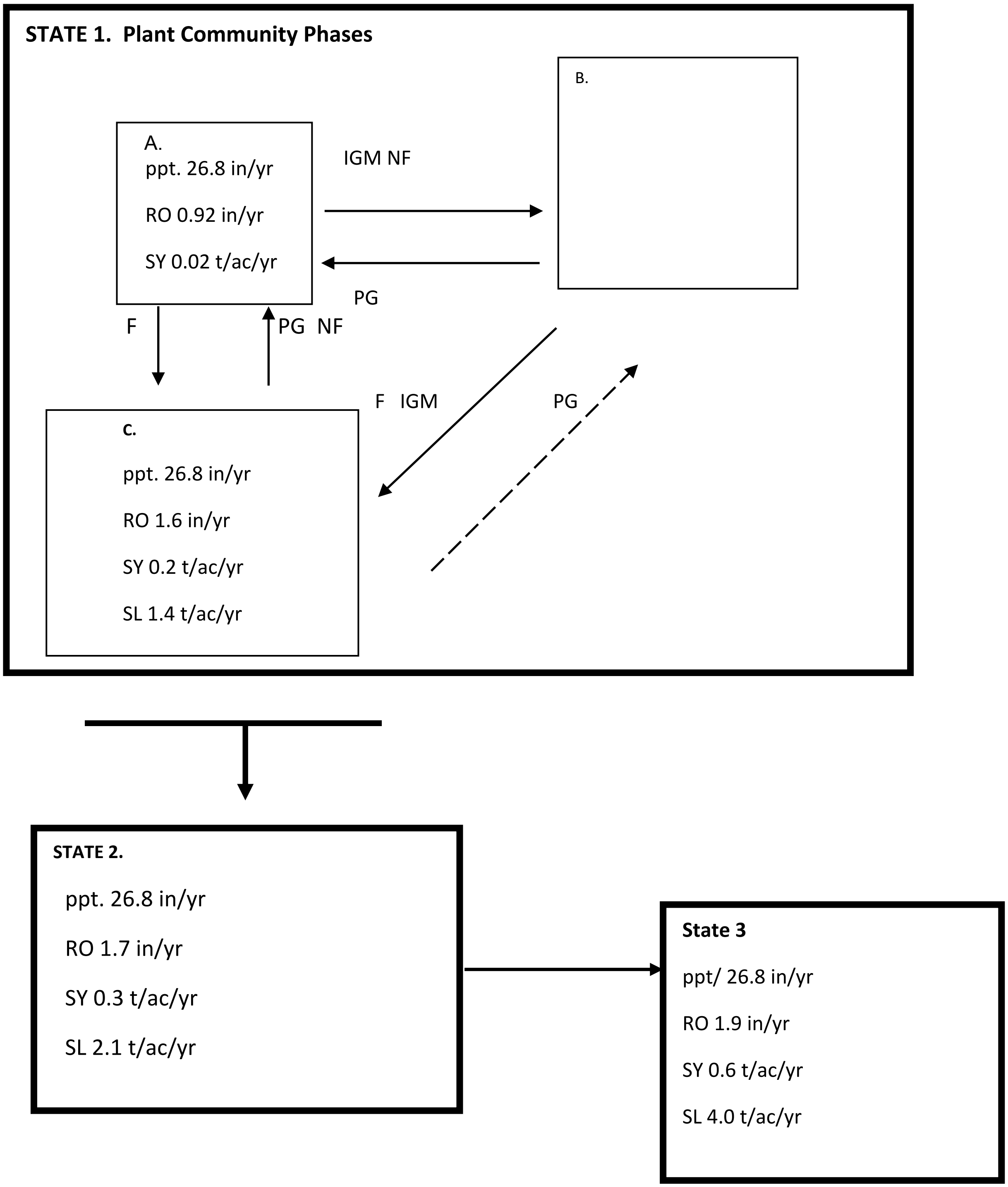
Site conditions relative to tall forb community type physiography; plant foliar, ground cover, and production dynamics; phenological and seasonal changes in plant composition; rodent activity; and grazing by livestock and wildlife all have an effect on hydrologic function. Since soil and surface stability, hydrologic function, and biotic integrity are of primary interest in the tall forb community type, the forthcoming Environmental Impact Statement should evaluate the dynamics of each of these assessments for the major environmental states associated with a benchmark State-and-transition model. Plant species composition and soils can be expected to change among various tall forb ecological sites (ES); however, developing and ES description based on a coarser resolution representing a tall forb association is an important first step to assessing hydrology and erosion dynamics with varied plant community composition and various management scenarios (see figure B-B-3). The Rangeland Hydrology and Erosion Model (RHEM) model utilizes foliar cover by plant growth form (note standing dead including caespitose grasses, sod forming grasses, forbs, shrubs, and trees), and ground cover which includes basal plant stems, litter, rock, and microphytes. Infiltration, runoff, and soil loss is strongly influenced by vegetal foliar cover, ground cover, and biomass (Wilcox et al. 1988; Spaeth et al. 1996 a,b; USDA-NRCS 2020). The effects of livestock grazing on hydrologic resistance/resilience are associated with the degree to which grazing affects surface soil conditions by altering the above dynamics of the plant community. The dynamics and role between foliar and basal cover, and biomass in protecting the soil surface are influenced by temporal changes throughout the year as plants grow and senesce (Spaeth 2021). The relationships of these three parameters are especially important in tall forb communities as vegetation and litter cover and biomass change significantly throughout the growing season.

**Figure B-B-2.** State-and-transition model: Adapted from Ecological Site Description: SUBALPINE LOAMY 22, Site ID: R043BY024ID; Major Land Resource Area E43B.



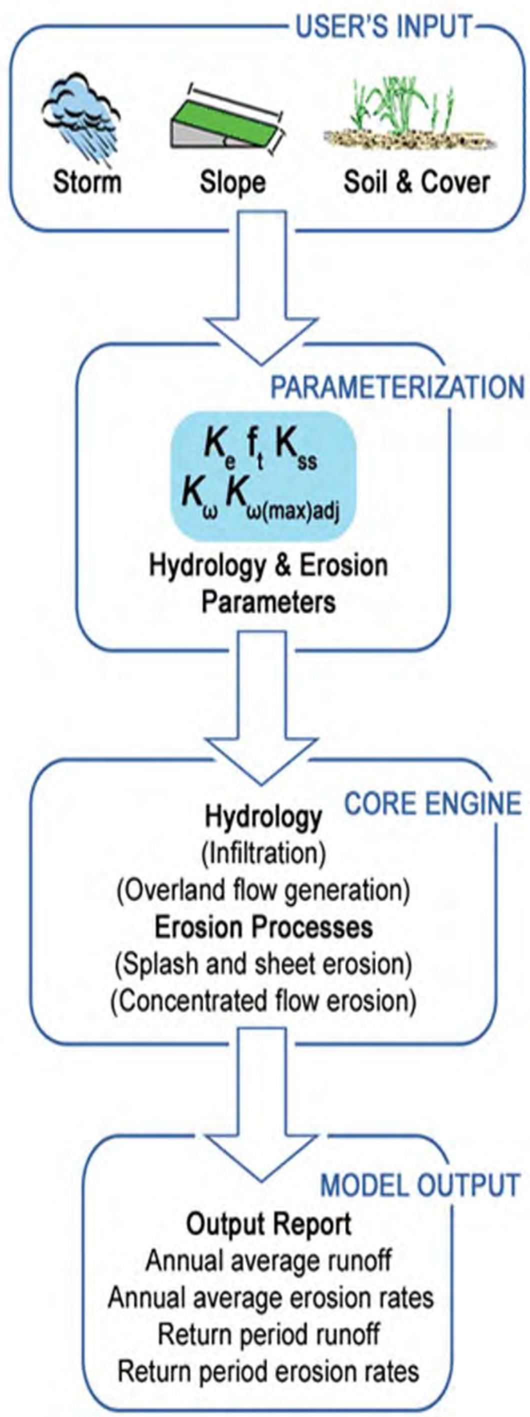

Plant Legend for States 1&2
BRMA4 - Mountain Brome
ELTR7 - Slender Wheatgrass
MESP - Purple Oniongrass
ARTRS2- Subalpine Big Sagebrush
POPR - Kentucky Bluegrass
POGR9 - Slender Cinquefoil
GEVI2 - Sticky Geranium

**Figure B-B-3.** State-and-transition model diagram with RHEM hydrology and erosion assessments. ppt= avg. annual precipitation inches., RO = runoff inches., SY – Sediment yield t/ac/yr, and SL = soil loss t/ac/yr.



The RHEM model is a physically based erosion prediction tool for rangeland applications and is based on fundamentals of infiltration, hydrology, plant science, hydraulics, and erosion mechanics (figure B-B-4) (Nearing et al. 2011).

**Figure B-B-4.** A flowchart of Rangeland Hydrology and Erosion Model (RHEM), from https://apps.tucson.ars.ag.gov/rhem/about.



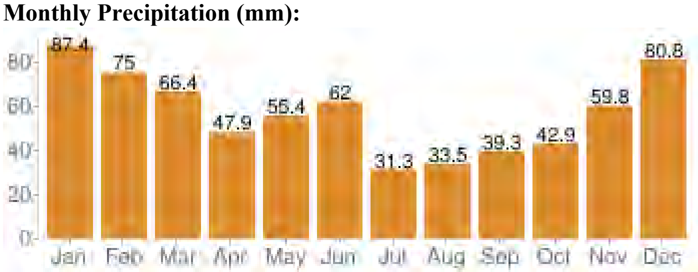
Site environmental variables are used as RHEM model inputs [soil texture, slope length, slope steepness, slope shape, dominant plant life form, percentage of canopy cover, and percentage of ground cover by component (rock, litter, basal area, and microbiotic crusts)]. Climate (precipitation intensity, duration, and frequency) is estimated with the Climate Stochastic Weather Generator (CLIGN) (Nicks et al. 1995) containing 300 years of daily precipitation data. The RHEM model provides estimates of the average annual soil loss during a 300-year time span and for 2-, 5-, 10-, 25-, 50-, and 100-year return runoff events, which provide an assessment of site vulnerability from heavier than average rainfall storm events and the consequences of accelerated soil loss from raindrop splash and sheet-flow, and rill soil-erosion processes.

**Table B-B-1.** Summary of RHEM parameters associated with State-and-transition model. Initial data parameterization of State 1 Reference.

| RHEM Parameters | State 1 Reference | State 1-C | State 2 | State 3 |
|---|---|---|---|---|
| **RHEM Version** | **2.3** | **2.3** | **2.3** | **2.3** |
| State ID | ID | ID | ID | ID |
| Climate Station | Island Park Dam | Island Park Dam | Island Park Dam | Island Park Dam |
| Soil Texture | Silty Clay Loam | Silty Clay Loam | Silty Clay Loam | Silty Clay Loam |
| Soil Water Saturation % | 25 | 25 | 25 | 25 |
| Slope Length (feet) | 164.04 | 164.04 | 164.04 | 164.04 |
| Slope Shape | Concave | Concave | Concave | Concave |
| Slope Steepness % | 18 | 18 | 18 | 18 |
| Bunch Grass Foliar Cover % | 8 | 10 | 15 | 5 |
| Forbs and/or Annual Grasses Foliar Cover % | 68 | 40 | 15 | 5 |
| Shrubs Foliar Cover % | 0 | 0 | 0 | 0 |
| Sod Grass Foliar Cover % | 0 | 0 | 2 | 2 |
| **TOTAL FOLIAR COVER %** | **76** | **50** | **32** | **12** |
| Basal Cover % | 12 | 3 | 2 | 1 |
| Rock Cover % | 10 | 10 | 10 | 10 |
| Litter Cover % | 20 | 5 | 5 | 2 |
| Biological Crusts Cover % | 2 | 2 | 1 | 1 |
| **TOTAL GROUND COVER %** | **44** | **20** | **18** | **14** |

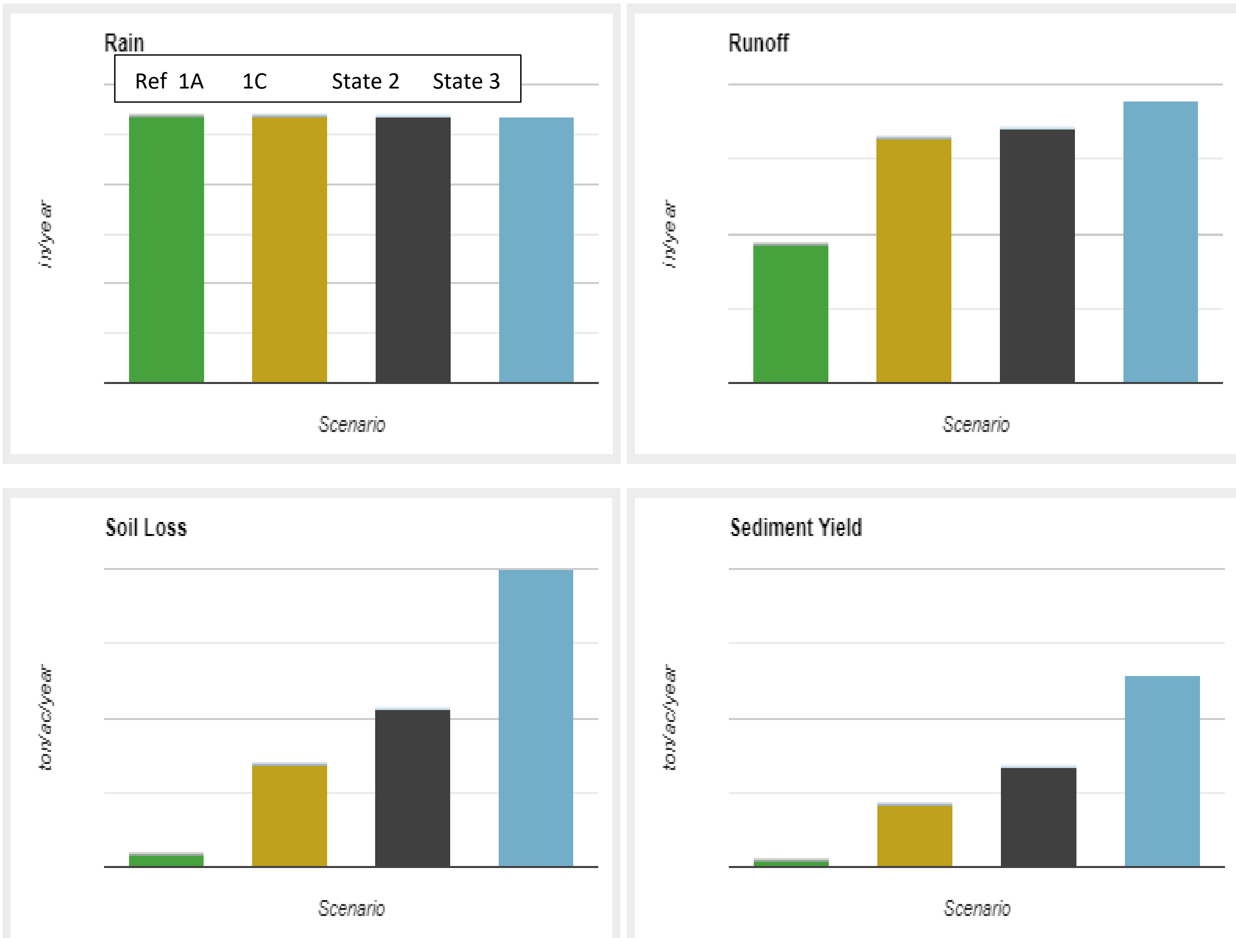
**Name: ISLAND PARK DAM**
**ID: 104598**
**Elevation: 1,920.24 m (6,300 ft)**
**Lat: 44.42 Long: -111.4**

**Avg. Precipitation: 681.66 mm ( 26.84 in )**
**Monthly Precipitation (mm):**




**Currently using this station!**

**Figure B-B-5.** Rangeland Hydrology and Erosion Model (RHEM) data estimates of four ecological states associated and described in State-and-transition model (figure B-B-3). State 1 = Reference State or Historic Plant Community, State 1-C a transitional phase in State 1, State 2, a new state with threshold transformation, and State 3, a new state with permanent threshold transformation.




| | State 1 A Reference | State 1-C | State 2 | State 3 |
|---|---|---|---|---|
| Avg. Precipitation (inches/year) | 26.8 | 26.8 | 26.8 | 26.8 |
| Avg. Runoff (inches/year) | 0.92 | 1.64 | 1.69 | 1.9 |
| Avg. Sediment Yield (ton/ac/year) | 0.02 | 0.21 | 0.34 | 0.6 |
| Avg. Soil Loss (ton/ac/year) | 0.15 | 1.36 | 2.13 | 4.0 |

Figure B-B-5 shows the RHEM output for State 1A, 1C, State 2 and State 3. The values in the graph and table are based on long-term average. In Case Study I, average precipitation is 26.8 in/yr (68 cm/yr). Runoff, soil loss, and sediment yield are shown in figure B-B-5). Runoff in the reference state is negligible (< 1 inch/yr), and almost double in State 1C, State 2, and State 3. Soil loss for reference State 1 was 0.15 tons/ac/yr, and increased 9-fold for State 1C (1.4 tons/ac/yr), 14-fold for State 2 (2.1 tons/ac/yr), and 27-fold for State 3 (4 tons/ac/yr) (for a point of reference, see Text Box 1). Soil loss tolerance factors are commonly used in NRCS (Spaeth 2021). The USDA-NRCS (2018) defines the T-factor as: "the maximum rate of annual soil loss that will permit crop ('or site productivity') productivity to be sustained economically and indefinitely on a given soil." Soil loss tolerance or permissible soil loss/sustainability factors are assigned to most soils by USDA Natural Resources Conservation Service T commonly ranges from 1 to 5 tons/ac/yr (2.2–11.2 Mg/ha/yr), the lower T value is typic of many arid and semiarid rangelands; the upper range is for class 1 cropland soils derived originally from grasslands. In conservation planning, if associated T-factors are less than the assigned value for the soil, then erosion is considered to be at sustainable limits. However, controversy surrounds the T value concept, especially on rangelands: Nearing (2002) contends that T values for US and soils worldwide are inadequate for two reasons: the original science is outdated, and environmental issues have changed. New research is needed and a more scientific approach to the concept is needed. Li et al. (2009) propose that three criteria be considered in developing or revising the concept: 1) soil formation should be considered in determining T values; 2) determine long-term relationships between erosion and productivity, and 3) examine the relationship between soil loss and deterioration of the soil and water quality both on-site and off-site. In figure B-B-5, erosion thresholds are included with state and transition states and phases (figure B-B-2).

Figure B-B-6 has three horizontal lines that represent critical soil loss similar to expected hydrologic and erosion risks with State 3, threshold soil loss which State 2 has crossed and State 1C is at a point where the community can shift to 1B and in time possibly to 1A. The alternatives for state 1C require immediate management changes and action. State 3 has transgressed beyond an environmental threshold and is representative of a permanent state change.

**Figure B-B-6.** RHEM data from figure B-B-5 above with runoff plotted on second Y axis.

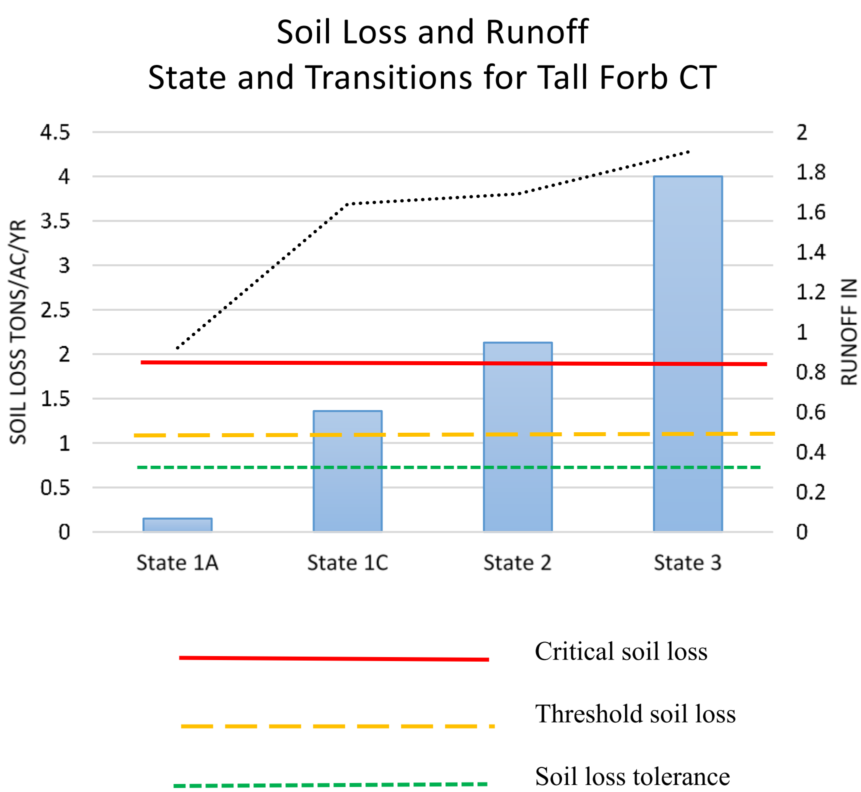
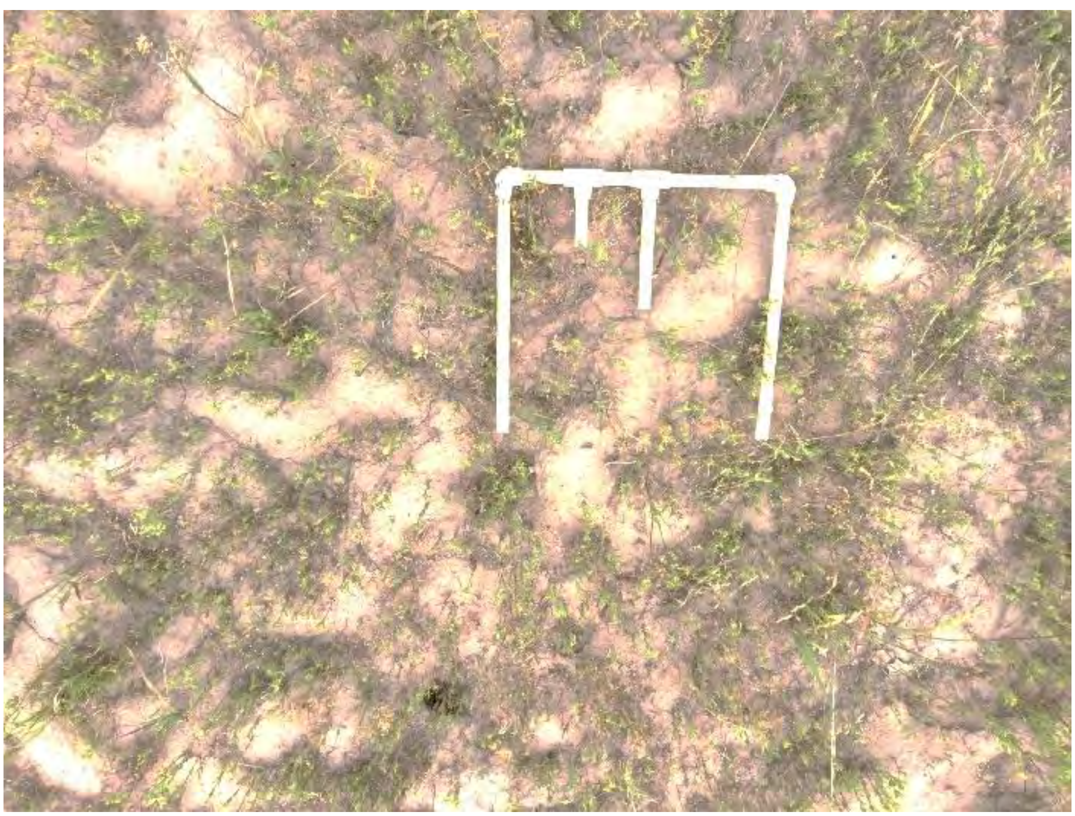


**Figure B-B-7. (a)** Tall Forb Community Type: visual examples of State 1A Reference (Historic Plant Community), **(b)** State 1C phase, **(c)** State 3, complete state transformation.

**a)**

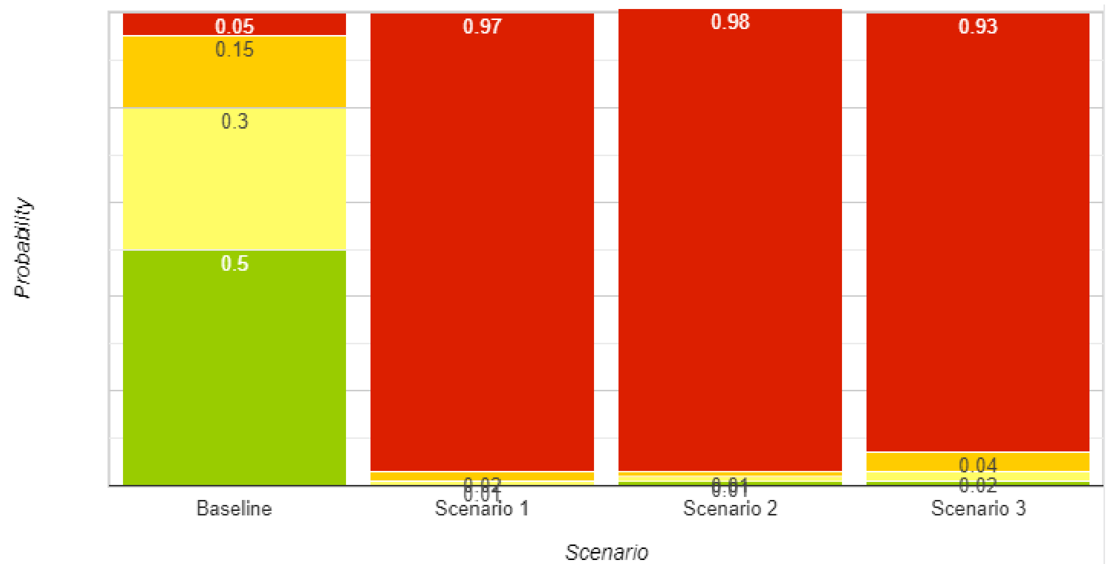
**b)**

c)



## Risk Analyses

**Figure B-B-8.** Graph represents probability classes (Low, Medium, High, or Very High) of soil loss occurrence for any simulation year. Low, Medium, High, and Very High thresholds are based on the 50, 80, and 95 percentiles for probability of occurrence of yearly soil loss for the baseline condition and corresponding comparison scenarios created on parameterization input screen.




For example, the baseline considers that 5% (red bars) of the years are categorized as “Very High” soil loss. The red bars in the other scenarios represent the fraction of years in the RHEM simulation that also fall in the that same range of yearly soil losses as defined in the Probability Classes Soil Loss table below graph. Note that RHEM is reporting soil losses here and not sediment yields, which will be different, particularly when using S-shape or concave slope shapes.

| Probability Classes Soil Loss tons/ac/yr | Baseline (State 1 Ref) | Scenario 1 State 1C | Scenario 2 State 2 | Scenario 3 State 3 |
|---|---|---|---|---|
| Low x < 0.149 | 0.5 | 0 | 0.01 | 0.01 |
| Medium 0.149 <= x < 0.249 | 0.3 | 0.01 | 0.01 | 0.02 |
| High 0.249 <= x < 0.373 | 0.15 | 0.02 | 0.01 | 0.04 |
| Very High x > 0.373 | 0.05 | 0.97 | 0.98 | 0.93 |

In assessing the probability risks for the reference plant community (State 1A), figure B-B-8 shows that there is a 50 percent chance that soil loss will be less than 0.149 tons/ac/yr, a 30 percent chance that soil loss will be between 0.149 and 0.249 tons/ac/yr, a 15 percent chance that soil loss will be between 0.249 and 0.373 tons/ac/yr, and a 5 percent chance that soil loss will be greater than 0.373 tons/ac/yr. In comparison, state 3 has a 1 percent chance that soil loss will be less than 0.149 tons/ac/yr, and a 98 percent chance that soil loss will be greater than 0.373 tons/ac/yr. In table B-B-5, note that average long-term average soil loss is 4 tons/ac/yr, which is a critical level of soil loss and will result in a transition to an eroded site without likely restoration to a facsimile of the original tall forb plant community and diversity dynamics.

**Risks Associated with Design Storm Events**

**Table B-B-2.** Return frequency storm events for Tall Forb Community Type State 1 Ref, State 1C, State 2, and State 3. A return frequency storm is the size of the largest runoff or erosion event that is expected to occur on average once during the designated time period 2–100 years.

2 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 1.388 | 1.388 | 1.388 | 1.388 |
| Runoff (inches) | 0.374 | 0.503 | 0.510 | 0.538 |
| Sediment Yield (ton/ac) | 0.007 | 0.066 | 0.106 | 0.202 |
| Soil Loss (ton/ac) | 0.054 | 0.417 | 0.654 | 1.184 |

5 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 1.826 | 1.826 | 1.826 | 1.826 |
| Runoff (inches) | 0.615 | 0.803 | 0.812 | 0.847 |
| Sediment Yield (ton/ac) | 0.018 | 0.159 | 0.256 | 0.477 |
| Soil Loss (ton/ac) | 0.101 | 0.754 | 1.167 | 2.089 |

10 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 2.215 | 2.215 | 2.215 | 2.215 |
| Runoff (inches) | 0.841 | 1.011 | 1.022 | 1.056 |
| Sediment Yield (ton/ac) | 0.026 | 0.224 | 0.357 | 0.673 |
| Soil Loss (ton/ac) | 0.132 | 0.976 | 1.521 | 2.671 |

25 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 2.701 | 2.701 | 2.701 | 2.701 |
| Runoff (inches) | 1.107 | 1.393 | 1.414 | 1.475 |
| Sediment Yield (ton/ac) | 0.042 | 0.341 | 0.542 | 1.019 |
| Soil Loss (ton/ac) | 0.176 | 1.307 | 2.020 | 3.566 |

50 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 2.912 | 2.912 | 2.912 | 2.912 |
| Runoff (inches) | 1.535 | 1.873 | 1.883 | 1.915 |
| Sediment Yield (ton/ac) | 0.051 | 0.410 | 0.632 | 1.250 |
| Soil Loss (ton/ac) | 0.199 | 1.523 | 2.400 | 4.095 |

100 YEAR RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

| | REF STATE 1A | STATE 1C | STATE 2 | STATE 3 |
|---|---|---|---|---|
| Rain (inches) | 3.989 | 3.989 | 3.989 | 3.989 |
| Runoff (inches) | 1.708 | 2.097 | 2.131 | 2.236 |
| Sediment Yield (ton/ac/yr) | 0.070 | 0.567 | 0.902 | 1.663 |
| Soil Loss (ton/ac/yr) | 0.278 | 2.013 | 3.164 | 5.740 |

**Table B-B-3. (a)** RHEM tables representing storm return frequencies on a daily time-step for State 2, State 2 has departed from reference HPC conditions and according to the State-and-transition model diagram (figure B-B-3) is most likely a permanent shift from State 1; **(b)** RHEM tables representing storm return frequency data based on yearly total.

**a)**

| **State 2: RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY** | | | | | | |
|---|---|---|---|---|---|---|
| **VARIABLE** | **2 YR** | **5 YR** | **10 YR** | **25 YR** | **50 YR** | **100 YR** |
| Rain (inches) | 1.4 | 1.8 | 2.2 | 2.7 | 2.9 | 4.0 |
| Runoff (inches) | 0.5 | 0.8 | 1.0 | 1.4 | 1.9 | 2.1 |
| Soil Loss (ton/ac) | 0.7 | 1.2 | 1.5 | 2.0 | 2.4 | 3.2 |
| Sediment Yield (ton/ac) | 0.1 | 0.3 | 0.4 | 0.5 | 0.6 | 0.9 |

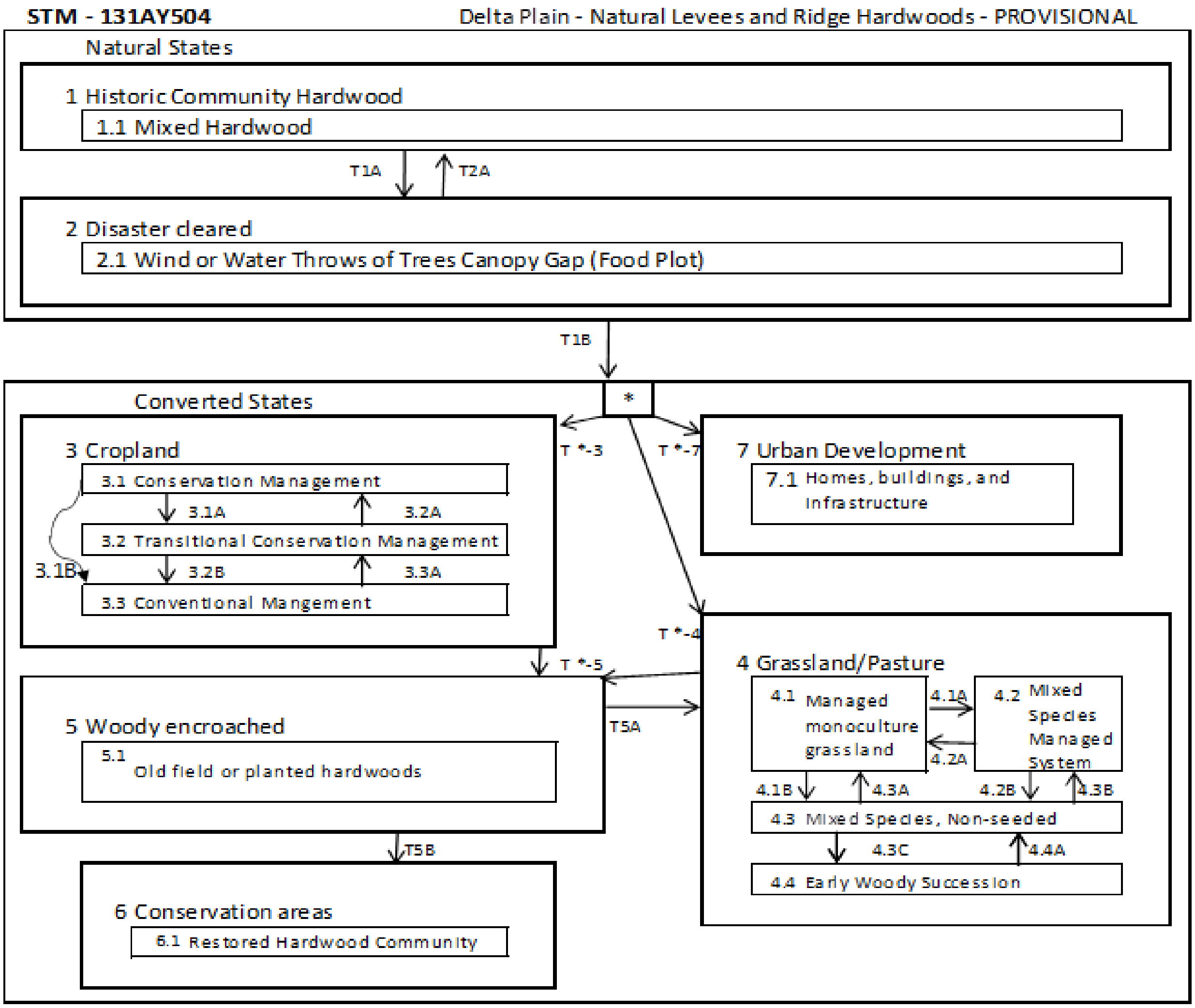
**b)**

| **State 2: RETURN FREQUENCY RESULTS FOR YEARLY TOTALS** | | | | | | |
|---|---|---|---|---|---|---|
| **VARIABLE** | **2 YR** | **5 YR** | **10 YR** | **25 YR** | **50 YR** | **100 YR** |
| Rain (inches) | 20.5 | 24.1 | 25.8 | 27.5 | 29.0 | 31.9 |
| Runoff (inches) | 1.5 | 2.5 | 3.0 | 3.8 | 4.5 | 4.9 |
| Soil Loss (ton/ac/yr) | 1.9 | 3.2 | 4.0 | 4.8 | 5.2 | 6.3 |
| Sediment Yield (ton/ac) | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 |

Table B-B-3 shows the hydrology and soil loss for 2 to 100-year return frequency storms. For example, the long-term average soil loss for state 2 is 2.13 tons/ac/yr (figure B-B-6); however, one 5-year storm event can generate 1.2 tons/acre of soil loss, and the yearly total with a 5-yr storm generated 3.2 tons/ac/yr (table B-B-3b). Likewise, in evaluating a 50-yr storm event for State 2, the long-term average soil loss is 2.13 tons/ac/yr, a 50-yr storm could generate 2.4 tons/ac/yr, and the yearly total including a 50-yr storm could generate 5.2 tons/ac/yr (table B-B-3b). On rangelands, and especially the tall forb plant community, events from single 2–100-year storm events can generate soil loss levels that are either close to or significantly greater than long-term average soil loss rates. It is the rare or high intensity storms that can cause hydrologic events that shift the plant community over a threshold, especially when coupled with low plant cover and improper management from grazing or other uses. Land managers must be cognizant of the effects and risks associated with intense storm events as they can initiate rills that eventually form gullies. In summary, range managers should not be complacent with seemingly low average annual soil loss values, and examine the risks associated with higher intensity storm events.

## Appendix B-C. – Example of Pastureland State as an Alternate Land Use

**Figure B-C-1.** Example of Pastureland state as an alternate land use with state-and-transition model. Ecological site F131AY504LA Delta Plain - Natural Levees and Ridge Hardwoods.



| Diagram Legend | |
|---|---|
| T1A | Wind or water Force causing canopy gaps. |
| T2A | Regeneration of Hardwood species. |
| T1B | Clear and established the desired Community |
| T *-3 | Establish and manage crop rotation. |
| 3.1A | Soil disturbance (Tillage) which reduces Soil Health. |
| 3.2A | No-till, Cover crops, Reduced Till - Soil Health Improvements |
| 3.1B/3.2B | Conventional tillage, seeding, and fertility Management for crops. |
| 3.3A | No-till, Cover crops, Reduced Till with Soil Health Improvements as a goal. |
| T *-4 | Establish desired forage species and manage for grazing. |
| 4.1A/4.3B | Seeding and/or Management for desired species composition |
| 4.2A/4.3A | Seeding, fertilizing, management/ removal of unwanted species |
| 4.1B/4.2B | Species Management without overseeding. |
| 4.3C | Lack of disturbance: No or minimal Mowing, burning, herbivory or Brush Mgmt. and/or Plant or natural regeneration of woody species. |
| 4.4A | Brush mgmt./ removal of unwanted plants |
| T *-5 | Plant or natural regeneration of woody species. |
| T5A | Heavy Brush mgmt. |
| T5B | Manage succession for historic community. |
| T *-7 | Construct and maintain urban infrastructure. |

**State 4**

**Converted State - Pasture or Grassland**

**Figure B-C-2.** Photo of converted state, pasture or grassland (see Fig. B-C-1 state-and-transition model).

**Pasture or Grassland**

This state is characterized by a monoculture or a mixture of forage species that have been planted or allowed to establish from naturalized species. Pasture and Hayland Group 2C - Deep bottomland soils with loamy surface layers and loamy subsoils. Somewhat poorly drained to well drained alkaline bottomlandsoils of high natural fertility. 0–8% slopes. Most slopes are 0–3%. Only a few soils occur on 3–5% slopes.

This site is suited for forage production; however, there are some natural wetness limitations. When site hydrology has been altered with drainage systems, forage species may be established. Drainage system control must be implemented and maintained as wet conditions will reduce forage growth production and limit the ability of livestock to graze. When the site is utilized for forage production, wetness conditions and/or flooding must be monitored to prevent loss of livestock or forage crop. Additionally, adjacent higher elevation areas or protected areas may be needed for the storage of harvested forage or holding of livestock when wet or flooded conditions occur. Some forage operations on this site may not experience extreme wetness events in any year; however, preplanning and resources to meet the needs of the livestock should be part of the operational plan.

Nitrogen fertilization is required for higher levels of grass production. It is not practical to apply high rates of fertilizer due to the wetness limitation potential of the site which normally occurs from December through June. To prevent extreme acidity in the subsoil when high rates of acidifying nitrogen are used, the surface soil should not be allowed to become more acid than 5.0 pH and lime should be applied at more frequent intervals.

**Adapted Grasses and Legumes**

Hybrid bermudagrass, common bermudagrass, dallisgrass, bahiagrass, and johnsongrass are the better adapted warm season perennials. Overflow hazards should be controlled to reduce the limitations of forage species. A variety of clover species are having varying degrees of success, depending on site conditions and annual climate trends (arrowleaf clover, berseem clover, crimson clover red clover, white clover, subterranean clover, ball clover, balsana clover, vetch, winter peas). Seeding dates range from mid-September to mid-November (see LSU Cool Season Pasture and Forage Varieties Pub. 2334). Legumes do not commonly persist as long-term perennial stands on this site. Periodic brush control is needed to prevent the area from reverting to woodland.

**Dominant Resource Concerns**

- Classic gully erosion
- Compaction
- Organic matter depletion
- Aggregate instability
- Nutrients transported to surface water
- Pesticides transported to surface water
- Objectionable odors
- Plant productivity and health Plant structure and composition
- Plant pest pressure
- Feed and forage imbalance
- Inadequate livestock shelter
- Inadequate livestock water quantity, quality, and distribution

**Community 4.1**

**Managed monoculture grassland**

Typically, this phase is characterized by planting forage species for hay production. Forage plantings generally consist of a single grass species. Introduced native and/or non-native forage species can be seeded. Forage is usually harvested as hay or haylage, although grazing may occur periodically. These sites are highly productive for forage and can provide ecological benefits to control soil erosion. Allowing for adequate rest and regrowth of desired species is required to maintain sustained productivity. Maintenance of monoculture stands also requires control of unwanted species which will require Pest Management and Nutrient Management to maintain the needed fertility for production of the species.

Generally, application of fertilizer and lime, is needed to establish and maintain improved desirable pastures. Bahiagrass and common bermudagrass, may be sustained under natural fertility and pH levels. Introduced legumes require higher pH, phosphorus, and potassium levels than most grasses. Introduced grasses, such as hybrid bermudagrass, require a higher level of sustained fertility, maintain pH above 6.0, and good surface drainage, to persist. Implementation of managed grazing of grass species will promote deeper root growth in the soil profile in order to tap into the available nutrient reservoir and available moisture.

Conservation practices should include Managed Grazing, or Forage Harvest Management, Nutrient and Pest Management and other site-specific facilitating practices.

**Dominant plant species**

- Bermudagrass (*Cynodon dactylon*)
- Bahiagrass (*Paspalum notatum*)
- Dallisgrass (*Paspalum dilatatum*)

Dominant resource concerns: Plant productivity and health Plant structure and composition Feed and forage imbalance.

**Table B-C-1.** Annual production by plant type.

| Plant Type | Low (lbs/Acre) | Representative Value (lbs/Acre) | High (lbs/Acre) |
|---|---|---|---|
| Grass/Grasslike | 6,000 | 8,000 | 10,000 |
| Total | 6,000 | 8,000 | 10,000 |

## Growth Curves

**Figure B-C-3.** Plant community growth curve (percent production by month). LA0001, Hybrid Bermuda grass.

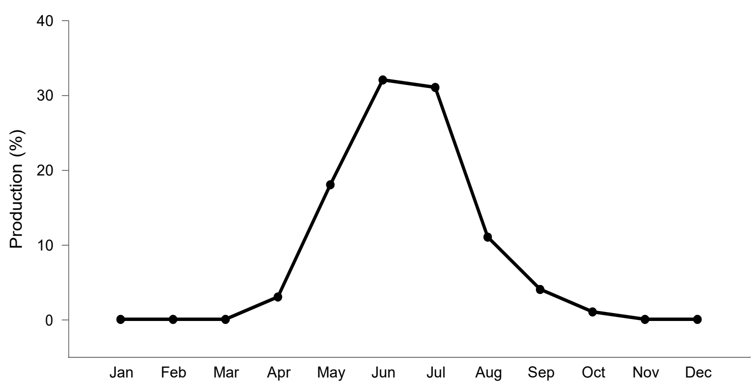


**Figure B-C-4.** Plant community growth curve (percent production by month). LA0006, Common Bermudagrass.

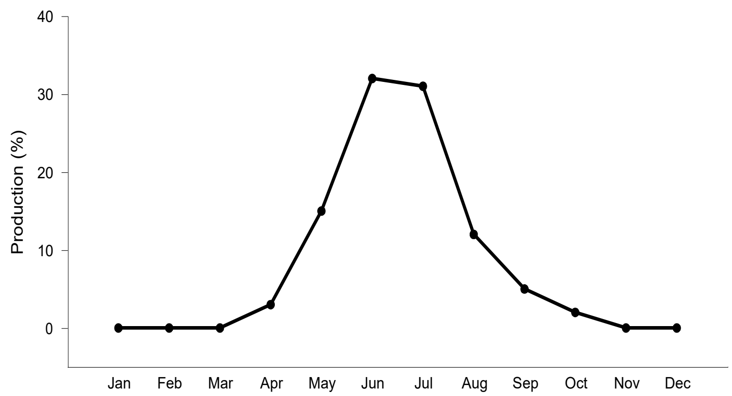



**Figure B-C-5.** Plant community growth curve (percent production by month). LA0012, Bahia grass.

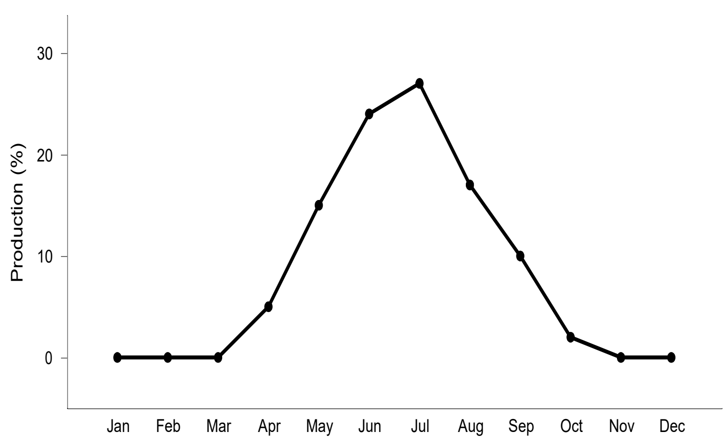
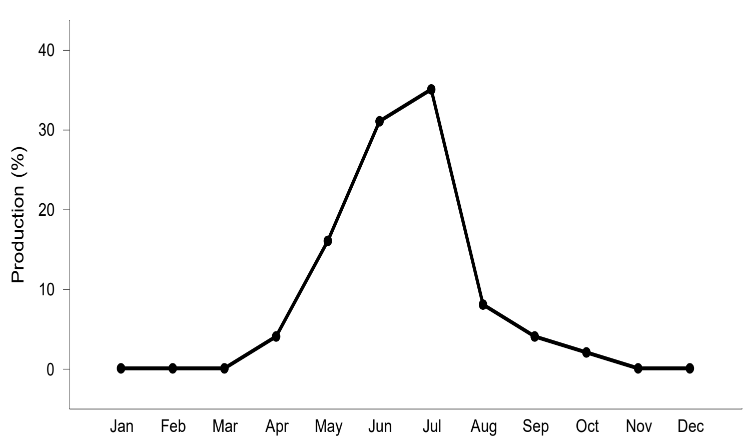



**Figure B-C-6.** Plant community growth curve (percent production by month). LA0016, Dallisgrass.



**Community 4.2**

**Mixed Species Managed System**

**Figure B-C-7.** Photo of mixed species managed system (see figure B-C-1 state-and-transition model).

This community is characterized by mixed species composition of grasses and legumes, which are planted or establish naturally. Typically introduced perennial warm season grasses are the foundation of the stand which is periodically over seeded with adapted cool season forages such as annual rye and legumes to extend the grazing season. This community phase can be highly productive for grazing and haying operations and can provide beneficial habitat for some wildlife species.

Maintenance of grass stands also requires a collection of management practices such as managed grazing, brush management, pest management, and nutrient management to maintain production of the desired species. Managed grazing includes maintaining proper grazing heights, timing, and stocking rates. Supporting or facilitating practices including fences, water lines and watering facilities can be used to maintain this state phase.

**Dominant resource concerns**

Compaction, inadequate livestock water quantity, quality, and distribution

## Community 4.3

### Mixed Species, Non-seeded

**Figure B-C-8.** Photo of mixed species, non-seeded pasture state (see figure B-C-1 state-and-transition model).

This community is characterized by a stand where non-seeded mixtures of native and naturalized non-native species occur. This state phase is associated with abandonment of cropping i.e., idle cropland that is not being utilized for forage production. This phase represents low management inputs after cropping such as no initial seeding of pasture species or periodic attempts of over seeding with adapted forage species. Forage is usually grazed and/or harvested as stored forage, hay or haylage. Common established species may include Bermudagrass, Bahia grass, Vasey grass, and carpet grass. This state is productive, forage and grazing management can maintain forage stands and protect soils from excessive runoff and erosion. A common hazard associated with this phase is overgrazing which favors less productive and less palatable weedy species, especially in areas where livestock congregate. Proper stocking rates and/or grazing systems that allow for adequate rest and plant regrowth are required to maintain productivity.

When forage species are afforded adequate recovery time between grazing intervals, they will develop deeper root systems and greater leaf area allowing for the capture of greater solar energy allowing adequate photosynthetic fixation of carbohydrates for plant growth. Conversely when plants are not allowed to recover adequately, root development will be restricted, and forage and biomass production will be reduced. Maintenance of grass stands also requires pest management for control of unwanted weedy and woody species.

### Dominant resource concerns

Sheet and rill erosion, compaction, plant productivity and health, plant structure and composition, feed and forage imbalance

**Community 4.4**

**Early Woody Succession**

**Figure B-C-9.** Photo of early woody succession state (see figure B-C-1 state-and-transition model).

When the ecological threshold is crossed to where the stem diameter exceeds 2–3 inches and tree densities exceed 100–300 stems per acre, the site has transitioned to the Woody Encroached State. This community is characterized by diverse species composition of grasses and forbs with an increasing composition of woody species (native and non-native) that are immature and low stature. If this community phase is not managed, and no brush management measures are taken, the plant community will transition to the woodland encroached State (5). Control of woody species will require input of extensive resources to return to a grassland or cropland state. In this phase, woody stature is large enough to inhibit agricultural cropping implements and equipment to return the site to a cropland phase. Woody invasive species grow quickly and can be difficult and expensive to control. Some Invasive woody species, such as tallow trees (*Triadica sebifera*) will invade and grow to produce seeds in as few as three years. If the restored hardwood community is desired, proper management is required to control invasive plants. This phase can be beneficial habitat for some wildlife species.

**Dominant Resource Concerns**

Sheet and rill erosion, compaction, plant productivity and health, feed and forage imbalance.

## Appendix B-D. – Example Rangeland health reference sheet

**Loamy Hills HX076XY115**

**Indicators**

1. **Rills:** No natural rill formation common on the Loamy Hills ecological site.

2. **Water flow patterns:** Natural water flow patterns are vegetated and non-scoured. Visual inspection should not find litter, soil, gravel redistribution, or pedestalling of vegetation or stones that intercept the flow of water as a result of overland flow. On steeper slopes, 15-30%, water flow patterns may be more apparent due to site steepness but remain stable and vegetated.

3. **Pedestals or terracettes:** There is no evidence of pedestals or terracettes that would indicate the movement of soil by water and/or by wind on this site.

4. **Bare ground:** Averages of less than 5% bare ground. Bare ground on this site is the remaining ground cover after accounting for ground cover [vegetation (basal and canopy [foliar] cover), litter, standing dead vegetation, gravel/rock, and visible biological crust (e.g., lichen, mosses, algae)].

5. **Gullies:** No evidence of accelerated water flow resulting in downcutting or formation of gullies.

6. **Wind scoured and/or depositional areas:** No wind-scoured or blowout areas where the finer particles of the topsoil have blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface. No areas of redeposited soil from other sites due to the wind erosion and deposition.

7. **Litter movement:** No evidence of litter movement (i.e., dead plant material that is in contact with the soil surface on shallow slopes). On slopes greater that 15%, some movement may be observable from recent higher intensity storms. Litter dams are not expected.

8. **Soil surface resistance to erosion:** Soil surface aggregates are stabilized by soil organic matter which has been fully incorporated into aggregates at the soil surface, adhesion of decomposing organic matter to the soil surface, and biological crusts. Soil stability from the soil stability test should be in the range of 5-6. Soil stability may temporarily decline following fire due to hydrophobicity of organic materials on the soil surface.

9. **Soil surface loss and degradation:** Labette OSD: Using clay loam surface texture, and Manhattan KS climate station. Cover values 95% bunchgrass, 1% sod grasses, 3% forbs, 1% shrubs.

   At 0–5% slope, Rangeland Hydrology and Erosion Model (RHEM) prediction < 0.6 tons/ac; 5–10% slope < 0.8 tons/ac; 10–15% slope < 1.0 tons/ac; 15–30% slope < 2.5 tons/ac.

**Table B-D-1.** RHEM Model parameters.

| RHEM parameters | 0–5% | 5–10% | 10–15% | 15–30% |
|---|---|---|---|---|
| Avg. Precipitation (inches/year) | 32.548 | 32.548 | 32.548 | 32.548 |
| Avg. Runoff (inches/year) | 8.321 | 8.415 | 8.447 | 8.443 |
| Avg. Sediment Yield (ton/ac/year) | 0.584 | 0.800 | 1.083 | 2.451 |
| Avg. Soil Loss (ton/ac/year) | 0.587 | 0.804 | 1.089 | 2.469 |

In the Interpreting Indicators of Rangeland Health manual, examples of using the RHEM model are not discussed. However, RHEM predictions of current soil erosion can provide an indicator of active erosion compared to a reference condition.

A--0 to 23 centimeters (0 to 9 inches); very dark gray (10YR 3/1) silty clay loam, very dark brown (10YR 2/2) moist; strong fine and medium granular structure; slightly hard, friable, slightly plastic and slightly sticky; few tubular pores; many fine roots; slightly acid; gradual smooth boundary, 15 to 30 centimeters thick (6 to 12 inches).

BA--23 to 38 centimeters (9 to 15 inches); very dark grayish brown (10YR 3/2) silty clay loam, very dark brown (10YR 2/2) moist; strong fine and very fine subangular blocky structure; hard, firm, slightly plastic and slightly sticky; many tubular pores; many fine roots; slightly acid; gradual smooth boundary, 0 to 20 centimeters thick (0 to 8 inches).

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10. **Effect of community composition and distribution on infiltration:** Deep rooted perennial bunchgrasses comprise the plant functional and structural groups of the Reference Plant Community (see functional and structural group worksheet) and plant composition tables in ESD. Transitions to sod forming species beginning in state 1.2 can be associated with higher runoff potential and less infiltration capacity. As the site transgresses toward state 1.2 and other states outside of reference conditions, overall site water balance is affected with less water storage for plant growth and subsequent production.

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11. **Compaction layer:** No compaction layers (0–6 in) occurs naturally on this site. Soil structure is similar to that described in Indicator 9. If soil is compacted, physical features will include platy, blocky, dense soil structure over less dense soil layers, horizontal root growth, and increase bulk density.

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12. **Functional/Structural Groups:** This site is dominated by native warm season tallgrasses, with lesser percentages of subdominant midgrasses and shortgrasses (about 86% of total production). Cool season native grasses are also an important component of this ecological site (0.4–2% of total production). Native forbs comprise about 12% of the total production, and shrub/vines about 2%.

**Relative Dominance of F/S Groups for Community Phases in the Reference State**
**Minimum expected number of species for dominant and subdominant groups is included in parenthesis**

**Dominance Category**

Dominant (5 FSG):

Group 1 Tallgrass dominant (30–60% of RV production; 1500–3000 lbs/ac). Big bluestem (1500–3000 lbs/ac); Indiangrass (200–610 lbs/ac), switchgrass (150–405 lbs/ac); composite dropseed (20–100 lbs/ac), and eastern gamagrass (0–405 lbs/ac).

Subdominant (4 FSG):
Group 2 Midgrass subdominant (16–22% RV production; 800–1100 lbs/ac). Little bluestem (800–1010 lbs/ac); sideoats grama (20–100 lbs/ac); purple lovegrass (0–50 lbs/ac); and porcupinegrass (0–50 lbs/ac).

Minor Graminoids (8 FSG):
Group 3 Shortgrass trace (1–2% RV production; 60–100 lbs/ac). Blue grama (0–70 lbs/ac), hairy grama (0–40 lbs/ac).
Group 4 Cool-season grass Trace (0.4–2% RV production; 20–100 lbs/ac). Western wheatgrass (10–50 lbs/ac), sedge (0–25 lbs/ac), Canada wildrye (10–50 lbs/ac), Virginia wildrye (0–30 lbs/ac), prairie junegrass (0–25 lbs/ac), Scribner's rosette grass (0–40 lbs/ac).
Minor Forbs (5 FSG, includes dominant forbs)
Group 5 forbs (5–12% RV production; 250–600 lbs/ac). Three most dominant forb species are compassplant, Nutgall's sensitive briar, and Illinois bundleflower. See reference plant community for entire list.
Minor Shrubs (2 FSG)
Group 6 shrub (0.5–2% RV production; 25–100 lbs/ac). leadplant (15–50 lbs/ac), Jersey tea 15–50 lbs/ac).

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13. **Dead of dying plant parts:** Recruitment of plants is occurring and there is a mixture of many age classes of plants. The majority of the plants are alive and vigorous. Some mortality and decadence is expected for the site, due to drought, unexpected wildfire, or a combination of the two events. This would be expected for both dominant and subdominant groups.

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14. **Litter cover and depth:** Plant litter is distributed evenly throughout the site. There is no restriction to plant regeneration due to depth of litter. When prescribed burning is implemented, there will be little litter the first half of the growing season.

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15. **Annual production:** Native species, current year growing season production is included in production data (introduced species are not calculated). Site potential (total annual production) ranges from 3,000 lbs in a below-average rainfall year and 6,500 lbs in an above-average rainfall year. The representative value for this site is 5,000 lbs production per year (see ESD species composition table).

---

16. **Invasive Plants:** Reference plant community--no noxious weeds present. Common invasive native plants are osage orange, honeylocust, elms, and eastern redcedar. These species are not components of the native plant composition on this site. Invasive species composition > 2% foliar cover is indicative of shifts to slight to moderate departure.

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17. **Vigor with an emphasis on reproductive capability of perennial plants:** Plants in all functional structural groups are capable of reproducing annually under normal climate conditions. Current management activities (principally grazing) do not adversely affect the capability of plants to reproduce.

## Appendix B-E. – Example of Ecological Site Matrix with Corresponding Rangeland Health Reference Sheet

**Ecological Site: R151XY005LA; Brackish Firm Mineral Marsh 55–64 PZ.**

**Reference data for rangeland health matrix.**

**State 1.1 Reference Community:** Saltmeadow cordgrass / Bulrush / Seashore Paspalum Community

Saltmeadow cordgrass (*Spartina patens*) is the dominant species in this phase. Saltmeadow cordgrass is typically found where salinity levels are between 3 and 9 ppt and water depth is up to 6 inches. Secondary herbaceous vegetation is directly influenced by factors such as elevation, water depth, and salinity. Variations in one or more of these factors can result in the plant community shifting back and forth from species that are typically associated with more saline conditions to species that are generally associated with fresh marsh.

Seashore paspalum (*Paspalum vaginatum*), chairmakers bulrush (*Schoenoplectus americanus*), saltmarsh bulrush (*Bolboschoenus robustus*), and California bulrush (*Schoenoplectus californicus*) are the most significant sub-dominant species. Seashore saltgrass is found in the drainageways within the site. Seashore paspalum can withstand more saline conditions and longer periods of inundation than saltmeadow cordgrass. Low growing and sod-forming grasses and grass-like plants such as dwarf spikerush (*Eleocharis parvula*), and fragrant flatsedge (*Cyperus odoratus*) are minor components of this plant community. Common reed (*Phragmites asutralis*) occurs in areas that are fresh water or slightly elevated. Widgeongrass (*Ruppia martitima*) is a submerged aquatic species that is typically found in open water areas within the brackish marsh and is an excellent duck food.

The primary forbs found on this site are southern cattail (*Typha domingensis*), saltmarsh morningglory (*Ipomoea sagittate*), and Virginia saltmarsh mallow (*Kosteletzkya virginica*). Shrubs are rare to non-existent on this site in its pristine state, however a few widely scattered shrubs may occur. Those shrubby species may include Jesuit’s bark (*Iva frutescens*), eastern baccharis (*Baccharis halimifolia*), and California desert-thorn (*Lycium carolinianum*). Fire is a major management tool for this plant community. Without fire the accumulated saltmeadow cordgrass not only suppresses other vegetation, but it can also reduce its own annual production because the old growth suppresses the potential for new, vigorous growth. Prescribed fire allows species such as dwarf spikerush and seashore saltgrass to increase both spatially and in biomass production.

**Table B-E-2.** Species production estimate Table for ESD.

| Plant Type | Low (lbs/acre) | Representative Value (lbs/acre) | High (lbs/acre) |
|---|---:|---:|---:|
| Grass/Grasslike | 4,500 | 11,150 | 13,500 |
| Forb | 500 | 750 | 1,250 |
| Shrub/Vine | 10 | 100 | 250 |
| Total | 5,010 | 12,000 | 15,000 |

**Figure B-E-1.** Evaluation Matrix: R151XY005LA; Brackish Firm Mineral Marsh 55–64 PZ.

*State*_________ *Office*_________ *Date* ____________
*Authors:*________________________________________________________________

| Departure from Reference Sheet | | | | | |
|---|---|---|---|---|---|
| **Indicator** | **Extreme to Total** | **Moderate to Extreme** | **Moderate** | **Slight to Moderate** | **None to Slight** |
| **1. Rills** | No past or recent rills evident. | No past or recent rills evident. | No past or recent rills evident. | No past or recent rills evident. | No past or recent rills evident. |
| **2. Water Flow Patterns** | Water flow patterns are extensive and numerous, unstable with active erosion/ scouring or extensive recent deposition. | More numerous than expected; deposition and cut areas common. | Nearly matches what is expected for the site; erosion is minor with some instability. Some deposition occurring. | Little evidence of minor erosion. Flow patterns are stable and occasional to frequent tidal surge or overwash from adjacent beach area. | Water flow patterns are stable and well vegetated. Minimal evidence of past or current deposition. |
| **3. Pedestals and/or Terracettes** | Abundant active pedestalling and numerous terracettes. | Moderate active pedestalling; Terracettes common. | Slight active pedestalling mainly in flow paths and interspaces. Occasional terracettes present. | No active pedestaling or terracette formation Some evidence of past pedestal formation especially in flow paths. | Typically none – Cordgrass spp. can pedestal naturally as material gets deposited around the plant and then gets naturally eroded off. |
| **4. Bare Ground** | Bare ground is >30%. | Bare ground 20–30%. | Bare ground 10–20%. | Bare ground 5–10%. | Generally, bare ground should be less than 5% and randomly distributed throughout. |
| **5. Gullies** | Common, with active erosion. No vegetation present. | Moderate in number with indications of active erosion, vegetation is infrequent. | Occasional in number with indications of active erosion; vegetation is intermittent. | Uncommon, vegetation is stabilizing the bed. No signs of active erosion. | Typical gullies are not evident on site. Scour channels from past storm events may be present but are stable. |
| **6. Wind Scoured, Blowout, and/or Depositional Areas** | N/A | N/A | N/A | N/A | N/A |

| Departure from Reference Sheet | | | | | |
|---|---|---|---|---|---|
| **Indicator** | **Extreme to Total** | **Moderate to Extreme** | **Moderate** | **Slight to Moderate** | **None to Slight** |
| **7. Litter Movement (wind or water)** | Large amounts of litter and debris are deposited, removed or moved from place to place on the site by intense storms or tidal surge. | Significant amounts of litter moved from place to place on the site by intense storms or tidal surge. | Moderate amounts of litter moved from place to place on the site by intense storms or tidal surge. | Slight movement except with intense storms or tidal surge. | Litter movement infrequent except with intense storms or tidal surge. |
| **8. Soil Surface Resistance to Erosion** | Soil surface stability is severely reduced. | Soil surface is slightly stable. | Soil surface is moderately stable. | Soil surface is stable but showing signs of reduced aggregates and organic matter. | Soil surface is typically stable. |
| **9. Soil Surface Loss or Degradation** | Surface organic layer rarely present and then only in association with protected areas. | 25–50% of the surface organic layer is absent. | Less than 25% of the surface organic matter is absent. | Some signs of past loss of surface organic matter with stable surface now. | 0–3 inches dark gray mucky clay, 3–48 inches very dark gray to gray clay, 48–52 inches gray loamy fine sand, 52–80 inches gray clay loam to gray clay. |
| **10. Effects of Plant Community Composition and Distribution Relative to Infiltration** | N/A | N/A | N/A | N/A | Hydrologic dynamics consist of high water table and saturated soil conditions 70% of the time. Plant community composition has little effect on infiltration. |

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| Departure from Reference Sheet | | | | | |
|---|---|---|---|---|---|
| **Indicator** | **Extreme to Total** | **Moderate to Extreme** | **Moderate** | **Slight to Moderate** | **None to Slight** |
| **11. Compaction Layer** | None | None | None | None | None |
| **12. Functional/ Structural Groups (F/S Groups)**<br><br>**See Functional/ Structural Groups Worksheet** | Few dominant plant functional groups dominate the site. Significant non dominant plants are present. | Dominant plant functional groups represented by scattered few individual species. Less dominant functional groups now dominate the site. | Dominant plant functional groups occur, but no longer dominate. Shift from dominant to subdominant functional group has occurred. | Dominant plant functional groups are diminished but still dominate. Sub dominant plants groups are represented in slightly higher proportion. Less number of species in most functional groups. | Dominant plants: Warm-season grass and grass-likes.<br><br>Sub dominant plants: Sod forming grasses.<br><br>Other plants: Annual grasses are infrequent. Perennial forbs present |

Relative Dominance of F/S Groups for Community Phases in the Reference State
Minimum expected number of species for dominant and subdominant groups is included in parenthesis

<u>Dominance Category</u>

Dominant grasses (2 FSG): saltmeadow cordgrass (1,000–16,000 lbs/ac), California bulrush (0–6,000 lbs/ac)

Subdominant grasses (3 FSG): seashore paspalum (500–4,000 lbs/ac), chairmakers bulrush (500–4,000 lbs/ac), coast cockspur grass (0–1,800 lbs/ac)

Forbs: Alligatorweed (3 FSG): (0–1,000 lbs/ac); southern cattail (0–500 lbs/ac), herb of grace (0–200 lbs/ac), saltmarsh morningglory (0–100 lbs/ac), and Virginia saltmarsh mallow (0–100 lbs/ac).

Minor shrubs (0–1 FSG): (0–100 lbs/ac): Jesuit's bark, eastern baccharis, California desert-thorn

| | | | | | |
|---|---|---|---|---|---|
| **13. Dead of Dying Plants or Plant Parts** | Significant amount of dead or decadent plants are present (greater than 30%). | Frequent amount of dead or decadent plants are present (20-30%). | Moderate amount of dead or decadent plants are present (10–20%). | Slightly greater (5–10%) dead and/or decadence present. | Perennial grasses will naturally exhibit a minor amount (less than 5%) of senescence and some mortality every year. |
| **14. Litter Cover and Depth** | N/A | N/A | N/A | N/A | Significant amount of litter from onsite plant production. Decomposition of litter is rapid above water table. |

| Departure from Reference Sheet | | | | | |
|---|---|---|---|---|---|
| **Indicator** | **Extreme to Total** | **Moderate to Extreme** | **Moderate** | **Slight to Moderate** | **None to Slight** |
| **15. Annual Production** | Productivity less than 20% of potential production. | Productivity 20–40% of potential production. | Productivity 40–60% of potential production. | Productivity 60–80% of potential production. | 6000 to 20,000 pounds per acre. |
| **16. Invasive Plants** | Dominate the site. | Common throughout the site. | Scattered throughout the site. | Present primarily in disturbed areas. | Chinese Tallow Tree. |
| **17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants** | Ability of plants to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions. | Ability of plants to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions. | Ability of plants to produce seed or vegetative tillers is somewhat limited relative to recent climatic conditions. | Ability of plants to produce seed or vegetative tillers is only slightly limited relative to recent climatic conditions. | All perennial species should be capable of reproducing every year unless disrupted by catastrophic events occurring immediately prior to, or during the reproductive phase. |

**Figure B-E-2. Rangeland Health Reference Sheet**

**Author(s)/participant(s):** ______________________________

**Date:** ______ **MLRA:** 151 **Ecological Site:** Brackish Firm Mineral Marsh Site ID: R151XY005LA___ This *must* be verified based on soils and climate (see Ecological Site Description). Current plant community *cannot* be used to identify the ecological site.

**Composition (Indicators 10 and 12) based on**: _X_ Annual Production, __Cover Produced During Current Year __Biomass

**Indicators.** For each indicator, describe the potential for the site. Where possible, (1) use numbers, (2) include expected range of values for above- and below-average years and natural disturbance regimes for **each** community within the reference state, when appropriate and (3) cite data. Continue descriptions on separate sheet.

1. **Number and extent of rills:** No recent or past rills evident

2. **Presence of water flow patterns:** Water flow patterns are stable and well vegetated. Minimal evidence of past or current deposition.

3. **Number and height of erosional pedestals or terracettes:** Typically, None – Cordgrass spp. can pedestal naturally as material gets deposited around the plant and then gets naturally eroded off.

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are *not* bare ground):** Generally, should be less than 5% and randomly distributed throughout.

5. **Number of gullies and erosion associated with gullies:** Typical gullies are not evident on site. Scour channels from past storm events may be present but are stable.

6. **Extent of wind scoured, blowouts and/or depositional areas:** None

7. **Amount of litter movement (describe size and distance expected to travel):** Litter movement slight except with intense storms or tidal surges.

8. **Soil surface (top few mm) resistance to erosion (stability values are averages – most sites will show a range of values):** Soil surface is typically stable.

9. **Soil surface Loss and Degradation):** 0–3 inches dark gray mucky clay, 3–48 inches very dark gray to gray clay, 48–52 inches gray loamy fine sand, 52–80 inches gray clay loam to gray clay

10. **Effect of plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Hydrologic dynamics consist of high-water table and saturated soil conditions 70% of the time. Plant community composition has little effect on infiltration

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** None

12. **Functional/Structural Groups (list in order of descending dominance by above-ground production or live foliar cover):**

**Dominance Category**

Dominant grasses (2 FSG): saltmeadow cordgrass (1,000–16,000 lbs/ac), California bulrush (0–6,000 lbs/ac)

Subdominant grasses (3 FSG): seashore paspalum (500–4,000 lbs/ac), chairmakers bulrush (500–4,000 lbs/ac), coast cockspur grass (0–1,800 lbs/ac)

Forbs: Alligatorweed (3 FSG): (0–1,000 lbs/ac); southern cattail (0–500 lbs/ac), herb of grace (0–200 lbs/ac), saltmarsh morningglory (0–100 lbs/ac), and Virginia saltmarsh mallow (0–100 lbs/ac)

Minor shrubs (0–1 FSG): (0–100 lbs/ac): Jesuit’s bark, eastern baccharis, California desert-thorn

**13. Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Perennial grasses will naturally exhibit a minor amount (less than 5%) of senescence and some mortality every year.

**14. Average percent litter cover (______%) and depth (______ inches):** Significant amount of litter from onsite plant production. Decomposition of litter is rapid above water table.

**15. Expected annual production (this is TOTAL above-ground production, not just forage production):**
6000 to 20,000 pounds per acre

**16. Potential invasive (including noxious) species (native and non-native). List species which characterize degraded states, and which have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions. (Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants.):** Chinese Tallow tree

**17. Perennial plant reproductive capability**: All perennial species should be capable of reproducing every year unless disrupted by catastrophic events occurring immediately prior to, or during the reproductive phase.

## Appendix B-F. – Determining the Ecological Site

The ecological site must be determined at each planning and/or monitoring evaluation area to ensure that the correct reference sheet is used to conduct the IIRH assessment. Ecological sites are delineated based on climate, physiographic, soil, water, hydrologic, and vegetation composition and production features. Soil surveys provide the foundation for describing and mapping ecological sites and help identify the soil map unit and corresponding soil components at the site evaluation area.

**Steps in Determining the Ecological Site**

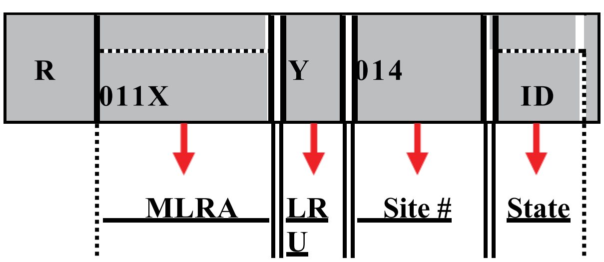
**(1) A list of the ecological sites that are likely to occur at an evaluation area should be compiled.**

This step does not determine the ecological site at a specific evaluation area as soil map units are commonly comprised of more than one soil map unit component. Each component in a soil map unit may be correlated to a different ecological site. In addition to the soil components listed in a soil map unit description, soil inclusions (soils representing less than 15% of the soil map unit area) are found in most soil map units and may be correlated to different ecological sites (Reid 2021; Pellant et al. 2020).

**(2) Use the unique ecological site ID, rather than the ecological site name.**

- Thisprevents accidentally using an ecological site description with the same name from a different land resource unit/major land resource area.
- Ecological sites are grouped into land resource units(LRUs), which are then grouped into major land resource areas (MLRAs) within each state. Refer to the U. S. Department of Agriculture Handbook 296 for further information. Each ecological site description has a unique code that identifies the MLRA, LRU, ecological site number, and state. For example, ecological site description code R011XY014ID is interpreted as shown in figure B-F-1.

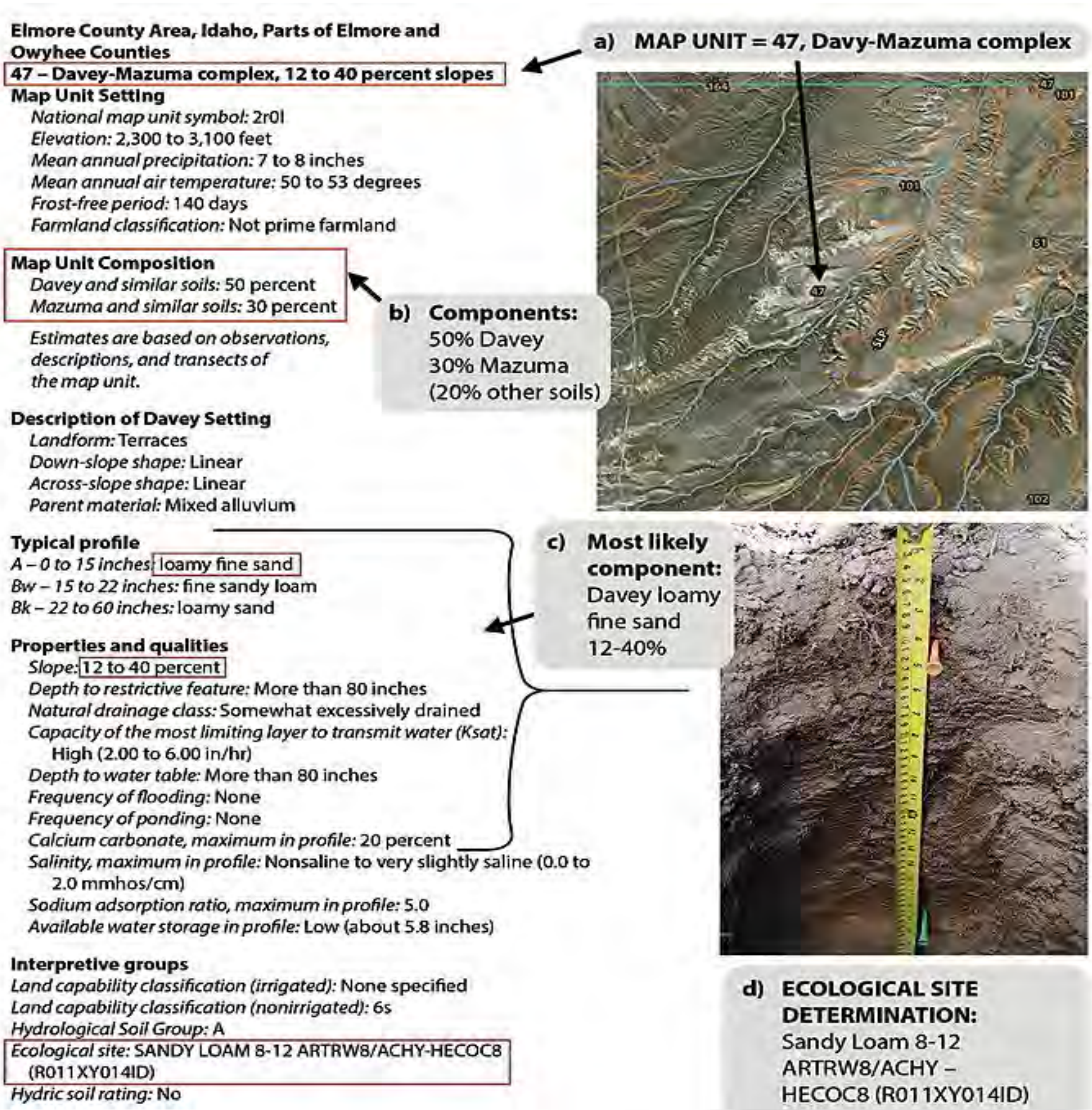
**Figure B-F-1.** Components of an ecological site description code. "R" at the beginning of the code shows it is a rangeland ecological site (Pellant et al. 2020).




**(3) Observe the site evaluation area soils and physiography.**

- After reviewing the soil survey map unit and component data and listing the possible correlated ecological sites in an evaluation area, the final ecological site determination is made in the field by observing the site evaluation area's soils and physiographic characteristics and comparing these characteristics to the descriptions provided in the ecological site description or soil survey. An example of an ecological site determination is shown in figure B-F-2.

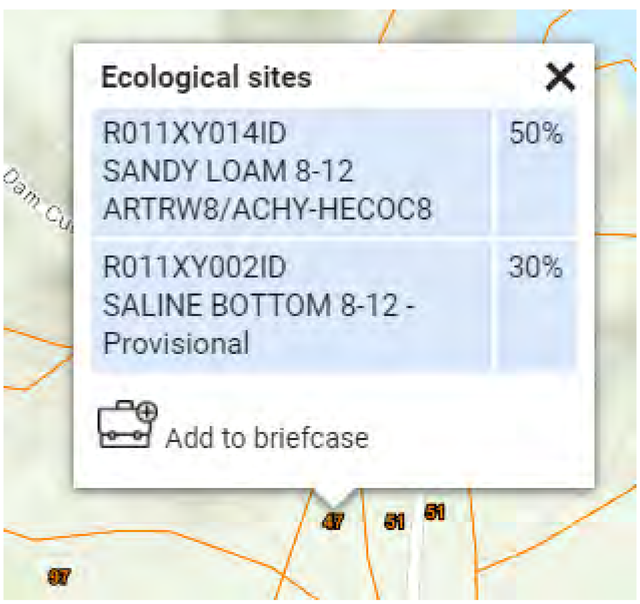
**Figure B-F-2.** Example of using a soil survey to identify the ecological site of a site evaluation area. **(a)** After determining the location of the evaluation Area of Interest (AOI), use the soil survey map to determine potential soils in the AOI. In this example, the evaluation area is in Map Unit 47 of the Elmore Area County Soil Survey. **(b)** Refer to the map unit composition to determine the soil component(s) in the evaluation area.




- For this area, the major components in map unit 47 are Davey (50%) and Mazuma (30%). **(c)** Compare physiographic features of the evaluation area with those of the soil component's setting and slope. In this example, the slope of the evaluation area matches the slope of the Davey soil component (12–40%). The soil component is then identified by digging a soil pit and comparing to the description of the Davey soil component **(d)** After determining the soil component in the evaluation area, document the information in the ecological site determination section on page 1 of the evaluation sheet (Pellant et al. 2020).

- Digging to a minimum depth of 20–25 inches (51–64 cm) is usually required to distinguish ecological sites in most areas. “Shallow” ecological sites are often distinguished by soils less than 20 inches (51 cm) in depth. It is strongly recommended to dig a deeper hole if possible; greater depths will increase the accuracy of soil and ecological site identification.
- Record observations of soil horizons and their depth, texture, and effervescence and other diagnostic characteristics, such as soil structure, color, grade, and size.
- Mobile apps and other technological tools are increasingly available and can facilitate soil identification when using soil pits. It is also recommended to consult a soil scientist or resource specialist familiar with soil identification if there is uncertainty about the soils.
- Ecological site mapping in EDIT (Ecosystem Dynamics Interpretive Tool). Visit the EDIT website (edit.jornada.nmsu.edu) and navigate to the ecological site descriptions catalog. Using the MLRA mapping feature, zoom in to the area of interest. The soil map unit polygons will appear as you zoom in. Click on the soil map unit. A list of ecological sites associated with the dominant soil components within that soil map unit will be provided if the ecological site correlations are available in the underlying database. The correlated soils and ecological site description status can be found by clicking on each listed ecological site.

**Figure B-F-3.** Snapshot of EDIT tool soil map feature with two soils components correlated to two different ecological sites (Reid 2021).




**(4) Obtain ecological site correlations from soil survey data.**

- When ecological site mapping correlations are not available in EDIT, or when additional soils information is required, consult electronic or hard copies of soils surveys. Most soil map unit descriptions include component ecological site correlations.
- The availability of soil surveys in paper or electronic format varies across the Western United States; however, most are available with internet searches. Soil surveys are now published electronically as they are revised and updated, so hard copies of soil surveys may no longer contain the most up-to-date information. Third-order soil surveys, which

are most commonly available for rangelands, are somewhat coarse and usually represent associations or complexes of multiple soils. They may also include soil inclusions, which may or may not be listed in the soil survey thereby making a precise correlation to an ecological site cannot be made.

**(5) Soil survey information can be accessed in the following ways:**

- Web Soil Survey (https://websoilsurvey.sc.egov. usda.gov) provides interactive tools for navigating to and delineating an area of interest. An area of interest, such as a management unit, can also be imported to Web Soil Survey as a shapefile. Multiple management units can also be attributed and imported into Web Soil Survey to give ecological site inventory statistics by management unit. Note that Web Soil Survey has a maximum area of interest resolution of 100,000 acres.
- Spatial and tabular soils data can be downloaded from Web Soil Survey, allowing these data to be used with other spatial data sets with desktop geographic information system applications, such as ArcGIS.
- If published soils data are not available for the area of interest, contact the local NRCS office to see if unpublished information is available.

**(6) Use soil survey information to identify ecological site correlations.**

- Using Web Soil Survey, import or navigate to and select the area of interest. Soil map units for the area of interest can now be viewed in the "Soil Map" tab (Pellant et al. 2020).
- There are multiple ways to view ecological site interpretations in Web Soil Survey depending on the user's needs. Perhaps the most efficient method to obtain ecological site information correlated to map unit components is to go to the "Soil Data Explorer" tab in the first tier and select the "Ecological Sites" tab in the second tier and then selecting "View All Ecological Sites Info" (figures B-F-4, 5, and 6) (Reid 2021).

**Figure B-F-4.** Soils Data Explorer tab and second tier Ecological Sites tab (tabs in red) (Reid 2021).

**Figure B-F-5.** View all Ecological Sites Info tab (Reid 2021).


**Figure B-F-6.** Summary of Ecological sites by map unit (Pellant et al. 2020).

Table — Ecological Sites by Map Unit Component —

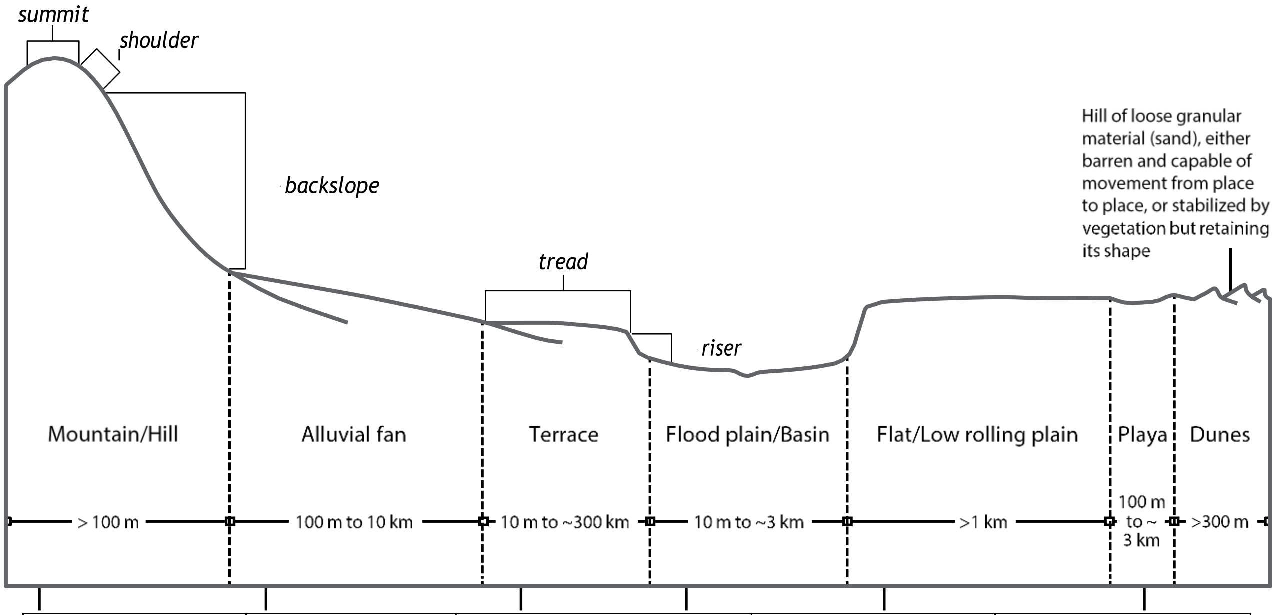
Elmore County Area, Idaho, Parts of Elmore and Owyhee Counties

Elmore County Area, Idaho, Parts of Elmore and Owyhee Counties

| Map unit symbol | Map unit name | Component name (percent) | Ecological site | Acres in AOI | Percent of AOI |
|---|---|---|---|---|---|
| 47 | Davey-Mazuma complex, 12 to 40 percent slopes | Davey (50%) | R011XY014ID — SANDY LOAM 8-12 ARTRW8/ACHY-HECOC8 | 15,941.8 | 0.6% |
| | | Mazuma (30%) | R011XY002ID — SALINE BOTTOM 8-12 - Provisional | | |

- Ecological site maps generated using Soil Data Viewer or Web Soil Survey will represent the site correlated with the dominate soil(s) in each soil map unit, whereas the EDIT interface provides a list of ecological sites associated with the major soil components and their percentages for the map unit. The user must determine which other ecological sites might occur based on the components of each soil map unit. The secondary major soil components and inclusions may represent different ecological sites, which are identified under the map unit component description in the soil survey (Pellant et al. 2020).
- Obtain the ecological site description(s). After compiling the list of expected ecological sites to be found in the field, refer to EDIT (edit.jornada.nmsu.edu) to obtain ecological site description reports. If the required ecological site description is not available online, contact the state NRCS rangeland management specialist to see if a draft is available for use. Examine copies of the relevant ecological sites and soil map unit and soil series descriptions, in the field as they may help with interpretation of soil profile and matching the discrete ecological site.
- In the evaluation area, compare the physiographic characteristics to the soil description in the ecological site description (i.e., are the ranges in elevation, slope, aspect, etc., within those described for the ecological site?). Use figure B-F-7 to help determine the topographic position of the site evaluation area. The site evaluation area's characteristics should fit with the ecological site descriptions physiographic characteristics.

**Figure B-F-7.** Generic landscape units (mountain/hill, alluvial fan, terrace, floodplain/basin, flat/low rolling plain, playa, dunes) to describe topographic position (Herrick et al. 2017).




| | | | | |
|---|---|---|---|---|
| Elevated area, nearly level, usually with a sink or depression. Summit area where water collects. Surrounded by no visible outlet. Surrounding slopes generally with steep sides. | Low, outspread mass of loose materials and/or rock material deposited by water, common with gentle slopes shaped like an open fan. | Step-like surface bordering a valley or shoreline that represents the former position of a flood plain, lake, or sea shore. | Nearly level plain that borders a stream and is subject to inundation under goo stage conditions. | Extensive region of comparatively smooth, level and/or |

- Be aware of the key characteristics that differentiate the potential ecological sites in the area. For example, the soil map unit may represent a soil complex that alternates between a shallow claypan with a restrictive layer at a given depth and a deeper loamy soil; another example is a soil map unit that contains loamy and sandy soils that result in different ecological sites. Knowing these likely soil differences will make the ecological site identification process easier and more efficient.
- Dig a sufficient number of soil pits in the evaluation area to confirm that it is within a single ecological site. If more than one ecological site occurs within the site evaluation area, each site must be assessed separately.
- To complete the ecological site determination, compare the observations from the evaluation area to those from the soil information source. If the soil characteristics observed in the evaluation area have major differences from those described in the soil information source, determine whether another information source, such as a different ecological site description or soil component description, better matches the evaluation area characteristics. In some instances, none of the soil components listed for the map unit will match the soils found at an evaluation area within that map unit. In this situation, it can be helpful to review soil descriptions from adjacent map units, or even adjacent soil

survey areas, to identify the correct soil and correlated ecological site description (Pellant et al. 2020).

## References:

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FBDSS. 2012. Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE. (page 2–38) https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052523.pdf)

Herrick, J.E., J.W. Van Zee, S.E. McCord, E.M. Courtright, J.W. Karl, and L.M. Burkett. 2017. Monitoring manual for grassland, shrubland, and savanna ecosystems. Volume I: Core methods, Second Edition. U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, Las Cruces, NM.

NRCS SSM. 2017. Soil Science Division Staff. Soil survey manual. C. Ditzler, K. Scheffe, and H.C. Monger (eds.). USDA Handbook 18. Government Printing Office, Washington, D.C. (chapter 3 – https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253)

Soil Survey Staff. 2021. Web Soil Survey. USDA Natural Resources Conservation Service. https://websoilsurvey.nrcs.usda.gov/app/ (accessed 06 October 2021).

USDA, 2021. USDA (United States Department of Agriculture) Natural Resources Conservation Service and Agricultural Research Service; Jornada Experimental Range; and New Mexico State University. 2021. Ecosystem Dynamics Interpretive Tool. https://edit.jornada.nmsu.edu/ (accessed 06 October 2021).

## Appendix B-G. – Describing and Hand-Texturing Soils

Soil texture is perhaps the most important soil properties used in conservation planning. Soil texture is an integral property related to hydrology, erosion dynamics, soil aggregate stability, intrinsic organic matter levels and dynamics, plant adaptability, and production. Soil texture influences plant growth by its effect on aeration, water intake rate, available water capacity, cation-exchange capacity, saturated hydraulic conductivity, erodibility, and workability (NRCS NSSH).

Describing and texturing soils can be determined after digging a soil pit or hole at the beginning of the soil determination process. By definition, soil texture is the relative proportion, by weight, of particle size classes (sand, silt, and clay) less than 2 mm in equivalent diameter (NRCS NSSH). Soil texture is directly related to parent material and the weathering processes of that material. Changes in texture as related to depth are an indication of how a soil was formed (NRCS NSSH).

Soil texture class can be determined fairly easily in the field by rubbing moist soil between the fingers (figure B-G-1). Good accuracy can be obtained from field estimates of soil texture if estimates are periodically validated against laboratory results or reference samples (NRCS NSSH). Generally, soil texture can be estimated by feeling the overall grittiness, which represents the sand particles, and estimating the overall contribution of fine particles based on plasticity and stickiness, which represents the silt and clay particles. There is no field quick mechanical-analysis procedure that is as accurate as the fingers of an experienced specialist, especially if standard reference samples are available and local conditions are considered (SSFLMM v2).

The basic soil textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay (figure B-G-2). The sand, loamy sand, and sandy loam classes may be further divided by specifying “coarse,” “fine,” or “very fine” (figure B-G-3). One must be familiar with local soil chemical and physical characteristics as certain soil properties can cause incorrect estimates of soil texture if not considered (NRCS 2020). Field criteria used to estimate texture class should be adjusted based on local conditions (NRCS SSM). In certain situations, the quantity of estimated clay may be too high based on some overriding soil physical or chemical property. Therefore, clay content must be adjusted lower than field estimates to provide an accurate estimation of texture class.

**For example:**

In some environments, clay aggregates are so strongly cemented together that they feel like fine sand or silt, with cementing agents varying by location. In humid climates, iron oxide may be the cementing agent, in desert climates, silica may be the cementing agent, and in arid regions, calcium carbonate can be the cementing agent. In this case, field estimation of soil texture takes prolonged rubbing in order to breakdown larger aggregates to reveal that soil separates are dominated by clays and not silt loams. (Pellant et al. 2020; SSFLMM v2).

Soils with large amounts of silt and sand sized platy minerals such as mica, vermiculite, and shale can make the texture seem finer than the texture determined in the laboratory (SSFLMM v2). The presence of sticky, plastic clays such as smectite can make the soil seem to have higher clay content than it does (SSFLMM v2).

Excessive salts can cause either overestimation or underestimation of clay. Large amounts of calcium carbonate, gypsum, or other salts tend to cause problems in determining soil textures. Some salts reduce the amount of stickiness and thus lead to an underestimation of clay and some salts like clay sized calcium carbonate often result in an overestimation of clay content. Sodium salts tend to make soil particles disperse and thus can lead to a higher estimate of clay content (SSFLMM v2).

Clay content in soils with high organic matter can result in an underestimation in clay content due to the organic matter lowering the plasticity and diluting the volume of mineral matter.

Some soils derived from granite contain grains that resemble mica but are softer. Rubbing breaks down these grains and reveals they are dominated by clay particles. These grains resist dispersion, causing field and laboratory determinations to disagree, unless proper precautions are taken (SSFLMM v2).

Many soil conditions and components previously mentioned can cause inconsistencies between field texture estimates and standard laboratory data. Cementing agents, sodium content, organic matter content, calcium carbonate content, large clay crystals and/or mineral grains are possible causes.

The following figures can help with hand-texturing soils and describing soil structure, rock fragment content, and effervescence.

**Figure B-G-1.** Guide to Texture by Feel (adapted and modified from Thien 1979).

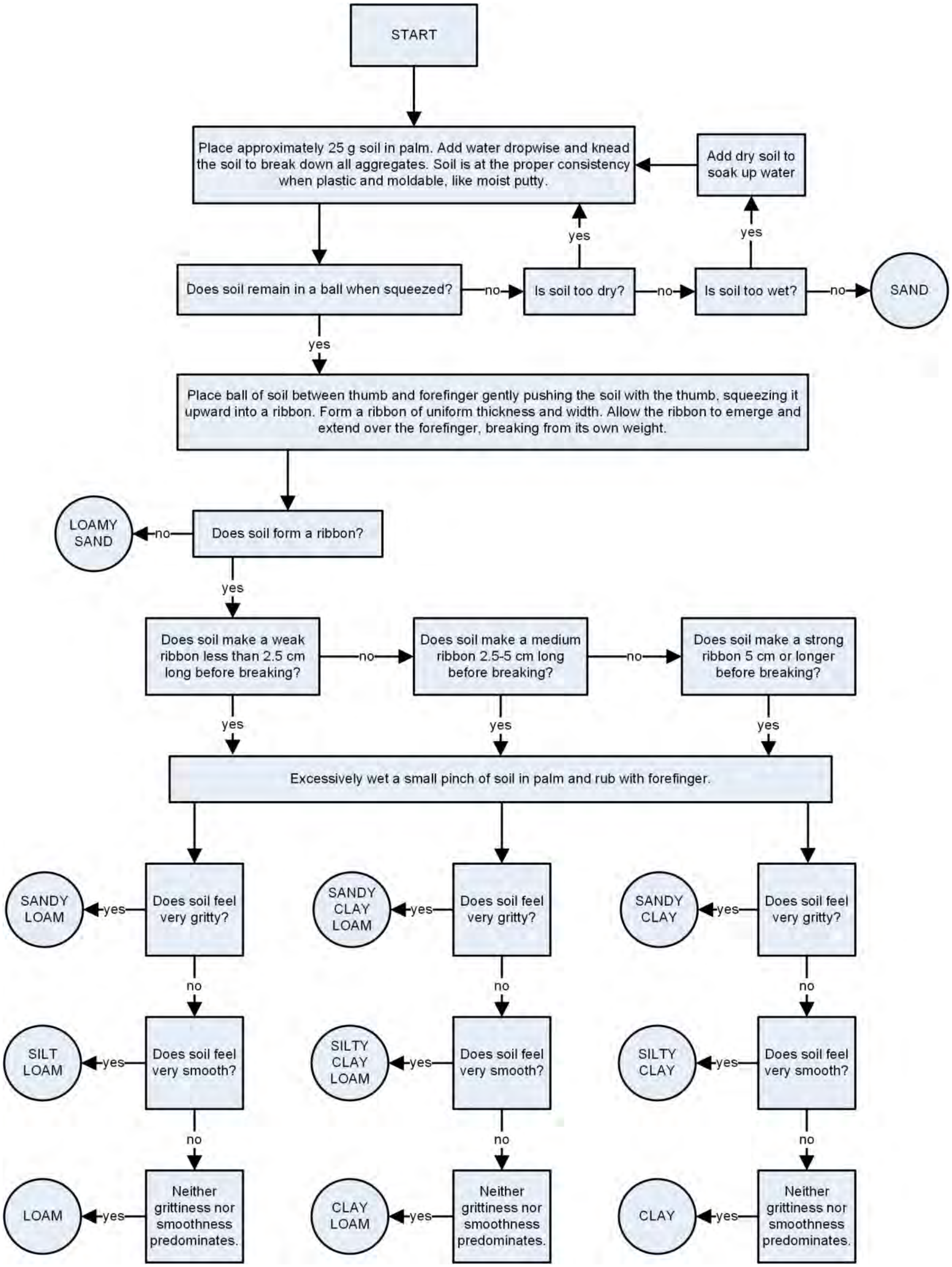
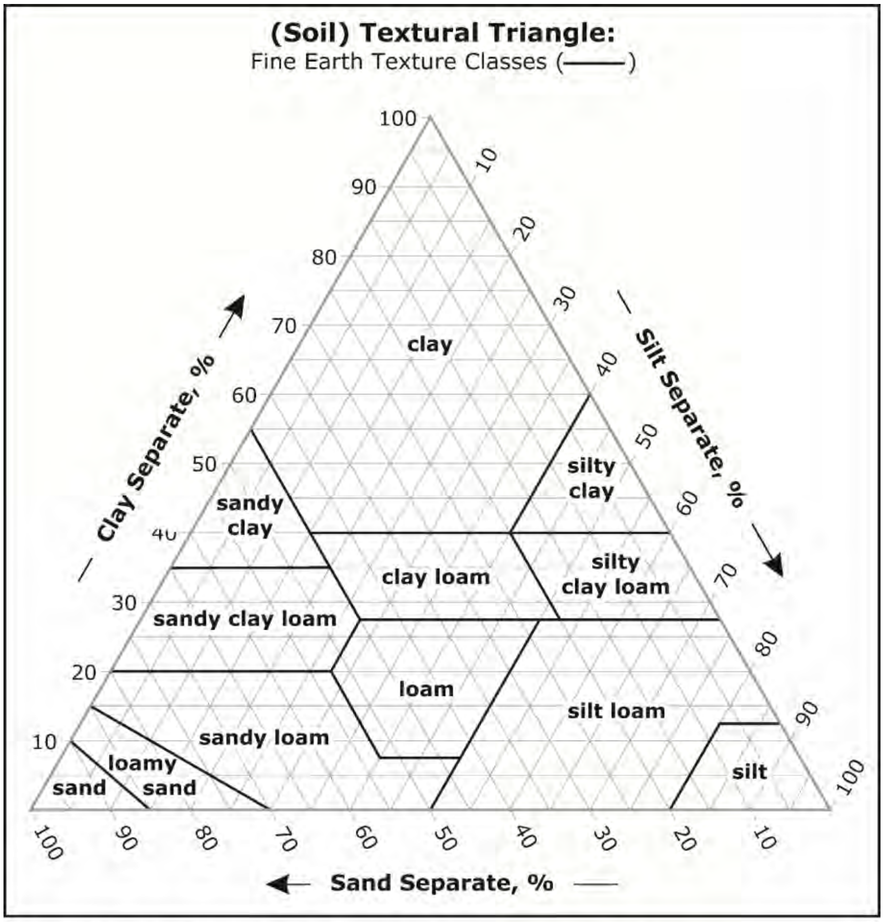


**Figure B-G-2.** Soil Texture Modifiers (FBDSS v 3.0).




**TEXTURE MODIFIERS**—Conventions for using "Rock Fragment Texture Modifiers" and for using textural adjectives that convey the "% volume" ranges for **Rock Fragments - Quantity and Size**.

| Frag. Content Vol. % | Rock Fragment Modifier Usage |
|---|---|
| <15 | No texture class modifier (noun only; e.g., *loam*). |
| 15 to <35 | Use fragment-size adjective with texture class; e.g., *gravelly loam*. |
| 35 to <60 | Use "**very**" with fragment-size adjective with texture class; e.g., *very gravelly loam*. |
| 60 to <90 | Use "**extremely**" with fragment-size adjective with texture class; e.g., *extremely gravelly loam*. |
| ≥90 | No adjective or modifier. If ≤10% fine earth, use the appropriate fragment-size class name for the dominant size class; e.g., *gravel*. Use **Terms Used in Lieu of Texture** (see table on p. 2–43). |

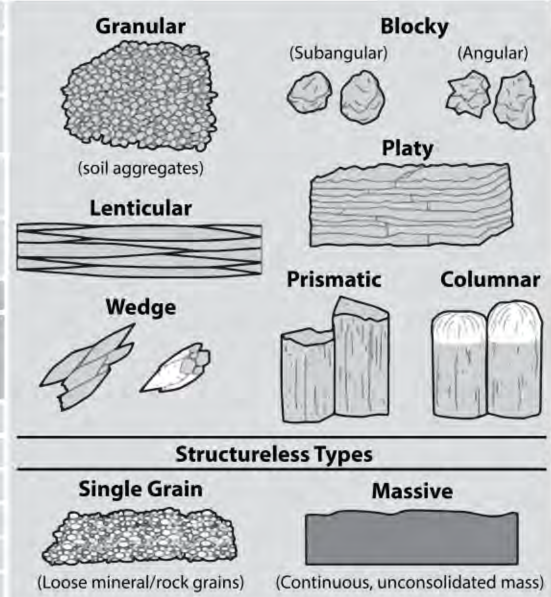
**Figure B-G-3.** Summary of common soil descriptors: **A.** Effervescence classes used to describe the entire soil matrix using 1 M HCL (Soil Science Division Staff 2017); **B.** Soil structure classes by size and shape; **C.** Examples of soil structure types; **D.** Soil structure grades and descriptions; and **E.** Particle size classes (Pellant et al. 2020).

| A. Effervescence class | Criteria |
|---|---|
| Noneffervescent | No bubbles form |
| Very slightly effervescent | Few bubbles form |
| Slightly effervescent | Numerous bubbles form |
| Strongly effervescent | Bubbles form low foam |
| Violently effervescent | Thick foam forms quickly |

**B. Soil Structure Classes by Size and Shape**

| Class | Platy and granular (mm) | Prismatic, columnar, and wedge (mm) | Blocky and lenticular |
|---|---|---|---|
| Very fine | < 1 | < 10 | < 5 |
| Fine | 1 to < 2 | 10 to < 20 | 5 to < 10 |
| Medium | 2 to < 5 | 20 to < 50 | 10 to < 20 |
| Coarse | 5 to < 10 | 50 to < 100 | 20 to 50 |
| Very coarse | ≥ 10 | 100 to < 500 | ≥ 50 |
| Extremely coarse | N/A | ≥ 500 | N/A |

**C. Examples of Soil Structure Types**




**D. Soil Structure Grades and Descriptions**

| | |
|---|---|
| **Weak** | The units are barely observable in place. When they are gently disturbed, the disturbed soil material parts into a mixture of whole and broken units, the majority of which exhibit no planes of weakness. |
| **Moderate** | The units are well formed and evident in undisturbed soil. When disturbed, the soil material parts into a mixture of mostly whole units, some broken units, and material that is not in units. Peds part from adjoining peds to reveal nearly entire faces that have properties distinct from those of fractured surfaces. |
| **Strong** | The units are distinct in undisturbed soil. They separate cleanly when the soil is disturbed. When removed, the soil material separates mainly into whole units. Peds have distinctive surface properties. |

**E. USDA Particle Size Classes**

| FINE EARTH | | | ROCK FRAGMENTS | | |
|---|---|---|---|---|---|
| Class | Subclass | Size (mm) | Class | Subclass | Size (mm) |
| Clay | Fine | < 0.0002 | Gravel | Fine | 2-5[1] |
| | Coarse | 0.0002-0.002 | | | |
| Silt | Fine | 0.002-0.02 | | Medium | 5-20 |
| | Coarse | 0.02-0.05 | | | |
| Sand | Very Fine | 0.05-0.1 | | Coarse | 20-76 |
| | Fine | 0.1-0.25 | | | |
| | Medium | 0.25-0.5 | Cobbles | - | 76-250 |
| | Coarse | 0.5-1.0 | Stones | - | 250-600 |
| | Very Coarse | 1.0-2.0 | Boulders | - | > 600 |

[1] Note that particles from 2-5 mm are considered gravel (rock) for purposes of soil description and identification. However, only fragments ≥ 5 mm are recorded as rock for purposes of calculating ground cover.

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# Part 645 – National Range and Pasture Handbook

## Subpart C – Resource Concerns and Trends on non-Federal Grazing Lands: National Resource Inventory (NRI) Analyses and Implications for Conservation Planning

### 645.0301 Introduction

Identifying resource concerns on rangelands and pasturelands is vital to developing strategically focused NRCS rangeland conservation programs. From an agency perspective, the rangeland NRI can identify resource concerns at national, regional, and State levels. In addition, conservation planners can identify and prioritize resource concerns at the farm and ranch.

Resource concerns, disturbances, interpreting indicators of rangeland health, similarity index trends, and apparent rangeland trend summaries in this subpart are derived from the rangeland on-site NRI study (2004–2018). Due to the current limited number of NRI pastureland points, this subpart outlines only the resource concerns, disturbances, and rangeland trend measures on non-Federal rangeland. As additional pastureland points become available and the data are analyzed, we will update this subpart.

### 645.0302 Rangeland Resource Concerns

A. Rangeland Resource Concerns (on-site NRI study).

In analyzing resource concerns with the on-site NRI study (2004–2018), 20 resource concerns are assessed in the field. The instructions in the handbook specify that the 20 concerns be determined for the conservation management unit (CMU) (USDA-NRCS 2020). The CMU is equivalent to the field (fenced or delineated by other means) where the NRI point resides. If no field boundary exists, a distance of 1,000 feet is used as a boundary. Public roads, railroads, or obvious ownership boundaries are not crossed within the 1,000-ft distance. Assessments of resource concerns are made for current use and conditions at the time of the sample: N=no resource concern and Y= specific resource concern exists. The resource concerns and definitions are given in table C-1.

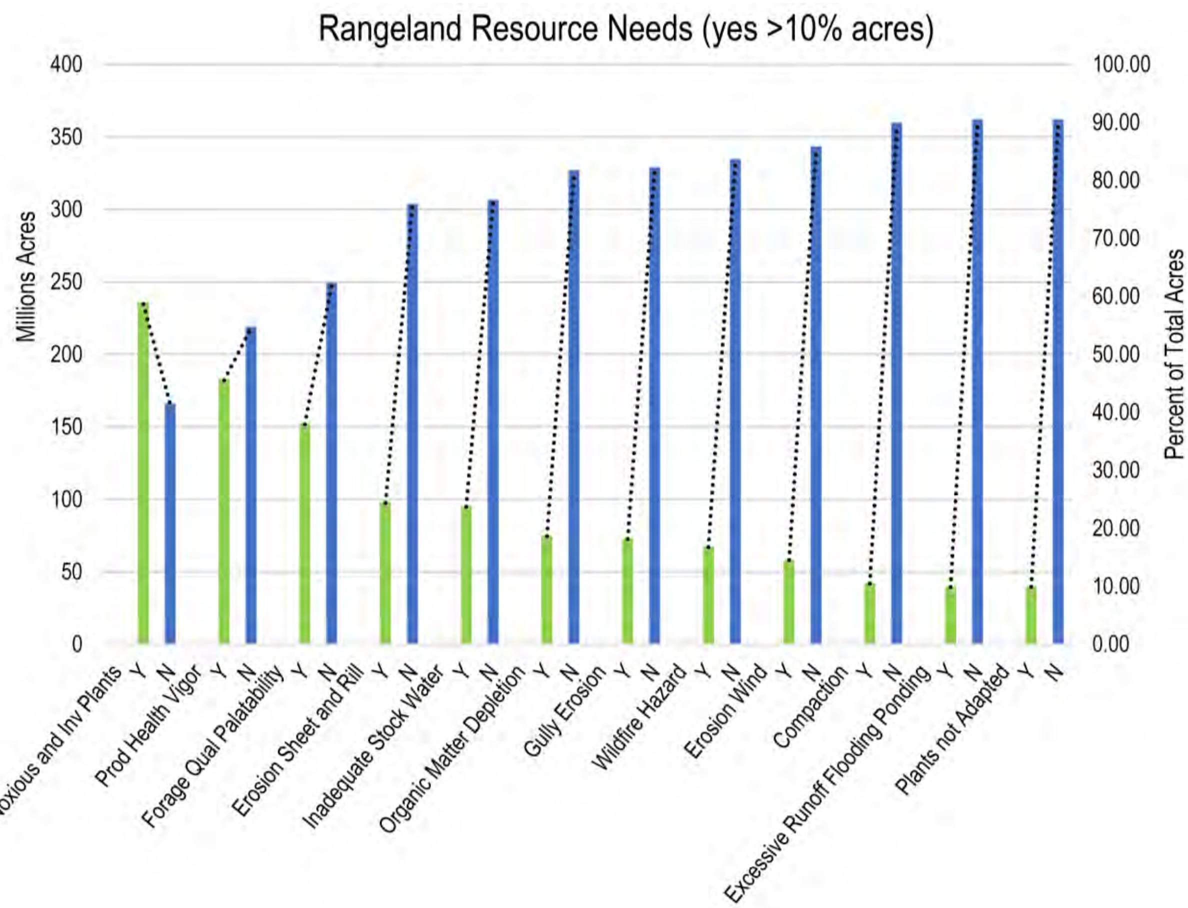
B. In figure C-1, the rangeland resource concerns are ranked from highest to lowest based on disturbance=yes. Each NRI point has an acre weighting factor. The NRI point represents an area in acres, and the weighting factors are used to calculate total acres in the following figures. Nine resource concerns were identified as occurring on more than 10% of the total rangeland acres. The number one concern based on acres was noxious and invasive plants identified on 59% of the NRI points, representing 236 million acres. The second, third, and forth concerns were production health, and vigor. Forage quality palatability concerns were present on 40% or greater of the total rangeland acres. Although these data represent the entire NRI data set representing national conditions, data can be reported upon request for specific States, regions, major land resource areas, and ecoregions.

**Table C-1.** NRCS Resource Concerns Definitions (USDA-NRCS 2020).

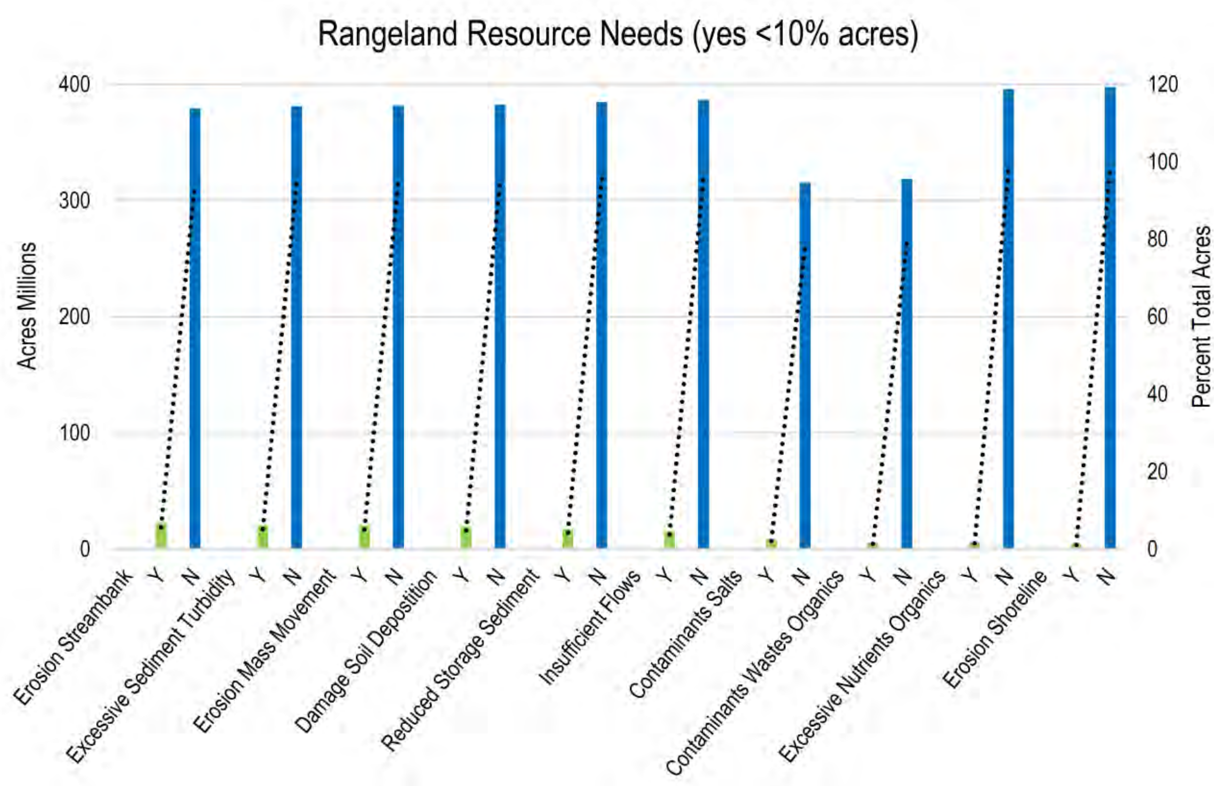
| Natural Resource | Resource Concern | Resource Problem | Definition |
|---|---|---|---|
| Soil | Erosion | Sheet and Rill | Detachment and transport of soil particles caused by rainfall splash and runoff degrade soil quality. |
| | | Wind | Detachment and transport of soil particles caused by wind degrade soil quality and damages plants. |
| | | Classic Gully | Deep, permanent channels caused by the convergence of surface runoff degrade soil quality. They enlarge progressively by head-cutting and lateral widening. |
| | | Streambank | Accelerated loss of streambank soils restricts land and water use and management. |
| | | Shoreline | Soil is eroded along shorelines by wind and wave action, causing physical damage to vegetation, limiting land use, or creating a safety hazard. |
| | | Mass Movement | Soil slippage, landslides, or slope failure, normally on hillsides, result in large volumes of soil movement. |
| | Condition | Organic Matter Depletion | Soil organic matter has or will diminish to a level that degrades soil quality. |
| | | Compaction | Compressed soil particles and aggregates caused by grazing and/or mechanical compaction. Compaction effects adversely affect hydrology and soil moisture relationships. |
| | | Damage from Soil Deposition | Sediment deposition damages or restricts land use/management or adversely affects ecological processes. |
| | Quantity | Excessive Runoff, Flooding, or Ponding | Water from runoff, flooding, or ponding having an adverse effect on land use and management. |
| | | Reduced Storage of Water Bodies by Sediment Accumulation | Sediment deposits in waterbodies reduce the desired volume capacity. |
| Water | Quantity | Insufficient Flows in Water Courses | Water flows are not consistently available in sufficient quantities to support ecological processes and land use and management. |
| | Quality | Excessive Nutrients and Organics in Surface Water | Pollution from natural or human induced nutrients, such as N, P, and organics (Including animal and other wastes), degrades surface water quality. |
| | | Excessive Suspended Sediment and Turbidity in Surface Water | Pollution from mineral or organic particles degrades surface water quality. |
| Plants | Condition | Plant Not Adapted or Suited | Plants are not adapted or suited to site conditions. |
| | | Productivity, Health and Vigor | Plants do not produce the yields, quality, and soil cover to protect the resource. |
| | | Noxious and Invasive Plants | The site has noxious or invasive plants present. |
| | | Forage Quality and Palatability | Plants do not have adequate nutritive value or palatability for the intended use. |
| | | Wildfire Hazard | The kinds and amounts of fuel loadings (plant biomass, dry litter) pose a wildfire risk to human safety, structures, and land resources. |
| Animals | Domestic Animals | Inadequate Stock Water | The quantity, quality, and distribution of drinking water are insufficient to meet the production goals for the kinds and classes of livestock. |

**Figure C-1. (a)** Rangeland resource needs data from on-site study (2004–2018). Resource concerns are ranked from highest to lowest (N=no concern, Y=concern), based on approximately 10% of total non-Federal acres. **(b)** Resource concerns are ranked from highest to lowest based on percent of total non-Federal acres affected by concern, < 10%.

**(a)**



**(b)**




## 645.0303 Resource Concern: Noxious and Invasive Plants

A. Since noxious and invasive plants were estimated on almost 60% of non-Federal rangeland acres, figure C-2 shows the ranking of introduced species, introduced grasses, and shrubs and trees on United States non-Federal rangeland. Plants in figures C-2a and b are all introduced species. Figure C-2c shows the dominant 22 species of shrub and tree species, which are native plants, with an estimate of > 5% of non-Federal rangeland acres. Although these 22 species are classified as native plants, many can be invasive and can increase to undesirable levels.

B. The geographic spread and the number of invasive plant species have increased significantly over the past 200 years as a result of human activities (di-Castri 1989). On rangelands, exotic annual grass invasion has been especially dramatic and has transformed many native plant community types throughout the United States (Mack 1981). This transformation has been rapid and ubiquitous; and when annual grass dominance occurs, ecosystem function can be compromised (Vitousek et al., 1997). On United States rangelands, non-native plants can negatively impact biotic integrity; ecosystem stability, composition and structure, natural fire cycles, diversity; soil biota, vegetation production, forage quality, wildlife habitat, soil physical properties, carbon balance, nutrient and energy cycles, and hydrology and erosion dynamics (Chapin et al., 2000; Evans et al., 2001; Pierson et al., 2002; Ehrenfeld 2003; Ogle et al., 2003, 2004; Brooks et al., 2004; Belnap et al., 2005; Hooper et al., 2005; Sommer et al., 2007, Boxell and Drohan 2008; and Herrick et al., 2010).

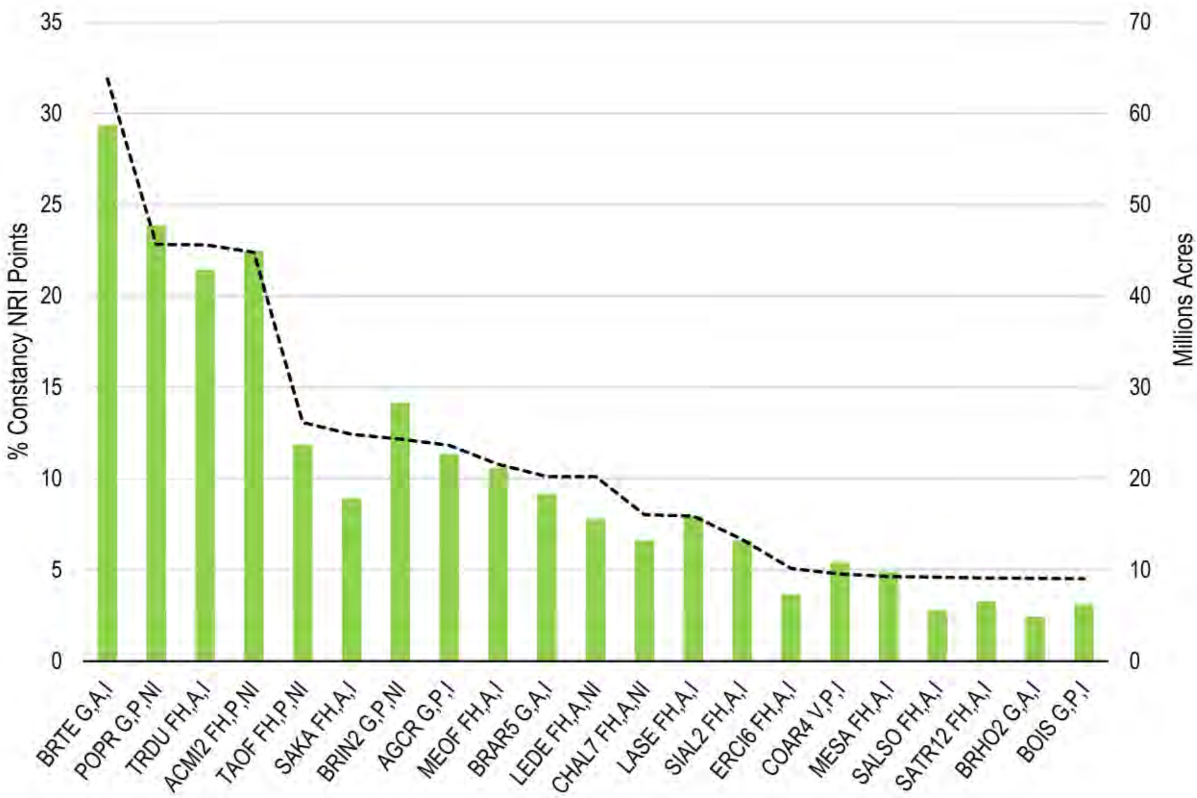
C. Generally, native grasses and forbs are preferred species for livestock and wildlife over exotic introduced species (DiTomaso 2000; Keane and Crawley 2002; and Smith et al., 2012). Invasive exotic weedy species impact livestock production, grazing practices, and lower yield and quality of forage. They increase costs for livestock management and production; diminish animal weight gains; reduce meat, milk, wool, and hide quality; and can poison livestock (DiTomaso 2000).

(1) Cheatgrass (*Bromus tectorum*) was the most frequently occurring invasive species and occurred on 29% of the NRI sample points (63.8 million acres). Kentucky bluegrass (*Poa pratensis*) (45.6 million acres) ranked second, and smooth bromegrass (*Bromus inermis*) ranked third (24.3 million acres). These are commonly introduced perennial cool season invasive sod-forming species in the northern Great Plains (Murphy and Grant 2005; Travnicek et al., 2005; Toledo et al., 2014; DeKeyser et al., 2015) (figure C-2b). Specific invasive species lists are available upon request for states, major land resource areas, ecoregions, and ecological sites where sufficient samples are available.

(2) Native invasive plant species can also be problematic on rangelands and can affect the rangeland ecosystem similarly to invasive exotic plant species (DiTomaso 2000). Mismanagement, particularly overgrazing and suppression of fire, can set the stage for native species encroachment above and beyond levels that are indicated in the ecological site description. In addition, many native species invade rangelands and are not endemic to the ecological site. Some of the most common invasive native species are cactus (*Opuntia* spp.), honey mesquite (*Prosopis glandulosa*), broom snakeweed (*Gutierrezia sarothrae*), and juniper (*Juniperus* spp.) (figures C-2c and d). Specific invasive species lists are available upon request for states, major land resource areas, ecoregions, and ecological sites.

**Figure C-2. (a)** Ranking of introduced non-native species (> 3% constancy of acres) on non-Federal rangeland (USDA-NRCS rangeland NRI 2009–2018). Right and left Y axes show millions of acres and percent constancy of NRI points and acres sampled, respectively. **(b)** Ranking of introduced grasses on United States non-Federal rangeland (>2.0% constancy of acres) (NRI data 2009–2018). **(c)** Ranking of dominant shrub and tree species (> 5% constancy of acres). **(d)** Ranking of dominant forb/herb and subshrub species (>8% constancy of acres). G=graminoid, FH=forb herb, S=shrub, T=tree, V=vine, A=annual, B=biennial, P=perennial, N=native, I=introduced, and NI=possible native/introduced. Constancy is the percentage of NRI points (acres) on which the plant species occurred. A plant species occurring on all plots would have a 100-percent constancy.

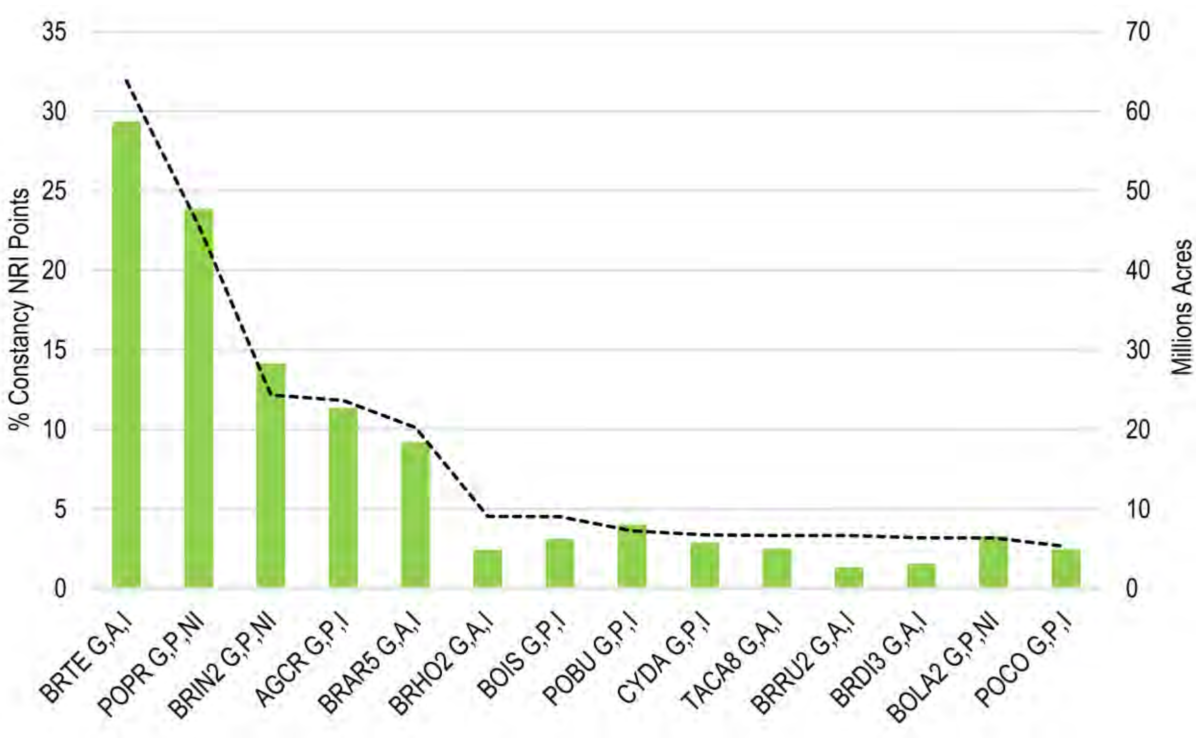
**(a)**




| Symbol | Sci Name | Common Name | Growth Habit Class | Duration | Native/Intro Status |
|---|---|---|---|---|---|
| BRTE G,A,I | *Bromus tectorum* | cheatgrass | G | A | I |
| POPR G,P,NI | *Poa pratensis* | Kentucky bluegrass | G | P | NI |
| TRDU FH,A,I | *Tragopogon dubius* | yellow salsify | FH | A | I |
| ACMI2 FH,P,NI | *Achillea millefolium* | common yarrow | FH | P | NI |
| TAOF FH,P,NI | *Taraxacum officinale* | common dandelion | FH | P | NI |
| SAKA FH,A,I | *Salsola kali* | Russian thistle | FH | A | I |
| BRIN2 G,P,NI | *Bromus inermis* | smooth brome | G | P | NI |
| AGCR G,P,I | *Agropyron cristatum* | crested wheatgrass | G | P | I |
| MEOF FH,A,I | *Melilotus officinalis* | sweetclover | FH | A | I |
| BRAR5 G,A,I | *Bromus arvensis* | field brome | G | A | I |
| LEDE FH,A,NI | *Lepidium densiflorum* | common pepperweed | FH | A | NI |
| CHAL7 FH,A,NI | *Chenopodium album* | lambsquarters | FH | A | NI |
| LASE FH,A,I | *Lactuca serriola* | prickly lettuce | FH | A | I |

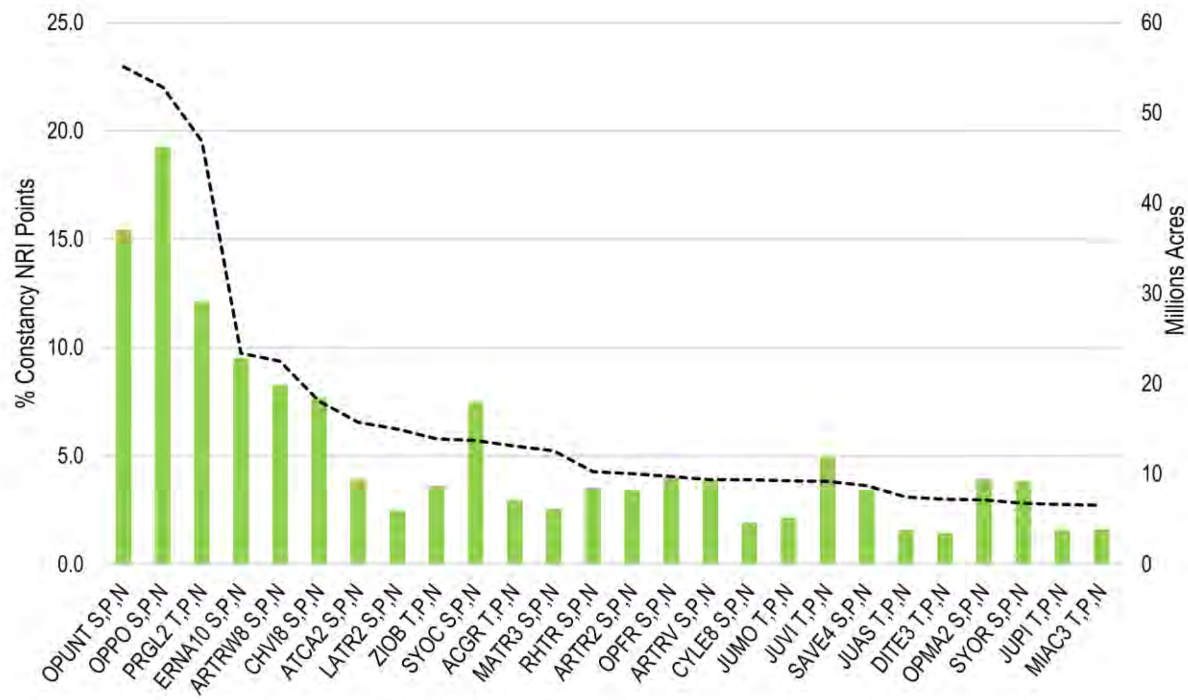
| Symbol | Sci Name | Common Name | Growth Habit Class | Duration | Native/Intro Status |
|---|---|---|---|---|---|
| SIAL2 FH,A,I | *Sisymbrium altissimum* | tall tumblemustard | FH | A | I |
| ERCI6 FH,A,I | *Erodium cicutarium* | redstem stork's bill | FH | A | I |
| COAR4 V,P,I | *Convolvulus arvensis* | field bindweed | V | P | I |
| MESA FH,A,I | *Medicago sativa* | alfalfa | FH | A | I |
| SALSO FH,A,I | *Salsola* | Russian thistle | FH | A | I |
| SATR12 FH,A,I | *Salsola tragus* | prickly Russian thistle | FH | A | I |
| BRHO2 G,A,I | *Bromus hordeaceus* | soft brome | G | A | I |
| BOIS G,P,I | *Bothriochloa ischaemum* | yellow bluestem | G | P | I |

**(b)**




| Symbol | Scientific Name | Common Name | Growth Habit Class | Duration | Native Status Class |
|---|---|---|---|---|---|
| BRTE G,A,I | *Bromus tectorum* | cheatgrass | G | A | I |
| POPR G,P,NI | *Poa pratensis* | Kentucky bluegrass | G | P | NI |
| BRIN2 G,P,NI | *Bromus inermis* | smooth brome | G | P | NI |
| AGCR G,P,I | *Agropyron cristatum* | crested wheatgrass | G | P | I |
| BRAR5 G,A,I | *Bromus arvensis* | field brome | G | A | I |
| BRHO2 G,A,I | *Bromus hordeaceus* | soft brome | G | A | I |
| BOIS G,P,I | *Bothriochloa ischaemum* | yellow bluestem | G | P | I |
| POBU G,P,I | *Poa bulbosa* | bulbous bluegrass | G | P | I |
| CYDA G,P,I | *Cynodon dactylon* | Bermudagrass | G | P | I |
| TACA8 G,A,I | *Taeniatherum caput-medusae* | medusahead | G | A | I |
| BRRU2 G,A,I | *Bromus rubens* | red brome | G | A | I |
| BRDI3 G,A,I | *Bromus diandrus* | ripgut brome | G | A | I |
| BOLA2 G,P,NI | *Bothriochloa laguroides* | silver beardgrass | G | P | NI |
| POCO G,P,I | *Poa compressa* | Canada bluegrass | G | P | I |

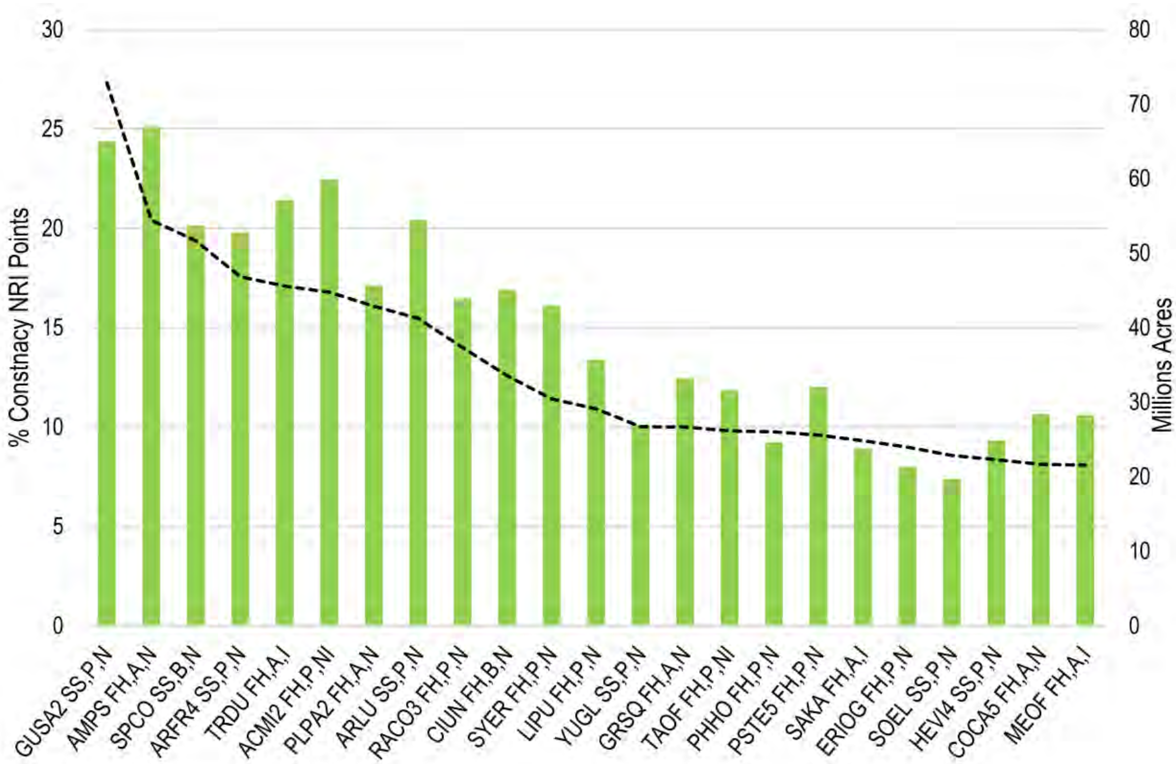
**(c)**




| Symbol | Scientific Name | Common Name | Growth Habit Class | Duration | Native Status Class |
|---|---|---|---|---|---|
| OPUNT S,P,N | *Opuntia* | pricklypear | S | P | N |
| OPPO S,P,N | *Opuntia polyacantha* | plains pricklypear | S | P | N |
| PRGL2 T,P,N | *Prosopis glandulosa* | honey mesquite | T | P | N |
| ERNA10 S,P,N | *Ericameria nauseosa* | rubber rabbitbrush | S | P | N |
| ARTRW8 S,P,N | *Artemisia tridentata ssp. wyomingensis* | Wyoming big sagebrush | S | P | N |
| CHVI8 S,P,N | *Chrysothamnus viscidiflorus* | yellow rabbitbrush | S | P | N |
| ATCA2 S,P,N | *Atriplex canescens* | fourwing saltbush | S | P | N |
| LATR2 S,P,N | *Larrea tridentata* | creosote bush | S | P | N |
| ZIOB T,P,N | *Ziziphus obtusifolia* | lotebush | T | P | N |
| SYOC S,P,N | *Symphoricarpos occidentalis* | western snowberry | S | P | N |
| ACGR T,P,N | *Acacia greggii* | catclaw acacia | T | P | N |
| MATR3 S,P,N | *Mahonia trifoliolata* | algerita | S | P | N |
| RHTR S,P,N | *Rhus trilobata* | skunkbush sumac | S | P | N |
| ARTR2 S,P,N | *Artemisia tridentata* | big sagebrush | S | P | N |
| OPFR S,P,N | *Opuntia fragilis* | brittle pricklypear | S | P | N |
| ARTRV S,P,N | *Artemisia tridentata ssp. vaseyana* | mountain big sagebrush | S | P | N |
| CYLE8 S,P,N | *Cylindropuntia leptocaulis* | Christmas cactus | S | P | N |
| JUMO T,P,N | *Juniperus monosperma* | oneseed juniper | T | P | N |
| JUVI T,P,N | *Juniperus virginiana* | eastern redcedar | T | P | N |
| SAVE4 S,P,N | *Sarcobatus vermiculatus* | greasewood | S | P | N |
| JUAS T,P,N | *Juniperus ashei* | Ashe's juniper | T | P | N |
| DITE3 T,P,N | *Diospyros texana* | Texas persimmon | T | P | N |
| OPMA2 S,P,N | *Opuntia macrorhiza* | twistspine pricklypear | S | P | N |

| Symbol | Scientific Name | Common Name | Growth Habit Class | Duration | Native Status Class |
|---|---|---|---|---|---|
| SYOR S,P,N | *Symphoricarpos orbiculatus* | coralberry | S | P | N |
| JUPI T,P,N | *Juniperus pinchotii* | Pinchot's juniper | T | P | N |
| MIAC3 T,P,N | *Mimosa aculeaticarpa* | catclaw mimosa | T | P | N |

**(d)**




| Symbol | Scientific Name | Common Name | Growth Habit Class | Duration | Native Status Class |
|---|---|---|---|---|---|
| GUSA2 SS,P,N | *Gutierrezia sarothrae* | broom snakeweed | SS | P | N |
| AMPS FH,A,N | *Ambrosia psilostachya* | Cuman ragweed | FH | A | N |
| SPCO SS,B,N | *Sphaeralcea coccinea* | scarlet globemallow | SS | B | N |
| ARFR4 SS,P,N | *Artemisia frigida* | prairie sagewort | SS | P | N |
| TRDU FH,A,I | *Tragopogon dubius* | yellow salsify | FH | A | I |
| ACMI2 FH,P,NI | *Achillea millefolium* | common yarrow | FH | P | NI |
| PLPA2 FH,A,N | *Plantago patagonica* | woolly plantain | FH | A | N |
| ARLU SS,P,N | *Artemisia ludoviciana* | white sagebrush | SS | P | N |
| RACO3 FH,P,N | *Ratibida columnifera* | upright prairie coneflower | FH | P | N |
| CIUN FH,B,N | *Cirsium undulatum* | wavyleaf thistle | FH | B | N |
| SYER FH,P,N | *Symphyotrichum ericoides* | white heath aster | FH | P | N |
| LIPU FH,P,N | *Liatris punctata* | dotted blazing star | FH | P | N |
| YUGL SS,P,N | *Yucca glauca* | soapweed yucca | SS | P | N |
| GRSQ FH,A,N | *Grindelia squarrosa* | curlycup gumweed | FH | A | N |
| TAOF FH,P,NI | *Taraxacum officinale* | common dandelion | FH | P | NI |
| PHHO FH,P,N | *Phlox hoodii* | spiny phlox | FH | P | N |
| PSTE5 FH,P,N | *Psoralidium tenuiflorum* | slimflower scurfpea | FH | P | N |

| | | | | | |
|---|---|---|---|---|---|
| SAKA FH,A,I | *Salsola kali* | Russian thistle | FH | A | I |
| ERIOG FH,P,N | *Eriogonum* | buckwheat | FH | P | N |
| SOEL SS,P,N | *Solanum elaeagnifolium* | silverleaf nightshade | SS | P | N |
| HEVI4 SS,P,N | *Heterotheca villosa* | hairy false goldenaster | SS | P | N |
| COCA5 FH,A,N | *Conyza canadensis* | Canadian horseweed | FH | A | N |
| MEOF FH,A,I | *Melilotus officinalis* | sweetclover | FH | A | I |

## 645.0304 Rangeland Disturbance

A. Rangeland Disturbance Indicators (on-site NRI study).

(1) During the evolution and development of rangeland ecological systems, various stresses, perturbations, and disturbances are natural (Archer and Stokes 2000). In human-influenced rangeland ecosystems, new disturbances and stressors are commonly introduced over time. Their frequency, intensity, duration, and spatial extent are often more frequent compared to the natural disturbance regime. Natural and anthropogenic disturbances co-occur, and the interaction and impacts on hydrologic function, soil and site stability, and biotic integrity in rangeland ecosystems are complex. Ecological site descriptions and state-and-transition models can provide some information relative to ecological state trends and changes and site resistance and resilience to disturbances. Anthropogenic activities can alter ecosystem attributes where state changes may be irreversible; however, positive and rapid feedbacks may also occur (Archer and Stokes 2000; Weltz and Spaeth 2012; Williams et al. 2016). Altered ecosystems occur when natural and anthropogenic disturbances are of "sufficient magnitude to affect ecosystem processes, causing long-term loss or displacement of native community types and loss of productivity" (Bunting et al., 2002). Understanding the effects of stressors and disturbances on specific rangeland ecological types can help conservationists and resource managers to:

(i) identify critical thresholds of ecological state changes.

(ii) mitigate anthropogenic disturbances before undesirable and irreversible state changes occur.

(iii) improve the successful application of management actions, conservation practices, and rehabilitation or restoration activities.

(2) The on-site rangeland NRI study examines the field macro plot and conservation management unit level (CMU) for 35 disturbance indicators (table C-2).

(3) The NRI instructions specify identification of disturbances that are easily and readily observed for the sample. One important note regarding the NRI is that the degree of displacement or dislocation of the natural state–either from human induced, natural events, or other occurrences–are not identified. However, the implication is that the disturbance factor has intensified beyond what is expected for the natural or reference state. Degree of displacement of the current plant community with the reference plant community as described in ecological site descriptions is measured by the similarity index (see subpart E). Rangeland health indicators and assessments can provide information about the degree of departure from a reference state of the existing plant community (see subpart E). Similarity indices and apparent rangeland trend can also be used to detect plant composition changes in the current plant community compared to the historic plant community or designated reference state (see below for respective discussions and data analysis).

B. NRI Definitions: Disturbance.

(1) NRI defines disturbance indicators as follow: displacement or dislocation of the natural state of a sample site resulting from human-induced, natural events, or other occurrences. Thirty-five visually observable features are rated for the degree of disturbance evident within

the 0.40-acre (150-foot diameter circular) sample area and the expanded conservation management unit plot (CMU) (USDA-NRCS 2020). The CMU is considered equivalent to the field where the NRI point resides (fenced or delineated by other means). If no field boundary exists, use a distance of 1,000 feet as a boundary. Do not cross public roads, railroads, or obvious ownership boundaries within the 1,000-ft distance.

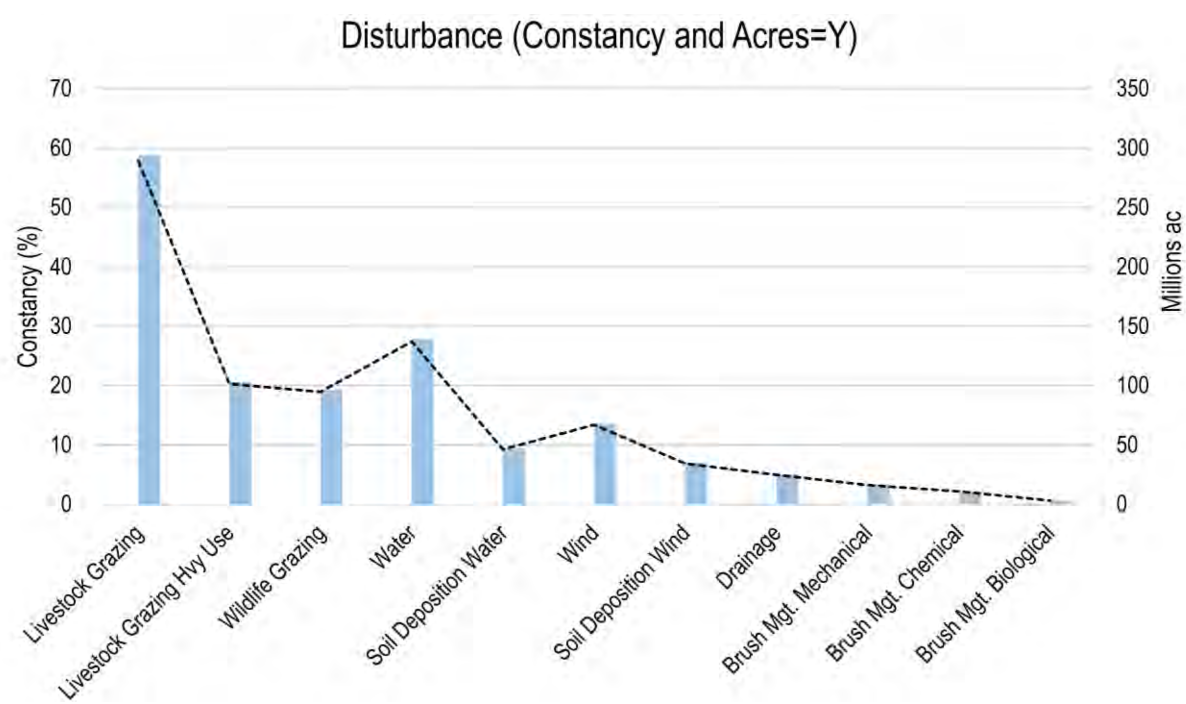
(2) Identified disturbances on approximately 20% or greater of the NRI points sampled (figures C-3a and b) included livestock grazing, livestock grazing heavy use, wildlife grazing, water, livestock tanks, small rodents, non-rodent animals, and insects. Although these data are from the entire NRI data set representing National conditions, data can be reported upon request for specific States, major land resource areas, and ecoregions.

**Table C-2.** List of rangeland disturbance indicators used in on-site rangeland NRI (USDA-NRCS 2020).

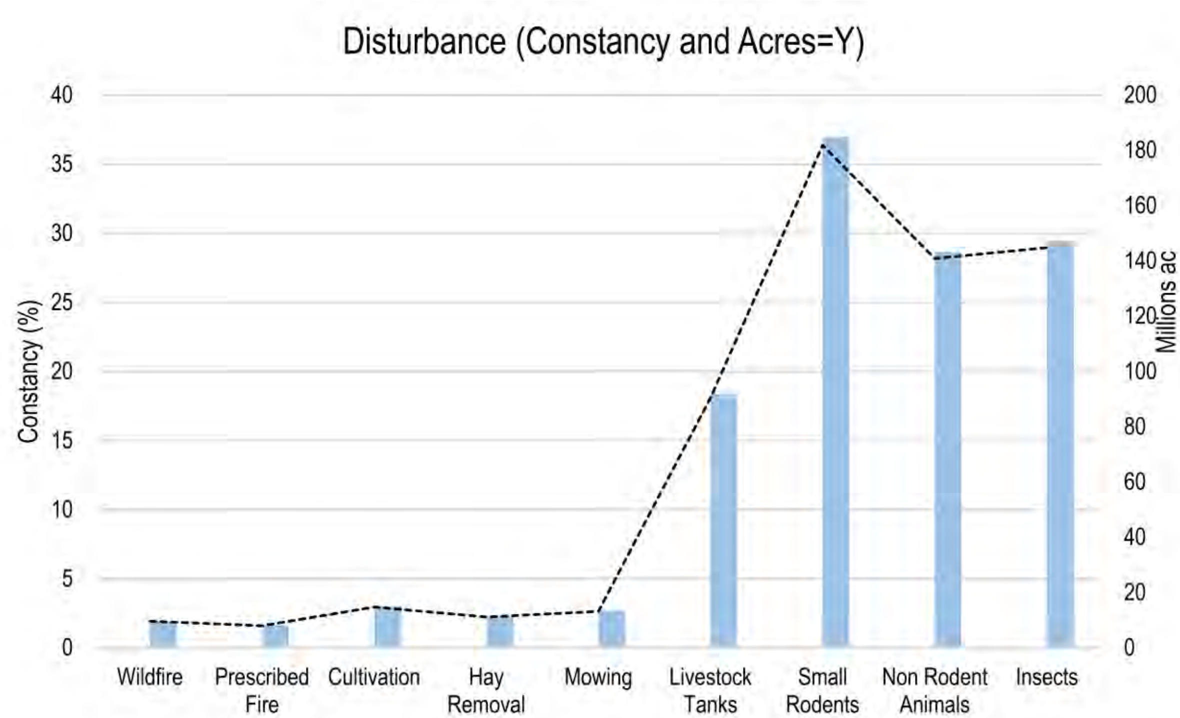
| **Disturbance Indicators** | |
|---|---|
| 1. Cultivation (plowing, disking, cultivator, etc.) | 19. Roads/lanes (paved) |
| 2. Mowing (clipping) | 20. Drainage or field ditch |
| 3. Hay removal | 21. Underground Utilities |
| 4. Heavy machinery (soil disturbance from) | 22. Overhead transmission |
| 5. Seedbed preparation (tillage implements, drill) | 23. Construction activities fence, pipeline, terraces etc.) |
| 6. Livestock tanks, spring development | 24. Water, flooding/ponding |
| 7. Livestock heavy use area | 25. Soil Deposition-water |
| 8. Livestock grazing | 26. Soil Deposition-wind |
| 9. Insects | 27. Water erosion |
| 10. Rodents | 28. Wind erosion |
| 11. Non-rodent animals | 29. Transported fill material |
| 12. Wildlife grazing impacts | 30. Wildfire |
| 13. Mining/Energy/equip. and operations | 31. Prescribed Fire |
| 14. Recreation (trails, foot traffic) | 32. Fire Fighting (machinery, clearing) |
| 15. Recreation (vehicles, bikes) | 33. Brush control (chemical) |
| 16. Livestock walkway, trailing | 34. Brush control (mechanical) |
| 17. Roads/Lanes (dirt) | 35. Brush mgt. biological treatment |
| 18. Roads/lanes (gravel) | |

**Figure C-3. (a)** Rangeland disturbance data from on-site study (2004–2018). Resource concern, Y=yes), constancy of occurrence and total non-Federal acres. **(b)** Continuation of disturbance concerns. Disturbance is defined as displacement or dislocation of the natural state of a sample site resulting from human induced, natural events, or other occurrences.

**(a)**




**(b)**



## 645.0305 Rangeland Assessment Measures (NRI Data)

A. The science of assessing rangelands has evolved over time (Briske et al., 2005). Specific models (qualitative) and indices (quantitative) are available to examine different environmental aspects of plant communities. The USDA-NRCS uses several assessment methods which address different aspects of rangeland conditions and health. These methods include similarity index, apparent rangeland trend, and interpreting indicators of rangeland health for assessing rangeland. Similarity is a quantitative measure based on comparisons of plant species composition (actual production, reconstructed production, cover, density, see subpart E). Apparent trend can be determined qualitatively as well as measured (see subpart E). Interpreting indicators of rangeland health can be assessed qualitatively (exception of soil surface resistance to erosion (Herrick et al. 2001). Indicators are visually assessed according to the reference sheet and departure determined from the matrix defining none to slight to extreme to total departure. Qualitative assessment provides a rapid observation of multiple factors related to each indicator within the evaluation area. Qualitative assessments are often supported by quantitative assessment methods (see Pellant et al. 2020, Section 6).

B. Similarity Index

(1) The use of similarity indices in plant ecology has been used since the early 1900s (Grieg-Smith 1964; Pielou 1969; Mueller and Ellenberg 1974; Egghe 2010; Chiclana et al., 2013). Similarity indices are used to quantitatively measure the degree to which species composition between quadrats, releves, stands of vegetation, communities, or sites are alike, or conversely different (see subpart E). The similarity index is used by the NRCS to assess current plant species composition with a reference community. The reference state is typically the historic plant community (HPC) as described in the ecological site description. However, another community state may be used or developed if the historic plant community is not documented or does not realistically exist due to long-term land use changes. Similarity indices can also be used to compare plant community composition between individual ecological sites to establish species similarities or differences. One strong point regarding the use of similarity index calculations from historic plant community composition is that the methodology is a *quantitative* measure of composition and status of native plants. The importance of quantifying native plants on rangelands is becoming increasingly important because of changing rangeland conditions. Degraded rangeland conditions have been implicated and correlated with declines of certain wildlife species, including a number of insects (many are pollinating species) and bird species. In contrast, stable or restored rangelands display upward plant community trends which support a variety of wildlife species (Monsen et al. 2004).

(2) Similarity indices are mathematical comparisons, based on the presence or absence of a species in a stand or specific plant composition (foliar cover, production, density, frequency of individual species). The USDA-NRCS typically uses similarity index to compare the present state of the vegetation on an ecological site (composition by dry weight) with the historic plant community or designated reference plant community for the site. Subpart E of this handbook details various methods for calculating similarity index. One important note needs to be emphasized with respect to similarity indices: they are a means to mathematically compare current specific species presence or absence, or individual species composition, with a reference plant community.

(i) Using similarity indices to establish overall rangeland condition is an inappropriate use. For example, if the similarity index of the current stand composition based on reconstructed production in relation to the ecological site composition by weight is 35%, compared to the historic plant community (e.g., reference state 1A), the interpretation is that the current stand composition of native plants is 35% similar to what would be expected from the reference state. Note that this is a measure of native plant composition because rangeland ecological site descriptions list dry weight production values and/or foliar cover for native plants. Invasive or other exotic plant species may be discussed in the ESD, but allowable production values are zero in the similarity index calculation.

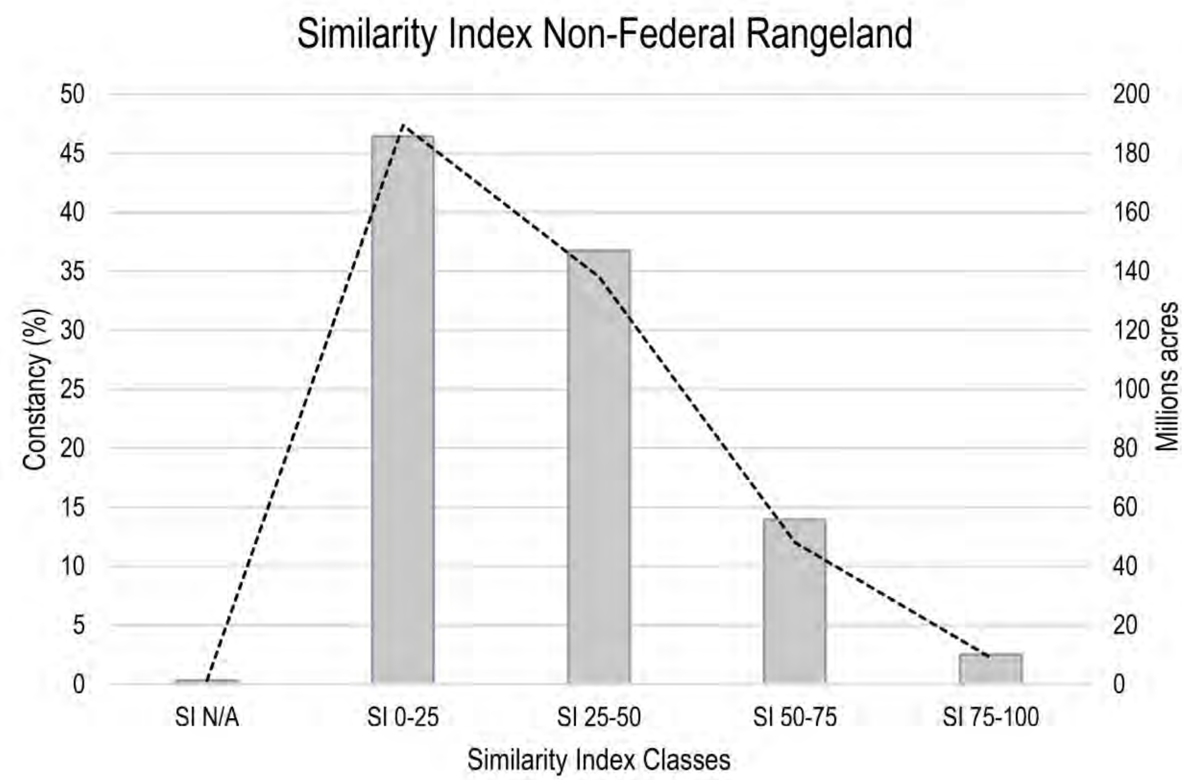
(ii) Using similarity indices to make inferences about soil health, soils and site stability, hydrology, or other health assessments is inappropriate. Some of these environmental factors may be correlated with increasing or decreasing similarity index measures, but other assessment tools such as IIRH can evaluate overall environmental aspects of the plant community in a more direct manner.

(3) In figure C-4, similarity was grouped into four categories: 0–25%, 25–50%, 50–75%, and 75–100%. The group, SI 0–25%, accounted for 49% of the total acres of non-Federal rangeland; SI 26–50%, 36%; SI 51–75%, 12%; and SI 76–100%, 2.3%. During the 1960s–1980s, percent similarity was associated with assessing rangeland conditions, and the respective SI classes were ranked poor, fair, good, and excellent condition (USDA-NRCS 1976).

(i) Similarity index is no longer used as a singular factor in evaluating rangeland condition because rangeland ecologists recognize that many environmental factors are relevant to the concept of rangeland health (Pellant et al., 2020). However, native plant composition is a very important consideration because native biodiversity is an important ecological concern (West 1993). Similarity indices are relevant because the measure does specifically represent, in mathematical terms, the percent similarity or dissimilarity of native plants of an existing stand of vegetation, compared with HPC or a defined reference condition. Obtaining information about native plants on rangeland sites during the planning and monitoring process with landowners is extremely important. The similarity index focuses on composition changes in the context of the historic plant community or designated reference state.

(ii) The use of similarity indices in conservation planning has decreased since the rangeland health model (Interpreting Indicators of Rangeland Health Pellant et al., 2020) has been introduced. However, it has become increasingly important to monitor native species on rangeland because they are, on the whole, more desirable by livestock and wildlife (DiTomaso 2000; Keane and Crawley 2002; and Smith et al., 2012). Conceptually, Interpreting Indicators of Rangeland Health focuses on plant structural functional groups; whereas, similarity index is specific to native plant species from the respective ecological site description. Note that introduced grasses and legumes on pastureland are a separate issue because they are the mainstay of forage in those land uses. Many native forbs comprise the majority of beneficial nectar sources for native butterflies (namely the monarch), and bees are native species (USDA-NRCS 2016; Agrawal 2017).

**Figure C-4.** Summary of similarity index on non-Federal rangeland. USDA-NRCS National Resource Inventory Data 2004–2018. Constancy is the percent of NRI points. Acres (M) are also shown for the respective similarity index classes.




C. Rangeland Health

(1) In 1994, the National Research Council discussed the concept of rangeland health as an alternative to range condition (NRC 1994). Since then, several versions of Interpreting Indicators of Rangeland Health (IIRH) have been published (Pellant et al., 2020). Both the determination of similarity, apparent trend, and IIRH are valuable in defining the status of rangeland from two perspectives. Determining similarity indices and apparent trend in NRCS are based on native plant composition listed in the ecological site description; whereas, IIRH focuses on functional plant groups as a whole. However, specific native dominant species can be stated in the IIRH plant functional group worksheet. These species then become the basis for the assessment for this indicator. IIRH is a qualitative approach that can be augmented with quantitative data and is designed to assess soil and site stability, hydrologic function, and biotic integrity (See Subpart E of this handbook for more details). The challenge is to translate rangeland health assessments into terms land managers and the public can comprehend and use.

(2) The IIRH assessment provides information about how ecological processes, such as the water cycle, energy flow, and nutrient cycle, are functioning, relative to the ecological site. "Rangeland health is the degree to which the integrity of the soil, vegetation, water, and air, as well as the ecological processes of the rangeland ecosystem, are balanced and sustained. Integrity is defined as the maintenance of the functional attributes characteristic of a local, including normal variability" (Pyke et al., 2002).

The evaluation process in the field uses 17 indicators, as shown in table C-3, to assess three ecosystem attributes at each NRI sample point (soil and site stability, hydrologic function, and biotic integrity). Pellant et al., 2020 defines the three assessments as follow:

- "Soil/site stability: the capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water and to recover this capacity when a reduction does occur.
- Hydrologic function: the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.
- Biotic integrity: the capacity of the biotic community to support ecological processes within the natural range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below ground."

**Table C-3.** Rangeland health indicators used to assess three ecosystem attributes: soil and site stability (SSS), hydrologic function (HF), and biotic integrity (BI).

| Rangeland Health Indicators | Applicable Ecosystem Attributes |
|---|---|
| 1. Rills | SSS, HF |
| 2. Water-flow patterns | SSS, HF |
| 3. Pedestals and/or terracettes | SSS, HF |
| 4. Bare ground | SSS, HF |
| 5. Gullies | SSS, HF |
| 6. Wind-scoured and/or deposition areas | SSS |
| 7. Litter movement (wind or water) | SSS |
| 8. Soil surface resistance to erosion | SSS, HF, BI |
| 9. Soil surface loss and degradation | SSS, HF, BI |
| 10. Effects of plant community composition and distribution on infiltration | HF |
| 11. Compaction layer | SSS, HF, BI |
| 12. Functional/structural groups | BI |
| 13. Dead or dying plants or plant parts | BI |
| 14. Litter cover and depth | HF, BI |
| 15. Annual production | BI |
| 16. Invasive plants | BI |
| 17. Vigor with an emphasis on reproductive capability of perennial plants | BI |

(3) A reference sheet is developed for each Ecological Site by experts with knowledge of soil, hydrology, and plant relationships to facilitate consistent application by integrating all available sources of data and knowledge for each of the 17 Range Health indicators (Pyke et al., 2002). The range of expected conditions is based on the natural variation within the historic plant community. The 17 indicators are evaluated on degree of departure (none-to-slight, slight-to-moderate, moderate, moderate-to-extreme, and extreme-to-total) from the expected levels in the ecological site description (Pellant et al., 2020). The three rangeland health attributes (soil and site stability, hydrologic function, and biotic integrity) are summarized from the preponderance of evidence from the 17 indicators.

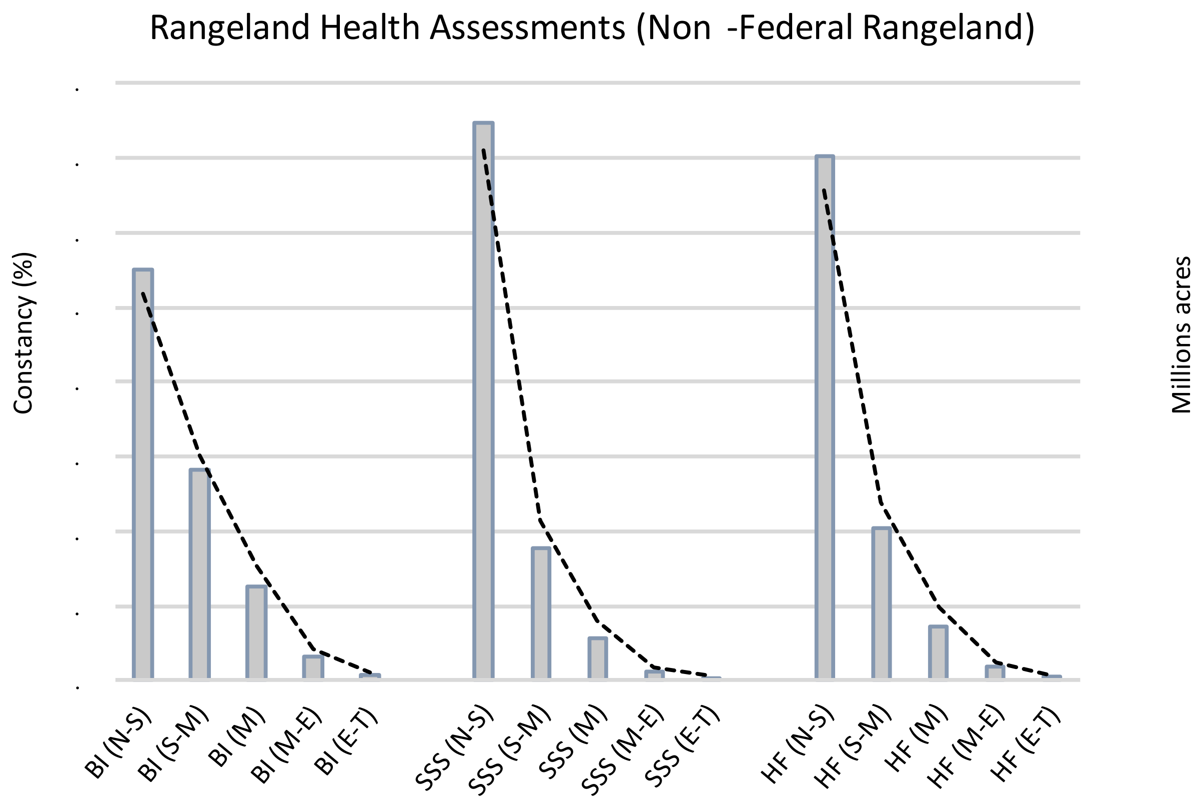
Interpreting indicators of rangeland health does not produce an overall condition or numeric score for a site and should be used in association with other quantitative monitoring approaches (Herrick et al 2005). The IIRH protocol is intended to communicate ecological concepts to the public and landowners, help identify possible land monitoring areas for more comprehensive conservation programs and provide "early warnings" of potential problems.

(4) Figure C-5 provides a summary of rangeland health determinations. Degrees of departure are shown for biotic integrity, soil and site stability, and hydrologic function. None to slight departure from reference for biotic integrity was determined on 55.2% of the NRI points, comprising 194 million acres; none to slight on 74.8% of sampled NRI points (266.2 million acres); and none to slight on 70.2% of NRI points (246.5 million acres). Correspondingly, the moderate of worse ratings for biotic integrity was 16.6% of NRI points (77.4 million acres); moderate or worse rating for soil and surface stability was 7.4% (38.4 acres); and moderate or worse rating for hydrologic function was 9.5% (49 million acres).

D. Apparent Trend

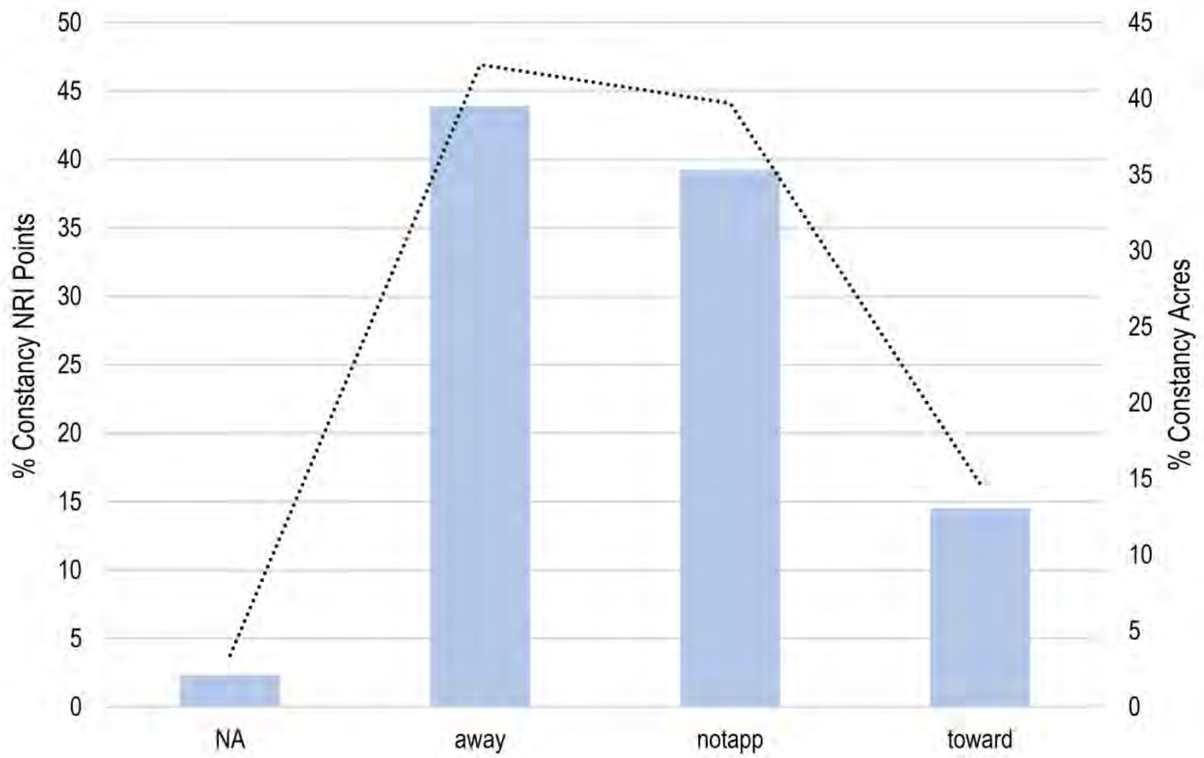
(1) Apparent trend is an assessment of the perceived direction of successional status of a plant community occurring over time in relation to an ecological site reference state (typically historic plant community) or another identified plant community state. Apparent trend encompasses seedling and young plant abundance; perceived changes in plant composition, plant litter, plant vigor, and condition; and status of the soil surface (erosion) in determining if the site is appearing to move toward or away from the desired plant community. Apparent trend is typically a subjective assessment; however various aspects of trend can be quantitatively measured, such as production or cover composition by species-similarity index). These quantitative measures give an indication of trend, but the dynamics of the drivers of successional status or change are not implied. This is the challenge of rangeland specialists and ecologists, evaluating plant communities from a multivariate perspective. What are the effects of current climate, soil health, disturbances (anthropogenic and natural), plant composition) coupled with past and current management? Apparent trend is a point in time determination of the direction of potential or projected change. The categories of apparent trend in the National Range and Pasture Handbook and the rangeland NRI are: "toward" – toward historic plant community (HPC), "notapp" – trend not apparent , "away" – away from HPC, and "NA" – annual rangeland/no ESD. Changes in apparent trend indicators can assist managers in determining the potential direction of change in the plant community.

**Figure C-5.** Summary of rangeland health assessments on non-Federal rangeland. USDA-NRCS National Resource Inventory Data, 2004–2018. Constancy is the percent of NRI points. Acres (M) are also shown for the respective rangeland health assessments. BI=Biotic Integrity; SSS-Soil and Site Stability; and HF=Hydrologic Function. N–S=none to slight departure from reference conditions; S–M=slight to moderate departure; M=moderate departure; M–E=moderate to extreme departure; and E–T=extreme to total departure.




(2) Determining apparent trend is an important part of the rangeland resource inventory process during conservation planning. It is significant when planning the use, management, and treatment needed to maintain or improve the resource. Existing and projected trend should be considered when making adjustments in grazing management. Apparent trend is only applicable on rangelands that have ecological site descriptions identifying the reference historic plant community state and phases.
In figure C-6, on non-Federal rangeland, 2.3% of the NRI points sampled were identified as not applicable (either no ecological site of annual grassland), 43.9% of the points were classified as away from historic plant community, 39.2% not apparent trend, and 14.5% toward historic plant community.

**Figure C-6.** Apparent trend (USDA-NRI 2004–2018). NA=not applicable; Away=moving away from the historic plant community; Not apparent=no change detectable; Toward=moving towards the historic plant community.

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# Part 645 – National Range and Pasture Handbook

## Subpart D – Conservation Planning on Grazing Lands

### 645.0401 General

A. NRCS utilizes multiple documents to guide conservation planning on agricultural lands. Each document listed here provides specific NRCS guidance for different aspects of planning, policy, methods, and procedures when working on grazing land.

B. General Manual Title 180, Part 409, "Conservation Planning Policy" establishes NRCS policy for providing conservation planning assistance to clients.

C. The NRCS National Planning Procedures Handbook, Title 180, Part 600 (180-NPPH-600) provides guidance on the planning process used by NRCS and many of its partners for developing, implementing, and evaluating individual conservation plans and areawide conservation plans and details the nine steps of conservation planning.

D. The NRCS National Range and Pasture Manual (NRPM) supplements NPPH Title 180, Part 600 to provide additional guidance on rangeland, grazed forestland, pastureland, hayland, and grazed cropland conservation planning.

E. The National Range and Pasture Handbook (NRPH) provides NRCS information and processes for assisting ag producers, organizations, other government agencies and groups in planning and applying conservation planning, specifically on grazing lands. The NRPH provides information on the use of ecological site descriptions (ESD), resource concerns, planning, inventorying, assessment and monitoring methods, adaptive management, livestock nutrition, practices, and other topics to help build conservation plans.

(1) In cases where the "grazed" land use modifier is used, the conservation plan will include Prescribed Grazing (528) as a primary practice for those Planned Land Units (PLUs) or Common Land Units (CLUs).
(2) The NRPH also provides the technical guidance for developing state specific resource information for inclusion in the Field Office Technical Guide (FOTG) to support planning on grazing lands.

F. General Manual Title 450, Part 401, "Technical Guides" establishes NRCS FOTG policy. The FOTG contains the technical information needed to assist clients in the development and application of conservation plans. It contains general resource information about the field office area, soil and ecological site information, planning criteria, guidance documents depicting the resource management planning thought process, practice standards and implementation requirements for all practices applicable to the local field office area, and examples of the conservation effects decision making process.

### 645.0402 Purpose

A. The objectives of conservation planning on grazing lands are to assist clients in:

(1) Understanding the basic ecological principles associated with managing their land, including soil, water, air, plant, animal, and energy resources.
(2) Developing an awareness of their socio-economic role in the complex ecosystem and how their management decisions influence the ecological changes that occur.

(3) Comprehending the importance of protecting the environment and maintaining options for future use of the resources.
(4) Developing a plan that meets the needs of the soil, water, air, plant, animal, and energy resources and addresses their management goals and objectives.

B. Conservation plans for grazing lands include decisions for managing key resources and ensuring that they are functioning at a sustainable level. Soil, water, air, plant, animal, and energy resources are intricately related and linked to each other and respond as a system. On grazing lands, the plant community directly affects soil, water, air, animal, and energy resources. While animals are one of the primary ecosystem resources, they can also be utilized as management tools for vegetation manipulation. Plant community management impacts soil health, water quality and quantity, and air quality. Grazing is a low energy input form of agriculture. Therefore, proper use of grazing and browsing animals in managing vegetation is a basic requirement for achieving the desired results of an ecologically sustainable grazing lands conservation plan.

C. Well-managed grazing lands, along with the carbon sink they provide, the clean water and air they support, the recreation opportunities they offer, and the plants, livestock, and wildlife they sustain, make a major contribution to the natural beauty of the landscape and to the maintenance of an ecological and economical sound environment. NRCS assists clients to manage their grazing lands to meet their objectives and, at the same time, meet the needs of the soil, water, air, plant, and animal resources. This plan, when coupled with any necessary facilitating and accelerating practices, should meet the planning criteria for resources established in the local FOTG and the objectives of the client. When properly implemented, conservation plans for ranches, dairies, and other livestock farms benefit the client, the local community, and the Nation.

## 645.0403 Developing Conservation Plans

NRCS conservation planning policy is detailed in 180-GM-409. Conservation Planning procedures are detailed in Title 180, National Planning Procedures Handbook, Part 600.

## 645.0404 Areawide Conservation Planning

A. Conservation plans are typically developed for an individual client. This client has the authority to make decisions on their property that address their resource problems and achieve their desired objectives. However, clients cannot always solve resource problems or meet the objectives of management on their own. There are times when the resource concerns are larger than their individual operating unit and potentially require working with their neighbors. Working together to develop a conservation plan that will solve their resource problems as a larger group, as well as taking advantage of possible socioeconomic opportunities can be included in a Coordinated Resource Management Plan or in a Watershed Management Plan or an Areawide Conservation Plan.

B. Listed below are some ways neighbors can work together to solve resource management problems and meet their socioeconomic and ecological objectives:

(1) Developing a common wildlife management and recreational hunting enterprise.
(2) Cooperating to solve water quality problems in a stream or lake.
(3) Cooperatively managing a riparian area that transverses their lands.
(4) Collaborate to manage a stream as a fishery and recreational fishing enterprise.
(5) Developing a hiking, trail riding, canoeing, bird-watching, or similar enterprise that requires cooperation of all the landowners.
(6) Improving soil health and carbon storage on those suitable soil types that may cross property boundaries.

(7) Developing a livestock grazing management plan across different ownerships to ensure sustainable plant health and productivity.
(8) Forming a prescribed burn association.

D. In many instances, landowners not only need to work together, but they also need to consider working with outside stakeholders that may include public land managers, resource management agencies, cities, soil and water conservation districts, counties, parishes, and various organizations. These groups may have a genuine interest in the conservation plan activities that may be occurring on the local area private lands due to the potential for offsite impacts. In these instances, an areawide plan can be considered for development in order to coordinate the activities of all concerned.

E. The National Planning Procedures Handbook (Title 180, Part 600) has a subpart on areawide planning (Subpart F).

## 645.0405 Conservation Planning Process – Preplanning

A. Typically, when a client contacts NRCS requesting assistance, they have identified an issue they perceive to be a problem and want to solve it. There may be times when the problem they have identified is only a symptom caused by another as-yet unidentified problem or may be a result of a cause they did not understand to be connected.

> An example of this might be a client who has recognized streambank erosion occurring, impacting springs and seeps, and decreasing overall forage production. These are definite issues; however, it may be that both are symptoms of repeated grazing and poor grazing distribution. Through continued grazing pressure, the plants in the pasture, particularly along the stream or near a seep/spring, have begun showing signs of reduced vigor and increased mortality. Over time, plants with reduced forage values have invaded into the open spaces left vacant by plants that have died. This created more open ground and a change in composition that has decreased water infiltration, increased runoff, increased erosion, increased sediment yield to the stream, impacted water quality, decreased water quantity in a seep/spring, reduced forage production and quality, reduced food and cover for wildlife, and continued reduction in forage for livestock production. Therefore, the problem was not what the client originally thought, and instead, the lack of Managed Grazing (528) resulted in the problems the client observed.

B. To determine if the problems identified by the client are the problem or a symptom of a larger or different problem, talking to the client and asking questions are key. Preplanning should always involve talking to the client, both about the planning process as well as the concerns they are seeing on their operations with their natural resources. Describing the planning process, ensuring goals and objectives remain forefront, understanding steps required in completing the process, identifying expected benefits, and explaining the roles and responsibilities of the client and NRCS are crucial in a successful plan.

C. Part of the preplanning process is preparation for a visit to the site. Gathering background information on the area should be a key part of the process. Information that may be required and should be considered include:

(1) Maps (aerial, topographic) for taking notes in the field, including location of infrastructure (fences and water sources, etc.)
  (i) Property boundaries of the ranch
  (ii) Land ownership (public land grazing allotments)

(iii) Prepare for inventory work by stratifying the ranch by Planning Land Units (PLU)[1], ecological sites, and differing plant communities (using aerial photography and/or remote sensing products.) This will be verified, corrected and refined during the field visit(s).

(2) Soils information (maps, map unit descriptions, and interpretations).
(3) ESDs, pasture and hay land interpretations.
(4) Existing vegetation maps (for example, Rangeland Analysis Platform) to field verify, guide inventory efforts, and assist with extrapolation of evaluation tools.
(5) Wildlife habitat evaluation guides.
(6) Grazing lands resource evaluation tools (Similarity Index, Apparent Trend, Rangeland Health Reference Sheets and matrices, Pasture Condition Score, Determining Indicators of Pastureland Health, and forage and livestock inventory).
(7) Equipment, such as forage clipping equipment, sharpshooter spade, knife, GPS, camera; other equipment needed for collecting data, like measuring tapes, pasture sticks, soil stability kit, soil web app, or other pertinent apps.
(8) Other informational material used to demonstrate techniques and principles to land managers.

D. Another essential part of the pre-planning process should include anticipating the knowledge you will need during conversations with the client and while on site visits. This can make time in the field and time spent with the client more efficient and successful. Some ways to prepare might include:

(1) Be knowledgeable about the basic ecological principles of pastureland, hayland, rangeland, grazable forestland, and naturalized pasture in your work area and be prepared to discuss them in a manner that land managers can understand.
(2) Be able to interpret maps, determine range similarity index, apparent trend, pasture condition score, indicators of rangeland health, indicators of pasture health, wildlife habitat evaluations, forage and animal inventories.
(3) Understand principal livestock husbandry practices applicable to the area.
(4) Understand the agency planning criteria for soil, water, air, plants, animals, and energy.
(5) Be knowledgeable of evaluation and monitoring protocols to determine effectiveness of conservation practices implemented.
(6) Understand and be proficient in the nine steps of conservation planning.
(7) Identify the principal client or clients that will participate in the planning process and their respective roles. Update client information. Determine who has decision making authority for the planning area.

E. Lastly, it is important during the preplanning process to make firm dates with the clients and discuss the purpose of the appointment. Ensure that they understand the time requirements needed to complete the visit and always arrive at the agreed upon time, prepared with everything necessary for the day's work.

## 645.0406 The Nine Steps of Conservation Planning on Grazing Lands (range, pasture, and all hayed or grazed land uses.)

A. Phase I: Collection and Analysis. Includes the first four steps of the conservation planning process, which are: identify problem(s), determine objectives, inventory resources, and analyze resource data. These four steps are interactive, usually occurring at the same time and not necessarily in the order shown in NPPH. Table D-1 shows the NRCS nine-step conservation planning process.

[1] PLU is the term used in CD and the NPPH. This is agency jargon and would not typically be used when communicating with landowners. A variety of terms such as field, pasture, or paddock are typically used in common parlance.

B. Phase II: Decision Support. Includes the formulation and evaluation of alternatives and making decisions on which to make the resulting plan. Phase II of the planning process begins with development of alternative strategies to address the identified problems.

C. Phase III: Application and Evaluation. Includes Implementation and Evaluation of the plan.

**Table D-1.** NRCS Conservation Planning Process Steps

| Analytical Phases | Conservation Planning Steps |
|---|---|
| Phase I: Collection and Analysis | (1) Identify problems and opportunities |
| | (2) Determine objectives |
| | (3) Inventory resources |
| | (4) Analyze resource data |
| Phase II: Decision Support | (5) Formulate alternatives |
| | (6) Evaluate alternatives |
| | (7) Make decisions |
| Phase III: Application and Evaluation | (8) Implement the plan |
| | (9) Evaluate the plan |

(1) Identify Problems and Opportunities

(i) Clients generally request NRCS to assist them with particular problems they have identified. If they do not understand the basic ecological principles, they may have recognized a symptom as a problem and not recognized the cause of the symptom. In reality, the cause is the real problem needing treatment. There is a logical sequence of phases that should be followed to ensure that the appropriate problems will be addressed and not just symptoms of a problem as discussed earlier in this subpart. These steps may occur concurrently, or in any order, and may need to be repeated during the planning process.

(ii) One cardinal rule in working with landowners: Never ask a question to which they might give the wrong answer. If they give the wrong answer, we are faced with telling them they are wrong—and this isn't good communication (USDA-NRCS, 1969). Talking with the client and asking important questions related to their operation and concerns will provide a good understanding of baseline grazing management and the goals and objectives they have for their property. Some good questions to ask might include:

- What does the client want from the property (forage production, wildlife habitat, recreation, open space, water quality, etc.)? Specifically:
  - Animal performance (gain, milk, breeding success, etc.)
  - Herd size (desire to change or maintain?)
  - Longer grazing season (reduce feed, supplements, etc.)
  - Marketing preferences (grass fed, organic, etc.)
  - Environmental benefits (wildlife, pollinators, water quality, etc.)
- What type of livestock enterprise(s) do they have (Cow/calf, stockers, purebred, leased or "custom" grazing, specialty livestock, etc.)?
- What values do they see as important in managing their land?
- What do they want to see continue, and what areas do they see are needing improvement?
- What problems are they having with their operation?

- What problems are they having with their natural resources?
- Are there areas of the property they cannot use? If so, why?
- What are the current management practices (prescribed fire, rotational grazing, etc.)?
- How many herds are there?
- What is the current (benchmark) stocking rate and grazing cycle for each pasture? Specifically:
  - When is it grazed (dates in and out)
  - Herd size
  - Typical residual (stubble height or percent utilization)
- How does the client determine when to move the animals?
- What are the needs of the individual herds (special separation needs, nutritional needs, fencing needs, pasture or range condition needs, etc.)?
- What is the history of the area?
- Are they familiar with techniques and methods in evaluating and monitoring management practices? (body condition scoring, utilization measurements, etc.)

(iii) While conducting the inventory, make sure to include the client. Let them participate in the inventory process and explain why each step is necessary. Use the opportunity to discuss other key information about the ecological principles of the area and their landscape, as well as grazing land principles. Some of the essential things that may be important for the client to know and understand include the following, which broadly fit into categories such as soil stability, water infiltration, and plant health and vigor:

- Ability to identify plants on their land
- Concepts of plant ecology and physiology (how plants grow)
- What plant vigor means and why it matters
- Effects of season (timing), duration (time), frequency and intensity of grazing use, frequency of or lack of fire, and other management decisions on the existing or planned reference plant communities or the pastureland plant communities
- Plant competition and how it applies to their land (how plants compete with each other)
- Ecological site concepts for their land (explain the soil-plant relationship)
- Interpreting the results of assessment tools used (i.e., Rangeland Health, Pasture Condition Scoresheet, Similarity Index, etc.)
- Differences between the use of assessments tools and monitoring tools in evaluating landscapes and management practices
- How adaptive management decision making is used in conjunction with monitoring to effectively evaluate conservation practices and determine if a management action or conservation practice needs to be adjusted to meet plan objectives
- What forest ecological and management principles are and how they impact understory reactions and how it relates to grazing management
- The variety of land uses or plant communities that could exist on their land (interpreting the state-and-transition model in the ESD)
- Concept of multiple use opportunities on grazing lands
- Concepts of soil erosion, condition, and contamination
- Concept of waste management on grazing lands
- Concept of targeted or managed grazing as a tool for protecting or improving water quality and water yield
- Principles of water use by plants and effect of grazing management with impacts
- How grazing management can protect or improve air quality (odors or wind-blown dust)

- The food, water, and shelter requirements of domestic animals
- The food, water, and cover requirements of wildlife

(iv) Building an understanding of these basic principles with the clients is essential to a quality conservation plan on grazing lands. Without some knowledge related to these topics, it will be difficult for the client to continue the required inventories, analyze their resources, recognize their problems and their causes, develop proper and obtainable objectives, formulate and evaluate treatment alternatives, plan a course of action, implement the plan, continue to evaluate and monitor their results and make adjustments or changes in management as needed.

(2) Determine the Client's Objectives

(i) It is the NRCS's role to help landowners and managers begin to understand and recognize the underlying problems, not just symptoms of the problem. If the current grazing management is the problem, the NRCS conservationist should not tell the producer that the problem is inappropriate grazing management. Instead, the conservationist must lead them through discussions to recognize that the type of grazing management may be leading to the resource concerns they are experiencing. This can be accomplished by helping them understand ecosystems and how systems function together. The process of recognizing the problem continues throughout Phase I and into Phase II of planning as monitoring data become available and are analyzed.

(ii) Prepare to listen. The most important element for working with landowners is to listen to them and be able to determine their goals, motivations, abilities, potential, desire, dedication, and their financial capability. They will usually not come right out and tell you these things directly and you will probably not want to come right out and ask, but your success in working with them will depend on your ability to discern these things (Nelle and Mills, 2011).

(ii) Objectives should be established by the client after ensuring there is an adequate understanding of their grazing lands ecosystem, after collecting inventory data, and after determining the cause of the resource concern to be addressed. It is often best to suggest that the objectives not be set until after this set of information has been evaluated and accomplished. It can sometimes be difficult to change a person's mind once they have made a firm commitment to a certain objective. Spend the necessary time assisting them through discussions and inventory of their grazing lands resources in order to identify the problems before they express their objectives.

Objectives should be defined as specific steps to reach a particular goal, including specifics on what is planned, where, and when.

(iii) Once the client understands the ecological principles of their grazing lands, they will generally ask some follow up questions. For example:

- "Is my land in good or poor condition?"
- "Is the condition of my land changing? Is it getting better or worse?"
- "How does my land compare to its potential?"
- "What kind of evaluation and monitoring tools are available to me to assess if my objectives are being met?"

(iv) At this point the client is beginning to understand the dynamics of the grazing lands ecology and how their land is a part of that ecosystem and how they can effectively and efficiently evaluate their objectives through monitoring activities.

Evaluation of progress towards objectives is critical to the success of the management plan. Integral to this is a monitoring plan that is clearly understood and do-able by the client.

(3) Inventory the Resources

(i) The process for resource inventory includes collecting data from the current condition of the natural resources found in the planning area. Some key observations should be made during the first field visit. Ideally, the landowner would come along during the first visit to the field. A drive-through reconnaissance of as much of the ranch as possible should be the first step taken. Walk the full extent of the property, if possible, and locate (GPS) all existing structures related to the operation. Identify existing resource conditions and concerns, which may include the following:

- Waterbodies, riparian areas, seeps and springs, and other sensitive areas
- Noxious, invasive, or poisonous species locations, density, and extent
- Areas of cultural significance
- Special wildlife habitat or areas of concern (i.e., wetland or riparian areas)
- Obvious concerns such as gullies, large bare ground patches, etc.

(ii) Field-verify that the ecological site and soil boundaries match mapped descriptions and evaluate the land to determine which states and plant community phases are present, as described in the state-and-transition model (STM) of the ESD. Take note of the plant community composition and compare to the communities described in the ESD. Are any of the plant communities at risk of crossing an ecological threshold? Have they already crossed a threshold? Note the vigor of the plants. Are they able to reproduce? Have the plants been grazed, and to what extent? Does litter remain from the previous year, and is the litter amount within the expected range described in the ESD? Is there evidence of new growth? What seedlings are establishing? Are they species that are expected? Are they species of specific concern? How does the plant community composition and vigor appear to be impacting soil, air, animal, and water resources?

(iii) When digging the hole to confirm the soils and ecological site (or potential), also pay attention to the soil moisture, soil fauna, plant roots and other signs of soil health. Look for signs of compaction. Does the soil structure match the soil description? Are they granular soils when they should be blocky? What might this mean? Is there evidence of adequate soil organic matter in the topsoil? What color is in the description, and what color is it currently? Consider the type of plants present. Do their rooting structures look as you might expect in the soil, or are they inconsistent with what is expected? Are they supposed to be deep and extensive roots that go many inches into the soil profile but are only an inch deep? Do they seem to be growing laterally along a boundary instead of down into the soil? What might this mean about how water is flowing through the soils and back into the plants?

(iv) Make note of animal trailing, pedestalling, water flow patterns on the soil surface, concentration areas, and note the presence and extent of bare ground. Is it more than expected, based on what's been described in the ESD, FSG, or experience? Are there signs of accelerated erosion? To what extent is erosion typical for this site? Locate (GPS) or draw out the extent of such areas.

(v) Note the infrastructure of the operation

- Where are the fences, corrals, water, buildings, or barns?
- Are they sited well?
- Are any changed needed concerning the structures?
- What equipment does the operation have or lack?

(vi) Where on the property is the livestock water and other physical facilities such as fence, handling facilities, roads, trails, and gates? Is it properly distributed across the property for better utilization and adequate to support wildlife needs? Do they provide supplements and where do they locate them? How does that appear to be impacting the resources? What is the condition of any associated natural water bodies, such as riparian areas along stream banks and in spring and seep areas. Is water quantity, quality, and availability adequate when livestock are present? Are water developments well maintained and constructed in a manner that conserves water when livestock are not present? Are float valves on troughs and tanks functional and wildlife escape ramps present?

(vii) Consider wildlife in the area. Could existing fences be made more wildlife friendly? Are there any traps for wildlife that should be considered for improvement? Are there opportunities to remove or relocate fences to improve grazing management or wildlife habitat? When are grazing wildlife present? Does the current grazing management support critical wildlife need, such as fawning and nesting periods? Are riparian areas along stream providing adequate cover and stable banks for fish habitat? Are seeps and springs being conserved to support diverse wildlife species?

(viii) Plant community inventory

- Part of collecting resource data includes conducting an inventory of total production, including forage. It should be stratified by Planning Land Unit (PLU), ecological site or soil, and state or plant community when possible, and then evaluated and aggregated for the entire operation during the data analysis process. Forage inventories will provide information on the species, current condition, and productivity, and can help develop key details on the goals for each management unit. Information should include:
  - Forage species
  - Forage quantity
  - Forage quality (i.e., growth stage when grazed)
  - History of the site
  - Utilization patterns (predicted, modeled, or observed)
  - Current stocking rates
- Determine current utilization levels and proceed to the more in-depth assessments if conditions require them, including Determining Indicators of Pasture Health and the Rangeland Hydrology Erosion Model (RHEM).

(ix) Animal Inventory

- Livestock
  - An inventory of the domestic animals occupying or planned to occupy the operating unit must also be developed. This inventory should be separated into the necessary herds to allow the desired husbandry to be practiced. Information to be inventoried should include:
  - --Numbers, kinds, and classes of animals
  - --Average weights in the herds
  - --Type of enterprise (cow-calf, stocker, dairy, etc.)
  - --Any special management needs or considerations
- Wildlife
  - Wild ungulates should also be accounted for by management unit, with inventory and forage requirements expressed in the same manner as livestock. If they are migratory, such as elk, the time they are expected in the management unit must be determined. Unique riparian habitats, including springs and seeps, deserve special management considerations for wildlife.

(4) Analyze Resource Data

(i) After the inventory process is complete, an analysis of the data is necessary to assist the client to identify and quantify problems. Again, it is imperative for clients to understand the grazing lands ecosystem and ecological concepts before they can analyze the resource data. Show them how you work through the calculations for forage supply and demand.

Talk to them about why you include some information and not other information. These discussions will assist in improving their understanding of the complex inter-relationships of the soil, water, air, plant, and animal resources in their ecosystems. By doing this, it creates more transparency, provides a better understanding of the information for them to describe on their own, and builds trust between the client and NRCS conservationist.

(ii) Typically, analyses include the results of assessment and monitoring tools, maps, tables of plant production, forage availability, and plant vigor and utilization. Planning criteria are used to determine which resource concerns are present. At this point in the planning process, there must be agreement on which of the identified resource concerns will be addressed during the remainder of the planning process. Upon completion of this planning step, the planning process moves into phase II. If other issues are identified or the client decides to address additional resource concerns, the planner may need to return to previous planning steps.

(5) Formulate Alternatives

(i) Managed Grazing (528) is a primary practice on grazing lands and should always be included in each alternative developed. Monitoring plans should also be prepared to evaluate applied grazing management, including a discussion of the predicted ecological or vegetation responses for each alternative.

(ii) Develop alternatives that treat the resource concerns the client chooses to address. Supporting practices, such as fences and water development, are planned when needed to enable the application of the primary vegetative and management practices.

(iii) NRCS employees will assist the client by developing treatment alternatives that meet planning criteria in the FOTG for resource problems chosen for treatment and that accomplish objectives of the client. A sufficient number of alternatives should be presented to the client to ensure that they are selecting alternatives that meet their needs. Revised treatment alternative(s) may be adopted and implemented if evaluation and monitoring show that the originally selected alternative(s) are not meeting management objectives.

(6) Evaluate Alternatives

Evaluate the alternatives to determine their effectiveness in addressing the client's identified resource concerns, opportunities, and objectives. Attention must be given to those ecological values protected by law or Executive order.

(7) Make Decisions

(i) After all the alternatives have been evaluated, the client makes a decision on which alternative(s) meets their objectives. The client considers the following when selecting alternatives: Will they be effective to alleviate the resource problems identified in an acceptable time frame? Are the alternatives economically feasible? Can the client carry them out (do they have the willingness, values, skills, and commitment)?

The success of a conservation plan is totally dependent upon the client's capabilities to make sound ecologically and economically feasible decisions on a daily basis. NRCS must provide and ensure the technical assistance needed so that clients obtain this type of information and understanding as it relates to the management and profitability of their operations.

(ii) The client will make the decision on which alternative is selected. Other alternatives that are considered, but not selected, maybe adopted through adaptive management decision support, if monitoring shows the selected alternative is not meeting plan objectives.

(iii) Practices should follow a logical sequence and be recorded in the conservation plan's schedule of operations. The following logic provides ideas for scheduling application.

- If livestock are on the operating unit, then Managed Grazing (528) should be scheduled and applied as soon as practical. If fencing and water development must be installed before applying the Managed Grazing (528) plan, then they would normally be installed first. Water developments generally are installed before fences because of risk and because the specific locations of planned ponds, wells, and pipelines may need to be moved to a new location, which may affect the location of the planned fence. Once the water developments are applied, then the fencing can be designed without worry that the pond can be built or the planned well will yield a sufficient water supply.

- After the fences and water distribution are installed, the Managed Grazing (528) plan can be initiated. Supporting practices such as brush management, herbaceous weed control, range planting, prescribed burning, grazing land mechanical treatment and critical area treatment, can now be performed because fencing and water development will allow the needed grazing management to successfully complete those practice requirements, such as deferment or rest periods. Each operating unit will have its unique set of circumstances that dictate the schedule of application. A major point to remember is that Managed Grazing (528) is the primary practice on grazed lands.
- Identify and consider activities affecting the Managed Grazing (528) schedule:
  - Husbandry practices
  - Nutrient and social requirements of animals
  - Forage quality requirements
  - Practice application requirements
  - Hunting season needs
  - Recreation Activities
  - Endangered plant and animal species
  - Watershed water quality and quantity needs
  - Riparian needs
  - Predator problems
  - Insect problems
  - Parasite problems
  - Poisonous plants
  - Animal shelter needs
  - Wildlife habitat needs
  - Aesthetic and social considerations
  - Cultural resources
  - Critical areas needing special treatment
  - Soil Health concerns
  - Ranch logistics and limits on labor and equipment
  - Specific requirements of varying livestock enterprises

(iv) Scheduling Grazing

- After the forage and animal inventory is done and other factors have been considered, calculate the estimated forage available in each management unit. Calculate the daily forage needs of each herd, in preparation for scheduling Managed Grazing (528). Have this available to assist the client as the client schedules livestock movement through the management units in a way that will:
  - Balance forage requirements with forage supply
  - Meet the growth needs of the plants
  - Meet the nutritional needs of the animals
  - Meet the husbandry needs of the livestock
  - Meet the needs of the wildlife of concern
  - Meet the needs of all other activities in the management unit and operating unit
  - Meet the client’s objectives

- Include any supplemental or substitutional feed requirements needed to meet the desired nutritional demand for the kind and class of livestock and browsing and grazing of wildlife. See Subpart H for guidance on animal nutrition.
- Many methods could be used to determine the appropriate stocking rate within a grazing unit. Often the past stocking history (producer records) and the trend of the plant community are the best indicators of a proper stocking rate.
  - Three techniques for forage inventory and stocking rates are described in Examples D-1, D-2, and D-3. Using different techniques and comparing the results will help refine the numbers used for planning.
  - NRCS does not establish grazing capacities. Neither does it require an agreed upon stocking rate in conservation plans. NRCS assists land users in making their own decisions concerning the number and kinds of animals to ensure economic and ecological sustainability. A beginning stocking rate is normally suggested, based on inventories.

**Example D-1.** Estimating stocking rate using producer records

Forage supply can be back-calculated from the producer's records. The equation is:

Number of AUs*AUE* Days Grazed = AUDs

Example:

100 cow *1.1 AUE*45 days grazed = 4,950 AUDs

The utilization rate that resulted from the recorded use should be taken into account by dividing the AUDs by the observed utilization rate then multiplying by the target utilization rate so the equation becomes:

Number of AUs*AUE*Days Grazed*Target Utilization rate/Observed Utilization rate = AUDs

Example:

100 cows* 1.1 AUE*45 days grazed/ 0.65 observed utilization*0.5 target utilization = 3,808 AUDs

This technique provides an accurate estimate of a proper stocking rate, but it is based on the actual production from the recorded year. Further adjustments would need to be made to use it as an estimate of a "representative" year.

**Example D-2.** Estimating stocking rate using field inventory

The results of vegetation measurement techniques used to inventory plant community production (described in 645.40 Subpart E Inventory, Assessment, and Monitoring of Grazing Lands) can be used to set appropriate stocking rates. To calculate stocking rates based on production data gathered in the field, several steps need to take place:

The production value(s) need to be extrapolated across the PLUs varying ESDs, soils, and/or plant communities, then aggregated (using a weighted average) into a total value for the PLU (usually in lbs./acre).

> Reconstruction of the production values back to a 'representative' year for multi-year planning (or no reconstruction for planning in the current season).
>
> Standard, estimated or modeled values for harvest efficiency and distribution (accounting for topography, distance to water, etc.) should be used to adjust the total forage values.

Convert lbs/ac production values into AU values using a constant for intake (NRCS standard is 2.6% oven dry or 3% air dry forage of body weight per day).

**Example D-3.** Estimating stocking rate using remote sensing products

Continuous coverage of annual production values of herbaceous vegetation is freely available through online tools such as the Rangeland Analysis Platform (RAP) and FuelCast. Past, present, and projected values for production are available. To calculate stocking rates based on remotely sensed production data, several steps need to take place:

> Values from remote sensing products should be field verified.
>
> For multi-year planning, the appropriate value can be chosen by analyzing several years of past production values. If planning for the current season, the present or predicted values should be used.
>
> Standard, estimated or modeled values for harvest efficiency and distribution (accounting for topography, distance to water, etc.) should be used to adjust the total forage values.

Convert lbs./ac production values into AU values using a constant for intake (NRCS standard is 2.6% oven dry or 3% air dry forage of body weight per day).

(viii) The planner can then work with the client on the timeframe for implementing the practices and begin developing the Conservation Plan.

(ix) The client's copy should contain:

- Client Objectives
- Grazing Lands Conservation Plan Maps:
  - Operating boundary (may be different than ownership boundaries)
  - Planned field boundaries, field number, land use, acres
  - Visual display of assessment results
  - Location of current and planned practices
  - Ecological Sites and/or soils

  - Key Area locations, photo point monitoring sites
  - Pertinent infrastructure (roads, sensitive areas, pipelines and troughs, etc.)
- Forage Inventory
- Livestock Inventory
- Feed and Forage Balance Worksheet
- All inventory data sheets
- Grazing Schedule
- Monitoring Plan
- Contingency Plan
- Practice schedule
- Practice Implementation Requirements

(x) The NRCS copy should contain all the above and:

- Directions to the location of the land unit
- Technical Assistance Notes
- Applied Practices

(xi) Contingency Plan

The plan will include a contingency plan that details potential problems (i.e., wetness, drought, wildfire) and a guide for adjusting the grazing prescription to ensure resource protection and economic feasibility and sustainability. The plan should include what evaluation protocols would be used in order for the client to recognize potential problems in the early phases (drought) and a plan of action that will be taken to offset and minimize the deterioration of the resources, livestock, and wildlife, and the economics of the operation.

(xii) Monitoring plan

A monitoring plan will be developed to help assess how the new management is or is not achieving the planned results. Adjustments may need to be made in management to achieve goals. The monitoring plan will be carried out using the established key area in each management unit. Adaptive management decision making should be used if monitoring shows adjustments in management practices and other treatment alternatives are needed to meet plan objectives.

(8) Implement the Plan

(i) NRCS employees assist clients in inventorying their grazing land ecosystems and the facilitating practices currently in place, along with current grazing management schemes, current husbandry practices, livestock performance, wildlife habitat and numbers, etc. This information helps complete needed evaluations of current ecological and performance status. During this process, the conservationist should develop an understanding of the client's available resources to implement the conservation plan.

(ii) The land manager is now ready to implement the plan. NRCS personnel shall provide technical assistance to the client in the application of all practices as needed and requested.

(iii) Primary Practices for grazed or hayed lands are Forage Harvest Management (511) and Managed Grazing (528). These are the most difficult and complex practices to plan and apply. These practices, respectively, are the proper application of hayland harvest and the proper manipulation of livestock number, kind, and class through pastures or rangeland in a time or manner that causes the plant community composition to move toward or maintain the desired community, while meeting the needs of the livestock and wildlife of concern. Managed Grazing (528) application is an iterative and ongoing process. For many clients, it is a change in lifestyle as it becomes a decision process that may affect their daily routine. For this to be successful, land managers often require close and continuous technical assistance from NRCS personnel as they learn to adapt and adjust management strategies and practices based on monitoring results. NRCS personnel must provide onsite assistance and follow-up in a timely manner to continually teach clients to observe, evaluate, and monitor their grazing lands, livestock, and wildlife to make adaptive grazing management decisions that will be flexible enough to ensure success.

(iv) Supporting Practices

- Supporting practices such as fences, ponds, wells, water storage facilities, pipelines, and troughs all need to be installed according to a technical design to ensure success. NRCS personnel shall provide on-the-ground technical assistance needed for design and installation to ensure technical adequacy and that NRCS standards and specifications are met.
- Practices, such as brush management, weed control, nutrient management, forest improvement, range planting pasture planting, prescribed burning, water spreading, critical area treatment, diversions, streambank and shoreline protection, and structures for water control could be primary or supporting practices depending on how they are addressing the resource concerns. All need to be installed according to a technical design to ensure success. NRCS shall provide the technical assistance needed for design and installation.

(9) Evaluate the plan (Follow up)

(i) After clients initiate application of their plan, NRCS should provide follow-up assistance. As previously stated, grazing management is an ongoing process. The client may need assistance from NRCS personnel to evaluate results of the applied Managed Grazing (528). It is a continuous learning process for the client and the NRCS personnel who are gaining experience. Grazing management can often be fine-tuned through monitoring and adaptive management actions and practices to accomplish their goals. Many times, clients increase their knowledge in grazing management and may elect to change to more intensive grazing management schemes as a result of monitoring their livestock performance and land resources. This often requires a plan revision to increase fences, water developments, or both, as well as a revision in the grazing schedule.

(ii) The client's objectives often change, or new technology arrives that the client should consider. New resource problems are often recognized as the technical and management knowledge of the client increases.

(iii) NRCS continuously gathers data from local grazing management application experiences. This information builds databases of responses to treatment. These response evaluations are necessary to assist future clients in the planning process and assist with adaptive management decisions.

(viii) The initial planning process is just the beginning of the learning and understanding of grazing management for many clients. Experience has shown that most clients will not and cannot successfully apply their plan without follow-up implementation assistance from trained NRCS personnel. For these reasons, periodic contact needs to be made with the client to ensure the continued success of the conservation plan and to collect response data for future assistance to clients.

(ix) Activities to Accomplish Follow-up

- Make a firm date with the client for follow up evaluation assistance. Explain the purpose of the contact so that they may prepare. Review on-the-ground results of the applied grazing management. Use the opportunity to teach and assist clients to recognize trends in plant community response. Assist them to adjust and adapt grazing management practices needed for the plant community to respond as desired, provide quantity and quality forage needed by livestock and wildlife of concern, and meet the needs of the soil, water, air, plant, and animal resources.

- Review the schedule of operations for the implementation of practices. Follow up and monitor those that have been applied to evaluate their continued success. Assist in improving the schedule of application. Assist in recognizing any maintenance need on applied practices. Encourage management flexibility and adopting other practices or treatment alternatives if original planned practices are not being met.
- Gather response data that will improve client's ability to predict future responses to treatment.
- Assist clients to identify new or developing resource concerns that may need attention.
- Provide clients new technical information applicable to their resource problems and invite client to any training that may occur.
- Host or coordinate training if several clients within a geographic area have similar resource concerns or are developing management strategies to address a unique or special resource concern.
- Assist the clients with their monitoring and evaluation efforts and any necessary revisions of alternative actions that maybe necessary to revise their management actions as needed.

## 645.0407 References

A. Nelle, Steve, and Kent Mills. 2011. Personal communication during the Working Effectively with Livestock Producers Course.

B. USDA-NRCS, 1969. Conservation Planning on Grazing Lands– The Art of Communication

# Part 645 – National Range and Pasture Handbook

## Subpart E – Inventory, Assessment, and Monitoring for Grazing Lands

### 645.0501 General Information

A. Purpose

The purpose of this subpart is to provide guidance on how to conduct inventories and assessments and how to set up monitoring plots on grazing lands. It provides a summary of remote sensing tools commonly used by NRCS and information on data capture and storage devices that are available. Information is included on how inventories, assessments, and monitoring data are used in conservation planning, developing ecological site descriptions, and used in National Resources Inventory (NRI). Instructions for using common tools for inventorying, assessing, evaluating, and rating areas of interest or planning areas are described in full; and the subpart provides information on vegetation sampling techniques, links, and references for ease in locating tools and helpful documents, if those procedures are not covered fully in this subpart.

B. Introduction

(1) Inventory, assessment, and monitoring resources are important activities conducted by range and pasture specialists in the conservation planning process. Collecting appropriate natural resource, economic, and social information about the planning area can be used to:
  (i) Identify existing or potential resource concerns or opportunities.
  (ii) Further define existing and potential resource concerns and opportunities.
  (iii) Clarify those resource concerns.
  (iv) Formulate and evaluate alternatives.
  (v) Gather pertinent information concerning the affected resources, the human considerations, and operation and management (NRCS, National Planning Procedures Handbook, 2020).
  (vi) Evaluate the effectiveness of implemented conservation practices to address resource concerns.

(2) The resource inventory is the identification of Soil, Water, Air, Plant, Animal, Energy and Human resources (SWAPAE+H) and Special Environmental Concerns (SECs) that are present and are the basis of all planning efforts. This information furthers the understanding of the presence of the natural resources in the planning area (NRCS, 2020).

(3) For NRCS staff, Step 1 (Identify Problems and Opportunities) and Step 2 (Determine Objectives) of the nine steps of Conservation Planning are the best guides to deciding what to inventory and the degree of detail that is needed in the process.

(4) There is no single method for collecting information on grazing lands. No single measurement or technique provides enough information to guide management in all situations (Smith et al. 2012). Inventory, assessment, and monitoring are different processes – although related – that usually require different protocols and sampling methods. It is important to distinguish between the respective purposes of inventory, assessment, and monitoring activities, with inventory and assessment activities typically preceding monitoring and contributing to where, what, and how things will be monitored later in the planning and evaluation process (Bern et al. 2006).

C. Uses of NRCS Grazing Land Inventory, assessment, and monitoring data

(1) Inventory, assessment, and monitoring data can be used not only for conservation planning but also to study conservation treatment effects, to establish the baseline data for monitoring, determine resource concerns, and other uses including:
  (i) Coordinating grazing history, stocking rate, and animal performance records in determining guides to initial stocking rates.

(ii) Development of ecological site descriptions and preparing soil survey manuscripts.
(iii) Studies of conservation practice treatment effects.
(iv) Analyzing wildlife habitat values.
(v) Planning watershed and river basin projects.
(vi) Assisting and training landowners and operators in monitoring vegetation trends and the impact of applied conservation practices and programs.
(vii) Exchanging information with research institutions and agencies.
(viii) Preparing guides and specifications for recreation developments, beautification, natural landscaping, roadside planting, and other developments or practices.
(ix) Directing Plant Material Center program activities.
(x) Developing modeling tools.
(xi) Helping to direct policy.

(2) Data collected during inventories, assessment, and monitoring results can be used for Ecological site description (ESD) development, with data collected for ESDs more extensive than data for conservation planning inventories. Ecological site development requires collections of biomass data, a review of local history related to reference plant communities, and correlation to a specific soil component. The National Ecological Site Handbook describes the tiers of data required for provisional and approved ecological site products: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcseprd1291232

(3) The Conservation Effects Assessment Project (CEAP) quantifies the environmental effects of conservation practices and programs. The process includes research, modelling, assessment, monitoring, and data collection. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

(4) The NRI Grazingland On-site Study collects and produces scientifically credible information by assessing the status, condition, and trends of land, soil, water, and related resources on the Nation's non-federal lands, in support of efforts to protect, restore, and enhance the lands and waters of the United States. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/

(5) Inventory data are used to determine and document the environmental effects of conservation decisions through the NRCS Environmental Effects policy and National Environmental Protection Act (NEPA) requirements. NEPA was written to ensure that Federal decision-makers take into account the environmental effects of their proposed actions and consider ways to avoid, minimize, or mitigate adverse effects before implementing the action. This is also the purpose of the NRCS environmental evaluation process. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/ecosciences/ec/?cid=nrcsdev11_000340.

(6) Hydrologic model development is an important activity in NRCS that requires data collection from a unique set of variables, including plant cover and slope. The Rangeland Hydrology and Erosion Model (RHEM) is a soil erosion model to predict soil loss specific to rangelands. Manuals, handbooks, and facts sheets are available for the RHEM tool and can be found on the NRCS Rangelands web site at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=STELPRDB1043345. More information on Ecohydrology on rangelands can be found in Subpart G of this handbook.

## 645.0502 Remote Sensing for Inventory, Assessment, and Monitoring of Grazing Lands

A. Remote sensing is a methodology for data collection, analysis, and the parameterization of environmental models from satellite data. Remote sensing requires an interdisciplinary approach to be able to interpret the data received and make it operational. Remote sensing technology is rapidly changing with frequent new developments. The USDA-NRCS Geospatial Sciences website is a source for current information at https://geospatial-sciences-nrcs.hub.arcgis.com/.

B. Remote sensing integration is the simultaneous use of field and remote-sensing data for inventory, assessment, and monitoring. Remote sensing technology can increase efficiency, reduce the amount of field data that needs to be collected, and allow better extrapolation of field data to the landscape, improving the ability to inventory and monitor large and diverse landscapes. Field data are used to validate remotely sensed data products and to provide information on indicators that cannot be remotely sensed. Remote sensing integration supported by the Bureau of Land Management's Assessment, Inventory and Monitoring (AIM) Strategy are also used by NRCS and includes the following from validation or characterization of remotely sensed products:

(1) Field data to validate remote-sensing based products like vegetation classification and landscape level maps of attributes such as bare ground, biomass production, and invasive species prevalence.
(2) Improving field-based estimates with remote sensing data. The precision of field-based estimates can be improved by adding remote sensing data as co-variants.
(3) Aiding in the selection of field sampling locations. Use remote sensing products such as vegetation indices and classifications to capture landscape patterns of interest for management (Toevs 2011).
(4) Supplement field-based sampling with image-based sampling. Unmanned Aircraft Systems (UAS) or drones can provide a collection of high-resolution images to supplement field plot-level data. Access issues, quantity of samples, and sampling intensity can be addressed using UASs. See GM-170-402 - Part 402 – Aviation Management – Unmanned Aircraft Systems for NRCS policy, procedures, and guidelines on the use of UAS.

C. Remote Sensing Tools and Products

(1) Remote sensing technology is a rapidly developing and changing field. Other remote sensing tools and products used for NRCS conservation planning will be reviewed as they are developed. An annotated catalog of geospatial workflow enhancements and geodatabase models developed is referenced here for use in NRCS Field, Area, State, and Regional offices used for conservation planning.
(2) Remote sensing products that are currently available provide estimates of:
   (i) Plant cover (by life form)
   (ii) Bare ground
   (iii) Biomass
   (iv) Annual production
   (v) Canopy height
   (vi) Elevation

D. The following remote sensing products are currently available for use in grazing land inventory, monitoring, and assessment. Each of these tools requires field validation:

(1) **Rangeland Brush Evaluation Tool (RaBET)** estimates canopy cover of woody plant species but is limited to use in specific Major Land Resource Areas (MLRAs). This operational product allows land managers and NRCS to assess spatial and temporal changes in woody vegetation over large heterogeneous landscapes and provides them with a tool to assess where the greatest need for treatment exists (Collins et al. 2018). More information can be found at: https://rangelandsgateway.org/dlio/15355.
(2) **Rangeland Analysis Platform (RAP).** The Rangeland Analysis Platform (RAP; https://rangelands.app) is a free online application providing vegetation maps (30m resolution) across rangelands of the western U.S. from 1986 to present. Products leverage satellite data, NRI, and other plot data to produce maps of annual percent cover of perennial forbs and grasses, annual forbs and grasses, shrubs, trees, and bare ground (Allred et al. 2021), as well as herbaceous production (lbs/ac) every 16 days and annually (Jones et al. 2021). RAP provides an easy-to-use interface for NRCS conservationists to visualize rangeland heterogeneity and analyze trends of vegetation cover and production

from pasture to watershed scales. RAP can be used throughout the NRCS Conservation Planning Process to help planners inventory rangeland resources, identify and prioritize areas for management, and evaluate outcomes of practices. Examples of applications include area-wide planning to reduce woody encroachment and invasive species, prescribed grazing and drought contingency planning, and monitoring vegetation responses to conservation practices. RAP Help Resources can be found at: https://support.rangelands.app.

(3) **Normalized Difference Vegetation Index (NDVI)** is a measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves are absorbed, and others are reflected). Chlorophyll is a health indicator, strongly absorbs visible light, and the cellular structure of the leaves strongly reflect near-infrared light. When the plant becomes dehydrated, sick, afflicted with disease, etc., the spongy layer deteriorates, and the plant absorbs more of the near-infrared light, rather than reflecting it. Thus, observing how NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health (Earth Observing System). For more information: https://eos.com/make-an-analysis/ndvi/.

(4) **GrassCast** is an optional tool that forescasts an area's peak standing grassland biomass for the whole growing season. Managers can use GrassCast to form a more educated guess about the upcoming growing season. It can help inform the design of proactive drought management plans, trigger dates, stocking dates, and grazing rotations.

GrassCast works by using well-known relationships between historical weather and grassland production. It combines current weather data and seasonal climate outlooks (from NOAA Climate Prediction Center) with a well-trusted grassland model (DayCent) to predict total biomass (lbs/acres) for individual counties, compared to their 38-year average. For more information: https://grasscast.unl.edu/.

(5) **FuelCast** is a fuel and rangeland production forecasting system. It leverages Google Earth Engine and Tensorflow to process near real-time weather and remote sensing data. It provides weekly forecast estimates of magnitude and timing of annual production and fuel across coterminous US rangelands with free, near real-time information to rangeland managers, fire specialists, and producers. For more information: https://www.fuelcast.net/dl.

(6) **Land PKS-Land Potential Knowledge System (LandPKS)**. See figures E-1 and E-2. The USDA-ARS Jornada provides a number of tools for soil and ecological site identification, data collection, and for accessing data, information, and knowledge. As of September 2021, the LandPKS mobile application provided the following functions for pastures and rangelands:

(i) Soil texture determination (video key)
(ii) Soil color determination (using a grey card or yellow Post-It Note© for reference)
(iii) Soil and ecological site for a location and adjacent map units using GPS, map, or hand-entered location (requires internet access, then stored on phone for location)
(iv) Soil and ecological site identification based on location + user inputs (e.g., soil texture by depth, soil color by depth, rock fragment volume by depth)
(v) Habitat information for ~ 100 species
(vi) Data collection (with on-phone and private or public cloud storage and data portal access)
(vii) NRI-compatible (but less detailed) vegetation cover, height, gap
(viii) Utilization
(ix) Soil health (NRCS Cropland In-Field Assessment with all methods)
(x) In-app user support (tap on question mark)

**Figure E-1.** Land PKS-Land Potential Knowledge System (LandPKS).


**Figure E-2.** Emilio Carrillo, NRCS Rangeland Management Specialist using Land PKS.

(xi) The current version requires a gmail login; future versions likely will not.

(xii) The Jornada, in cooperation with the BLM, NRCS, and other partners, will continue to make these and additional functions available in the future, and any data collected will continue to be available. Like all technology, these tools are constantly being updated and improved, and the specific form may change. More information: https://landpotential.org/. https://jornada.nmsu.edu/

(7) **Light Detection and Ranging (LiDAR)** is a remote sensing method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths are used to make a digital 3-D point cloud of the target. As with all remote sensing products, each individual LiDAR data collection is a "snap-shot in time" and is created with a variety of sensors that are constantly changing in capabilities and performance over time. Differences in the type of elevation product and the quality of the digital data for different applications are a result of the sensor and processing techniques. Guidance on quality standards and how data quality is assessed and are available from the Federal Geographic Data Committee (FGDC) National Standards for Spatial Data Accuracy, NSSDA Part 3, and the USGS 3DEP Standards and Specifications. NRCS also provides guidance for Using LiDAR for Planning and Designing Engineering Practice: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=36637.wba.

(i) The classified LiDAR point cloud can be used to create high resolution elevation raster datasets of the Digital (bare earth) Terrain Model (DTM) and the Digital

Surface Model (DSM). A properly classified LiDAR point cloud can be used to model vegetation structure and produce maps of canopy height for each raster cell location. Generally, the elevation data derivatives are most effective in determining woody plant canopy heights that are greater than four feet. However, this would need to be validated for each data collection by examination of the product's metadata or ground truth verification.

(ii) LiDAR is also used to obtain information on the height distribution of plant communities and for interaction of Digital Surface Model (DSM) plant heights with satellite or aerial photography imagery for plant communities. The user of LiDAR elevation derivatives for vegetation analysis will need to be aware of the "snap-shot in time" factor because many of the LiDAR data sources for NRCS are several years old. Current developments in UAV technology are making it possible to have a digital surface model available for current vegetation characterization.

(iii) LiDAR elevation derivatives are also used to develop stream flow networks, model hydrology, and detect concentrated flow areas and gully erosion, even under significant forest canopy conditions. This is a very complex topic and not easily generalized. NRCS has provided support for the production of several recorded video sessions describing how LiDAR elevation derivatives can be processed and applied for hydrology and terrain analysis.

(iv) Not all NRCS field offices have access to LiDAR imagery. Contact the NRCS State GIS Specialist for information on LiDAR image coverage for the area of interest.

## 645.0503 Data Capture and Storage

A. Electronic devices for capturing inventory, assessment, and monitoring information are available in NRCS field offices. The use of these devices assists in quick data capture and reduces transcription errors from paper copy to data analysis programs and reports.

B. Data storage of inventory, assessment, and monitoring information for conservation planning is typically kept in the individual client's hard copy casefiles or electronically within the Documents Management System (DMS).

C. The Conservation Assessment Ranking Tool (CART) is a database system that captures resource concerns and existing conditions based on resource inventory questions, along with existing practices, planned condition, and planned practices. The CART data are geo-spatially referenced to planning land units (PLUs) within a client's conservation desktop (CD) practice schedule in the client's case file. CART data are stored in the National Planning and Agreements Database (NPAD), allowing the data to be queried for analytical purposes.

D. Other options exist with partnering organizations to store inventory data in databases such as with the Jornada's Database for Inventory, Monitoring and Assessment (DIMA; https://jornada.nmsu.edu/monit-assess/dima). DIMA is an Access© database which enables field data collection. It also provides calculations and reports upon completion of data collection (handy for Interpreting Indicators of Rangeland Health and comparing data to previous years while in the field). Core methods monitoring data (e.g., data collected according to Herrick et al. 2018 and IIRH v5) can also be stored and accessed through ARS's Landscape Data Commons, which houses interagency inventory monitoring and assessment data, including BLM, AIM, and NRI data.

E. Environmental Systems Research Institute (ESRI) products are an example of other software systems available to NRCS for developing data collection apps like ArcGIS Survey 123. This can document the georeferenced point of assessment, soils, ESDs, photos, and indicator and attribute ratings for the Interpreting Indicators of Range Health (IIRH) protocol in the field via an iPhone. These data are stored in geoportals and displayed using geoportal or ArcMap. Other options include developing a dashboard to display current data. The data collected in the field are stored and applied to support conservation planning process, program delivery, and ESD development.

F. Few software systems are available to NRCS that provide the full range of standardized NRCS rangeland, pastureland, and grazed forestland inventory, assessment, and monitoring methods. The Vegetation GIS Data System (VGS) is one program available to NRCS that offers a robust system for efficiently capturing and storing inventory, assessment, and monitoring data electronically. See figure E-3. Calculations and reports are created from the data and are available immediately for review and discussion while in the field with land managers. Access to photographs from previous data collections can be compared while in the field, and the GPS unit support spatially links data to the collection site. The VGS program, support information, and training resources are available at: https://vgs.arizona.edu/.

G. Point data collected for ecological site description development are presently stored within the National Soil Information System (NASIS). This database includes plot data collected on Production and Composition Records forms such as Estimating and harvesting (double sampling) Production Form, Grazable Forest Land Evaluation-Forest Land Status and Condition Record Data Sheet (ECS-4 Appendix E-A, Exhibit E-A-1 and Exhibit E-A-2) and the Soil-Woodland Correlation Field Data Sheets (ECS-5, Appendix E-A, Exhibit E-A-3). Refer to the National Ecological Site Handbook for instruction on accessing, entering, or editing data collected for ecological site development.

**Figure E-3.** NRCS Rangeland Management Specialist, Josh Tashiro is performing the Line Point Intercept monitoring protocol; and NRCS Range Specialist Rian Nials records on a tablet with VGS software the foliar cover of the plant species and ground cover touched by the pin on the Stark Ranch, Texas.

## 645.0504 Inventory and Assessment

A. Natural resource inventorying is the process of acquiring information and objective data about the planning area, including the presence, condition, distribution, and abundance of vegetation, soil, water, biotic communities, natural and human-induced changes in resources, severity of resource concerns, and to help identify opportunities for improvement and determine which strategies may be most appropriate in given conditions. Inventories and assessments can be used to establish the baseline data for monitoring, in addition to the primary objective of generating the contextual soil, climate, topographic, and other information that is necessary to interpret assessment and monitoring data. They should be spatially explicit and geospatially locatable to enable data storage and retrieval.

B. Step 3 is the inventory phase of NRCS's nine steps of conservation planning. Collecting the appropriate natural resource, economic, and social information about the planning area is used to:

(1) Identify existing or potential resource concerns or opportunities.
(2) Further define known existing and potential resource concerns and opportunities.
(3) Clarify resource concerns.
(4) Formulate and evaluate alternatives.
(5) Gather pertinent information concerning the affected resources, the human considerations, and operation and management.
(6) Evaluate the effectiveness of implemented conservation practices in addressing resource concerns.

C. Some primary purposes and commonly conducted inventories are to document the occurrence, location, and current condition of physical habitats and features – or determine site conditions, forage production, species diversity, identify rare or threatened plant communities, endangered species, or locate and characterize fragile, rare, or sensitive areas.

D. Assessments are part of the inventory process that provide a rating of deviation from what is happening onsite to some value that is considered normal or within the natural range of variation for the site. Assessments are the estimation or judgement of the status of ecosystem structure, function, or processes, and can be conducted by gathering, synthesizing, and interpreting information from inventories or by completing specific protocols, such as Interpreting Indicators of Rangeland Health (IIRH). They can be a combination of quantitative and qualitative data. When associated with inventory information and quantitative monitoring, assessments can provide early warnings of potential resource problems and opportunities and can be used to help select monitoring sites and protocols in the development of monitoring programs.

E. In this subpart, several important inventory, assessment, and monitoring tools on range and pasturelands are described with directions for use and examples provided. Additional tools, especially those used in the NRCS National Resource Concern List and Planning Criteria, have referrals to the protocol documents with URL links provided. Predictive tools are covered in Subpart F: Managing Grazing lands.

(1) For use on Rangelands:
  (i) **Interpreting Indicators of Rangeland Health (IIRH)**, Version 5 will be used for assessing the condition of ecological functions on rangelands and is a specific assessment tool recognized in NRCS planning criteria to identify resource concern criteria thresholds. IIRH is essential for conservation planning on rangelands (Technical Reference 1734-6 V5, Interpreting Indicators of Rangeland Health; Pellant et al. 2020). https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=stelprdb1068410.
  (ii) **Similarity Index** is used to compare current vegetation in terms of kinds, proportions, and amounts on an ecological site to the documented composition of any plant community.
  (iii) **Rangeland Trend Worksheet** is a rating of the direction of change that may be occurring on a site. The plant community and the associated components of the ecosystem may either be moving toward or away from the reference state or another desired plant community or state.
  (iv) Other methods for collecting data on rangelands are the National Resources Inventory (NRI) method. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/processes/?cid=nrcs143_014072 and the Bureau of Land Management Assessment, Inventory, and Monitoring (AIM) Strategy at: https://landscape.blm.gov/geoportal/catalog/AIM/AIM.page#:~:text=The%20Assessment%2C%20Inventory%2C%20and%20Monitoring,on%20the%20nation's%20public%20lands.

(2) For use on Pasturelands:
  (i) **Guide to Pasture Condition Scoring (PCS)** is used for assessing the ecological condition on pastureland through the visual evaluation of 10 indicators, which rate pasture vegetation and soils. This is a specific assessment tool recognized in NRCS planning criteria to identify resource concern criteria thresholds on pasture. (Ogles et al. 2020). https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/pasture/?cid=stelprdb1045215
  (ii) **Describing Indicators of Pasture Health (DIPH)** is designed to provide information about how well ecological processes – such as the water cycle, energy flow, and nutrient cycling – are functioning on pastureland. This also is a specific assessment tool recognized in NRCS planning criteria to identify resource concern criteria thresholds on pastureland (Spaeth 2021). The entire DIPH protocol is found later in this subpart.
  (iii) Other methods for collecting data on pasturelands are the National Resources Inventory (NRI) method. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/processes/?cid=nrcs143_014072 and the Bureau of Land Management Assessment, Inventory, and Monitoring (AIM) Strategy at: https://landscape.blm.gov/geoportal/catalog/AIM/AIM.page#:~:text=The%20Assessment%2C%20Inventory%2C%20and%20Monitoring,on%20the%20nation's%20public%20lands.

(3) For use on all grazing lands:
  **Sampling Vegetation Attributes**, Interagency Technical Reference, is an interagency inventory/monitoring guide that provides the basis for consistent, uniform, and standard vegetation attribute sampling that is economical, repeatable, statistically reliable, and provides many of the primary sampling methods used across the West (Culloudon 1999). https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044175.pdf.

(4) For use on riparian areas:
  (i) **Stream Visual Assessment Protocol, V2 (SVAP2)** is a stream assessment tool for qualitatively evaluating the condition of aquatic ecosystems associated with wadeable streams and is used to determine the presence of a resource concern, or to document the current condition of a suspected resource concern in NRCS planning (Boyer 2009). https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/ndcsmc/?cid=nrcs143_009158.
  (ii) **Proper Functioning Condition (PFC) Assessment for Riparian Areas**. The PFC protocol addresses the physical functioning of perennial or intermittent lotic (flowing water) riparian systems, such as rivers or streams (Dickard 2015). https://www.blm.gov/documents/national-office/blm-library/technical-reference/riparian-area-management.
  (iii) **Riparian Area Management Proper Functioning Condition Assessment for Lentic Areas**. This technical reference provides instruction for the application of the lentic PFC protocol and addresses the physical functioning perennial or intermittent lentic riparian-wetland systems, such as swamps, ponds, or marshes (Gonzalez, M.A. and S.J. Smith 2020). https://www.blm.gov/sites/blm.gov/files/docs/2020-12/TR%201737-16%20Layout%20121020.pdf.

## 645.0505 Production as Part of Inventorying and Assessment

A. Production data collected by NRCS are most commonly based on weight measurements. Weight is the most useful expression of the productivity of a plant community or an individual species. The terminology associated with vegetation biomass is normally related to production. It has a direct relationship to forage units for grazing animals that other measurements do not have. It indicates the amount of energy flow through the ecological system and represents the total quantity of organic material produced within a given period by vegetation (Society for Range Management 1998; Technical Note 190-PM-76 "Rangeland Vegetation Measurements"). Addressing and managing plant productivity and health is one of the main resource concerns for NRCS in conservation planning on grazing lands.

B. Production is determined by estimating the annual aboveground growth of vegetation and is valuable for comparing different ecological sites or states within a state-and-transition model in an ESD. Production data by species help characterize the site and provide information on potential resource concerns with structure and composition of the plant community, supply information on useable forage for livestock, and can help evaluate habitat for wildlife needs. Production and composition in an area are influenced by soils, topography, climate, weather, ecological site, fertilization, cultivation history, grazing history, irrigation, and other natural and human-caused activities.

C. Production data should be obtained at a time of year when measurements are valid for comparison with similar data from other years, other sites, and various conditions being evaluated. Timing in collecting production data is an important factor influencing results, as some growth is used by insects and rodents, some is lost to weathering, affected by recent weather conditions, or the data are taken early in the growing season before full production is reached. Therefore, these determinations are typically reconstructed to correct for these factors.

D. When considering vegetation data, it is important to understand what vegetation attribute is being referenced. There are five basic attributes of vegetation that are measured (TN 190-PM-76):

(1) Production
(2) Frequency
(3) Density
(4) Cover
(5) Structure

E. Each vegetation attribute includes different types, sampling techniques, and data interpretation possibilities. A clear understanding of the variety of types (definitions) is needed to interpret and compare data. Some definitions of production are included below. Frequency, density, cover, and structure are described in more detail under their respective headings later in this subpart. Figure E-4 shows one method for measuring production.

**Figure E-4.** Production techniques involve clipping, weighing and plot frames at some point to directly measure, correct estimates, or extrapolate data (TN 190-PM-76). Photo credit: Nebraska Extension Service.

(1) Gross primary production is the total amount of organic material produced, both above-ground and below-ground (Coulloudon et al. 1999).
(2) Biomass is the total amount of living plants and animals above and below-ground in an area at a given time (Society for Range Management 1998).
(3) Standing crop is the amount of plant biomass present above-ground at any given point in time. It is often modified to include above-ground and below-ground portions and may further be modified by the descriptors "dead" or "live" to more accurately define the specific type of biomass (Society for Range Management 1998).
(4) Peak standing crop is the greatest amount of plant biomass above-ground present during a given year (Coulloudon et al. 1999).
(5) Total Annual Production is all above-ground plant biomass produced during a single growing year, including woody material and regardless of palatability or accessibility to grazing animals. Total annual production is expressed in pounds per acre (lb/ac) (Herrick et al. 2009).
(6) Total forage production is vegetation production that is palatable and utilized by herbivores (Coulloudon 1999).
(7) Useable forage production is that amount of total forage production expected to be used by a type of livestock or wildlife. Different types of herbivores have differences in what useable forage is to them. Example would be the difference in cattle versus deer diets.
(8) Allocated forage is the difference of the desired amount of residual material subtracted from the total forage (Coulloudon 1999).
(9) Browse is the portion of woody plant biomass accessible to herbivores (Coulloudon 1999).
(10) Aboveground Net Primary Production is an indicator of an ecosystem's ability to capture solar energy and covert it to organic carbon or biomass. It can be affected by environmental variability and is typically measured by clipping peak live plant material.
(11) Net primary production (NPP) is the net increase in plant biomass within a specified area and time interval. It is the amount of carbon uptake during photosynthesis after subtracting plant respiration. This measure is an important indicator for studying the health of plant communities. NPP may change in response to seasonal and drought-related drying conditions and topography.

F. Definition of production for various kinds of plants:

(1) Herbaceous plants—These plants include grasses (except bamboos), grass-like plants, and forbs. Annual production includes all above-ground growth of leaves, stems, inflorescences, and fruits produced in a single year (Habich 2001).
(2) Woody plants
   - Deciduous trees, shrubs, half shrubs, and woody vines—Annual production includes leaves, current twigs, inflorescences, vine elongation, and fruits produced in a single year (Habich 2001).
   - Evergreen trees, shrubs, half-shrubs, and woody vines—Annual production includes current year leaves (or needles), current twigs, inflorescences, vine elongation, and fruits produced in a single year (Habich 2001).
   - Yucca, agave, nolina, sotol, and saw palmetto—Annual production consists of new leaves, the amount of enlargement of old leaves, and fruiting stem and fruit produced in a single year. If current growth is not readily distinguishable, consider current production as 15 percent of the total green-leaf weight plus the weight of current fruiting stems and fruit (Habich 2001).
(3) Cacti, Pricklypear, and other pad-forming cacti—Annual production consists of pads, fruit, and spines produced in a single year plus enlargement of old pads in that year. If current growth is not readily distinguishable, consider current production as 10 percent of the total weight of pads plus current fruit production (Habich 2001).

(4) Barrel-type cactus—Consider annual production as five percent of the total weight of the plant, other than fruit, plus the weight of fruit produced in a single year (Habich 2001).
(5) Cholla-type cactus—If current growth is not readily distinguishable, consider annual production as 15 percent of the total weight of photosynthetically active tissue plus the weight of fruit produced in a single year (Habich 2001).

G. Methods for determining production and composition for specific situations. Collecting production and composition data for ecological site determinations

(1) Production is one of the characteristics used to describe an ecological site where plant community productivity and species composition of the plant community are evaluated. The ESD is the main source of information on rangeland and is used for assessing the productivity and health, and structure and composition of the plant community during conservation planning.
(2) The species composition and production amounts in ecological sites are based on the plant communities that are typical and known to occur. Therefore, interpretations of a plant community are not limited solely to species that have value for domestic livestock. For more information on ESDs see Subpart B. For more guidance on sampling for ESD site development refer to the National Ecological Site Handbook (NESH).

H. Methods for determining plant production and species composition in the field

(1) Production and composition of a plant community can be determined by one of the following ways. All three methods require some adjustment depending on factors like timing, growth stage, drying and utilization, etc. The method selected depends on the intended use of the data and circumstances around collecting the data.
    (i) estimating a plot
    (ii) a combination of estimating and harvesting (double sampling) a plot
    (iii) harvesting a plot
(2) Some plants are on state lists of threatened, endangered, or otherwise protected species. Some plants also have harvesting restrictions due to cultural significance in an area. Regulations concerning these species may conflict with harvesting procedures described. For example, barrel-type cactus in some states is a protected species, and harvesting is not allowed. The weight of such plants is to be estimated unless special permission for harvesting is obtained. Conservationists determining production should be aware of such plant lists and regulations.
(3) Production and composition data of a plot can be collected by one of the three methods listed above. However, setting up the transect to collect the plot data is consistent across the three collection methods. Complete instructions for running a production-composition transects are found under the Double sampling plot method below.
(4) When estimating or harvesting plants for NRCS, include all parts of all plants within the quadrat. Include all parts of herbaceous plants and shrubs outside the vertical projection of the quadrat, as long as the base is within the quadrat. See figure E-8. Other agencies, such as BLM, may have different protocols for determining plot-based above-ground vegetation production. Both agency approaches are comparable when adequate plots are sampled.

I. Estimating

(1) Weight units—The relationship of weight to volume is not constant. Therefore, production and composition determinations are based on weight estimates, not on comparison of relative volumes. The weight unit method is an efficient means of estimating production and lends itself readily to self-training. This method is based on the following:
    (i) A weight unit is established for each plant species occurring on the area being examined.

(ii) The size and weight of a unit varies according to the kind of plant (figure E-9). For example, a unit of 5 to 10 grams is suitable for small grass or forb species. Weight units for large plants may be several pounds or kilograms (Habich 2001).

(2) Other considerations—length, width, thickness, and number of stems and leaves, ratio of leaves to stem growth, form, and relative compactness of species (Habich 2001).

(3) The following procedure (exhibit E-1) can be used to establish a weight unit for a species. A video demonstration of the procedure is available on the Agriculture Research Service-Jornada Experimental Range website at: https://www.youtube.com/watch?v=hIgYAEWHUHI or under Plant Production at: https://jornada.nmsu.edu/monit-assess/training/videos.

**Exhibit E-1.** How to establish a weight unit for a species (Habich 2001):

Step 1. Decide on a weight unit (in pounds or grams) that is appropriate for the species.

Step 2. Visually select part of a plant, an entire plant, or a group of plants that will most likely equal this weight.

Step 3. Harvest and weigh the plant material to determine actual weight.

Step 4. Repeat this process until the desired weight unit can be estimated with reasonable accuracy.

Step 5. Maintain proficiency in estimating by periodically harvesting and weighing to check estimates of production.

**The procedure for estimating production and composition of a single plot is:**

Step 1. Estimate production by counting the weight units of each species in the plot.

Step 2. Convert weight units for each species to grams or pounds.

Step 3. Harvest and weigh each species to check whether estimates of production are higher or lower than actual weight for the species from the plot.

Step 4. Compute species composition for the plot based on actual weights to check species composition estimates.

Step 5. Repeat the process until proficiency in estimating is attained.

Step 6. Periodically repeat the process to maintain proficiency in estimating.

Step 7. Keep the harvested materials, when necessary, for air-drying and weighing to convert from field (green) weight to air-dry weight.

J. Steps for Conducting an inventory using the Estimating and harvesting method (double sampling). For more information see Coulloudon et al. 1999.

(1) The double-sampling method is used to make most production and composition determinations. Whenever feasible, obtain production data from vegetation that has not been grazed since the beginning of the current growing season. Make determinations near or shortly after the end of the growing season of the major species and give consideration to species that mature early in the growing season.

(2) Equipment—The following equipment is needed:
- (i) Production form (see figures E-10 and E-11)
- (ii) Sampling frames or hoops
- (iii) One stake: 3/4- or 1-inch angle iron not less than 16 inches long
- (iv) Herbage Yield Tables for Trees by Height, DBH, or Canopy
- (v) Clippers
- (vi) Paper bags
- (vii) Kilogram and gram spring-loaded scales with clip
- (viii) Tree diameter measuring tape
- (ix) Steel post and driver
- (x) Oven for drying vegetation
- (xi) Air-dry weight conversion tables
- (xii) Rubber bands
- (xiii) Pin flags

(xiv) Compass

(3) Step 1—The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to conduct the study. Transects and sampling points need to be randomly located within the critical or key areas. Determine if the planning area needs to be stratified or separated out by certain differences such as diverse vegetation types or condition, different ecological sites, or is influenced by management changes. Additional stratification criteria are selected where production and composition information are needed to address a specific resource concern, such as pollinator habitat or riparian area condition. In conservation planning, a strict statistical randomization design is not needed. Determine the sample area based on "subjectivity without preconceived bias." More information on stratifying can be found in Volume II Monitoring Manual-Design, Supplementary methods and Interpretation, Herrick et al. (2009).

(4) Step 2—Verify the soil and ecological site by digging a hole and documenting soil features on the data collection form (see Subpart B for more instructions). Where more than one ecological site exists in the planning area, determine the acreage of the major ecological sites that occupy the largest areas. Collect production data on each major ecological site and plant community phase in the planning area.

(5) Step 3—Select a randomized transect layout. Numerous layout designs can be used in different protocols. Several are mentioned here with references. Other systematic sampling procedures can be used to fit the need during the inventory process.

(i) An example of a linear layout is referenced in Sampling Vegetative Handbook (Coulloudon et al. 1999) attributes with an example provided here in figure E-5. If a linear transect is chosen, determine the transect bearing and select a prominent distant landmark such as a peak, rocky point, etc., that can be used as the transect bearing point.

(ii) The 2021 National Resources Inventory Grazingland Instructions uses the following production protocol: Herbaceous production quadrats are centered on transect marks at 12.5, 37.5, 62.5, 112.5, and 137.5 feet on the NE/SW and NW/SE transects for the ESD option. See figure E-6. For the NRI data collection option, herbaceous production quadrats are centered on marks at 12.5 and 137.5 feet on the NW/SE transect and 37.5, 62.5 and 112.5 feet on the NE/SW transect. Quadrat size can be 1.92, 4.8, or 9.6 square feet. More information is at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

(iii) The Interpreting Indicators of Rangeland Health Version 5 protocol gives an example of a five-plot minimum random layout where one plot is near the center of the evaluation/study area and then four plots are established in each quarter of the evaluation area. To randomly establish the plots in this way, select a random direction (azimuth) between 0 and 360 degrees and a random number less than 10. In the middle of the evaluation area, face the random direction and then take steps equal to the random number less than 10. This will be the starting point for the first production plot (figure E-7). Place the frame on the ground with the edge against your toe. Next, select four random bearings within each quarter of the evaluation area (0–90, 91–180, 181–270, and 271–360 degrees) and four random numbers less than 10 to pace along each bearing starting from plot 1. Make sure the random pace numbers remain within the evaluation area.

**Figure E-5.** Randomized Linear Plot Design.

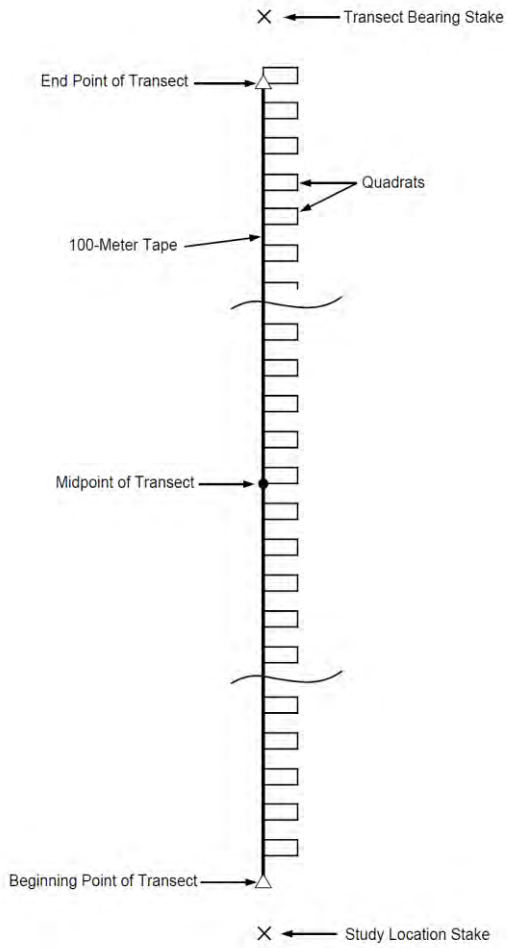



**Figure E-6.** Transects and associated production quadrats for the NRI data collection option (USDA, National resources inventory grazing land on-site data collection, Handbook of instructions, 2021).

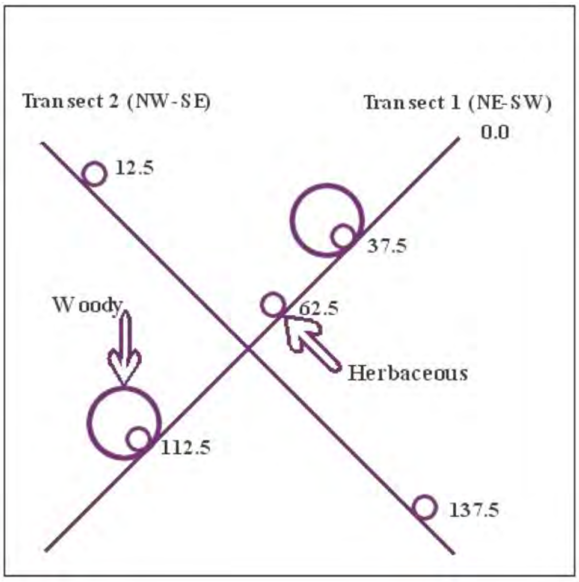


**Figure E-7.** Example of five annual production plot locations that were selected randomly in an evaluation/study area (Pellant et al. 2005, 2020).

(6) Step 4—Number of Quadrats. The number of quadrats selected depends on the purpose for which the estimates are to be used, uniformity of vegetation, and other factors. Different recommendations are associated with a minimum number of plots needed for different protocols, but usually a minimum of 5 to 10 plots is selected for data to be used in determining production. If vegetation is very irregular, and 10 plots will not provide an adequate sampling, additional plots should be selected. See the estimating required sample size table at the end of this section for the number of samples required at a percent probability level.

(i) The size and shape of quadrats must be adapted to the vegetation community to be sampled. Plots can be circular, square, or rectangular. The area of a plot can be expressed in square feet, acres, or square meters. If vegetation is short enough to allow plot markers to be easily placed, use 1.92-, 2.40-, 4.80-, and 9.60-square foot plots to determine production in lbs/acre. The 9.6-square foot plot is generally used in areas where vegetation density and production are light, generally less than 3,000 lbs/acre. The smaller plots, especially the 1.92-square foot plot, are satisfactory in areas of homogeneous, dense vegetation generally greater than 3,000 lbs/acre like that occurring in meadows, some pastures, and throughout the plains and prairie regions. Plots larger than 9.6 square feet should be used where vegetation is very sparse and heterogeneous.

(ii) If the vegetation is very sparse or consists of trees or large shrubs, larger plots must be used. If the tree or shrub cover is uniform, a 66- by 66-foot plot or 0.1 acre is suitable. If vegetation is unevenly spaced, a more accurate sample can be obtained by using a 0.1-acre plot, that is 4.356 feet wide and 1,000 feet long. For statistical analyses, 10 plots of 0.01 acre are superior to a single 0.1-acre plot. If vegetation is mixed, two sizes of plots generally are needed. A series of 10 square or rectangular plots of 0.01 acre and a smaller plot, such as the 9.6-square foot plot nested in a designated corner of each larger plot, is suitable. The 0.01-acre plot is used for trees or large shrubs, and the smaller plot for lower growing plants. Weights of the vegetation from both plots are then converted to pounds per acre. If the plots are nested, production from both plots must be recorded in the same units of measure.

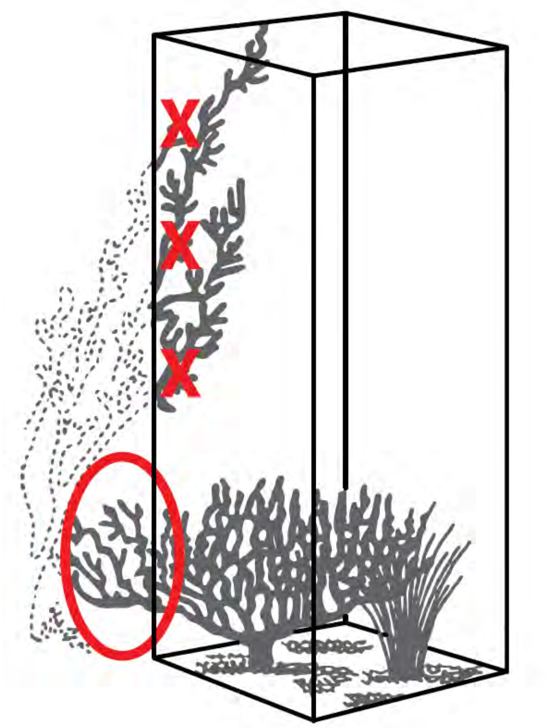
(7) Step 5—Mark the location of each study site with a reference point. It is common to take a GPS reading to be able to go back to the site or upload the information into an electronic folder or download onto a map.

(8) Step 6—Weight Units. Double sampling requires the establishment of a weight unit for each species occurring in the study area to be sampled. All weight units are based on current year's growth.

Procedures for Establishing Weight Units: Decide on a weight unit that is appropriate for each species (figure E-9). A weight unit could be an entire plant, a group of plants, or an easily identifiable portion of a plant, and can be measured in either pounds or grams.

- Visually select a representative weight unit.
- Harvest and weigh the plant material to determine the actual weight of the weight unit.
- Maintain proficiency in estimating by periodically harvesting and weighing to check estimates of production.

**Figure E-8.** Example of NRCS approach for estimating annual production in a plot. This approach includes portions of plants rooted inside the plot that extend outside the plot (circled). This approach does not include portions of plants rooted outside the plot that overhang inside the plot (red Xs) (Pellant et al. 2005, 2020).



- Estimating Production of a Single Quadrat:
  – Estimate production by counting the weight units of each species in the quadrat.
  – Convert weight units for each species to grams or pounds.
  – Harvest and weigh each species to check estimate of production.
  – Repeat the process until proficiency is attained.
  – Periodically repeat the process to maintain proficiency in estimating.
  – Keep the harvested material, when necessary, for air-drying and weighing to convert from green weights to air-dry weights.
- Alternate Method of Establishing Weight Units:
  – Decide on a weight unit that is appropriate for each species (figure E-9). A weight unit could be an entire plant, a group of plants, or an easily identifiable portion of a plant, and can be measured in either pounds or grams.
  – Visually select a representative weight unit.
  – Instead of weighing the material, save it by securing it with rubber bands so portions are not lost.
  – Use this as a visual model for comparison at each quadrat in the transect. Record on the proper forms only the number of weight units. Do not record the estimated weights.

– Weigh each weight unit at the conclusion of the transect. Weighing the weight unit before the conclusion of the transect might influence the weight estimates.
– Convert the weight units on the form to actual weight by multiplying the number of units by the weight of the unit.
– Harvested weight unit material is not saved for determining air-dry weight conversion. Air-dry conversions are determined from clipped quadrats.

(9) Step 7—Temporarily mark the quadrat by placing a pin flag next to the quadrat so that it can be relocated later if this quadrat is selected for clipping. Be sure to flag every quadrat.

(10) Step 8—Estimate and record the weight of each species in the quadrat by means of the weight-unit method (method selected in Step 6).

(11) Step 9—Continue the transect by establishing additional quadrats according to layout design selected.

(12) Step 10—After weights have been estimated on all quadrats, select the quadrats to be harvested.

(i) The quadrats selected should include all or most of the species in the estimated quadrats. If an important species occurs on some of the estimated quadrats but not on the harvested quadrats, it can be clipped individually on one or more other quadrats.

(ii) The number of quadrats harvested depends on the number estimated. At least one quadrat should be harvested for each seven estimated to adequately correct the estimates (see table E-1).

**Table E-1.** Number of Quadrats Harvested per Number Estimated (Coulloudon, TR 1734-4, 1999).

| Number of quadrats Estimated | Minimum Number of Quadrats to be Weighed |
|---|---|
| 1–7 | 1 |
| 8–14 | 2 |
| 14–21 | 3 |
| 22–28 | 4 |
| 29–35 | 5 |
| 36–42 | 6 |

(13) Step 11—Harvest, weigh, and record the weight of each species in the quadrats selected for harvesting. Harvest all herbaceous plants originating in the quadrat at ground level. On rangeland, harvest all of the current year's leaf, twig, and fruit production of woody plants located in the quadrats. On native pasture and grazable woodland, harvest the current leaf, twig, and fruit production of woody plants within the plot up to a height of 4 1/2 feet above the ground (Coulloudon 1999).

(14) Step 12—Correct estimated weights by dividing the harvested weight of each species by the estimated weight for the corresponding species on the harvested quadrats. This factor is used to correct the estimates for that species in each quadrat. A factor of more than 1.0 indicates that the estimate is too low. A factor lower than 1.0 indicates that the estimate is too high.

(15) Step 13—Reconstruct values for percent of growth made during the year, and percent of growth grazed or otherwise lost. Use growth curves from the ecological site description to reconstruct weights to 100 percent of annual growth values. See the Similarity Index form for instructions on reconstructing the production of a site.

(16) Step 14—After quadrats are estimated and harvested and correction factors for estimates are computed, air-dry percentages are determined by air-drying the harvested materials or by selecting the appropriate factor from an airdry percentage table (Appendix E-D). Values for each species are then converted to air-dry pounds per acre or kilograms per hectare for all quadrats.

(17) Step 15—Average weight and percentage composition can then be computed for the sample area by multiplying the weight by the number of acres within each area to get the total pounds available. Add the total areas together within an operating unit, for example

by pasture to calculate total production for that planning area. Use table E-2 to convert grams to pounds per acre.

**Table E-2.** Conversion to pounds per acre (# of plots x size = total area).

| | | | | |
|---|---|---|---|---|
| 10 x 0.96 | = 9.6 ft$^2$ | multiply grams times 10.0 | = | pounds per acre |
| 10 x 1.92 | = 19.2 ft$^2$ | multiply grams times 5.0 | = | pounds per acre |
| 10 x 2.40 | = 24.0 ft$^2$ | multiply grams times 4.0 | = | pounds per acre |
| 10 x 4.80 | = 48.0 ft$^2$ | multiply grams times 2.0 | = | pounds per acre |
| 10 x 9.60 | = 96.0 ft$^2$ | multiply grams times 1.0 | = | pounds per acre |
| 10 x 96.0 | = 960.0 ft$^2$ | multiply grams times 0.1 | = | pounds per acre |

(i) Data Analysis—This technique involves destructive sampling (clipped pots), so permanent transects or quadrats are not recommended. Since the transects are not permanently marked, use the appropriate nonpaired test. When comparing more than two sampling periods, use ANOVA. See table E-3 to estimate the required number of samples.

(ii) If plant communities consist of a mixture of warm and cool-season species, at least two determinations may be needed during a single production year. The following procedure should then be used:

- Select two periods that will yield the best estimate of the growth of most of the important species.
- At the first determination, estimate and harvest only the species that are mature or nearly mature.
- At the second determination, select a new set of plots for estimating and harvesting all other species, but record the data on the same form used for the first determination.

K. Use the following procedure to estimate the vegetative production and composition of a conservation planning area:

(1) Determine if the planning area needs to be stratified or separated out by certain differences such as diverse vegetation types or condition, different ecological sites, or is influenced by management changes. Additional stratification criteria will be selected where production and composition information are needed to address a specific resource concern, such as pollinator habitat or riparian area condition.
(2) Where more than one ecological site exists in the planning area, determine the acreage of the major ecological sites that occupy the largest areas. Select one of the inventory methods to estimate the production of each major ecological site and plant community phase in the planning area.
(3) Estimate or harvest production, in pounds per acre for each of the stratified areas within the planning unit. See figures E-10 and E-11.
(4) Compute species composition, by weight, of each of the areas from the production data.
(5) Adjust the production and composition values to air dry weight.
(6) Reconstruct values for percent of growth made during the year and percent of growth grazed or otherwise lost. Use growth curves from the ecological site description to reconstruct weights to 100 percent of annual growth values (see the Similarity Index form for instructions on reconstructing the production of a site).
(7) The Estimating required sample size chart in table E-3 provides a method for determining the number of plots required for an adequate sample or use a minimum plot sample size feature in vegetation collection systems like the Vegetation Geospatial Data System (VGS) when available.

**Figure E-9.** Examples of Weight Units.

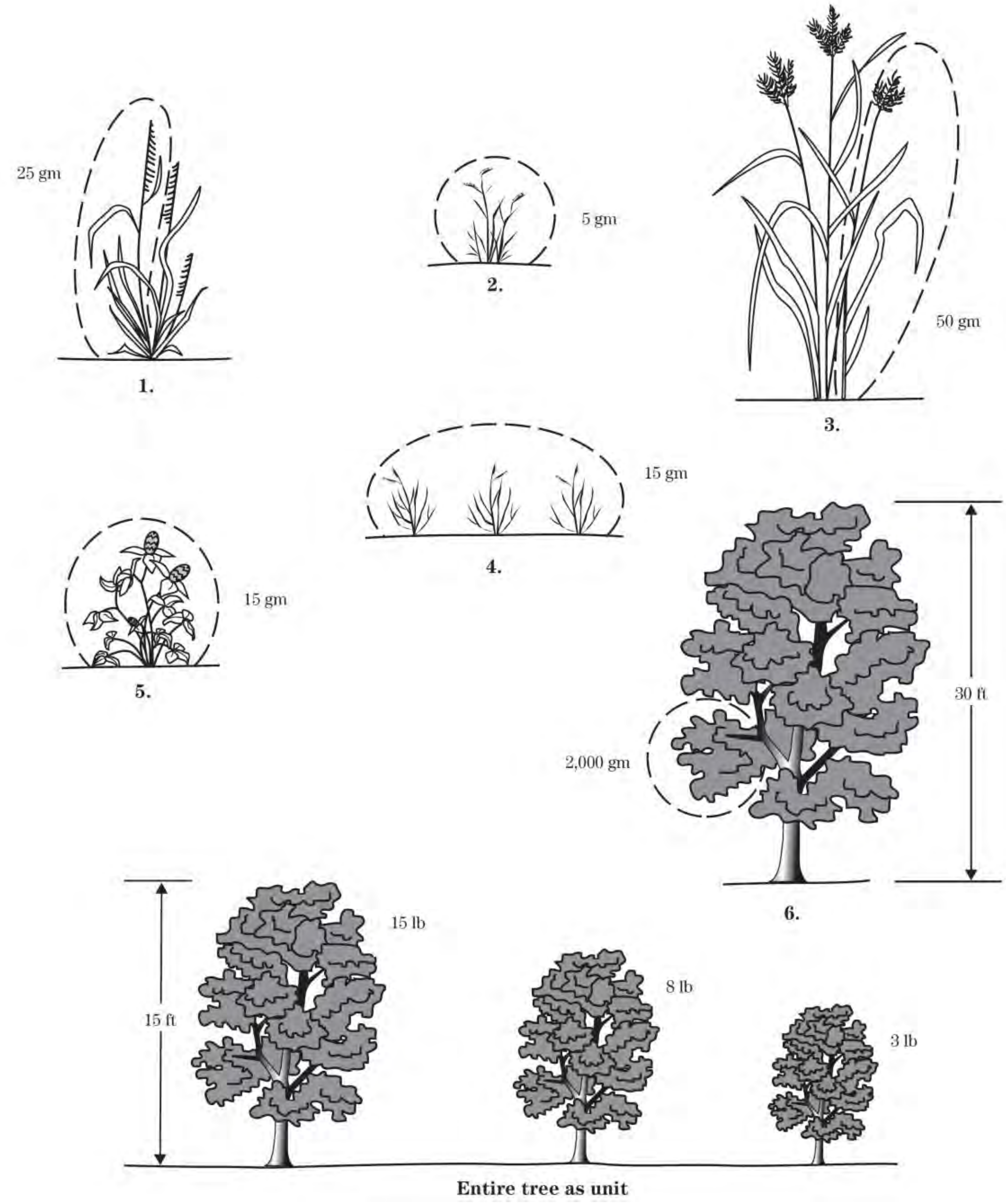


**Figure E-10.** Estimating and harvesting (double sampling) Production Form.

Page ____ of ____

## Production

| Study Number | Date | Examiner | Allotment Name & Number | Pasture |
|---|---|---|---|---|

| Transect Location | Quadrat Size | Transect Bearing |
|---|---|---|

| | Plant | Estimated or Clipped Weight Per Species | | | | | | | | | | Wt Clipped Plots | | | QCF | %Dry | Wt All | Avg | Pct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Name | Symbol | (Circle Plots that are Clipped) (3) | | | | | | | | | | Est | Clip | Dry | | Wt | Plots | Yield | Comp |
| (1) | (2) | P-1 | P-2 | P-3 | P-4 | P-5 | P-6 | P-7 | P-8 | P-9 | P-10 | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| | | | | | | | | | | | | | | | | | | | |
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| Totals | | | | | | | | | | | | | | | | | | | |

Notes (use other side or another page)

**Figure E-11.** Estimating and harvesting (double sampling) Production Form Example.

Page 1 of 1

## Production

| Study Number 13N-41E-27-04 | Date 9/30/95 | Examiner Rex Johnson | Allotment Name & Number Round Mtn 11078 | Pasture Ridge |
|---|---|---|---|---|
| Transect Location 2 miles north of Jack's well on the left hand side of the road. | | Quadrat Size 9.6 sq. ft. | | Transect Bearing 225° |

| | Plant | Estimated or Clipped Weight Per Species | | | | | | | | | | Wt Clipped Plots | | | QCF | %Dry | Wt All | Avg | Pct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Name | Symbol | (Circle Plots that are Clipped) (3) | | | | | | | | | | Est | Clip | Dry | | Wt | Plots | Yield | Comp |
| (1) | (2) | P-1 | P-2 | (P-3) | P-4 | P-5 | P-6 | P-7 | P-8 | P-9 | (P-10) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Black Grama | BOER 2 | 12 | 16 | 5 | | 16 | 8 | | 3 | 8 | 3 | 8 | 9 | | 1.12 | 55 | 71 | 43.7 | 12 |
| Curly Mesquite | HIbe | 7 | | 12 | 7 | | 4 | 9 | | 3 | | 12 | 13 | | 1.08 | 60 | 42 | 27.2 | 8 |
| Blue Grama | BOGR 2 | 3 | 4 | 3 | 7 | 4 | | 1 | 8 | | 5 | 8 | 7 | | .87 | 60 | 35 | 18.3 | 5 |
| Sideoats Grama | BOCU | | 8 | | 1 | | 12 | 5 | | 7 | 3 | 3 | 4 | | 1.33 | 55 | 36 | 26.3 | 7 |
| Bush Muhly | MUPO 2 | | | | | (3) | | | | | | 3 | 3 | | 1.00 | 55 | 3 | 1.6 | 1 |
| Sixweeks Grama | BOBA | | | 1 | | | | | 6 | 2 | 6 | 7 | 8 | | 1.14 | 60 | 15 | 10.3 | 3 |
| 3-AWN | ARIST | | | 10 | | | | 5 | | | 8 | 18 | 16 | | .88 | 60 | 23 | 12.1 | 3 |
| | VUOC | | | | | 3 | 1 | | | 3 | 3 | 3 | 2 | | .66 | 55 | 10 | 3.6 | 1 |
| | GiliA | 3 | | 5 | 8 | | 1 | | 2 | 12 | 1 | 6 | 7 | | 1.16 | 40 | 32 | 14.8 | 4 |
| Lotus | | 2 | 1 | | 3 | 5 | | 1 | 5 | | 6 | 6 | 7 | | 1.16 | 40 | 23 | 10.7 | 3 |
| Lupin | | | 3 | 2 | | 6 | 1 | 7 | | 2 | 1 | 3 | 4 | | 1.33 | 40 | 22 | 11.7 | 3 |
| Pepperweed | | | | | 2 | | 2 | | 3 | 4 | 3 | 3 | 4 | | 1.33 | 40 | 14 | 7.4 | 2 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| Burroweed | HAGR | 25 | | 18 | 12 | | | 30 | | 7 | | 18 | 20 | | 1.11 | 65 | 92 | 66.4 | 18 |
| Mesquite | PRJU | | 32 | | | 20 | 45 | | 15 | | 28 | 28 | 31 | | 1.10 | 50 | 140 | 77 | 21 |
| Wolfberry | Lyph | | | 20 | | | | 12 | | 15 | | 20 | 22 | | 1.10 | 65 | 47 | 33.6 | 9 |
| Totals | | | | | | | | | | | | | | | | | | 364.7 | 100 |

Notes (use other side or another page)

**Table E-3.** Estimating required sample size chart. A preliminary sample of five quadrats (4.8 ft²) yielded the following weights in grams:

| **Sample Number:** | **Weight (grams)** |
|---|---|
| 1 | 200 |
| 2 | 250 |
| 3 | 275 |
| 4 | 300 |
| 5 | 250 |
| 6 | 225 |
| | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | |
| 16 | |
| 17 | |
| 18 | |
| 19 | |
| 20 | |

| **Number of Samples (n) required to estimate the mean within 10% of the Sample Mean:** | |
|---|---|
| 95% probability level: | 14.0 |
| 90% probability level: | 9.0 |
| 80% probability level: | 5.0 |

| | |
|---|---|
| 250.0 | □ = mean |
| 6 | Number of samples (n) |
| 1250.00 | Variance of sample x (s)2 |

L. Harvesting—This method is like the double-sampling method except that all plots are harvested. The double-sampling procedures for estimating weight by species and the subsequent correction of estimates do not apply. If the harvesting method is used, selection and harvest of plots and conversion of harvested weight to air-dry pounds per acre are performed according to the procedures described for double sampling.

M. Dry-weight rank

(1) The dry-weight rank method determines species composition. It consists of observing various quadrats and ranking the three species which contribute the most weight in the quadrat. It is important to establish a photo plot and take both close-up and general view photographs with this method.

(2) Dry-weight rank results are expressed only as percentage values. The benefit of the method is that a large number of samples can be obtained very quickly. It also deals with estimates of production, which allows for better interpretation of the data to make management decisions. The method is suitable on rangeland, pastureland, and understory of forest lands with small shrubs. It does not work well on large shrubs and trees themselves. The dry-weight rank method is described in detail in Sampling Vegetation Attributes, Interagency Technical Reference 1734-4, 1999. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044175.pdf.

N. Rising Plate Meters

(1) The rising plate meter is a commonly used tool for estimating forage mass in pastures with one to two forage plant species. See figure E-12. This method relies on both plant height and density. It is a device that consists of a weighted plate that slides over a shaft. As the meter is placed over forage, the forage is compressed to the point where it supports the plate. The plate meter measures the compressed height or density of the forage. This

measurement is correlated with forage bulk density and then converted to dry matter yield using a calibration equation. The rising plate meter method is more precise than the pasture ruler but requires a greater investment in both time and money. Calibration of the plate meter is required for the type of forage to be measured, especially in pastures with multiple forage species whose yield estimations are influenced by differences in growth habit and growth rate of the forages. The level of error in measuring forage mass with rising plate meters can vary widely. Therefore, striving for a calibration error of 10 percent or less of clipped pasture yields is recommended to avoid major miscalculations in forage budgeting.

(2) Commercial manufacturers of rising plate meters often have instructions for collecting and using calibration samples to predict pasture dry matter. University extension services may also have developed conversion factors needed to convert plate meter heights to dry matter in lbs/acre for various species. Pastures are usually not uniform, so when estimating pasture dry matter, the more rising plate meter readings that are taken, the more accurate the estimate will be. It is recommended to take at least 30 measurements, or a measurement every few steps while walking through a sample area.

**Figure E-12.** Rising Plant Meter. Photo credit: The Samuel Roberts Noble Foundation.

(3) Using and calibrating a rising plate meter is described in detail in Determining Pasture Yield from Pennsylvania State University at: https://extension.psu.edu/determining-pasture-yield.

(4) Video demonstration by the Dairy Farmers of America is available titled Measuring Pasture with a Rising Plate Meter at: https://www.youtube.com/watch?v=9zp8PRConnM.

O. Pasture Sticks

(1) Pasture rulers or pasture sticks are used to assist in estimating forage yield and provide a beneficial tool for helping conservation planners and land managers calibrate their visual estimates and knowledge of pasture production. See figures E-13 and E-14.

(2) Pasture sticks vary from state to state and offer different features for estimating forage production based on forage type, and dry matter yield for those forages. They are usually developed in partnership with a university and based on correlation research work of forage height to dry matter yield. It is important that the correct pasture stick is used for the area to be sampled.

(3) Grazing sticks look like simple measuring devises but are really a measurement system (Smith et al. 2010). Most pasture sticks consist of a ruler to measure forage height, a density meter to estimate stand density, a table to convert density to dry matter yield, and guidance on start and stop grazing heights for various plant species. Forage height is observed and recorded by walking through a pasture at a set step or pace interval, usually 25 to 30 depending on the size of the sampling area. Ensuring all spots are measured, including the height of bare spots as well as areas of dense growth, and are recorded avoids bias and miscalculated yields. Keeping your eye on the horizon until you land on a point to sample also helps prevent bias on where to sample.

(4) The number of observations or estimates needed is dependent upon the size of the pasture, topography, and uniformity of the forage stand. Adequate sample numbers are key to obtaining a reliable estimate of production for the area. If pastures have more than one soil type that exhibits a different pasture state or different forage group, then each of the soil types should be sampled. Height data is averaged and then divided by the number of samples. Calibration of the stick through harvest methods will improve the accuracy of the estimates. General instructions taken from the University of Kentucky's Using a Grazing Stick for Pasture Management (Smith 2010) are:
   (i) Step 1—Select estimation areas consisting of one soil taxonomic unit. This should be a benchmark soil or taxonomic unit that is an important component of an ecological site. Use the stratification guidelines in subpart B for pastures that are not uniform in soils, ecological site, topography, or forage yield.
   (ii) Step 2—Identify the plant species or mix of plant types for each estimation area.
   (iii) Step 3—Use the ruler to measure forage height. Height is not a measure, but rather an average of the tallest plants. Spread your hand and lower it onto the canopy. The average height is measured at the point where you feel very modest resistance from the plant canopy. Record the height for each sample location in the pasture and then calculate the average height for the pasture.
   (iv) Step 4—Determine density of the forage stand at each location where a height measurement was obtained by sliding the stick under the grass canopy with the density meter visible. Count the markings visible and record the density reading. Stand density is the amount of ground surface covered with standing forage. For the Kentucky protocol, the goal is to place the pasture into one of three density categories (< 75 percent, 75–90 percent, or > 90 percent). Some sticks have a density-yield chart on them to obtain the estimated dry matter per inch of height in pounds per acre.
   (v) Step 5—Estimate forage dry matter yield per inch for the plant type in the sampling area by calculating the average stand density for each location and compare to the density yield table on the stick. For example, in measuring a tall fescue pasture, and the estimate is that the available forage covers 85 percent of the ground area, this pasture would be assigned to the middle density category of 75 to 90 percent cover. According to table E-4, this density rating would be between 150 and 200 lbs of DM per acre-inch. Based on the assessment of the stand, assign a yield. The thicker the stand, the closer the yield will be to the upper end of the range. Since 85 percent is in the upper end of this density category, 200 lbs of DM per acre-inch would be a good estimate. If the average stand height is eight inches and the goal is to maintain three inches of stubble after grazing, available forage equals: 5 inches x 200 lbs/acre-inch = 1,000 lbs DM/acre.
   (vi) Step 6—Calculate the forage yield of the planning area by adding the estimated forage yields of each sampling area.

**Table E-4.** Estimated dry matter yield per acre inch based on density and forage type. (Smith 2010).

| Forage | Density | | |
|---|---|---|---|
| | **<75%** | **75–90%** | **>90%** |
| | **Dry Matter Yield (lbs)** | | |
| Tall fescue or orchardgrass | 50–150 | 150–200 | 200–300 |
| KY Bluegrass | 50–100 | 100–175 | 175–250 |
| Cool-season grass (clover) | 50–125 | 125–200 | 200–275 |
| Bermudagrass | 100–200 | 200–300 | 300–400 |
| Alfalfa | 75–150 | 150–225 | 225–300 |
| Red clover | 75–125 | 125–175 | 175–250 |

**Figure E-13.** Estimating Density with a Pasture Stick. Photo Credit: NRCS Churchville, Maryland.

**Figure E-14.** Using a pasture stick. Photo credit: NRCS Churchville, Maryland.

(5) Detailed instruction for using and calibrating a pasture stick are described in the University of Kentucky Cooperative Extension Service publication, Using a Pasture Stick for Pasture management-AGR-191. http://www2.ca.uky.edu/agcomm/pubs/agr/agr191/agr191.pdf.
   (i) A video demonstration using a pasture stick developed for South Dakota is available at: https://www.youtube.com/watch?v=c9CylrlqVvI.
   (ii) Consult your local Land Grant University or Extension Agent for more localized information if it has not been developed in your area.

(6) Units of production and conversion factors

All production data are to be expressed as air-dry weight in pounds per acre (lb/ac). The field weight must be converted to air-dry weight. This may require drying or the use of locally developed conversion tables. Conversion tables for metric weights is listed in table E-5.

**Table E-5.** Conversion factors.

| To convert | To | Multiply by |
|---|---|---|
| **Metric units** | | |
| Kilogram per hectare | Pounds per acre | 0.891 |
| Kilograms | Pounds | 2.2046 |
| Hectares | Acres | 2.471 |
| **English units** | | |
| Pounds per acre | Kilograms per hectare | 1.12 |
| Pounds | Kilograms | 0.4536 |
| Acres | Hectares | 0.4047 |

(7) Converting green weight to air-dry weight

(i) If precise production figures are needed or if air-dry weight percentage figures have not been previously determined and included in locally developed tables, retain and dry enough samples or harvested material to determine air-dry weight percentages. Tables of the percentage of total weight that is air-dry weight for various types of plants at different stages of growth are provided in tables E-6 through E-10. These percentages are based on currently available data and are intended for interim use. Air-dry weight percentages listed in the tables can be used for other species having growth characteristics like those of the species listed in the tables. States that have prepared their own tables of air-dry percentages based on actual field experience should substitute them for these tables. Local conservationists are encouraged to develop these tables for local conditions and species. Some interpolation must be done in the field to determine air-dry percentages for growth stages other than those listed. Appendix E-D (NRCS Oregon Range Technical Note No. 27 – Dry Weight Percentages of Selected Oregon Grasses, Grass-likes, Forbs, Vines, Shrubs, and Trees) provides additional dry weight percentages of selected Oregon plant species.

(ii) The relationship of green weight to air-dry weight varies according to such factors as exposure, amount of shading, time since last rain, and unseasonable dry periods. Several samples of plant material should be harvested and air-dried each season to verify the factors shown or to establish factors for local use. Fresh samples should be brought from the field in paper sacks and kept long enough (usually 10 days) until all water is lost, and the weight of the sample stabilizes for an accurate final weight.

**Table E-6.** Percentage of air-dry matter in harvested grass plant material at various stages of growth.

| Season | Grasses | Before heading out, initial growth to boot stage (%) | Headed out, boot stage to flowering (%) | Seed ripe; Leaf tips drying (%) | Leaves dry; Stems partly Dry (%) | Apparent dormancy (%) |
|---|---|---|---|---|---|---|
| Cool Season | wheatgrasses<br>Perennial bromes<br>bluegrasses<br>Prairie junegrass | 5 | 45 | 60 | 85 | 95 |
| Warm Season Tall Grasses | bluestems<br>Indiangrass<br>switchgrass | 30 | 45 | 60 | 85 | 95 |
| Warm Season Midgrasses | Sideoats grama<br>tobosa<br>galleta | 40 | 55 | 65 | 90 | 95 |
| Warm season short grasses | Blue grama<br>buffalograss<br>Short three-awns | 45 | 60 | 80 | 90 | 95 |

**Table E-7.** Percentage of air-dry matter in harvested tree material at various stages of growth.

<table>
<tr><th colspan="2">Trees</th><th>New leaf and twig growth until leaves are full size (%)</th><th>Older and full-size green leaves (%)</th><th>Green fruit (%)</th><th>Dry fruit (%)</th></tr>
<tr><td rowspan="4">Evergreen coniferous</td><td>Ponderosa pine, slash pine-longleaf pine</td><td rowspan="4">45</td><td rowspan="4">55</td><td rowspan="4">35</td><td rowspan="4">85</td></tr>
<tr><td>Utah juniper</td></tr>
<tr><td>Rocky mountain juniper</td></tr>
<tr><td>Spruce</td></tr>
<tr><td>Live oak</td><td></td><td>40</td><td>55</td><td>40</td><td>80</td></tr>
<tr><td rowspan="3">Deciduous</td><td>Blackjack oak</td><td rowspan="3">40</td><td rowspan="3">50</td><td rowspan="3">35</td><td rowspan="3">85</td></tr>
<tr><td>Post oak</td></tr>
<tr><td>hickory</td></tr>
</table>

**Table E-8.** Percentage of air-dry matter in harvested shrub material at various stages of growth.

<table>
<tr><th colspan="2">Shrubs</th><th>New leaf and twig growth until leaves are full size (%)</th><th>Older and full-size green leaves (%)</th><th>Green fruit (%)</th><th>Dry fruit (%)</th></tr>
<tr><td rowspan="5">Evergreen</td><td>big sagebrush</td><td rowspan="5">55</td><td rowspan="5">65</td><td rowspan="5">35</td><td rowspan="5">85</td></tr>
<tr><td>bitterbrush</td></tr>
<tr><td>ephedra</td></tr>
<tr><td>algerita</td></tr>
<tr><td>gallberry</td></tr>
<tr><td rowspan="5">Deciduous</td><td>snowberry</td><td rowspan="5">35</td><td rowspan="5">0</td><td rowspan="5">30</td><td rowspan="5">85</td></tr>
<tr><td>rabbitbrush</td></tr>
<tr><td>snakeweed</td></tr>
<tr><td>Gambel oak</td></tr>
<tr><td>mesquite</td></tr>
<tr><td rowspan="3">Yucca and yucca-like plants</td><td>yucca</td><td rowspan="3">55</td><td rowspan="3">65</td><td rowspan="3">35</td><td rowspan="3">85</td></tr>
<tr><td>sotol</td></tr>
<tr><td>saw-palmetto</td></tr>
</table>

**Table E-9.** Percentage of air-dry matter in harvested form material at various stages of growth.

<table>
<tr><th colspan="2">Forbs</th><th>Initial growth to flowering (%)</th><th>Flowering to seed maturity (%)</th><th>Seed ripe; leaf tips dry (%)</th><th>Leaves dry; stems drying (%)</th><th>Dry (%)</th></tr>
<tr><td rowspan="5">Succulent</td><td>violet</td><td rowspan="5">15</td><td rowspan="5">5</td><td rowspan="5">60</td><td rowspan="5">90</td><td rowspan="5">100</td></tr>
<tr><td>waterleaf</td></tr>
<tr><td>buttercup</td></tr>
<tr><td>bluebells</td></tr>
<tr><td>Onion, lilies</td></tr>
<tr><td rowspan="5">Leafy</td><td>lupine</td><td rowspan="5">20</td><td rowspan="5">40</td><td rowspan="5">60</td><td rowspan="5">90</td><td rowspan="5">100</td></tr>
<tr><td>lespedeza</td></tr>
<tr><td>compassplant</td></tr>
<tr><td>balsamroot</td></tr>
<tr><td>tickclover</td></tr>
<tr><td rowspan="3">Fibrous leave or mat</td><td>phlox</td><td rowspan="3">30</td><td rowspan="3">50</td><td rowspan="3">75</td><td rowspan="3">90</td><td rowspan="3">100</td></tr>
<tr><td>mat eriogonum</td></tr>
<tr><td>pussytoes</td></tr>
</table>

**Table E-10.** Percentage of air-dry matter in harvested cacti material at various stages of growth.

| Succulents | New growth pads and fruits (%) | Older pads (%) | Old growth in dry years (%) |
|---|---|---|---|
| Pricklypear and barrel cactus | 10 | 10 | 15+ |
| Cholla cactus | 20 | 25 | 30+ |

(8) Determining production of tree or large shrub vegetation

(i) Determining production of trees and large shrubs by harvesting portions of stands is time consuming and impractical for regular field conservation planning procedures. Research scientists have devised, with some success, methods for calculating the relationship between current year's production as it relates to measurements of crown width or height and basal area. Because of these limitations, it is recommended that range and pasture management specialists are to use the following procedures in preparing guides for determining tree and large shrub production values on rangeland and naturalized pastureland:

- Select a few sample trees for each species. Samples should reflect variations in tree size, form, and spacing.
- Determine production through a combination of estimating and harvesting. For estimates, establish appropriate weight units. These units can be an entire small tree or a branch or cluster of branches from large trees (see figure E-9). Determinations from sample trees should include all components of current year's production including current twig growth (< ¼ inch). Exclude bark and wood. Current leaf and twig production can be easily identified for some species. Field determinations of production can be based on current leaf production only if data are available to indicate the percentage that various components contribute to total production. For species requiring two years for fruit maturity, half the weight of mature fruit represents the current production of fruit.
- Expand woody plot estimates to 0.1 acre or larger. Record production for each tree or large shrub. If the 0.1- or 0.01-acre or the 400-square meter plots are used in stands of trees, the likelihood of the plot boundary hitting the bole of a tree is high. Include trees with 50 percent or more of their bole rooted in the plot. List component species, tree size, aspect, growth forms, number of trees, and density of the canopy.
- Repeat this process for stands of various kinds of trees or large shrubs. Based on data thus collected, prepare guides that list the approximate annual production of stands of various kinds of trees or large shrubs (see figures E-15, E-16, and E-17).

(ii) Instructions for use of figures E-15 and E-16 Foliage denseness classes:

Determine yields of juniper and pinyon pine by:

– On 0.1- or 0.01-acre plots selected by random, tally crown diameter per tree and foliage denseness (sparse, medium, and dense) on each tree. From the figures, find yield per tree for each tree by crown diameter and foliage denseness from the proper table (range site) and record this opposite each tree. Add this column of weights. Multiply by 10 on 0.1-acre plots and by 100 on 0.01-acre plots. This number is pounds per acre annual yield.

– On 0.1- or 0.01-acre plots selected by random, tally crown diameter and foliage denseness for each tree. Average the crown diameter for the dense foliage trees; likewise, for the medium and sparse separately. Find the weight per tree in the proper tables opposite for average crown diameter and multiply this figure by the number of trees in the foliage class. Do this for each foliage class. Add the three figures. Multiply by 10 on the 0.1-acre plots and by 100 on the 0.01-acre plots to get yield per acre.

**Figure E-15.** Foliage denseness classes graphic.

**Dense**

**Medium**

**Sparse**

**Figure E-16.** Foliage denseness classes for juniper trees.

**Guide for Determining Current Yield of Utah Juniper in Utah Upland Stony Loam (Juniper) Site**
**Current Yield Air Dry Pounds**

| Crown diameter ft) | Weight per tree | 10 trees | 50 trees | 100 trees | 200 trees | 300 trees | 400 trees | 500 trees |
|---|---|---|---|---|---|---|---|---|
| **Sparse foliage** | | | | | | | | |
| 1 | 0.1 | 1 | 5 | 10 | 20 | 30 | 40 | 50 |
| 2 | 0.3 | 3 | 15 | 30 | 60 | 90 | 120 | 150 |
| 3 | 0.6 | 6 | 30 | 60 | 120 | 180 | 240 | 300 |
| 4 | 1.0 | 10 | 50 | 100 | 200 | 300 | 400 | 500 |
| 5 | 1.3 | 13 | 65 | 130 | 260 | 390 | 520 | 650 |
| 6 | 1.6 | 16 | 80 | 160 | 320 | 480 | 640 | 800 |
| 7 | 1.9 | 19 | 95 | 190 | 380 | 570 | 760 | 950 |
| 8 | 2.3 | 23 | 115 | 230 | 460 | 690 | 920 | 1150 |
| 9 | 2.6 | 26 | 130 | 260 | 520 | 780 | 1040 | 1300 |
| 10 | 2.9 | 29 | 145 | 290 | 580 | 870 | 1160 | 1450 |
| 11 | 3.3 | 33 | 165 | 330 | 660 | 990 | 1320 | 1650 |
| 12 | 3.6 | 36 | 180 | 360 | 720 | 1080 | 1440 | 1800 |
| 13 | 4.0 | 40 | 200 | 400 | 800 | 1200 | 1600 | 2000 |
| 14 | 4.4 | 44 | 220 | 440 | 880 | 1320 | 1760 | 2200 |
| 15 | 4.7 | 47 | 235 | 470 | 940 | 1410 | 1880 | 2350 |
| 16 | 5.1 | 51 | 255 | 510 | 1020 | 1530 | 2040 | 2550 |
| 17 | 5.5 | 55 | 275 | 550 | 1100 | 1650 | 2200 | |
| 18 | 5.8 | 58 | 290 | 580 | 1160 | 1740 | 2320 | |
| 19 | 6.2 | 62 | 310 | 620 | 1240 | 1860 | 2480 | |
| 20 | 6.6 | 66 | 330 | 660 | 1320 | 1980 | 2640 | |
| **Medium foliage** | | | | | | | | |
| 1 | 0.1 | 1 | 5 | 10 | 20 | 30 | 40 | 50 |
| 2 | 0.3 | 3 | 15 | 30 | 60 | 90 | 120 | 150 |
| 3 | 0.6 | 6 | 30 | 60 | 120 | 180 | 240 | 300 |
| 4 | 1.0 | 10 | 50 | 100 | 200 | 300 | 400 | 500 |
| 5 | 1.4 | 14 | 70 | 140 | 280 | 420 | 560 | 700 |
| 6 | 1.9 | 19 | 95 | 190 | 380 | 570 | 760 | 950 |
| 7 | 2.5 | 25 | 125 | 250 | 500 | 750 | 1000 | 1250 |
| 8 | 3.1 | 31 | 155 | 310 | 620 | 930 | 1240 | 1550 |
| 9 | 3.8 | 38 | 190 | 380 | 760 | 1140 | 1520 | 1900 |
| 10 | 4.6 | 46 | 230 | 460 | 920 | 1380 | 1840 | 2300 |
| 11 | 5.4 | 54 | 270 | 540 | 1080 | 1620 | 2160 | 2700 |
| 12 | 6.2 | 62 | 310 | 620 | 1240 | 1860 | 2480 | |
| 13 | 7.2 | 72 | 360 | 720 | 1440 | 2160 | | |
| 14 | 8.1 | 81 | 405 | 810 | 1620 | 2430 | | |
| 15 | 9.1 | 91 | 455 | 910 | 1820 | 2730 | | |
| 16 | 10.2 | 102 | 510 | 1020 | 2040 | | | |
| 17 | 11.3 | 113 | 565 | 1130 | 2260 | | | |
| 18 | 12.4 | 124 | 620 | 1240 | 2480 | | | |
| 19 | 13.6 | 136 | 680 | 1360 | | | | |
| 20 | 14.8 | 148 | 740 | 1480 | | | | |
| **Dense foliage** | | | | | | | | |
| 1 | 0.1 | 1 | 5 | 10 | 20 | 30 | 40 | 50 |
| 2 | 0.3 | 3 | 15 | 30 | 60 | 90 | 120 | 150 |
| 3 | 0.7 | 7 | 35 | 70 | 140 | 210 | 280 | 350 |
| 4 | 1.2 | 12 | 60 | 120 | 240 | 360 | 480 | 600 |
| 5 | 1.9 | 19 | 95 | 190 | 380 | 570 | 760 | 950 |
| 6 | 2.7 | 27 | 135 | 270 | 540 | 810 | 1080 | 1350 |
| 7 | 3.6 | 36 | 180 | 360 | 720 | 1080 | 1440 | 1800 |
| 8 | 4.7 | 47 | 235 | 470 | 940 | 1410 | 1880 | 2350 |
| 9 | 5.9 | 59 | 295 | 590 | 1180 | 1770 | 2360 | |
| 10 | 7.2 | 72 | 360 | 720 | 1440 | 2160 | | |
| 11 | 8.6 | 86 | 430 | 860 | 1720 | 2580 | | |
| 12 | 10.2 | 102 | 510 | 1020 | 2040 | | | |
| 13 | 11.9 | 119 | 595 | 1190 | 2380 | | | |
| 14 | 13.7 | 137 | 685 | 1370 | 2740 | | | |
| 15 | 15.6 | 156 | 780 | 1560 | | | | |
| 16 | 17.7 | 177 | 885 | 1770 | | | | |
| 17 | 19.9 | 199 | 995 | 1990 | | | | |
| 18 | 22.2 | 222 | 1110 | 2220 | | | | |
| 19 | 24.6 | 246 | 1230 | 2460 | | | | |
| 20 | 27.2 | 272 | 1360 | 2720 | | | | |

**Figure E-17.** Foliage denseness classes, continued.

## Annual Foliage and Fruit Production per Juniper Tree on Different Sites and for Different Foliage Classes

| Crown diameter | Site Upland loam foliage and fruit sparse/medium/dense | | | Upland stony loam foliage and fruit sparse/medium/dense | | | Upland gravelly loam foliage and fruit sparse/medium/dense | | | Upland shallow loam foliage and fruit sparse/medium/dense | | | Upland shallow hardpan foliage and fruit sparse/medium/dense | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 |
| 2 | 0.2 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.2 | 0.2 | 0.5 | 0.3 | 0.4 | 0.5 |
| 3 | 0.4 | 0.6 | 0.9 | 0.7 | 0.6 | 0.7 | 0.6 | 0.7 | 0.9 | 0.4 | 0.5 | 1.0 | 0.7 | 0.9 | 1.4 |
| 4 | 0.6 | 1.1 | 1.5 | 1.0 | 1.0 | 1.2 | 1.0 | 1.1 | 1.5 | 0.7 | 0.8 | 1.6 | 1.2 | 1.6 | 2.4 |
| 5 | 0.9 | 1.6 | 2.1 | 1.3 | 1.4 | 1.9 | 1.3 | 1.6 | 2.1 | 1.0 | 1.3 | 2.2 | 1.8 | 2.6 | 3.8 |
| 6 | 1.3 | 2.1 | 3.1 | 1.6 | 1.9 | 2.7 | 1.7 | 2.1 | 2.7 | 1.4 | 1.8 | 2.9 | 2.7 | 3.7 | 5.4 |
| 7 | 1.6 | 2.8 | 4.0 | 1.9 | 2.5 | 3.6 | 2.1 | 2.6 | 3.5 | 1.7 | 2.4 | 3.8 | 3.6 | 5.0 | 7.4 |
| 8 | 2.0 | 3.5 | 5.1 | 2.3 | 3.1 | 4.7 | 2.6 | 3.2 | 4.3 | 2.2 | 3.1 | 4.6 | 4.7 | 6.5 | 9.6 |
| 9 | 2.5 | 4.3 | 6.3 | 2.6 | 3.8 | 5.9 | 3.1 | 3.9 | 5.1 | 2.6 | 3.8 | 5.6 | 6.0 | 8.2 | 12.2 |
| 10 | 3.0 | 5.2 | 7.6 | 2.9 | 4.6 | 7.2 | 3.6 | 4.6 | 6.0 | 3.1 | 4.6 | 6.6 | 7.4 | 10.1 | 15.1 |
| 11 | 3.5 | 6.2 | 9.0 | 3.3 | 5.4 | 8.6 | 4.1 | 5.3 | 7.0 | 3.6 | 5.5 | 7.6 | 9.0 | 12.1 | 18.2 |
| 12 | 4.0 | 7.2 | 10.5 | 3.6 | 6.2 | 10.2 | 4.7 | 6.1 | 8.0 | 4.2 | 6.5 | 8.8 | 10.7 | 14.4 | 21.7 |
| 13 | 4.6 | 8.3 | 12.1 | 4.0 | 7.2 | 11.9 | 5.2 | 6.9 | 9.1 | 4.7 | 7.6 | 9.9 | 12.6 | 16.9 | 25.5 |
| 14 | 5.2 | 9.4 | 13.9 | 4.4 | 8.1 | 13.7 | 5.8 | 7.8 | 10.2 | 5.3 | 8.7 | 11.2 | 14.6 | 19.5 | 29.6 |
| 15 | 5.9 | 10.6 | 15.6 | 4.7 | 9.1 | 15.6 | 6.5 | 8.7 | 11.3 | 6.0 | 9.9 | 12.4 | 16.7 | 22.4 | 33.9 |
| 16 | 6.5 | 11.9 | 17.5 | 5.1 | 10.2 | 17.7 | 7.1 | 9.6 | 12.5 | 6.6 | 11.1 | 13.8 | 19.0 | 25.5 | 38.6 |
| 17 | 7.2 | 13.2 | 19.4 | 5.5 | 11.3 | 19.9 | 7.8 | 10.5 | 13.7 | 7.3 | 12.4 | 15.1 | 21.5 | 28.7 | 43.6 |
| 18 | 8.0 | 14.6 | 21.5 | 5.8 | 12.4 | 22.2 | 8.4 | 11.5 | 15.0 | 8.0 | 13.8 | 16.6 | 24.1 | 32.1 | 48.9 |
| 19 | 8.7 | 16.1 | 23.7 | 6.2 | 13.6 | 24.6 | 9.1 | 12.5 | 16.3 | 8.7 | 15.3 | 18.0 | 26.9 | 35.5 | 54.5 |
| 20 | 9.5 | 17.6 | 26.0 | 6.6 | 14.8 | 27.2 | 9.8 | 13.6 | 17.6 | 9.5 | 16.8 | 19.6 | 29.8 | 39.5 | 60.4 |

## General Soil Features Associated with Sites Named in "Guides for Determining Current Yield of PIMO and JUOS in Utah"

| Site name | Precipitation zone (in) | Range in slope (%) | Soil depth | Coarse fragments in profile | Range in AWC (in) |
|---|---|---|---|---|---|
| Upland stony loam | 12–16 | 5–30 | Deep to very deep over bedrock | 50% (45 60% at soil surface) | 2–4 (6) |
| Semidesert stony loam | 8–12 | 5–30 | 50 in over bedrock | 50% (45-60% at soil surface) | 2–4 |
| Upland gravely loam | 12–16 | 4–15 | 35–40 in | 35–65% | 2–3 |
| Upland loam | 12–16 | 3–20 | 40 in to bedrock | 35–60% (in upper profile | 3–6 |
| Upland shallow hardpan | 12–16 | 5–20 | 6–20 in over hardpan | 15–60% (often nonskeletal) | 1.5–3 |
| Upland shallow loam | 12–16 | 8–60 | 14–20 in (15 in) to bedrock | 75% | 0.5–1.5 |

## 645.0506 Density and Frequency

A. Several variables important to grazing land health and trend cannot be quantified using production data alone; therefore, other techniques must be used to quantify vegetation characteristics of an area. For instance, density and frequency measurements can be helpful in attributing the vegetative community within an area of interest. Density is often used to determine the effects of management practices or vegetation treatments targeting a specific plant. A measure of the target plant density is taken before and after treatment to determine the degree of control achieved by the treatment. Frequency records the presence of species in quadrants or plots placed repeatedly across a stand of vegetation. Frequency reflects the probability of finding a species at any location in the vegetated area (USDA Landscape Toolbox 2021).

B. Density is the number of individual plants rooted per unit area. Density measurements are useful where cover varies widely and can provide information important for conservation practice planning. Choosing a plot size, the number, and placement within the plots is all that is required for simple density techniques (TN 190-PM-76).

C. Density measurements are used to determine the establishment success of seedings or for monitoring specific plant species of concern such as threatened or endangered plants or noxious weeds. The density of plants that contribute to heavy fuels such as trees and shrubs is important information when planning for prescribed burns. The lack of continuity of fuels for carrying fire can also be determined from plant density measurements. With rhizomatous plants, there can be confusion about how an individual is counted, since a single organism can comprise large areas, exhibiting multiple stems (TN 190-PM-76).

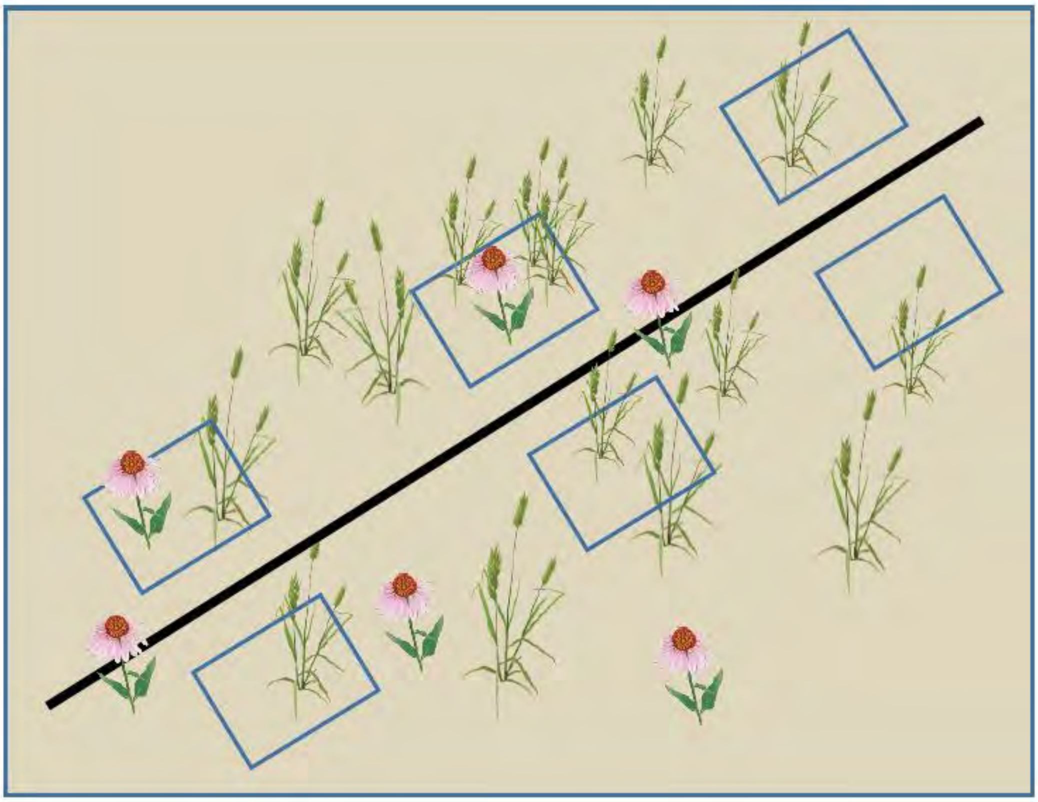
D. Methods for determining plant density

(1) Density is the number of individual plants per unit of area. It should only be used to compare plants of similar life forms, e.g., annuals to annuals, shrubs to shrubs. Two methods used for determining density are described in Volume 2 of Monitoring Manual for Grassland, Shrubland and Savannah Ecosystems (Herrick et al. 2009):
  (i) quadrat frame
  (ii) belt transects

(2) Remote sensing imagery may be useful for determining density of trees. Use the belt transect method to validate small tree or large shrub density measurements obtained from remote sensing products.

(3) Density measurements for grasses and forbs are desired in the example shown in figure E-18. For density, plants are counted within quadrats of a known size. Here, there are seven grasses in the six 1-m² quadrats, so grasses receive a score of 7/6 or 1.17 plants/m². Likewise, there are two forbs in the six quadrats, thus receiving a score of 2/6 or 0.33 plants/m².

**Figure E-18.** Density example.



E. Frequency is the ratio between the number of sample units that contain a species and the total number of sample units. The concept of frequency is only the presence or absence of species in a specified size of plot. These measurements provide information about the spatial distribution of different species and is used to help determine if a change in vegetation is occurring. The size of the plot used has a great influence on the outcome (TN 190-PM-76).

Choosing the appropriate size for the plot frame is a key variable in making frequency data meaningful, sensitive to changes, and statistically valid. "Nested" plot techniques allow for multiple plot sizes in a frame to choose an appropriate size for each species. Frequency frames may be implemented as paced or measured transects (Coulloudon, TR 1734-4, 1999). "Rooted" frequency (requiring a plant to be rooted in the frame to be counted) is one variation in this technique that can affect results (TN 190-PM-76).

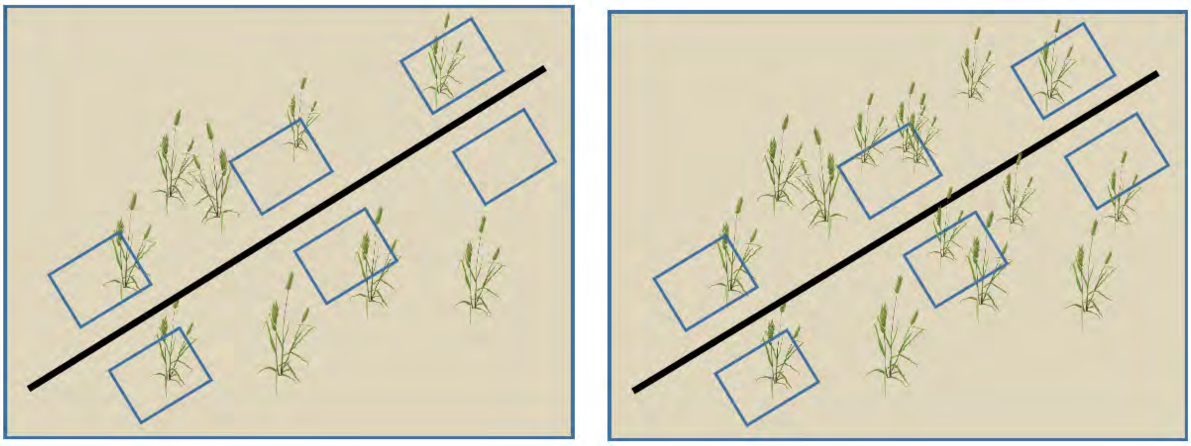
F. Methods for Determining Frequency

(1) Frequency methods describe the abundance and distribution of species and is useful as a baseline in an inventory for detecting changes in a plant community over time. Frequency is generally expressed as a percentage of the number of times a species is present in a given number of sampling units.

(2) Frequency methods should not be the only data collected on a site. It should accompany cover data to assist in later interpretation of changes that may be occurring on the site through follow-up monitoring. The Rapid method and the Intensive method are both described in the Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems Volume II Design, supplementary methods and Interpretation (Herrick et al. 2009) https://jornada.nmsu.edu/files/Core_Methods.pdf.

(3) A frequency example is shown in figure E-19. A transect is laid out with six 1-$m^2$ quadrats in subsequent years. In year one (left) four of the quadrats contain plants rooted in the frame, therefore receiving a frequency of 4/6 or 66 percent. In year two (right) more plants have established, and now five of the quadrats contain target species, therefore receiving a frequency of 5/6 or 83 percent. With frequency, it does not matter that there may be multiple target species within the quadrat. Only quadrats containing target plants are counted (TN-190-PM-76).

**Figure E-19.** Frequency example.



## 645.0507 Cover

A. Definitions and differences in terms used for cover.

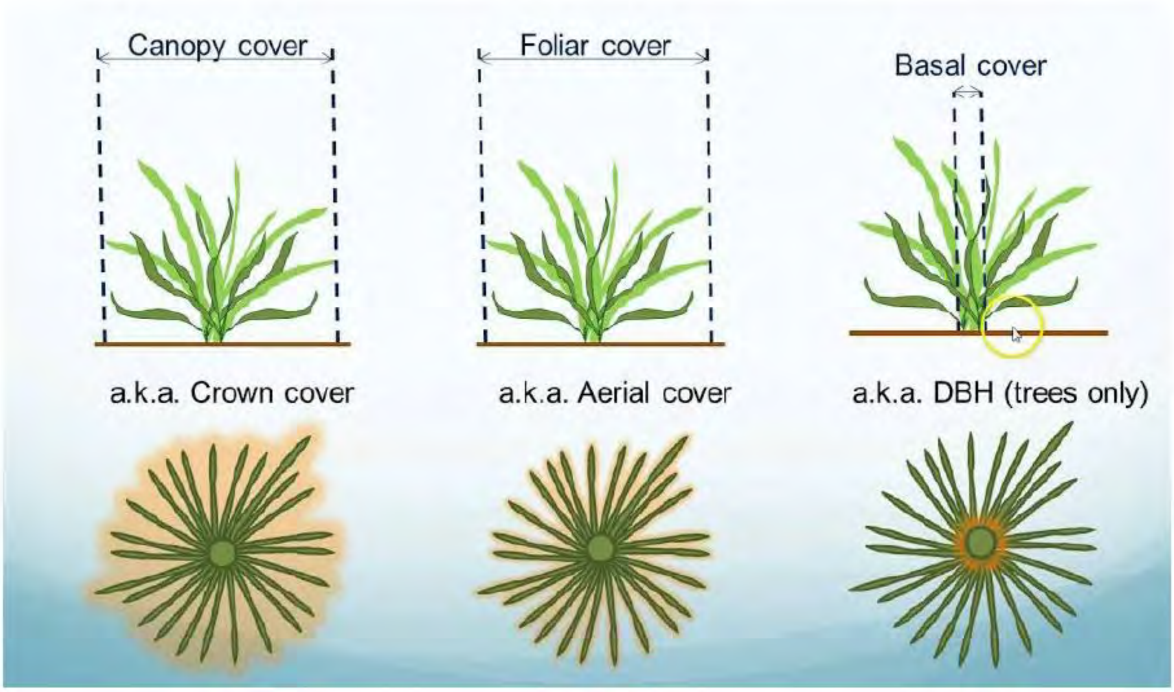
(1) Cover measurements can be used to quantify ground cover of litter, seedlings, microphytes (algae, lichen, and moss), and the exposure and condition of the soil surface. Cover is generally referred to as the percentage of ground surface covered by vegetation (Coulloudon, TR 1734-4, 1999). Cover is also important from a hydrologic perspective where the variables of interest might include basal cover of perennial and annual species, litter, coarse fragments, rills, and foliar and canopy cover above the soil surface. Collecting vegetation data can be labor intensive and time consuming, even when using remote sensing technology, because field verification is required to validate remotely sensed data. Therefore, monitoring environmental change using other non-destructive

techniques such as cover, or a combination of techniques, such as cover and density, is often used depending upon the resource information needed.

(2) Numerous concepts and definitions of cover exist. Cover is generally referred to as the percentage of ground surface covered by vegetation. The resource objective being measured will determine the definition and type of cover measured (Coulloudon, TR 1734-4, 1999) (see figure E-20).
   (i) Vegetative cover, live or dead, is total cover of vegetation on a site.
   (ii) Foliar cover is the area of the soil surface covered by the vertical projection of the aerial portions of plants. Small openings in the canopy are excluded. Essentially, it is any area of a plant that a raindrop would intercept before hitting the soil surface.
   (iii) Canopy cover is the area of the ground covered by the vertical projection of the outermost perimeter of the natural spread of plant foliage, either living or dead, that is still attached to the root. Small openings within the canopy are included. Remote sensing products measure canopy cover.
   (iv) Basal cover is the cross-sectional area of the stem or stems of a plant or of all plants in a stand that occupy the ground surface.
   (v) Ground cover is the cover of all plants, litter, rock, and gravel on a site. This includes lichens, moss, and biocrusts.
   (vi) Bare ground is all land surface not covered by vegetation rock or litter.

(3) This variety of concepts can cause confusion and potential incompatibility between data sets. To be of value, the same type of cover measurement must be used and documented for each evaluation of a given experiment or project.

**Figure E-20.** Illustration of three different cover concepts (Laurie Abbott, NMSU, TN 190-PM-76).




B. Methods for determining cover

(1) Remote sensing methods—Several remote sensing methods for determining cover are developing and changing rapidly. Section 645.0501 mentions four methods that can provide estimates of cover at various scales. The level of detail needed and the purpose for which the information is to be used will determine which method to select. The following ground-based methods are used to validate cover data obtained from remote sensing products.

(i) Methods for determining canopy cover, foliar cover, basal cover, and bare ground.

(ii) Choosing a technique for cover measurements depends largely on the concept of the cover that is of interest. Some techniques can record observations for multiple concepts of cover simultaneously. Cover measurements are usually expressed as a percentage.

- Techniques that utilize a 2-dimensional plot frame (i.e., Daubenmire) (Coulloudon, TR 1734-4, 1999) are well suited to record canopy or basal cover (TN 190-PM-76), as shown in figure E-21.
- Techniques that utilize a linear transect (i.e., line intercept) (Coulloudon, TR 1734-4, 1999) are well suited to record canopy cover (TN 190-PM-76).
- Techniques that utilize points (i.e., line point intercept, step-point) (Coulloudon, TR 1734-4, 1999) are well suited to record foliar cover (TN 190-PM-76).
- Techniques that record cover gaps (i.e., canopy gap or basal gap intercept) (Herrick, et al. 2005) observe an inverse of cover for the size and distribution of areas without vegetation canopy cover (TN 190-PM-76).
- Various techniques have rule sets to deal with issues such as live vs. dead vegetation, overlapping cover, and proximity to the ground surface. These must be clearly defined when interpreting and reporting results (TN 190-PM-76).

C. Interpretation—A variety of interpretations can be made from cover data, including plant community composition (where species specific data is recorded). Cover data are used to inform several tools and models including wildlife habitat evaluation guides (WHEG), Interpreting Indicators of Rangeland Health (IIRH), and the Rangeland Hydrology and Erosion Model (RHEM). For monitoring purposes, trend is implied depending on if the particular species cover is increasing or decreasing. Basal cover is considered preferable for this purpose because it is less sensitive to annual weather or growing conditions. However, basal cover should only measure the live portion of a plant such as a bunch grass, not the former crown that may have died (TN 190-PM-76).

D. Additional information on Cover can be found in the NRI/AIM protocols.

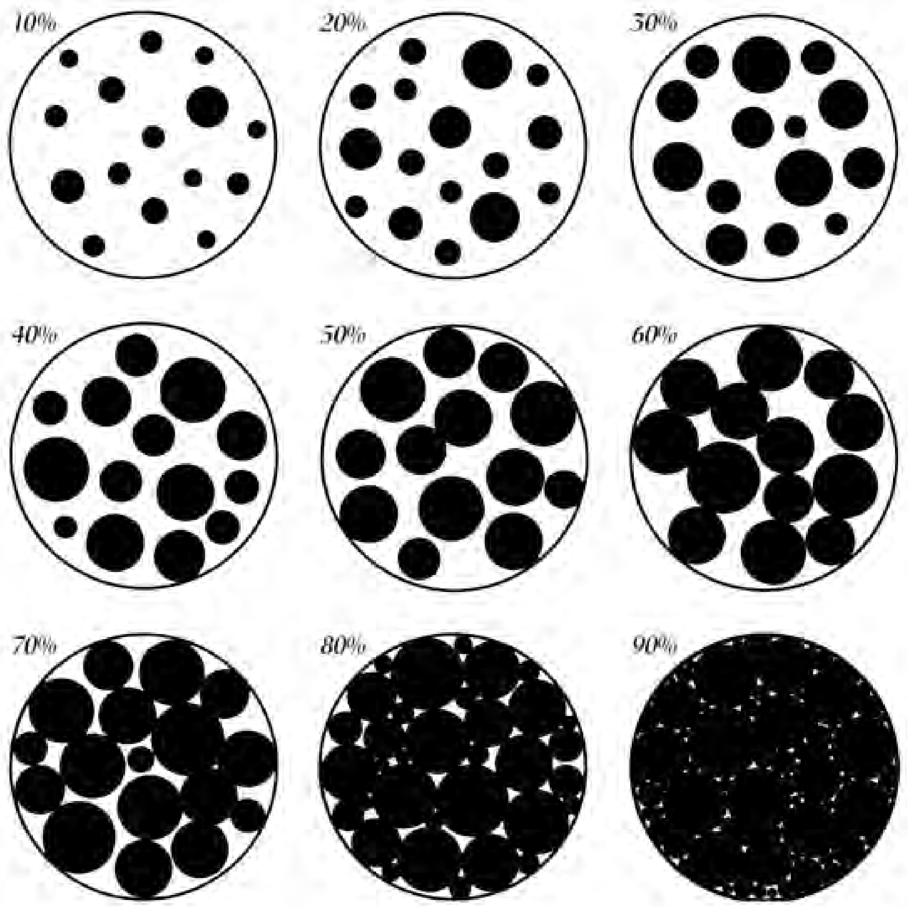
## 645.0508 Composition

A. Composition is a calculated attribute rather than one that is directly collected in the field. It is the proportion of various plant species in relation to the total of a given area. It may be expressed in terms of relative cover, relative density, or relative weight.

B. Composition has been used to describe ecological sites and to assist in evaluating the condition of range, pasture, and grazed forest land. Composition can provide information about plant species of interest such as pollinator plants, threatened or endangered plants, or noxious and invasive plants. Composition is calculated by dividing the individual value (weight, density, percent cover) for a species or group of species by the total value of the entire population (Coulloudon, TR 1734-4, 1999).

C. Comprehensive interpretation of plant production and composition determinations requires that data be representative of all species having measurable production. Rangeland, pastureland, and other grazing lands may be used or have potential for use by livestock and wildlife, including insects such as pollinators, as recreation areas, as a source of certain wood products, for scenic viewing, and for other soil and water conservation purposes. The value of plant species for domestic livestock grazing is often not the same as that for wildlife, recreation, beautification, and watershed protection. The principles and concepts of ecological sites are based on the total plant community. Therefore, interpretations of a plant community are not limited solely to species that have value for domestic livestock.

**Figure E-21.** Visual guide to different levels of cover using a 2-dimensional circular frame (TN 190-PM-76).




## 645.0509 Structure

A. Structure is the vertical and horizontal distribution of vegetation in space, the height and area occupied by different plants or life forms (and spatial diversity) in a community (Herrick et al. 2005). The concepts of structure include height, area, shape, foliage density, and visual obstruction. The most common use of structure is for wildlife habitat interpretations (TN 190-PM-76).

B. Structure techniques, like the Robel Pole (figure E-22), typically measure vegetation in layers on vertical planes.

C. Measurements generally look at the vertical distribution by either estimating cover of each layer or by measuring the height of the vegetation (Coulloudon, TR 1734-4, 1999; Herrick et al. 2005; TN 190-PM-76).

D. Some techniques use photo guides to assign foliage density classes.

E. percent visual obstruction and foliage height diversity are examples of interpretations from structure data. Specific interpretations of wildlife habitat quality for particular species can be made from structure data (TN 190-PM-76).

**Figure E-22.** Using a Robel Pole to measure structure. Photo credit: Lesser Prairie Chicken Initiative.org.

## 645.0510 Utilization

A. Utilization data and residual measurements are important in evaluating the effects of grazing and browsing (Coulloudon, TR 1734-3, 1999).

(1) Utilization measures the percentage of annual herbage production that has been removed. It is generally the percentage of available forage that has been consumed or destroyed.

(2) The main purpose for determining utilization is to consider whether seasonal or within-season adjustments are needed in grazing management or stocking rate. Utilization data, in combination with the phenological growth stage of the plants being grazed, and weather data are used to make day-to-day adaptive grazing management decisions.

(3) Residual measurement is the determination of herbage material or stubble height left. Residual measurements and utilization data can be used to: (a) identify use patterns, (b) help establish cause-and-effects interpretations of range trend data, and (c) aid in adjusting stocking rates when combined with other monitoring data (Coulloudon, TR 1734-3, 1999). https://www.blm.gov/sites/blm.gov/files/documents/files/Library_BLMTechnicalReference1734-03.pdf.

B. NRCS does not specify universal utilization standards for grazing use. The concept of "take half-leave half" has traditionally been a generalization used to make short term grazing management decisions, but the amount of forage planned for grazing use is site-by-site dependent upon the plant species being grazed, how much forage is present to begin with, resource conditions, and objectives set toward meeting a specific plant health productivity goal or site goal. Utilization data alone do not provide adequate information to determine whether management actions are meeting management objectives. Targeting a planned utilization level or stubble height is one way to achieve short-term land management, while cover, frequency or density measurement can help evaluate long-term management objectives.

C. Determining the actual use of key species in key grazing areas is the first of many factors considered in assessing baseline grazing management. If the key species and key grazing areas are correctly selected, it is an indicator of the degree of grazing use for the total plant community.

Utilization is expressed as a percentage of the proportion of current year's forage production that is consumed or destroyed by animals. All methods of determining utilization are estimates, with most utilization studies using peak standing crop as an estimate of current-year production, which is always less than total production.

D. Utilization Studies and Residual Measurements (Interagency Technical Reference, 1999) contains detailed information on the short and long-term use of utilization data, frequency, and timing of collecting data, various methods for making determinations of utilization for herbaceous and woody plant species, and instruction for mapping utilization patterns for determining livestock distribution. NRCS documentation of utilization and stubble height is recorded electronically through VGS or on hardcopy forms in each state's FOTG, usually on a Proper Grazing Use Form, such as pictured in figures E-23 and E-24.

> Montana NRCS has put together a short video on the importance of rangeland utilization monitoring and the benefits to ranching operations. The video can be accessed at: https://www.youtube.com/watch?v=t1ktrC6S09c&list=UUIMKAToX5kCtp9KCfnX2BFg&index=6.

E. Methods for determining utilization of key plant species

(1) Utilization Cages—Weight comparisons of grazed versus ungrazed plants within a grazed area using utilization cages offer an opportunity to visually observe and quantitatively measure the seasonal level of grazing use. Ungrazed plants of key species occurring within movable exclosures, located in key grazing areas, are clipped and weighed at the end of the grazing season within the grazed area. The weight of these plants is then compared with that of grazed plants of the key species clipped outside the exclosure. Figure E-25 is an example of an exclosure.

(i) There are several cage types, including:

- Enclosure—one to more than 25 acres to test grazing systems.
- Exclosure—smaller plots to measure recovery rates or natural trends.
- Seasonally Protected—an exclosure within the enclosure plot where various management systems are applied to represent multiple kinds of animals due to their preference and seasonal use of different forage and browse plants.

(ii) Sizes: Because of construction and maintenance costs, exclosures are inherently limited in size. Small exclosures are susceptible to site-specific peculiarities of litter accumulation and fence effects. The interior of a small exclosure is more likely to be influenced by its surroundings, so exclosures should be large enough that the area inside the fence can potentially develop along an independent trajectory from the area outside. This is important for the type of animals that might influence herbage removal. Exclosures, at a minimum, should be large enough so that several normal sized plants of the species of interest can be observed.

- The minimum size needed to effectively capture natural variation can vary according to ecological circumstances and therefore present a challenge when sites are very heterogeneous. Size of utilization exclosures is generally not as complex on pasturelands.

**Figure E-23.** Standard Proper Grazing Use Form.

## Proper Grazing Use

**Cooperator**______________________________________

| Grazing unit | Acres | Species of grazing animal | Season of Use | Location of Key Grazing Area | Key Plant(s) for Judging Proper Grazing Use | Minimum Percent of Key Species at End of Grazing Period (or Pounds per Acre) | Actual percent or pounds remaining | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 19___ | 19___ | 19___ | 19___ | 19___ |
| | | | | | | | | | | | |
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| | | | | | | Initials of Conservationist Assisting with Application | | | | | |
| | | | | | | Dates of Application Checks | | | | | |

Conservationist Assisting with Planning

______________________________________

Name and Date

Proper Grazing Use Directions

Grazing Unit: Enter in this column the name of the pasture or field used by the cooperator or the number from the conservation plan map.

Acres: Enter in this column the acreage of the grazing unit.

Species of Grazing Animal: Enter in this column the species and class of livestock being grazed such as: dry cows, cow-calves, ewes and lambs, yearling cattle, 2-year steers, yearling sheep, goats, deer, horses, elk, etc.

Season of Use: Enter in this column the season that unit will be grazed such as: fall, winter, spring, summer, or by months: Sept. - Oct, Nov. - Mar, May- Jul, etc.

Location of Key Grazing Area: Enter in this column a description of the key grazing area. This may be an ecological site, it may be a portion of a site, or it might be a particular location within the grazing unit such as: S-W portion of grazing unit starting about 200 yards from pond to fence.

Key Plant(s) for Judging Proper Grazing Use: Enter in this column the species by common name on which you and the cooperator decide proper grazing use will be judged. There may be occasion when you will select two species, in this case enter the name of both species.

Minimum Percent of Key Species at End of Grazing Period: Enter in this column, the percent by weight, of the current year's growth of the key species that should be left ungrazed at the end of the grazing season. Where specifications call for a certain number of pounds of forage to be left ungrazed per acre of the key species, then the specified pounds per acre should be entered in this column.

Actual Percent or Pounds Remaining: Enter in this column, by calendar year, the percent, by by weight, or pounds remaining of the selected key species in the grazing unit. This measurement should be based on the key species on the key grazing area, at or near the end of the grazing call for use in percent of current year's growth, enter percentage of growth ungrazed. If use is specified in amount of forage to be left ungrazed in pounds per acre, then enter pounds per acre left ungrazed.

**Figure E-24.** Proper Grazing Use Form Example.

**Cooperator** Farmer Joe

| Grazing Unit/Field | Species of Grazing Animal | Season(s) of Use | Location of Key Grazing Area | Key Species | Planned Percent Utilization or Stubble Height of Key Species | Applied Utilization or Stubble Height | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 20 17 | 20____ | 20____ | 20____ |
| 1 | Cattle | Spring | (coordinates) | pubescent wheatgrass | 6" | 7" | | | |
| 2 | Cattle | Spring, Sum, Fall | Near Transect 1 | bluebunch wheatgrass | 35% | 30% | | | |
| | | | | green needlegrass | 35% | 35% | | | |
| 3 | Cattle | Spring, Sum, Fall | 1/2 mi N of reservoir | western wheatgrass | 50% | 40% | | | |
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| | | | | | Initials of Conservationist Assisting w/ Application | SD | | | |
| | | | | | Dates of Application Checks | 9/1/2017 | | | |

Cooperator -- Name and Date

Sunny Day 5/1/16

NRCS Conservationist Assisting with Planning -- Name and Date

**Figure E-25.** 8-foot x 8-foot Grazing Exclosure. Photo credit: Brenda Simpson, National Grazing Land Team.

(iii) Uses:

- Exclosure terminology, placement, size, maintenance, monitoring data, monitoring study design, and documentation are all parts of a plan to deploy an exclosure. The objective is to provide a comparison of the amount of herbage left compared with the amount of herbage produced during a time period. Regular, repeated monitoring is needed to account for inter-annual variation attributable to precipitation and growing conditions. Monitoring schedules should also be consistent with respect to seasonal variation in livestock and wildlife use.
- Exclosures are flexible range management tools that can trigger management decisions and be used to inform:
  – Relatively short-term evaluation of herbivore influence on range productivity and composition.
  – Relatively moderate-term monitoring of trends and changes in plant community phases or state transitions.
  – Relatively long-term identification of the normal range of variation characteristic of natural plant communities.
- Cage movement should be based on the objectives of what is being monitored. Many times, annual movement is recommended to reduce the side effects of the cage itself and to better reflect only the effects of removing grazing for that current year.
- Limitations:
  – Exclosures are tools to manage the use of vegetation by certain types of animals – a dynamic ecological process. A tool intended to control a constantly changing process will need constant attention and adjustment.
  – A reliable monitoring program is characterized by a set of representative monitoring sites, consistent data collection methodology, committed time, funding, and frequent evaluation.
  – Objectivity is required to recognize the difficulties of field sampling due to the many variables encountered on rangeland. The more elements present, the greater the chance for variation in the vegetation.
  – Cages used to protect plants from grazing can affect growth, usually positively, by altering microclimate, addition of nutrients by birds perching on the cage, or other factors (Owensby 1969; Fults 2017).
  – Cages can also reduce wind speed and insolation by 10–20 percent, create more stable and generally higher relative humidity, and in most instances, reduce temperature, particularly during periods of high insolation.

  - Even if a large number of paired exclosures are selected (grazing versus no grazing), the error of estimation could be significantly high if the vegetation is non-uniform.
  - Plant responses to protection can be negative. Tueller and Tower (1979) and Fults (2017) found that within two years of exclosure, bitterbrush significantly reduced production of browse, leaves and fruit (from stagnation). Other studies have noted a reduction in nutritional values such as decline in crude protein of plants inside the cage (Fults 2017).
- Placements:
  - Cages should be rigid and strongly set in locations of general grazing pressure. If cages are going to be moved annually, they need to be built with mobility in mind.
  - They should be constructed or placed away from other structures, roads, watering points, and travel paths. Many times, exclosures will be placed in key grazing areas.
  - Reasons to leave cages for more than one growing season include monitoring for plant diversity and potential viable seed sources within the soil bank (Fults 2017).
- Use in Grazing Management Plans:
  - Exclosure cages help determine utilization at the end of the grazing or growing season. The analysis considers whether to increase or decrease stocking during the next grazing season. Exclosures help measure the degree of use of the key forage species during the next grazing season. Monitoring exclosures can help meet the basic management objective to remove no more than 50 percent (by weight) of the current year's growth or some other desired percent (Fults 2017).
  - An approach to fine tuning a grazing management plan is to use multiple exclusion cages, placing one cage on a representative location at the beginning of the growing or grazing season. Place the second on a similar location but add a clipping treatment to remove standing vegetative growth. This results in a uniform beginning height. Be sure not to clip so close to the ground that the growing points are harmed. The first cage allows a comparison of overall differences between utilized and dormant. The second cage allows comparison of growth and vigor under use and non-use conditions (Fults 2017).
- Another method for gathering comparison grazed data is to do a step transect measuring the height of key species plants that are grazed, then compare this to the heights in the protected exclosure cages. Develop a height-weight relationship by:
  - Sample several ungrazed key species of normal size or similar number of culms.
  - Clip the plant to within ¼ inch of the ground. Wrap the clipped plant with thread from base to top to retain all leaves and culms.
  - Measure heights of clipped plants to the nearest inch and determine the average height and average weight.
  - Clip the top inch, weigh plant, record and repeat at one-inch intervals until the last inch of the plant base is reached.
  - Determine the average height-weight relationship.
  - Measure the key species height inside of the exclosure and compare to key species outside the exclosure. A step transect outside of the exclosure can provide an average of the key species in the grazed area.
  - Key species height (ht.) utilization = (species ht. inside exclosure) – (species ht. outside the exclosure) / species ht. inside exclosure X 100%.
    - Example: 16 inches (inside) – 5 inches (outside)/16 inches X 100 = 68.75% of height.
    - Convert height to weight and use the same formula for key species weight utilization (Fults 2017).

– An abbreviated procedure that gives a strong visual guide is to balance the clipped and wrapped ungrazed plant on your finger to determine the stubble heigh at 50 percent, then further estimation can be made from that point. See figure E-26.

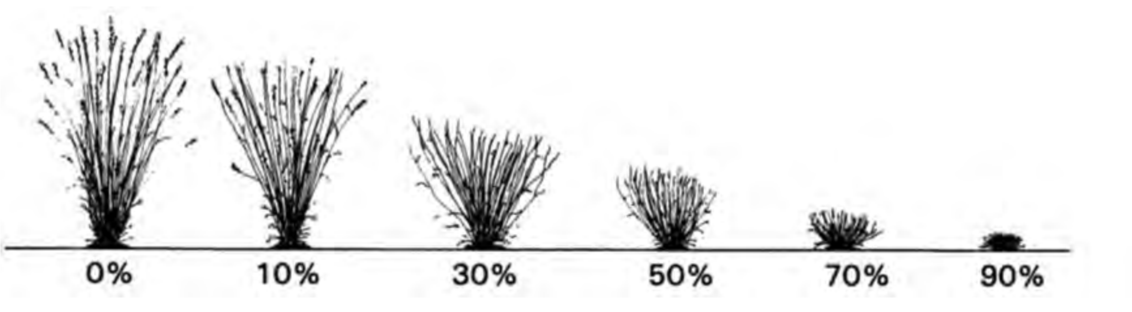
**Figure E-26**. Balancing 50 percent by weight using your finger. Photo credit: Shane Green, NRCS National Grazingland Team.

(2) Use of grazed-class photo guides

(i) In some locations, series of photographs illustrating various degrees of grazing use, expressed in percentage by weight, are available for some plant species. Guides based on actual clipping and weighing of plants of the key species provide a relatively simple and rapid means of determining approximate grazing use. These guides are helpful in illustrating how plant weight is not evenly distributed throughout the height of any given plant species.

(ii) Photo guides should be used only in the locality where they are prepared and only for the plant species specifically appraised. The procedure is to visually compare a series of plants of the key species with photographs illustrating various degrees of plant use, and to tally the number of plants occurring in each grazed class. Extremes in growing condition must be considered when using photo guides. See figure E-27 for example.

**Figure E-27.** Grazed Class Photo Guides (Kingery et al. 1992).




(3) Stubble heights – stop grazing heights – residual heights needed

(i) The concept of this method is to measure stubble height, or height (in centimeters or inches) of herbage left ungrazed at any given time. This method would be used after stubble height standards for specific plant communities have been developed (Colloudon 1999). It can be used when minimum residual herbaceous heights help address or prevent a resource concern. As an example, a stubble height of four inches might be specified to provide streambank protection, to trap sediments in a certain area, and rebuild degraded stream channels in riparian areas. Another example would be that minimum stubble heights are needed on bunch grasses to help ensure nesting habitat requirements for ground-nesting birds are available.

(ii) Stubble height is expressed in inches and can be correlated to production on pasture sticks. Accuracy in stubble height measurement is affected by plant community characteristics. Sites with inconsistent plant composition and varying palatability can make stubble height measurements and interpretation of data difficult. For these reasons, stubble height measurements should focus on key plant species, or species groups. Stubble height should be recorded and averaged by key species, not averaged across multiple species. Averaging or grouping the data should only be done among species with relatively similar growth forms.

(iii) Enough stubble height measurements should be collected to reflect grazing use variability across the extent of the sampling area. Select species groups, where appropriate, to reduce the total sampling requirements or increase precision within a given sample number.

(iv) Follow the methods described in Utilization Studies and Residual Measurements, Interagency Technical Reference, 1999, for procedural instructions on obtaining utilization data. Further guidance may be found in state technical notes and Land Grant University publications.

(4) Utilization Gauges

(i) Utilization gauges developed by the US Forest Service primarily in the Southwestern Region (R-3) provide height-weight relationships to help land managers better determine utilization. The gauge was developed from height-weight curves for forage species within the southwest region. See figure E-28.

(ii) The gauge is easily portable and is easily read and understood by landowners. The ungrazed height is set at the top of the dial, the grazed height is read across the dial, and the percent utilization is read in the window by species (Aldon et al. 1984). Clip and weigh procedures should periodically occur to validate the reliability of the gauge for the region it is being used in.

**Figure E-28.** US Forest Service Utilization Gauge. Photo credit: Monte Topmiller, NRCS Range Specialist.


(5) Ocular estimates of percentage grazed

Qualified conservationists who are trained and experienced in making actual weight comparisons of grazed versus ungrazed plants can make ocular estimates of the percentage removal of key species in a key grazing area. If this method is used, it is important to demonstrate the actual weight procedure to the cooperator on one or more gazing units.

J. Determining utilization of browse plants

(1) The degree of utilization of current growth of browse plants is an important factor needed for properly planning and managing land for use by wildlife or livestock. However, utilization of browse has seasonal limitations during the early part of the growing season or before current use has taken place on seasonal range. Several other indicators are also of value in appraising the general trend in production of a stand of browse plants. These indicators often reveal more about the stand than current utilization alone. These can be observed and interpreted at any time of the year. These indicators include:

(i) Age classes of key plant species—Age class is probably the most important single factor in judging trend in a stand of browse plants. If all plants are mature, the stand is not maintaining itself and will thin out as older plants die. The presence of adequate numbers of seedlings and young plants of the key species is indicative of a healthy, self-perpetuating stand. Browse plants generally do not reproduce every year, resulting in pulses of several age classes represented in a healthy stand. Animals usually prefer seedlings and young plants. Consequently, a degree of use for mature plants often results in overutilization of younger plants. Each age class needs separate degrees of use to judge proper utilization.

(ii) Evidence of hedging of the key plant species—The degree of hedging reflects past use and the productive ability of browse plants. Moderate hedging may be desirable for some species because it stimulates growth and keeps plants from growing out of reach of animals. Severe hedging results in the death of many branches and, if continued for a long time, may cause death of entire plants. If only a single year's growth extends beyond old-hedged contours, recent use has been heavy. Parts of two or more years' growth beyond old-hedged contours suggest that browsing pressure has recently been reduced and that trend is upward.

(iii) Use of plant growth more than one year old—When overall utilization is heavy, browsing animals often consume parts of plants that are older than the current growth. Continued use of older growth results in rapid decline and death of plants.

(iv) Evidence of browse lines—If a browse line is apparent, plant growth within reach of animals has declined. Very distinct browse lines indicate that plants have already grown beyond the reach of animals. Such plants may be vigorous and productive because of unused growth above reach of animals, but they produce little or no available forage.

(v) Presence of dead twigs and branches—Some mortality of plant parts is normal, but excessive amounts of dead or weak limbs, branches, twigs, or even entire plants indicate that past use was too heavy and that the stand is deteriorating.

(vi) Relative size of plant parts—Light pruning or browsing often stimulates growth of leaves and sprouts to more than normal size. Continued heavy use, however, results in small and weak leaves, twigs, and fruiting stems. Repeated heavy use of sprouts gradually reduces their size. If properly used, species of root-sprouting ability produce sprouts following fire or other disturbances. However, weakened plants do not. Overutilization reduces or eliminates fruit and seed production.

(vii) Significant use of low-preference species—Plants of low preference are ordinarily lightly used unless species of higher preference are not available or have been too heavily used. If significant use is made of a species that animals ordinarily use sparingly or not at all, the key species is being abused.

(viii) Amount of reproduction of low-preference species—Excessive reproduction of a low preference species generally indicates that the key species has declined to the extent that it is unable to compete with other plants.

(ix) Condition of animals—The physical condition and reproductive ability of wildlife or livestock reflect the amount and quality of plants available for forage. This indicator is not infallible because animals may remain in good condition for a while, even on seriously abused ranges, if succulent growth is available. Also, supplemental feeding of animals often masks the effect of inadequate natural forage supplies.

(2) None of the indicators, by itself, is a completely reliable indicator of the overall utilization of the plant community. All evidence must be carefully evaluated as a basis for determining needed adjustments in management or stocking and for determining needed harvest of browsing animals.

(3) The Browse Resource Evaluation worksheet (see figure E-29) can be used for judging composition, trend, and utilization of the browse plant resource. Figures E-30 and E-31 illustrate how to use the worksheet. Figure E-30 records the determination of trend and records utilization during the next three fall and winter seasons. Figure E-31 illustrates the same location following a prescribed burn. The change in trend is recorded, and utilization will be recorded at the appropriate time.

K. Utilization mapping to determine grazing animal distribution

(1) Utilization is seldom uniform on rangeland, pastureland, and grazed forest land. Utilization patterns may result from factors such as topography, distance from water, supplementation areas, locations of shade and shelter, as well as animal preferences for plant species in specific locations. These factors cause grazing animals to either concentrate or distribute themselves over an area in a pattern that can change seasonally or remain the same from season to season.

(2) The installation of facilitating practices such as fences and providing shade and watering sources, along with managed grazing and strategic locations of salt and supplemental feed and livestock herding are the main NRCS conservation practices planned and installed to manipulate livestock distribution. Develop a utilization pattern map for those planning areas where livestock distribution may be a management concern before installation of these facilitating practices. Use GIS tools to delineate ecological sites, areas of steep topography and other barriers to the grazing animal and distance to water sources. See Subpart F Management of Grazing Lands for more information.

L. Regrowth following utilization

Regrowth is plant growth that occurs following grazing. Residual measurements are based on the amount of forage used at a point in time and is independent of annual production. The term utilization refers to the amount of forage use annually (the entire season). Residual measurements recorded for various periods of use during the year cannot be added together to get utilization for the entire year.; i.e., 30 percent utilization of 6 inches of plant growth available in the spring, and 30 percent utilization of 12 inches of plant growth in the fall do not add up to 60 percent utilization for the year.

## 645.0511 Assessments

A. Field assessments on range and pastureland are integral steps in USDA-NRCS conservation planning and in National Resource Inventory (NRI) Field Studies. The science and the tools for assessing both range and pastureland continue to evolve and are necessary for NRCS planning and National Resource Inventory activities to describe land condition, health, and the functionality of ecological processes.

B. Conservation planning assistance to rangeland owners and managers should include the use of assessment tools, as well as incorporating professional judgment that is based on experience and knowledge of the rangeland ecosystems. For more information on NRCS conservation planning, see Subpart D of this handbook and the National Planning Procedures Handbook.

**Figure E-29.** Browse Resource Evaluation worksheet.

# Browse Resource Evaluation

Cooperator: ______________________ Ecological site: ______________________
Pasture: ______________________ Location in pasture: ______________________
Kinds of browsing animals: ______________________ Examiner: ______________________
Goals for browse resource: ______________________

Date of initial evaluation: ____/____/____

| | Browse composition | | | Browse trend | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Occurrence | | | Hedging or browse line | | | Reproduction | | |
| | Abundant | Common | Scarce | Not evident | Moderate | Severe | Abundant | Adequate | Not adequate |
| **Preferred species** | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Desirable species** | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| **Non-preferred species** | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**Browse composition**

Judge composition and trend based on majority of evidence

Good
Fair
Poor

**Browse trend**

Upward
Stable or not apparent
Downward

Note: ______________________

## Utilization of current year's growth

| Key species | Season of use | Planned use percent | Actual use percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Years | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | Date observed | | | | | | | |

## Instructions for Browse Resource Evaluation Worksheet

The worksheet can assist managers evaluate the composition and trend of the browse resource, as well as document the actual use of key browse species over time. This information is used to identify problems, formulate alternatives, and measure progress in attaining browse management goals.

**Browse composition** evaluates the occurrence of browse species according to preference categories. Species are designated as preferred, desirable, or non-preferred based on the species of browsing animal and the appropriate ecological site descriptions.

**Occurrence:** After a thorough observation of the area, determine the occurrence of each listed species and place a checkmark or an x in the appropriate block as defined.

***Abundant*** The species dominates or characterizes the area observed; it makes up greater than 5% canopy and often greater than 20%.

***Common*** The species is easily found, but is not present in abundance; it usually makes up 1–5% canopy.

***Scarce*** Insignificant amounts of the species is present and may be difficult to find; it usually makes up far less than 1% canopy.

Browse composition is judged as good, fair, or poor based on the preponderance of entries in the shaded boxes. For example, if there were four entries in the fair blocks, one in the good blocks, and 2 in the poor blocks, the overall browse composition would be judged as fair.

**Browse trend** evaluates the health and vigor of the browse resource based on signs of past use and on reproduction. Hedging and browse lines are distinctive growth forms that occur on shrubs or trees subjected to long term heavy use. After a thorough examination of the selected species in the area, determine the level of hedging or browse line and status of reproduction and place a check mark or x in the appropriate block as defined below.

**Hedging or browse line:** Hedging is evaluated on short shrubs which are entirely or mostly within reach of browsing animals. Browse line is evaluated on taller shrubs and trees where a portion of the plant is above browsing height.

***Not evident*** On shorter plants, there is little or no evidence of hedging. On taller plants, there is little or no reduction of lower growth. Production of lower branches and twigs is similar to those above the reach of animals.

***Moderate*** On shorter plants, most recent year's twigs have been browsed, resulting in branching and rebranching from lateral buds; growth form is somewhat compact. On taller plants, there is a visible thinning of growth up to browsing height; lower branches and twigs are considerably less productive than those beyond reach of the animals.

***Severe*** Shorter plants are very compact or have a stunted appearance; may be characterized by very short twigs, stubby branches, small leaves, low production or excessive number of dead branches. On taller plants, a browse line is strikingly evident; there is little or no production on twigs within reach of animals; most lower branches are absent.

Browse trend is judged as upward, stable (or not apparent), or downward based upon the preponderance of entries in the shaded boxes.

**Reproduction:** A reproduction evaluation is made to determine the future potential of a species in the community. The presence of young seedlings is only one measure of reproduction. The survival of new plants for the first 1 to 5 years is often the limiting factor, even though new seedlings or root sprouts may be present in some abundance in some years. A good distribution of various age plants from young to fully mature is a better indicator of successful reproduction.

***Abundant*** The population of a species is increasing in the community; more young plants are present than are old plants.

***Adequate*** Sufficient seedlings and young plants are present to approximately maintain the appropriate population status of the species in the community; plants that are decadent or dying are being replaced by new plants.

***Inadequate*** Few or no seedlings or young plants are present; population is either declining or stagnated with mature plants.

**Utilization of current year's growth**—This section is used to record the actual degree of use on key species in the same area over a period of years. Browse use is usually determined sometime between late fall and late winter. Degree of use is expressed as the percentage, by weight, of the current year's twig and leaf production within reach of browsing animals that has been consumed. Use is most easily estimated by comparing accessible twigs to twigs which are inaccessible to browsing animals. Determinations should be made by observing many twigs on a number of different plants. Current year's twig growth is distinguished from older twigs by color, texture, and size.

**Figure E-30.** Completed Browse Resource Evaluation worksheet showing trend and utilization.

## Example - Browse Resource Evaluation

Cooperator: B.J. Smith
Ecological site: Low Stony Hill
Pasture: Lower Canyon
Location in pasture: 3/4 mile N of spring
Kinds of browsing animals: Goats, deer
Examiner: L. Jones
Goals for browse resource: Recovery of preferred species; Reduction in juniper

Date of initial evaluation: 6 / 12 / 94

| | Browse composition | | | Browse trend | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Occurrence | | | Hedging or browse line | | | Reproduction | | |
| | Abundant | Common | Scarce | Not evident | Moderate | Severe | Abundant | Adequate | Not adequate |
| **Preferred species** | | | | | | | | | |
| Mt. mahogany | | X | | | | X | | X | |
| Spanish oak | | X | | | | X | | | X |
| Hackberry | | X | | | | X | | | X |
| Redbud | | X | | | | X | | X | |
| **Desirable species** | | | | | | | | | |
| Shin oak | X | | | | X | | | X | |
| Evergreen sumac | X | | | | X | | | X | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Non-preferred species** | | | | | | | | | |
| Juniper | X | | | X | | | X | | |
| Persimmon | | X | | | X | | X | | |
| | | | | | | | | | |
| | | | | | | | | | |

**Browse composition**

Judge composition and trend based on majority of evidence

- Good (stippled)
- Fair (white)
- Poor (shaded)

**Browse trend**

- Upward (stippled)
- Stable or not apparent (white)
- Downward (shaded)

Note: Goats removed Dec. 94; Deer only in 95; Presburn Feb. 96; Goats in summer 96.

### Utilization of current year's growth

| Key species | Season of use | Planned use percent | Actual use percent – Years: 94 | 95 | 96 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Mt. mahogany | Sp-fall | 50 | 80+ | 70 | 60 | | | | | |
| Hackberry | Sp-fall | 50 | 80+ | 60 | 60 | | | | | |
| Shin oak | Sp-fall | 50 | 65 | 20 | 35 | | | | | |
| EG sumac | Yearlong | 50 | 50 | 20 | 35 | | | | | |
| Date observed | | | 12-4 | 10-9 | 11-6 | | | | | |

**Figure E-31.** Completed Browse Resource Evaluation worksheet showing change in trend at same site as used in Example 1.

## Example - Browse Resource Evaluation

Cooperator: B.J. Smith
Ecological site: Low Stony Hill
Pasture: Lower Canyon
Location in pasture: 3/4 mile N of spring
Kinds of browsing animals: Goats, deer
Examiner: L. Jones
Goals for browse resource: Continue recovery of preferred species

Date of initial evaluation: 7 / 30 / 97

| | Browse composition | | | Browse trend | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Occurrence | | | Hedging or browse line | | | Reproduction | | |
| | Abundant | Common | Scarce | Not evident | Moderate | Severe | Abundant | Adequate | Not adequate |
| **Preferred species** | | | | | | | | | |
| Mt. mahogany | | | X | | | X | | X | |
| Spanish oak | | X | | | X | | | X | |
| Hackberry | | X | | | X | | | X | |
| Redbud | | X | | | X | | X | | |
| **Desirable species** | | | | | | | | | |
| Shin oak | X | | | X | | | X | | |
| Evergreen sumac | X | | | X | | | X | | |
| Flameleaf sumac | | | X | | X | | X | | |
| | | | | | | | | | |
| **Non-preferred species** | | | | | | | | | |
| Juniper | | | X | X | | | | | X |
| Persimmon | | X | | X | | | | X | |
| | | | | | | | | | |
| | | | | | | | | | |

**Browse composition**

Judge composition and trend based on majority of evidence

- (dotted box with X) Good
- (white box) Fair
- (gray box) Poor

**Browse trend**

- (dotted box with X) Upward
- (white box) Stable or not apparent
- (gray box) Downward

Note: Fire killed much mahogany; Fire killed all juniper; Sumacs invigorated by fire.

### Utilization of current year's growth

| Key species | Season of use | Planned use percent | Actual use percent – Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Mt. mahogany | Sp-fall | 50 | | | | | | | | |
| Hackberry | Sp-fall | 50 | | | | | | | | |
| Shin oak | Sp-fall | 50 | | | | | | | | |
| EG sumac | Yearlong | 50 | | | | | | | | |
| | | | | | | | | | | |
| | | | Date observed | | | | | | | |

C. Use on Rangelands

(1) Ecological sites on rangeland are evaluated with the client during the collection and analysis phase of the planning process so that a greater level of understanding of the rangeland resource can be achieved by both the NRCS employee and the client. The inventory process and evaluations of ecological sites on a grazing unit provide the

opportunity to work with the client to identify resource concerns and sources, as well as opportunities to maintain or improve the land, and increase the knowledge level of the client. Ecological Site Descriptions can be found in the Ecosystem Dynamics Interpretive Tool (EDIT), and more information on ESDs can be found in Subpart B.

(2) A rangeland ecological site may be assessed in at least three distinct, but associated ways: Trend, Similarity Index, and Interpreting Indicators of Rangeland Health. Although the three methods are associated, they are not interchangeable. These assessments and ratings cannot be extrapolated from one to the other. These three assessment tools evaluate the rangeland site from different perspectives and are not necessarily correlated.

## 645.0512 Trend

A. Trend is a rating of the direction of change that may be occurring on a site. The plant community and the associated components of the ecosystem may be either moving toward or away from the reference plant community or some other desired plant community or vegetation state, rangeland trend, or planned trend, respectively. At times, it can be difficult to determine the direction of change. See Subpart B for more information on Ecological Sites and State-and-transition models.

B. The kind of trend (rangeland trend or planned trend) being evaluated must be specified. Trend is an important tool used in the NRCS planning process and is significant when planning the use, management, and treatment needed to maintain or improve the resource. Trend is a tool used in the national resources concern list and planning criteria. This rating indicates the direction of change in the plant community on a site. It provides information necessary for the operational level of management to ensure that the direction of change will enhance the site and meet the objectives of the manager. The present plant community is a result of a sustained trend over a period of time and should be considered when making grazing management decisions.

(1) Rangeland trend is defined as the direction of change in the present on-site plant community relative to the reference state in an ESD state-and-transition model. It is only applicable on rangelands that have ecological site descriptions identifying the reference plant community. It can be determined as apparent trend or measured trend. Apparent trend is a point in time determination of the direction of change. Measured trend requires measurements of the trend indicators over a period of time. Rangeland trend can be monitored on all rangeland ecological sites. It is described as:
(i) Toward – moving towards the reference or top state of the plant community
(ii) Not apparent – no change detectable
(iii) Away from – moving away from the reference or top state of the plant community

(2) Planned trend is defined as the change in plant composition within an ecological site from one plant community type to another relative to management objectives. The desired plant community should be stable and provide protection to the soil, water, air, plant, and animal resources (SWAPA). It is described as:
(i) Positive – moving towards the desired plant community or objective
(ii) Not apparent – change not detectable
(iii) Negative – moving away from the desired plant community or objective

(3) Planned trend provides feedback to the manager and grazing land specialist about how well the grazing management plan is working on a site-by-site basis. It can provide an early opportunity to make adjustments in stocking rates, timing, duration, and frequency of grazing. Planned trend can be monitored on all native and naturalized grazing land plant communities. It may also be determined on any ecological site where a plant community other than the reference plant community is the desired objective, but where SWAPA resource concerns are also met.

C. Attributes for determining trend

(1) The relative importance of the factors used in trend analysis vary in accordance with differences in vegetation, soils, and climate. Evaluating any one of these factors on an

ecological site may indicate whether the plant community is improving or declining. A more accurate evaluation of trend, however, can be ascertained if all or several of the factors are considered in their proper relation to each other. Figure E-32 is a worksheet for determining range and planned trend.

(2) Invading undesirable plants—Native plant communities evolve within their environment and slowly change over time as environmental factors change. Major short-term changes in the plant composition, however, do not normally occur unless induced by significant disturbances. These disturbances include but are not limited to heavy continuous grazing by livestock, severe or prolonged drought, abnormally high precipitation, exotic species invasion, or unnatural burning frequencies.

(i) If the plant community is changing as a result of heavy grazing, the perennial species are most sensitive to damage by grazing decrease. This may lead to a relative increase in species of lower forage value or successional stages, or both. When improved management occurs in areas where the plant cover has been severely depleted, increases in low-quality plants may indicate improvement since these plants may be the first to respond and re-establish.

(ii) When disturbances that caused a decline in the plant community are removed, the present plant community may respond in one of several ways. It may appear to remain in a steady or static state that is departed from the reference plant state, or it may transition along pathways leading to one of several identifiable plant communities including those in the reference state

(iii) Original species that have declined in abundance because of past misuse will often increase over time. For this to occur, seed or vegetative parts must still be available, growing conditions must be similar (soil profile, hydrologic characteristics, microclimate), and space for re-establishment must be available and not have been displaced by other species such as exotic annual and perennial grasses, forbs, shrubs, or trees.

(iv) Once established, certain woody and other long-lived perennial plants may persist and may require high energy expenditures, such as prescribed burning, herbicide application, mechanical treatment, or other applications of supporting practices to restore a more desired state or reference plant community.

(v) Invasive plants on the site indicate a major change in the plant community. Some invaders, particularly annuals, however, may flourish temporarily in favorable years, even when the existing plant community may be moving towards management objectives. A significant, though temporary, increase in annuals and short-lived perennials may also occur during a series of wet years even though the general trend is toward the desired objectives.

(vi) Changes in species composition from one plant community type to another generally follow a pattern. Although all changes in amounts of species on a site are not always predictable, general successional patterns for specific sites, plant species, climates and rangeland use often can be predicted. These successional changes in plant composition are usually not linear and vary because of localized climatic history and past use patterns.

(2) Seedlings and young desired plants—Changes in a plant community depend mainly on successful reproduction of the individual species within the community. Evidence of this reproduction can be by young seedlings, plants of various ages, and tillers, rhizomes, and stolons. The extent to which any of these types of reproduction occurs varies according to the growth habits of the individual species, site characteristics, current growing conditions, and the plant's use. In some plant communities, reproduction is often largely vegetative, so the mere absence of seedlings does not always indicate a change in plant community. A significant number of seedlings and young plants of species indigenous to the site, however, usually indicates a positive trend. Variation in seedling recruitment resulting from abnormal weather patterns should be recognized.

(3) Plant residues and litter—The extent to which plant residue accumulates depends primarily on the production level of the plant community, the amount of plant growth

removed by grazing, haying, fire, insects, wind or water, and the decomposition rate of the plant biomass on the site. In hot and humid climates, the rate of decomposition of plant residue may be so great that little or no net accumulation occurs. Conversely, in cold climates decomposition is generally slow. When using plant residue to judge trend in plant communities, careful consideration should be given to the level of accumulation that can be expected for the specific ecological site, plant species, and climate.

Excessive grazing, below-normal production, recent fires, and abnormal losses caused by wind or water erosion may result in an accumulation of plant residue below what is considered reasonable for the site. In the absence of these factors, progressive accumulation of plant residue generally indicates positive changes in the plant community. Residue may accumulate rapidly for some kinds of plants, especially woody species or annuals. When the amount characteristic for the reference plant community is exceeded, such accumulations of residue are not necessarily an indication of an improving plant community.

(4) Vigor of desired key plants is reflected primarily by the size of a plant and its parts in relation to its age and the environment in which it is growing. Many plants that form bunches or tufts when vigorous may assume a sod form if their vigor is reduced. Length of rhizomes or stolons is also a good indication of the vigor of a parent plant, as these parts are usually fewer and shorter if a plant is in a weakened status. Periodic drought is common in many rangeland environments and will lower the apparent vigor and annual productivity of ecological sites, while often retaining the current plant community.

Cryptogamic plants like mosses, lichens and ferns develop new growth during favorable periods that add to the total structure and biomass of the plant community. When considerable amounts of live cryptogamic material are destroyed, several years may be required for these plants to fully replace lost tissue.

(5) Soil factors—Unfavorable conditions of the soil surface may significantly affect trend. Compaction, splash erosion, and crusting may occur if plants or plant residue are lacking on the soil surface.

(i) Compaction and crusting impede water intake, inhibit seedling establishment and vegetation propagation, and increases soil surface temperature. These conditions often increase rates of water runoff and soil loss, reduce effective soil moisture, and generally result in unfavorable plant, soil, and water relationships. Improvement in the plant cover following good management is delayed if such soil conditions exist. Bare ground, soil crusting, stone cover, compaction from trampling, plant hummocking, or soil movement may indicate a negative trend in a plant community.

(ii) These soil indicators, however, can sometimes be misleading as they can also occur naturally under certain circumstances. For example, plant hummocking is natural on silty soil sites that are subject to frost heave. Other sites do not support a complete plant cover. Bare ground crusting, rock fragments on the soil surface, and localized soil movement may be normal for the site. Even when induced by misuse, the soil surface trend indicators are not nearly as sensitive as those changes in the plant cover. For information on normal characteristics of a site, see the appropriate correlated Ecological Site Description.

**Figure E-32.** Trend Determinations.

## Trend Determinations

Ecological Site_______________________________________________
Reference Plant Community_____________________________________
Location______________________________________________________
Cooperator____________________

**Initial Trend Determination**: Date:________ Conservationist____________

**Plant Factors** (circle as appropriate)

| | | | |
|---|---|---|---|
| Vigor of desired key plants: | Good | Fair | Poor |
| Seedlings & young desired plants: | Abundant | Some | None |
| Decadent plants: | Many | Some | None |
| Plant residues & litter: | Abundant | Adequate | Inadequate |
| Invading undesirable plants: | None | Some | Many |

**Soil Factors** (circle as appropriate)

| | | | |
|---|---|---|---|
| Surface erosion: | Slight | Moderate | Severe |
| Crusting: | Slight | Moderate | Severe |
| Compaction: : | Slight | Moderate | Severe |
| Percent bare ground: | Less than expected | Normal | More than expected |
| Gullies & rills: | None | Few | Numerous |
| Overall soil degradation: | Slight | Moderate | Severe |

**Other Factors**
Major invading species:_____________________________________________
Canopy and/or cover percent_________________________________________

**Overall Trend Rating (s)**: (Circle the appropriate kind of trend and rating)

**Range Trend** (Toward or away from historic climax plant community)

**Toward** **Not apparent** **Away from**

**Planned Trend** (Toward or away from desired plant community)

**Positive** **Not apparent** **Negative**

**Followup Trend Determination**: Date:________ Conservationist__________
(to be made in subsequent years following initial trend determination)

**Plant Factors** (circle as appropriate)

| | | | |
|---|---|---|---|
| Vigor of desired key plants: | Good | Fair | Poor |
| Seedlings & young desired plants: | Abundant | Some | None |
| Decadent plants: | Many | Some | None |
| Plant residues & litter: | Abundant | Adequate | Inadequate |
| Invading undesirable plants: | None | Some | Many |

**Soil Factors** (circle as appropriate)

| | | | |
|---|---|---|---|
| Surface erosion: | Slight | Moderate | Severe |
| Crusting: | Slight | Moderate | Severe |
| Compaction: : | Slight | Moderate | Severe |
| Percent bare ground: | Less than expected | Normal | More than expected |
| Gullies & rills: | None | Few | Numerous |
| Overall soil degradation: | Slight | Moderate | Severe |

**Other Factors**
Major invading species:_____________________________________________
Canopy and/or cover percent_________________________________________

**Overall Trend Rating (s)**: (Circle the appropriate kind of trend and rating)

**Range Trend** (Toward or away from historic climax plant community)

**Toward** **Not apparent** **Away from**

**Planned Trend** (Toward or away from desired plant community)

**Positive** **Not apparent** **Negative**

## 645.0513 *Section Reserved for Similarity Index.*

## 645.0514 Interpreting Indicators of Rangeland Health Assessments

A. The following section is a review of some of the main concepts of the Interpreting Indicator of Rangeland Health Assessments Tool (IIRH)(Technical Reference 1734-6, Version 5) for information. To use the IIRH assessment, you must refer to the IIRH Technical Reference itself for complete instructions. TR 1734-6 can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=stelprdb1068410 or Interpreting Indicators of Rangeland Health v5 – Landscape Toolbox.

Note: Consistent assessments require precisely following the guidance in the Technical Reference. Wherever it provides different or more complete information, the official guidance is the Technical Reference.

B. The ability to assess rangelands consistently between scientists, landowners, and agency personnel, and in terms that the public can understand, is important. Identifying functioning and non-functioning ecological processes and resource concerns needs to be communicated in common and recognizable terms (Pellant et al. 2005, 2020). Interpreting Indicators of Rangeland Health (IIRH) is a qualitative assessment that provides a relatively rapid technique to rate three attributes of ecological processes, including biotic integrity, soil/site stability, and hydrologic functioning. Seventeen observable indicators are assessed separately and are used to develop the score collectively for the three attribute level ratings (table E-19).

**Table E-19**. Attributes with Indicators

<table>
<tr><th>Soil/Site Stability</th><th>Hydrologic Function</th><th>Biotic Integrity</th></tr>
<tr><td colspan="2">1. Rills</td><td>12. Functional/Structural Groups</td></tr>
<tr><td colspan="2">2. Water Flow Patterns</td><td>13. Dead or Dying Plants or Plant Parts</td></tr>
<tr><td colspan="2">3. Pedestals and/or Terracettes</td><td>15. Annual Production</td></tr>
<tr><td colspan="2">4. Bare Ground</td><td rowspan="2">16. Invasive Plants</td></tr>
<tr><td colspan="2">5.Gullies</td></tr>
<tr><td>6. Wind-Scoured and/or Depositional Areas</td><td colspan="2">14. Litter Cover and Depth</td></tr>
<tr><td>7. Litter Movement</td><td>10. Effects of Plant Community Composition and Distribution on Infiltration</td><td>17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants</td></tr>
<tr><td colspan="3">8. Soil Surface Resistance to Erosion</td></tr>
<tr><td colspan="3">9. Soil Surface Loss and Degradation</td></tr>
<tr><td colspan="3">11. Compaction Layer</td></tr>
</table>

C. Rangeland Health has been defined by an interagency committee as "The degree to which the integrity of the soil, vegetation, water, and air, as well as the ecological processes of the rangeland ecosystem are balanced and sustained. They defined integrity to mean maintenance of the functional attributes characteristic of a locale, including normal variability."

D. The IIRH procedure was developed to be used by individuals who are experienced and knowledgeable with the protocol, either through formal training or working with those who have training and experience. This procedure requires a solid understanding of ecological processes, vegetation, and soils for each of the sites where it is applied. The protocol is designed to be used within the context of landscape classification systems, such as ecological sites or an equivalent unit, and be used with an appropriate reference sheet describing the natural range of variability for the 17 indicators at a given site. IIRH relies on the use of a qualitative (non-measurement) procedure to assess the functional status of each indicator to provide a preliminary evaluation of the three attributes of rangeland health (Pellant et al. 2005, 2020).

E. The purpose and intended application of the IIRH is to provide guidance in making range health assessments. The IIRH tool is designed to:

(1) Be used within the context of a landscape classification system, such as ecological sites or equivalent units.
(2) Be used with an appropriate reference sheet describing the natural disturbance regime within the natural range of variability for the 17 indicators at a given site.
(3) Be used only by people who are knowledgeable and experienced with the protocol and the ecological system being evaluated (including formal training or working closely with others who have training and experience).
(4) Provide a preliminary evaluation of the three attributes of rangeland health (soil/site stability, hydrologic function, and biotic integrity) at an evaluation area by rating all 17 indicators and considering them in the attribute rating step of the assessment.
(5) Be used to communicate fundamental ecological concepts to a wide variety of audiences.
(6) Improve communication by focusing discussion on critical ecosystem properties and processes.
(7) Assist in identifying monitoring priorities and selecting monitoring sites.
(8) Assist land managers in identifying areas that are at risk of degradation and where resource problems or management opportunities currently exist.
(9) Be used as a tool for prioritizing landscapes for potential types of restoration (Pyke 2011; Pyke et al. 2018).

F. The IIRH tool is not to be used to:

(1) Identify the cause(s) of resource problems.
(2) Make grazing and other management decisions.
(3) Monitor land or determine trend.
(4) Independently generate national or regional assessments of rangeland health.

G. Training is available for NRCS staff through the AgLearn "Interpreting Indicators of Rangeland Health" web-based course and through the AgLearn in-person "Interpreting Indicators of Rangeland Health" course. Interested individuals outside the NRCS agency may have opportunities for training through partnering agencies and organizations like the National Grazing Land Coalition and instructional videos on the Jornada Website https://jornada.nmsu.edu/monit-assess/manuals/assessment.

H. The Interpreting Indicators of Rangeland Health Technical Reference 1734-6 Version 5, complete with all instructions, can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=stelprdb1068410.

I. NRCS Use:

(1) NRCS uses the IIRH Assessment in helping decide where resource concerns are found on rangelands. Since the tool's purpose is to help provide a qualitative analysis of ecological processes, it is a suitable assessment tool to delineate thresholds where resource concerns within the biotic integrity, the soils/site stability, and hydrologic function of a site exist. NRCS considers a resource concern as a resource condition that does not meet minimum acceptable levels as established by resource planning criteria in section III of the Field Office Technical Guide and the National Resource Concern List and Planning Criteria document (NRCS 2020).
(2) A resource concern implies degradation of the soil, water, air, plant, animal, or energy resource base to the extent that sustainability or the intended use of the resource is impaired. Planning criteria is a quantitative or qualitative statement of the minimum level of treatment required to address a given resource concern and may be assessed using

specific tools or through client and planner observation (NRCS 2020). For rangelands, the IIRH assessment is used to set planning criteria thresholds for multiple resource concerns.

J. Attributes of Rangeland Health—The final product of this qualitative assessment is not a single rating but an assessment of the three attributes. The three attributes are defined as:

(1) Soil/site stability—the capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water and recover this capacity when a reduction does occur.
(2) Hydrologic function—the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.
(3) Biotic integrity—the capacity of the biotic community to support ecological processes within the natural range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below the ground (IIRH 2020).

K. Each of these three attributes is summarized at the end of the evaluation form (figures E-43 and E-44) based on a preponderance of evidence approach, using the applicable indicators. An example of the preponderance of evidence is in part where the majority of indicators for each attribute fall. For example, if four of the soil/site stability indicators are in “moderate” and six are in “slight to moderate,” the departure for the soil/site stability attribute would be rated as “slight to moderate” assuming that the interpretation of knowledge of ecological site properties, processes, and other information and local knowledge support the rating (Pellant et al. 2005, 2020).There are cases however when some indicators need to be weighted more heavily in the decision of the attribute rating.

L. “Weighting” or placing more value on specific indicator(s) may be appropriate and allowable in some cases. For example, if several of the four indicators that were rated “moderate” are particularly important to this site, a “moderate” rating for the entire attribute can be supported (Pellant et al. 2005, 2020). Critical indicators such as functional structural groups, invasive plants and vigor with an emphasis on reproductive capability of perennial plants are indicators that could be important to “weight”. For example, on a site that has several invasive plant species trending towards dominating the area, the impact of these species on the native plant composition and future integrity of the site would warrant weighting these indicators (USDA-NRCS NGLT 2022). Conversely, when an indicator has a “none to slight” rating due to the indicator having a low possibility of occurrence to the site, then that indicator may be given a lower weight for the final attribute score. For example, rills developing in a playa may be nearly impossible to occur, as rills rarely form in these bottomland positions, so a “none to slight” rating may be assigned, but a lower weighting or consideration of the rill indicator may be appropriate in the final attribute score (Pellant et al. 2005, 2020).\

M. It is important that the assessor complete the field notes section on the evaluation form (figures E-43 and E-44) for all indicators and specifically document why the process is modified to fit specific cases.

N. There are also cases when additional indicators to the standard 17 indicators are appropriate. These 17 are not meant to be all inclusive for all rangelands. The indicators of the protocol should always be evaluated, but in cases where additional indicators may add to or improve sensitivity in detecting changes to the attributes, they are appropriate to use and should be ranked (Pellent et al. 2005, 2020).

O. Optional indicators must significantly improve the quality of the evaluation by providing additional information about ecological function of the system and site being evaluated and must be relative to at least one of the three attributes (Pellant et al. 2005, 2020). For example, a biological soil crust indicator may be applied in ecological sites where these crusts play a particularly important biological or physical role (see figure E-40) (e.g., nitrogen fixation or soil stabilization). A generic evaluation matrix example for this optional indicator is shown here in table E-20. Other examples of additional indicators could be native plant diversity and pollinator forb species (with more examples in the IIRH Technical Note). Also, weigh the benefits of maintaining a consistent protocol against the expected improvement in the assessment when using optional indicators. Coordinate the development of optional indicators with the NRCS State range management specialist (Pellant et all, 2005, 2020).

**Figure E-40.** Biological soil crust-El Morro National Monument-photo credit Brenda Simpson, National Grazingland Team.

**Table E-20.** Generic descriptors of the five departure categories for the optional indicator of biological soil crusts.

| Optional Indicator | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
|---|---|---|---|---|---|
| Biological Soil Crusts | Occurring only in protected areas; very limited suite of life forms. | Largely absent in plant interspaces; occurring mostly in protected areas. | Occurring in protected areas and with a minor component in interspaces. | Occurring throughout the site but continuity is broken. | Largely intact and nearly matches site potential. |

P. Evaluating rangeland health ecological attributes

(1) The attributes represent a suite of interrelated ecological properties such as species composition and processes like the water cycle (the capture, storage and redistribution of precipitation), energy flow (conversion of sunlight to plant and then animal matter), and the nutrient cycle (the cycle of nutrients through the physical and biotic components of the environment).

(2) Due to complexity of ecological processes and their interrelationships, direct measures are usually not feasible. However, observable biological and physical components can be used as indicators of the functional status of these processes. These three attributes are rated with five possible categories which describe the degree of departure from conditions described in the reference sheet. See table E-21.

**Table E-21.** The three attributes of rangeland health and the rating categories for each attribute.

| Soil/Site Stability (SSS) | | Hydrologic Function (HF) | | Biotic Integrity (BI) |
|---|---|---|---|---|
| Attribute ratings are based upon departure from ecological site descriptions in these categories | | | | |
| Extreme to Total | Moderate to Extreme | Moderate | Slight to moderate | None to slight |

(3) Evaluations of rangeland health ecological attributes must be able to distinguish between changes that are within the natural range of variability and those that are outside the natural range of variability of the ecological site (ES). The natural range of variability is defined as the deviation of characteristics of biotic communities and their environment that can be expected given natural variability in climate and natural disturbance regimes. The natural disturbance regime describes the kind, frequency, and intensity of natural disturbance events that would have occurred on an ecological site prior to European influence (ca.1600) (Winthers et al. 2005; Pellant et al. 2005, 2020).

(4) Natural disturbances include, but are not limited to, native insect outbreak, wildfires, native wildlife activities (herbivory, burrowing, etc.) and weather cycles including extremes like drought, wet periods, varying temperatures, snow, and wind events.

(5) The natural range of variability does not include influences of nonnative plant or animal species and also does not encompass soil degradation, such as accelerated erosion, organic matter loss, changes in nutrient availability, or soil structure degradation, beyond what would be expected (Pellant et al. 2005, 2020).

(6) The ecological site description (ESD) provides the standard from which indicators will be evaluated. All attributes, both measured and observed, must be compared to the attributes as described in the ecological site description reference sheet. The relative importance of the attributes is site dependent, and values and degree of variability for each attribute may be different from site to site. To the extent possible, the natural range of variability and types and sources of spatial and temporal variability should be described for each indicator in the reference sheet (table E-22).

Q. Indicators

Ecological processes are difficult to observe or measure in the field because most rangeland ecosystems are complex. Indicators are components of a system whose characteristics (presence or absence, quantity, distribution) are used as an index of an attribute (three rangeland health attributes: SSS, HF or BI) that is too difficult, inconvenient, or expensive to measure. There is no one indicator of ecosystem health. Instead, a suite of key indicators is used for the assessment (Karr 1992). Just as the Dow Jones Index is used to gauge the strength of the stock market, different combinations of the 17 indicators are used to gauge the attributes of soil/site stability, hydrologic function, and biotic integrity (table E-22). For each indicator, the same five departure descriptors are used to describe what is seen on the site, based upon departure from the ecological site description: None to Slight, Slight to Moderate, Moderate, Moderate to Extreme, and Extreme to Total (Pellant et al. 2005, 2020).

R. Evaluation Area

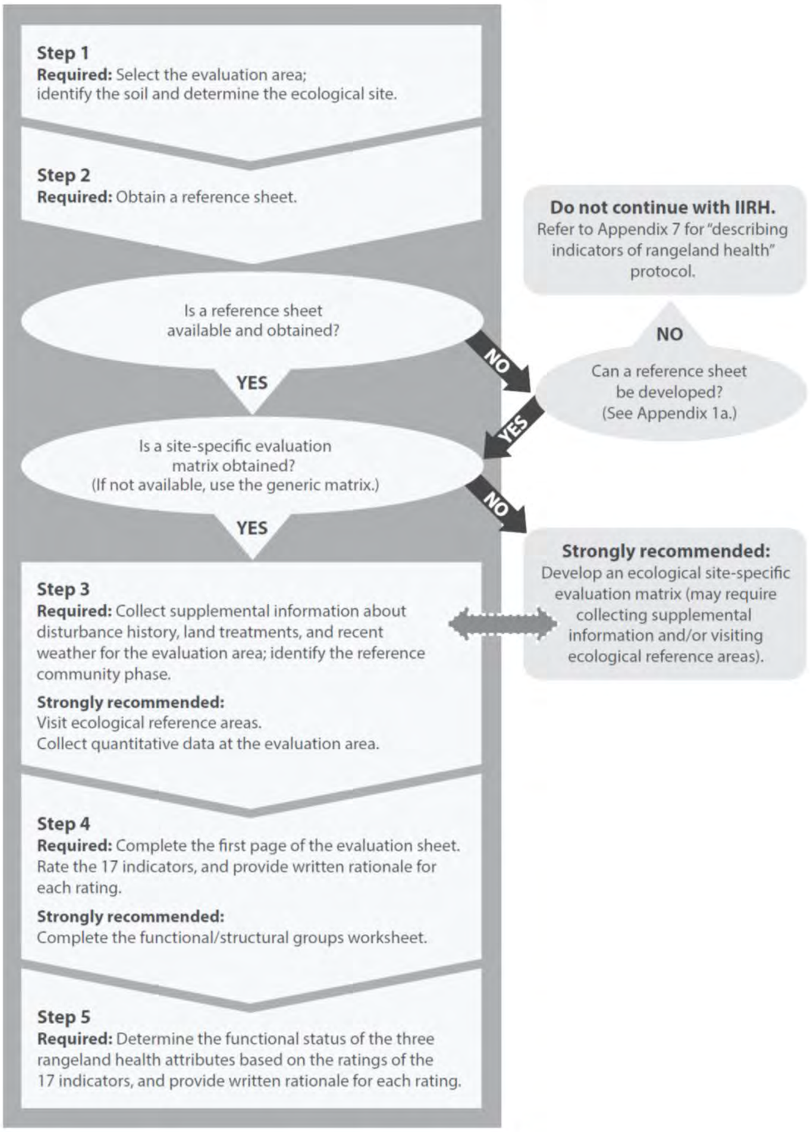
(1) The rangeland health evaluation is site specific using the rangeland ecological site description reference sheet as the standard for comparison. The evaluation area (area of interest) should be large enough to include the natural variability associated with each ecological site being assessed. Interest in an evaluation area may be based on concerns about current conditions, lack of information on conditions, or public perceptions of conditions (Pellant et al. 2005, 2020).

(2) When selecting the IIRH evaluation areas, it is important to consider how the resulting assessments may be combined to evaluate the condition of a larger landscape. Properly developed sample designs that incorporate randomized site selection and meet specific

assessment objectives can allow assessment results to be extrapolated across larger landscape units (e.g., management unit, watershed, ecoregion). This can help identify areas where management actions may potentially have the greatest impact (Pellant et al. 2005, 2020).

(3) Timing is also a factor in planning assessments. Although IIRH is a point-in-time, it should be conducted when the indicators are accessible and readily observed. During, or soon after the growing season, is generally the optimal time to conduct an assessment. Knowledge of local phenology patterns can assist evaluators in conducting the assessment when plant species are still recognizable (e.g., forbs) and their potential for reproduction can be rated. See the flowchart in figure E-41 from the IIRH Technical note on steps to completing a IIRH assessment (Pellant et al. 2005, 2020).

**Figure E-41.** Flowchart for completing an assessment of rangeland health using the IIRH protocol.




(4) Upon arrival at the location, the evaluator(s) should use observations of landscape position and soil profile characteristics to determine the ES. Assessments are conducted on an ecological site basis, so it is preferable to select evaluation areas that do not encompass more than one ecological site. If there are small components of other ES within the evaluation area, do not include them in the assessment; or if more than one major ES occurs in an evaluation area, complete a separate assessment for each site

(Pellant et al. 2005, 2020). It is advisable to spend some time walking the site to become familiar with the plant species, soil surface features, and the variability of the area.

(5) It is important that the correct ESD is used for the site. Soil surveys provide the foundation for describing and mapping ecological sites. The Web Soil Survey tool provides soils and ESD identification with the use of the Area of Interest tool: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. After an Area of Interest is identified, the tool can attribute the area with soil map delineations and correlated ES. Note that there may be multiple correlated ecological sites to a soil map unit because ESs are correlated at the soil map unit component scale. Although the tool provides valuable information, all data should be verified on-site in the field. See Subpart B for instructions on identifying an ecological site on an evaluation area and for describing and hand-texturing soils on a site.

(6) An IIRH assessment cannot be completed without a reference sheet, and a reference sheet cannot be generated without an ES or equivalent unit with which it is associated. See Appendix 7 in the IIRH Technical Reference to help determine whether an IIRH assessment can be completed. If not, complete a protocol called "Describing Indicators of Rangeland Health" or DIRH to document information on the soil profile and the current status of IIRH indicators (Herrick et al. 2019; IIRH 2020). Instructions for completing the DIRH protocol are found in Appendix 7 of the IIRH Technical Reference.

(7) The DIRH protocol is designed to be used in two ways. First, where the DIRH protocol is completed on what are believed to be relatively undegraded lands based on other evidence (e.g., knowledge of historic disturbance regimes), data from similar intact locations in the same ecological site can be combined and used to help develop or revise the reference sheet. Second, DIRH data can be collected on land with no known reference, regardless of its level of degradation, and then used at a later date to support completion of an IIRH assessment after a reference sheet has been developed. For more information on using the DIRH protocol see the IIRH Technical Reference at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=stelprdb1068410.

S. Ecological Site Description Reference Sheets

(1) The reference sheet describes the range of expected spatial and temporal variability of each indicator within the natural disturbance regime based on the ES (or equivalent unit) and is required to conduct an IIRH assessment. Reference sheets are part of most ESDs. If a reference sheet is not available, one must be developed using the directions and the checklist in Appendix 1a in the Interpreting Indicators of Rangeland Health Technical Reference (TR) 1734-6 Version 5, also found in Subpart B.

(2) Before developing or revising a reference sheet, refer to the EDIT (Ecosystem Dynamics Interpretive Tool) website: https://edit.jornada.nmsu.edu/ and contact the NRCS State rangeland management specialist to determine if there is a reference sheet developed. Complete instructions on developing a reference sheet are in Appendix 1a of the IIRH TR 1734-6. Table E-22 and E-23 shows a correctly populated reference sheet.

**Table E-22.** Example of a completed reference sheet for ecological site R010XY019ID.

Ecological Site Name: Loamy 12"–16" p.z. Ecological site code: R010XY01ID
Author(s)/participant(s): J. Thompson
Contact for lead author: stateRMS@nrcs.gov (555) 555-1234
Composition based on (check one): ☐ Cover ☐ Annual Production
Metadata storage location: Contact lead author or NRCS Idaho state conservationist's office

Indicators. For each indicator, describe the potential for the site using the reference sheet checklist. Where possible, (1) use quantitative measurements; (2) include expected range of values for above- and below-average years and natural disturbance regimes for each community phase within the reference state, when appropriate; and (3) cite data sources used. Continue descriptions on separate sheet.

1. Rills: Rills are not expected on this site, except 1–2 years after wildfire or multiyear droughts. Following these events, shallow rills < 1 m in length may develop on slopes > 10 percent.

2. Water flow patterns: Water flow patterns rarely occur on this site on slopes < 5 percent. On slopes > 5 percent, narrow (< 12"), short (1–5' long), and disconnected water flow patterns may occur following high precipitation storms, affecting < 20 percent of the site. Water flow patterns occurring on > 5 percent slopes may nearly double in length, width, and connectivity for 1–3 years following wildfire or after multiyear droughts.

3. Pedestals and/or terracettes: Neither pedestals nor terracettes are expected to occur on slopes < 10 percent, except for 1–2 years following wildfires or multiyear droughts. Occasional pedestals may occur around bunchgrasses in shrub interspaces on slopes > 10 percent in association with water flow patterns.

4. Bare ground: Bare ground ranges from 15–20 percent. Bare ground patches should be small (< 12" diameter) and not connected. Bare ground may increase to as much as 30 percent 1–3 years after wildfire, and bare soil patches may be up to 24" in diameter. Animal activity (burrows and ant mounds) may occasionally result in isolated bare patches up to 5' in diameter.

5. Gullies: Gullies do not occur on this site.

6. Wind-scoured and/or depositional areas: Wind-scoured areas do not occur on this site. Occasionally, thin, isolated soil deposits may be observed under shrubs, affecting < 5 percent of the site.

7. Litter movement: On slopes < 5 percent, fine litter is expected to move less than 6", and coarse litter does not move. On slopes > 5 percent, as much as half of the fine litter falling in the interspaces may move up to 12", but coarse litter generally does not move. Litter accumulations, if any, are small and usually occur at the bases of perennial bunchgrasses in the shrub interspaces on slopes > 5 percent. Litter dams are not expected.

8. Soil surface resistance to erosion: Stability class ratings from the soil stability test should be > 4.5 overall, with ratings of 4 or greater in the interspaces and 5 or greater under perennial plant canopy. Finer textured soils within this ecological site are expected to have overall ratings of > 5. Soil stability may temporarily decline up to 1 category following wildfire, due to decreases in biotic soil crusts and organic matter.

9. Soil surface loss and degradation: The surface horizon (A) should be 6–10" (roots growing throughout) with a moderate, very fine granular structure and a diversity of soil pores throughout. The subsurface (B) horizon is friable; structure is medium subangular blocky. The surface (A) horizon color is 7.5YR 3/2 (moist), and the subsurface (B) horizon color is 10YR 4/3 (moist).

10. Effects of plant community composition and distribution on infiltration: Deep-rooted perennial bunchgrasses are dominant, nonsprouting shrubs are subdominant, and perennial forbs are a minor component. Following wildfire (1–5 years), deep-rooted perennial grasses dominate, with a

subdominant component of perennial forbs. For the first year following wildfire or a multiyear drought, infiltration will be slightly reduced due to lack of ground cover. After 1 year following the preceding disturbances, deep-rooted perennial bunchgrasses and shrubs are again distributed evenly to provide sufficient ground cover to catch snow and increase infiltration. These processes are particularly important on slopes > 10 percent, where runoff has the potential to increase in the absence of well-distributed perennial grasses

11. Compaction layer: No compaction layers occur naturally on this site. No natural soil features that may be confused with a compaction layer occur on this site.

12. Functional/structural groups: The site is dominated by perennial grasses and nonsprouting shrubs, depending on the time since fire. Nonsprouting shrubs may become dominant 15–30 years post-fire. Following wildfire, nonsprouting shrubs are greatly reduced, and perennial forbs become a subdominant component. Expected diversity of perennial forbs is higher at the upper end of the precipitation range for this site (> 5 species). The expected fire return interval across which the three phases develop is 15–30 years.

13. Dead or dying plants or plant parts: A few (< 10 percent) dead centers naturally occur in bunchgrasses and will increase to 15 percent following a multiyear drought. Nonsprouting shrubs may have up to 10 percent dead branches as plants age, usually occurring in community phase 1.1. Sagebrush may have a large increase in dead branches with moderate mortality in patches up to 3 acres as a result of Aroga moth infestation.

14. Litter cover and depth: Total litter cover is expected to be 20–30 percent and at a depth of 0.25–0.5 inches under shrubs and < 0.1 inches under grass canopy. Litter may be reduced to 10–20 percent in cover and near zero depth for 1–2 years following wildfire or multiyear drought.

15. Annual production: Annual production is 1,100 pounds per acre in a year with normal precipitation and temperatures. Low and high production years should yield 850 and 1,400 pounds per acre, respectively. Annual production may be reduced by 40–60 percent the first year following a wildfire or following a multiyear drought. Annual production may increase for 3–6 years following wildfire due to perennial bunchgrass response.

16. Invasive plants: Western juniper, cheatgrass, medusahead, spotted knapweed, and rush skeletonweed. Western juniper may occur in trace amounts in community 1.3 but has the potential to increase to a subdominant or dominant in the absence of wildfire and act as an invasive on this site. Other than western juniper, the listed invasives are not expected to occur in the reference state. The site has increased susceptibility to invasion by rush skeletonweed, spotted knapweed, and exotic annual grasses following wildfire.

17. Vigor with an emphasis on reproductive capability of perennial plants: Plants in all functional/structural groups should be capable of reproducing annually under normal weather conditions. Vigorous mature cool-season, deep-rooted perennial grasses typically have a basal diameter of > 10 cm. Vigor and reproductive capability may be somewhat reduced during drought or for 1 year following a wildfire. At least 50 percent of plants should still have reproductive capability during droughts that last 1–2 years

**Table E-23.** Example Indicator 12 Functional/Structural Groups for ecological site R010XY019ID.

| Dominance Category1 | Relative Dominance of F/S Groups for Community Phases in the Reference State Minimum expected number of species for dominant and subdominant groups is included in parentheses. | | |
|---|---|---|---|
| | Dominance based on1: Annual Production X or Foliar Cover | | |
| | Phase 1.1 (5–15 years post-fire) | Phase 1.2 (1–5 years post-fire) | Phase 1.3 (15–30+ years post-fire) |
| Dominant | Cool-season, deep-rooted perennial bunchgrasses (4) | Cool-season, deep-rooted perennial bunchgrasses (4) | Nonsprouting shrubs (2) |
| Subdominant | None | Perennial forbs (3) | Cool-season, deep-rooted perennial bunchgrasses (4) |
| Minor | Nonsprouting shrubs; sprouting shrubs; cool-season, shallow-rooted perennial bunchgrasses | Sprouting shrubs; cool-season, shallow-rooted perennial bunchgrasses | Perennial forbs; cool-season, shallow-rooted perennial bunchgrasses; biological soil crusts[1] |
| Trace | Perennial forbs; biological soil crusts[1] | Nonsprouting shrubs; biological soil crusts[1] | Sprouting shrubs; evergreen trees[2] |

[1] Biological soil crust dominance is determined based on cover, rather than production. If biological soil crusts are an expected dominant or subdominant group, the number of expected life forms (e.g., lichen, moss) is listed, rather than number of individual species.
[2] May not occur on the site.

T. Obtain an Evaluation Matrix

(1) The matrix is required to conduct an IIRH assessment. The matrix provides general descriptions of key characteristics and degrees of departure, forming a relative scale from “none to slight” to “extreme to total” departure for each of the 17 indicators. The descriptor for “none to slight” comes from the reference sheet and reflects the effects of the natural disturbance regime and natural range of variability of each indicator in the reference state (Pellant et al. 2005, 2020).

(2) See the IIRH Technical Reference, Version 5, Appendix 2 for a generic evaluation matrix and in table E-25 in this subpart. The generic evaluation matrix can be used to conduct an IIRH assessment using the ecological site classification system (ecological site descriptions and appropriate reference information are available). But it is strongly recommended to obtain or develop an ecological site-specific evaluation matrix because it can more accurately describe the possible range of variation for each indicator compared to the generic evaluation matrix. Instructions for developing a specific site evaluation matrix are included in Appendix 2 of the IIRH Technical Reference (Pellant et al. 2005, 2020).

U. Collect Supplemental Information

Supplemental information improves an evaluator’s ability to conduct an informed and accurate assessment. Local knowledge is a valuable source of this supplemental information which includes:

(1) recent weather (required), including precipitation for the past two years
(2) land treatments and disturbance history (required)
(3) information about wildlife, livestock, recreation, or other uses (recommended)
(4) photographs of the evaluation area (strongly recommended)
(5) quantitative data to help train evaluators in rating some indicators and support assessments (strongly recommended, see table E-24 in this subpart; table 5 in the IIRH Technical Reference)

**Table E-24.** Selected indicators of rangeland health and associated measurement methods that are commonly used to collect related quantitative indicator values.

| Rangeland Health Indicator | Measurement Method[1] | Quantitative Indicator Value |
|---|---|---|
| Bare ground (indicator 4) | **Line point intercept** | Bare ground percent |
| | **Gap intercept** | Size of intercanopy or basal gaps |
| Soil surface resistance to erosion (indicator 8) | **Soil stability test** | Soil surface stability values |
| Effects of plant community composition and distribution on infiltration (indicator 10) | Production by species[2] | Functional/structural group composition by weight |
| | **Line point intercept** | Functional/structural group composition by cover |
| Functional/structural groups (indicator 12) | **Line point intercept** | Functional/structural group composition by cover |
| | Production by species[2] | Functional/structural group composition by weight |
| Dead or dying plants or plant parts (indicator 13) | **Line point intercept** | Proportion of dead plants or plant parts intercepted |
| | Belt transect | Proportion or density of dead or dying plants |
| Litter cover and depth (indicator 14) | **Line point intercept** | Litter cover |
| Annual production (indicator 15) | Total harvest[2]<br>Weight units[2] | Total annual production |
| Invasive plants (indicator 16) | Production by species[2] | Invasive plant composition by weight |
| | **Line point intercept** | Cover of invasive species |
| | Belt transect | Density of invasive plants |

[1] Core methods are bold.
[2] Note that the protocol outlined in Appendix 8 provides a measurement of total annual production. Refer to subpart E 645.0502.F for protocols to determine species composition by weight.

V. Rate the 17 Indicators

(1) The recommended protocol to conduct an IIRH assessment is for the evaluator(s) to complete a general reconnaissance of the evaluation area to determine how much variability exists for each indicator on the site. This enables the evaluator(s) to become familiar with the plant species, relative dominance of functional/structural groups, soil surface features, rangeland health indicators, and variability associated with the ecological site in the evaluation area. When completing the IIRH protocol as an interdisciplinary team, indicators are rated using a consensus approach (Pellant et al. 2005, 2020).

(2) The reference sheet describes the range of expected spatial and temporal variability for each indicator within the natural disturbance regime for an ES. The rating of each indicator in the evaluation area is based on that indicator's degree of departure from the "none to slight" category, which is taken from the appropriate reference sheet. When indicator conditions match the description for the reference, the indicator is rated "none to slight" (Pellant et al. 2005, 2020).

(3) Refer to the evaluation matrix or ecological site-specific evaluation matrix (if available) to determine which descriptor best describes the departure from the "none to slight" descriptor and enter that rating on the evaluation form (figures E-43 and E-44). The narrative descriptors for each indicator form a relative scale from "none to slight" to "extreme to total" departure. The evaluation matrix often includes several short sentences describing characteristics of the departure of an indicator. Not all indicator departure descriptors will match indicator conditions observed in the evaluation area, particularly when using the generic evaluation matrix. Evaluators should select the departure rating for which the majority of the descriptors best describe the departure of the indicator (e.g.,

use a "best fit" approach) while strongly considering those descriptors that fall in greater departure rating categories (see IIRH Technical Reference Table 6). Each indicator rating should be supported with comments in the spaces provided on the evaluation form (figures E-43 and E-44) (Pellant et al. 2005, 2020).

(4) Short descriptions of each of the 17 indicators taken from the Technical Reference (Pellant et al. 2005, 2020) are included here for information, but it is critical to read and refer to the IIRH Technical Reference to get all the instructions, photos, and examples on running the protocol correctly.

The Technical Reference can be assessed here: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/range/?cid=stelprdb1068410.

- Rills (Indicator 1)
  Rills are small, intermittent watercourses with steep sides, usually only several centimeters deep (SSSA 1997). They are generally linear erosion features that mostly run parallel to the slope. For most soils and ecological sites, the potential for rill formation increases as the degree of disturbance (loss of cover) and slope increases. Rills usually end at a concentrated water flow pattern, a terracette, or an area where the slope flattens, and deposition occurs. Rills may connect into a drainage and erosion network on some sites, but for most sites, rills will not be connected.
- Water Flow Patterns (Indicator 2)
  Water flow patterns are the paths that water takes as it moves across the soil surface during periods when surface water from rain or snowmelt exceeds soil infiltration capacity. This process is commonly referred to as sheetflow or overland flow. Water flow patterns follow the natural microtopography of the landscape. These patterns are generally evidenced by litter, soil or gravel redistribution, or pedestalling of vegetation or stones that break or divert the flow of water (Morgan 1986). Length, width, and number of water flow patterns are influenced by the number and kinds of obstructions to water flow provided by basal intercepts of living or dead plants, biological soil crusts, persistent litter, or rocks. They may be continuous or appear and disappear as the slope, perennial plant density, and microtopography change.
- Pedestals and/or Terracettes (Indicator 3)
  – Pedestals indicate the movement of soil by water or wind from the base of plants or from around rocks or persistent litter, giving them the appearance of being elevated. Accelerated erosion is likely to be occurring on a site when the number of pedestals is more than what is defined as expected for the site in the reference state (within the natural disturbance regime). In some cases, plant roots may be exposed due to this accelerated erosional process.
  – Terracettes are "benches" of sediment deposition that form behind or between obstacles, such as rocks, plant bases, or large litter, when soil and other materials are redistributed by water movement. As the degree of soil movement by water increases, terracettes may become more numerous, and the area of soil deposition becomes larger. The relatively higher elevation of the soil on the upslope side of a terracette is an indication of soil deposition by moving water or of soil erosion below the terracette.
- Bare Ground (Indicator 4)
  Bare ground is exposed mineral soil not covered by vegetation (live or dead and basal and canopy cover), gravel/rock, visible biological soil crusts, or litter. These ground surface cover materials intercept raindrops, reduce soil particle detachment (raindrop splash erosion), and reduce soil movement by water and wind (Weltz et al. 1998; Pellant et al. 2020).
- Gullies (Indicator 5)

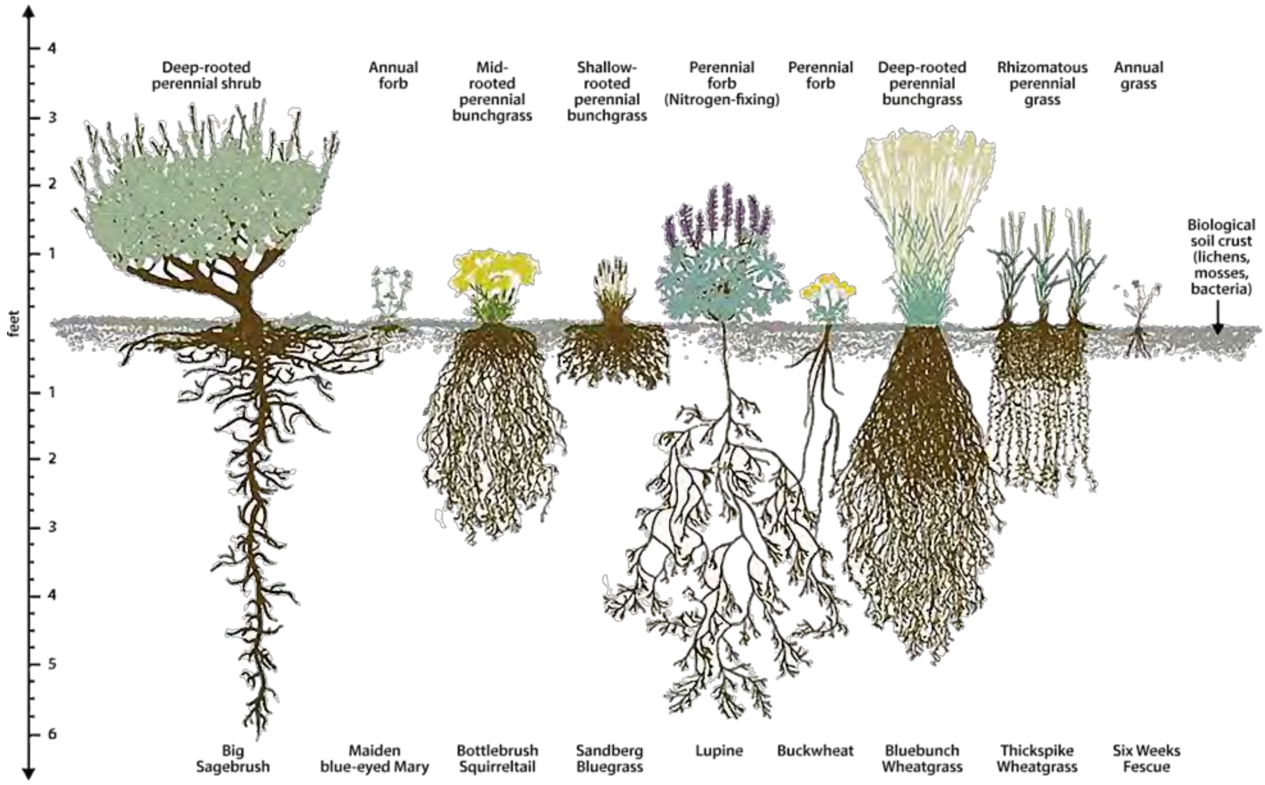
Gullies are well-defined channels cut into the soil by ephemeral water flow that normally follow natural drainage channels. Gullies can develop from enlarged rills; however, gully formation may be much more complex and usually involves an interrelationship between the: (1) volume, speed, and type of runoff; (2) susceptibility of the soil to erosion; and (3) changes in ground cover caused by inappropriate land uses and treatments (Morgan et al. 1997; Pellant et al. 2020).

- Wind Scoured and/or Depositional Areas (Indicator 6)
  Wind-scoured areas, including blowouts, are formed as finer particles of the topsoil are blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface (Anderson 1974). Blowouts are defined as "a hollow or depression of the land surface, which is generally saucer or trough-shaped, formed by wind erosion, especially in an area of shifting sand, loose soil, or where vegetation is disturbed or destroyed" (SSSA 1997). Blowouts are included within the following discussion of wind-scoured areas and within the assessment of this indicator. Depositional areas are locations where windblown soil accumulates; the deposited soil may originate from either on- or offsite. Soil deposition due to water movement is not included when assessing this indicator.
- Litter Movement (Indicator 7)
  - Litter is the uppermost layer of organic debris on the soil surface – essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this technical reference, litter includes dead plant material, including leaves, stems, and branches, that are detached from the plant. Duff (dead plant material that is decomposed so that leaves, stems, and branches are difficult to recognize) is not included in the litter movement indicator.
  - Litter movement refers to the change in location of litter due to water or wind. The distance, amount, and size of litter being moved are signs of the extent to which water or wind erosion may be occurring.
- Soil Surface Resistance to Erosion (Indicator 8)
  - This indicator assesses the resistance of the soil surface to erosion by water. Resistance depends on soil stability and on the spatial variability in soil stability relative to vegetation and microtopographic features (Morgan 1986). Soil surfaces may be stabilized by: (1) soil organic matter that has been fully incorporated into aggregates at the soil surface; (2) adhesion of decomposing organic matter to the soil surface; and (3) biological soil crusts (Wills et al. 2017).
  - The presence of one or more of these factors is a positive indicator of soil surface resistance to erosion (Blackburn et al. 1992; Pierson et al. 1994). Soil texture (especially clay content and sand size) and clay mineralogy affect potential stability: coarse sandy soils have inherently lower stability. This indicator is more highly correlated with water erosion (Blackburn and Pierson 1994; Pierson et al. 1994) than with wind erosion. However, susceptibility to wind erosion also declines with an increase in soil organic matter (Fryrear et al. 1994) and biological soil crust cover (Belnap and Gillette 1998).
- Soil Surface Loss and Degradation (Indicator 9)
  Soil surface loss and degradation is the reduction in soil surface depth, organic matter, porosity, and structure as a result of wind or water erosion, and it is indicative of long-term change in rangeland health. The loss or degradation of part or all of the soil surface layer or horizon is an indication of a loss in site potential (Dormaar and Willms 1998; Davenport et al. 1998).
- Effects of Plant Community Composition and Distribution on Infiltration (Indicator 10)
  This indicator reflects effects of vegetation composition and spatial distribution on the infiltration capacity of the soil within the evaluation area and the amount of time water is retained on the soil surface. The term infiltration for this

indicator encompasses both the entry of water into soil and the movement of water into the soil profile.

- Compaction Layer (Indicator 11)
  A compaction layer is a near-surface layer of dense soil caused by impact on or disturbance of the soil surface. A compaction layer can be caused by application of weight or pressure at or below the soil surface. Compaction layers restrict water percolation (Willat and Pullar 1984; Thurow et al. 1988a), plant growth (Wallace 1987), and nutrient cycling (Hassink et al. 1993), potentially reducing infiltration and increasing runoff and changes in plant composition and production.
- Functional/Structural Groups (Indicator 12)
  – Functional/structural groups are plant species (including nonvascular plants such as visible biological soil crusts) that are grouped together on the basis of similar growth forms or ecophysiological roles (table E-23 and figure E-42).
  – Function typically refers to the ecophysiological role that plants and biological soil crusts play on a site. This may include the plant's life cycle (e.g., annual, monocarpic perennial, or perennial), phenology, photosynthetic pathway, nitrogen fixer associations, sprouting ability, and water infiltration (including biological soil crusts).
  – Structure refers to plant growth forms (e.g., trees, vines, shrubs, grasses, forbs, and nonvascular plants, such as visible biological soil crusts) within the community. Structure may be subdivided to group species with similar growth forms based on height, growth patterns (bunch, sod-forming, or spreading through long rhizomes or stolons), root structure (fibrous or tap), rooting depth, or sprouting ability.
  – The functional/structural groups indicator assesses shifts in expected types and proportions of functional/structural groups within the context of the plant community phases that are described for an ecological site under the natural disturbance regime (Pellant et al. 2005, 2020).
  – For instruction on developing the Functional/Structural Groups table in the Reference Sheet, see the Technical Reference Version 5 Appendix 1b.
- Dead or Dying Plants or Plant Parts (Indicator 13)
  Dead or dying plants and dead or dying stems, branches, leaves, etc., are a natural phenomenon in all perennial plant communities. Ecological reference areas in the same ecological site can provide a point of comparison to determine expected dead or dying plants or plant parts given recent weather at the time of assessment.
- Litter Cover and Depth (Indicator 14)
  Litter is the uppermost layer of organic debris on the soil surface—essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this technical reference, it includes dead plant material, including leaves, stems, and branches, detached from the plant.
- Annual Production (Indicator 15)
  Annual production represents the energy captured by plants through the process of photosynthesis, given recent weather conditions. It is the net quantity of aboveground vascular plant material produced within a growing season. It is not a measurement or estimate of total standing biomass (which includes the previous growing season production).

**Figure E-42.** Root morphology of common plants in a sagebrush steppe ecosystem (adapted from Sage Grouse Initiative 2016). See Natura (1995) for a similar diagram of root morphology of common plants in a mixed prairie ecosystem (Pellant et al. 2005, 2020).




- Invasive Plants (Indicator 16)
  Invasive plants (for purposes of the IIRH protocol) are plant species that are typically not found on the ecological site or should only be in the trace or minor categories under the natural disturbance regime and have the potential to become a dominant or codominant species on the site if their establishment and growth are not actively controlled by natural disturbances or management interventions. A primary characteristic of invasive plant species is their ability to persist on an ecological site and influence ecological processes (Chambers et al. 2014). See the Technical reference for more information on ruderal, noxious, introduced and native plant applicability.
- Vigor with an Emphasis on Reproductive Capability of Perennial Plants (Indicator 17)
  Plant vigor relates to the robustness of a plant in comparison to other individuals of the same species. Vigor is reflected primarily by the size of the plant and its parts in relation to the plant’s age and the local environment in which it is growing (SRM 1999). A plant’s reproductive capability is dependent on having adequate vigor and the ability to reproduce given the constraints of climate and herbivory. Inflorescence (e.g., seed stalks) and flower production are basic measures of reproductive potential for sexually reproducing plants and clonal production (e.g., tillers, rhizomes, or stolons) for vegetatively reproducing plants.

**Table E-25**. IIRH Generic Evaluation Matrix.

| Departure from Reference Sheet Indicator | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
|---|---|---|---|---|---|
| 1. Rills | Numerous and frequent throughout. Nearly all are wide, deep, and long. Occur in exposed and vegetated areas. | Moderate in number at frequent intervals. Many are wide, deep, and long. Occur in exposed areas and in some adjacent vegetated areas. | Moderate in number at infrequent intervals. Moderate width, depth, and length. Occur mostly in exposed areas. | Scarce and scattered. Minimal width, depth, and length. Occur in exposed areas. | Reference sheet narrative inserted here. |
| 2. Water Flow Patterns | Extensive. Long and wide. Erosional and/ or depositional areas widespread. Usually connected. | Widespread. Longer and wider than expected. Erosional and/ or depositional areas common. Occasionally connected. | Common. Lengths and/or widths slightly to moderately higher than expected. Minor erosional and/ or depositional areas. Infrequently connected. | Scarce. Length and width nearly match expected. Some minor erosional and/ or depositional areas. Rarely connected. | Reference sheet narrative inserted here. |
| 3. Pedestals and/or Terracettes | Pedestals extensive; roots frequently exposed. Terracettes widespread. | Pedestals widespread; roots commonly exposed. Terracettes common. | Pedestals common; roots occasionally exposed. Terracettes uncommon. | Pedestals uncommon; roots rarely exposed. Terracettes scarce. | Reference sheet narrative inserted here. |
| 4. Bare Ground | Substantially higher than expected. Bare ground patches are large and frequently connected. | Much higher than expected. Bare ground patches are large and occasionally connected. | Moderately higher than expected. Bare ground patches are moderate in size and sporadically connected. | Slightly higher than expected. Bare ground patches are small and rarely connected. | Reference sheet narrative inserted here. |
| 5. Gullies | Sporadic or no vegetation on banks and/ or bottom. Numerous nickpoints. Significant active bank and bottom erosion, including downcutting. Substantial depth and/or width. Active headcut(s) may be present. | Intermittent vegetation on banks and/ or bottom. Nickpoints common. Moderate active bank and bottom erosion, including downcutting. Significant depth and/or width. Active headcut(s) may be present. | Occasional vegetation on banks and/ or bottom. Occasional nickpoints and/or slight downcutting. Moderate depth and/or width. Active headcuts absent. | Vegetation on most banks and/or bottom. Few nickpoints and/or minimal downcutting. Minimal gully depth and/or width. Headcuts absent. | Reference sheet narrative inserted here. |

| Departure from Reference Sheet Indicator | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
|---|---|---|---|---|---|
| 6. Wind-Scoured and/or Depositional Areas | Extensive. Wind scours usually connected. Large soil depositions around obstructions. | Common. Wind scours frequently connected. Moderate soil depositions around obstructions. | Occasionally present. Wind scours infrequently connected. Minor soil depositions around obstructions. | Infrequent and few. Wind scours rarely connected. Trace amounts of soil deposition around obstructions. | Reference sheet narrative inserted here. |
| 7. Litter Movement (Wind or Water) | Extreme movement of all size classes (including large). Significant accumulations around obstructions or in depressions. | Moderate to extreme movement of small to moderate size classes. Moderate accumulations around obstructions or in depressions. | Moderate movement of mostly small size classes. Small accumulations around obstructions or in depressions. | Slight movement of small size classes. Minimal or no accumulations around obstructions or in depressions. | Reference sheet narrative inserted here. |
| 8. Soil Surface Resistance to Erosion | Extremely reduced throughout. | Significantly reduced in most interspaces or plant canopies and moderately reduced throughout. | Significantly reduced in at least half of plant interspaces or plant canopies or moderately reduced throughout. | Some reduction in plant interspaces or plant canopies or slightly reduced throughout. | Reference sheet narrative inserted here. |
| 9. Soil Surface Loss and Degradation | Soil surface horizon very thin to absent throughout. Soil surface structure similar to or more degraded than subsurface. No distinguishable difference between surface and subsurface organic matter content. | Severe soil loss or degradation throughout. Minor differences in soil organic matter content and structure between surface and subsurface layers. | Moderate soil loss or degradation in plant interspaces with some Degradation beneath plant canopies. Soil organic matter content is markedly reduced. | Slight soil loss or degradation, especially in plant interspaces. Minor change in soil organic matter content. | Reference sheet narrative inserted here. |
| 10. Effects of Plant Community Composition and Distribution on Infiltration | Changes in plant community (functional/ structural groups) composition and/or distribution are expected to result in a severe reduction in infiltration. | Changes in plant community (functional/ structural groups) composition and/ or distribution are expected to result in greatly decreased infiltration. | Changes in plant community (functional/ structural groups) composition and/ or distribution are expected to result in a moderate reduction in infiltration. | Changes in plant community (functional/ structural groups) composition and/ or distribution are expected to result in a slight reduction in infiltration. | Reference sheet narrative inserted here. |

| Departure from Reference Sheet Indicator | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
|---|---|---|---|---|---|
| 11. Compaction Layer | Extensive and/ or strongly developed (thickness and density); may severely restrict root penetration. | Widespread and/ or moderately to strongly developed (thickness and density); may greatly restrict root penetration. | Moderately widespread and/ or moderately developed (thickness and density); may moderately restrict root penetration. | Not widespread and/or weakly developed (thickness and density); may weakly restrict root penetration. | Reference sheet narrative inserted here. |
| 12. Functional/ Structural (F/S) Groups | | | Indicator rating is based on the greatest departure of the four subindicators. | | |
| 12a. Relative dominance | All expected dominant F/S groups are now minor, trace, or missing. | Dominant F/S group(s) has become minor or trace, or a minor or trace group is now dominant. | Dominant F/S group(s) has become subdominant. | Subdominant F/S group has become minor or trace, or a minor or trace F/S group has become subdominant. | Resembles expected relative dominance.[1] |
| 12b. F/S groups not expected | F/S group(s) not expected is now dominant. | F/S group(s) not expected is now subdominant. | F/S group(s) not expected is now minor. | F/S group(s) not expected is now trace. | None. |
| 12c. Number of expected F/S groups[2] | Severely reduced (missing ≥ 76% of expected F/S groups). | Greatly reduced (missing 51–75% of expected F/S groups). | Moderately reduced (missing 26–50% of expected F/S groups). | Slightly reduced (missing ≤ 25% of expected F/S groups). | All expected F/S groups are present.[1] |
| 12d. Total combined number of species expected in dominant and subdominant F/S groups | Severely reduced (missing ≥ 76%). | Greatly reduced (missing 51–75%). | Moderately reduced (missing 26–50%). | Slightly reduced (missing 10–25%). | Missing less than 10% of expected number of species in dominant and subdominant F/S groups.[1] |
| 13. Dead or Dying Plants or Plant Parts (dominant, subdominant, and minor functional/ structural groups | Extensive mortality and/ or dying plants/ plant parts in species within expected functional/ structural group(s). | Widespread mortality and/ or dying plants/ plant parts in species within expected functional/ structural group(s). | Moderate mortality and/ or dying plants/ plant parts in species within expected functional/ structural group(s). | Occasional mortality and/ or dying plants/ plant parts in species within expected functional/ structural group(s). | Reference sheet narrative inserted here. |
| 14. Litter Cover and Depth | Largely absent with minimal depth or extensive with much greater depth relative to site potential and recent weather. | Greatly reduced or greatly increased cover and/or depth relative to site potential and recent weather. | Moderately more or less cover and/ or depth relative to site potential and recent weather. | Slightly more or less cover and/or depth relative to site potential and recent weather. | Reference sheet narrative inserted here. |

| Departure from Reference Sheet Indicator | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
|---|---|---|---|---|---|
| 15. Annual Production[3] | 20% or less of potential production based on recent weather. | 21–40% of potential production based on recent weather. | 41–60% of potential production based on recent weather. | 61–80% of potential production based on recent weather. | Reference sheet narrative inserted here (annual production > 80% of potential). |
| 16. Invasive Plants | Dominant throughout. | Common throughout. | Scattered throughout. | Uncommon. | Nonnative invasive plants not present. If native invasive species are present, composition matches that expected for the ecological site. |
| 17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants (dominant, subdominant, and minor functional/ structural groups) | Vigor and capability to produce seed or vegetative tillers in species within the expected functional/ structural group(s) are extremely reduced, or functional/ structural group(s) is no longer functionally present. | Vigor and capability to produce seed or vegetative tillers in species within the expected functional/ structural group(s) are greatly reduced. | Vigor and capability to produce seed or vegetative tillers in species within the expected functional/ structural group(s) are moderately reduced. | Vigor and capability to produce seed or vegetative tillers in species within the expected functional/ structural group(s) are slightly reduced. | Reference sheet narrative inserted here. |

[1] For the appropriate reference community phase.
[2] Must be functionally present.
[3] When developing an ecological site-specific evaluation matrix, use these same percentage categories.

**Figure E-43.** Blank Evaluation Form for Interpreting Indicators of Rangeland Health.

| Interpreting Indicators of Rangeland Health Version 5 Evaluation Form (page 2) | | |
|---|---|---|
| Evaluation area name or ID: | | Date: |
| **Departure from Expected** | **Code** | **Instructions** |
| None to slight | N-S | (1) Assign 17 indicator ratings, record comments and any measurements. |
| Slight to moderate | S-M | (2) In the attribute rating tables at the bottom of the form, write the indicator number in the appropriate column for each indicator applicable to the attribute. |
| Moderate | M | (3) Assign overall rating for each attribute based on preponderance of evidence. |
| Moderate to extreme | M-E | (4) Provide rationale for each attribute rating in writing. |
| Extreme to total | E-T | |

| Indicator | Rating | | | Comments |
|---|---|---|---|---|
| 1. Rills | S | H | | |
| 2. Water flow patterns | S | H | | |
| 3. Pedestals and/or terracettes | S | H | | |
| 4. Bare ground (observed): _____ % | S | H | | |
| 5. Gullies | S | H | | |
| 6. Wind-scoured and/or depositional areas | S | | | |
| 7. Litter movement (wind or water) | S | | | |
| 8. Soil surface resistance to erosion<br>Interspace: _____ Plant canopy: _____ | S | H | B | |
| 9. Soil surface loss and degradation | S | H | B | |
| 10. Effects of plant community composition and distribution relative to infiltration | | H | | |
| 11. Compaction layer | S | H | B | |
| 12. Functional/structural groups<br>a. Relative dominance: ____<br>b. F/S groups not expected at the site: ____<br>c. Number of F/S groups: ____<br>d. Spp # in dom & subdom F/S groups: ____ | | | B | |
| 13. Dead or dying plants or plant parts | | | B | |
| 14. Litter cover and depth Observed cover:<br>____ % Depth: ____ cm / in | | H | B | |
| 15. Annual production: Pounds or Kilograms<br>Observed: ____ ÷ Expected ____ = ____ | | | B | |
| 16. Invasive plants | | | B | |
| 17. Vigor with an emphasis on reproductive capability of perennial plants | | | B | |

| **Soil/Site Stability "S"** *(10 indicators)* | | **Hydrologic Function "H"** *(10 indicators)* | | **Biotic Integrity "B"** *(9 indicators)* | |
|---|---|---|---|---|---|
| Attribute Rating: ____ | Rationale: | Attribute Rating: ____ | Rationale: | Attribute Rating: ____ | Rationale: |
| E-T \| M-E \| M \| S-M \| N-S | | E-T \| M-E \| M \| S-M \| N-S | | E-T \| M-E \| M \| S-M \| N-S | |

**Figure E-44.** Example of Populated Evaluation Form.

**Interpreting Indicators of Rangeland Health Version 5 Evaluation Form (page 2)**

| Evaluation area name or ID: Big Sage_CM_14 | Date: 8/14/2018 |
|---|---|

| Departure from Expected | Code | Instructions |
|---|---|---|
| None to slight | N-S | (1) Assign 17 indicator ratings, record comments and any measurements. |
| Slight to moderate | S-M | (2) In the attribute rating tables at the bottom of the form, write the indicator number in the appropriate column for each indicator applicable to the attribute. |
| Moderate | M | |
| Moderate to extreme | M-E | (3) Assign overall rating for each attribute based on preponderance of evidence. |
| Extreme to total | E-T | (4) Provide rationale for each attribute rating in writing. |

| Indicator | Rating | Comments |
|---|---|---|
| 1. Rills | S H<br>N-S | No rills observed in evaluation area |
| 2. Water flow patterns | S H<br>S-M | Short, disconnected waterflow patterns 3' long and up to 1' wide in plant interspaces on slopes > 5% |
| 3. Pedestals and/or terracettes | S H<br>S-M | Occasional pedestalled bunchgrasses associated with water flow patterns on slopes > 5% |
| 4. Bare ground (observed): 32 % | S H<br>M-E | Bare ground is much higher than expected, with bare patches > 2' that are occassionally connected |
| 5. Gullies | S H<br>N-S | None |
| 6. Wind-scoured and/or depositional areas | S<br>N-S | Minor soil deposits found around perennial plant bases; no wind scours noted – matches what is expected for the site |
| 7. Litter movement (wind or water) | S<br>S-M | Displacement of fine material up to 2' associated with water flow patterns on slopes > 5%. Coarse litter does not appear to be moving |
| 8. Soil surface resistance to erosion<br>Interspace: 3.2 Plant canopy: 3.8 | S H B<br>M | Observed values are consistently 1-2 categories lower than expected |
| 9. Soil surface loss and degradation | S H B<br>S-M | A-horizon is thinner (5 cm) and lighter (10yr 4/2) in color than expected |
| 10. Effects of plant community composition and distribution relative to infiltration | H<br>S-M | Deep-rooted perennial grasses are somewhat reduced, resulting in slightly less infiltration, especially on steeper slopes |
| 11. Compaction layer | S H B<br>S-M | Thin, weakly developed compaction layer in interspaces, ~2" thick |
| 12. Functional/structural groups<br>a. Relative dominance: S-M<br>b. F/S groups not expected at the site: M<br>c. Number of F/S groups: N-S<br>d. Spp # in dom & subdom F/S groups: N-S | B<br>M | Annual grasses are not expected for this site, but now a minor component; relative dominance has shifted towards shrubs with a decrease in perennial grasses. Biological crust cover is substantially lower than expected |
| 13. Dead or dying plants or plant parts | B<br>S-M | Approx. 20% of deep-rooted bunchgrasses have slight crown die-out which is not expected given the normal precipitation over the past two years |
| 14. Litter cover and depth Observed cover: 38 % Depth: 0.1 cm / (in) | H B<br>N-S | Amount is slightly higher than expected however depth is on the lower end of what is expected for site |
| 15. Annual production: (Pounds) or Kilograms<br>Observed: 775 ÷ Expected 1100 = 70% | B<br>S-M | Production is reduced relative to that expected relative to recent weather (normal year) based on ocular estimate |
| 16. Invasive plants | B<br>M-E | Cheatgrass is common |
| 17. Vigor with an emphasis on reproductive capability of perennial plants | B<br>N-S | Perennial plants at the site are producing seed and have good vigor. Crown diameter is an average of 4-6" on mature bunchgrasses |

**Soil/Site Stability "S"** *(10 indicators)*

Attribute Rating: S-M

Rationale: Bare ground is higher than expected & soil stability has declined impacting site stability

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 5 | |
| | | | 9 | |
| | | | 7 | 6 |
| | | | 3 | 5 |
| | 4 | 8 | 2 | 1 |

**Hydrologic Function "H"** *(10 indicators)*

Attribute Rating: S-M

Rationale: Bare ground is higher than expected and soil stability has declined; Soil compaction & degradation of A horizon may impact hydrologic function

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 11 | |
| | | | 10 | |
| | | | 9 | 5 |
| | | | 3 | 14 |
| | 4 | 8 | 2 | 1 |

**Biotic Integrity "B"** *(9 indicators)*

Attribute Rating: M

Rationale: Annual grasses invading site; biotic integrity & site productivity are moderately affected

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 15 | |
| | | | 13 | |
| | | 12 | 11 | 17 |
| | 16 | 8 | 9 | 14 |

W. Determine the Functional State of the Three Attributes

The IIRH protocol relies on the collective experience and knowledge of the evaluator(s) to classify each indicator and then to interpret the collective rating of the indicators into one summary rating of departure for each attribute of rangeland health. The interpretation process is the critical link between indicator observations and determining the status of each rangeland health attribute. Therefore, evaluators should complete the attribute ratings before leaving the evaluation area. Record justification for the attribute ratings at the bottom of the evaluation form (figures E-43 and E-44). Use tables E-26, E-27, and E-28 for information about the interrelationships between the indicators as they relate to each attribute.

**Table E-26.** Interrelationships of the indicators associated with the soil/site stability attribute rating.

| Indicator | Relationship to the Soil/Site Stability Attribute Rating |
|---|---|
| 1. Rills | Increased occurrence of rills is indicative of loss of soil stability and accelerated erosion by water. Rills can transport significant amounts of soil, which may be lost from or redistributed on the site. |
| 2. Water Flow Patterns | Increased occurrence of water flow patterns indicates accelerated water erosion resulting in soil movement within (and possibly off) a site. Water flow patterns are visual evidence of interrill erosion caused by overland flow, which has been identified as the dominant sediment transport mechanism on rangelands (Tiscareño-Lopez et al. 1993). |
| 3. Pedestals and/or Terracettes | Increased occurrence of pedestals indicates accelerated soil erosion by water or wind. Increased occurrence of terracettes is evidence of reduced soil stability resulting in acceleratederosion by water. Erosional pedestals within a site may be associated with soil surface loss and degradation where soil has eroded around numerous plant or rock pedestals. |
| 4. Bare Ground | Increased bare ground leaves soil more vulnerable to water erosion resulting from raindrop impact, splash erosion, and soil particle disaggregation and to wind erosion resulting from saltation of soil particles. When soils lack protective cover of vegetation, biological soil crusts, and rocks, water or wind may move across the soil surface leading to accelerated soil erosion. Bare ground found in large patches may contribute to a greater amount of soil erosion than the same amount of bare ground found in many small patches. |
| 5. Gullies | Gullies are concentrated areas of soil loss from accelerated water erosion. They are a natural feature of very few landscapes and are usually indicative of significant landscape instability. Considerable amounts of soil may be lost from sides and headcuts of gullies. The amount of loss of soil and water through a gully can be greater than from rill and inter-rill erosion, and the effects are more concentrated. Gullies can also affect physical soil properties at a site (Poesen et al. 2003). |
| 8. Soil Surface Resistance to Erosion | Increased incidence of wind-scoured areas indicates reduced soil and site stability resultingin soil loss by wind erosion. Once wind erosion has begun, soil material below the surface layer that may have been protected by litter or soil crusts may be more susceptible to erosion.Increased incidence of depositional areas is indicative of wind erosion that may be occurring within the evaluation area or in adjacent areas. Soil is usually deposited as disaggregated particles, which may be more susceptible to subsequent wind or water erosion. |
| 9. Soil Surface Loss and Degradation | Litter movement from the point of origin indicates that water or wind erosion may be occurring. Litter concentration has been shown to be closely correlated with inter-rill erosion (water flow patterns). |

| Indicator | Relationship to the Soil/Site Stability Attribute Rating |
|---|---|
| 10. Effects of Plant Community Composition and Distribution on Infiltration | Soil stability is directly tied to the soil surface's resistance to water erosion. Higher soil aggregate stability means soil particles are more strongly "glued" to each other and thereforeless likely to be detached by raindrop impact, overland flow, or wind. Soil surface resistance to erosion may have a spatial relationship with other indicators such as bare ground, which also influences soil/site stability. Reduced soil surface resistance to erosion is associated with reduced infiltration rate, increased runoff, and increased erosion. |
| 11. Compaction Layer | Soil surface loss and degradation indicates past erosion. Signs of soil degradation, including structure changes and reduction of organic matter, may also increase susceptibility to futureerosion. Soil surface loss and degradation is an indicator of long-term change in rangeland health and often persists after vegetation cover has recovered. The degree of soil surface lossand degradation may help determine whether a site has the capability to recover ecosystem function or whether a physical threshold has been crossed. |
| 14. Litter Cover and Depth | Soil stability may be impacted when the compaction layer reduces infiltration to the point thatsurface runoff increases, which increases the potential for water erosion. |

**Table E-27**. Interrelationships of the indicators associated with the hydrologic function attribute rating.

| Indicator | Relationship to the Hydrologic Function Attribute Rating |
|---|---|
| 1. Rills | Rills concentrate and facilitate rapid water movement on slopes causing water to be lost from or redistributed on the site. Increased occurrence of rills indicates reduced hydrologic function resulting from decreased infiltration. |
| 2. Water Flow Patterns | Increase in number, length, depth, and width and connectivity of water flow patterns indicates increased water movement (overland flow) on (and possibly off) a site. Increases in size and connectivity of water flow patterns are likely associated with an increased size and number of bare ground patches. Connected water flow patterns can form a drainage network which may connect to rills or gullies. When the soil surface is stable, but infiltration is reduced, overland flow may form water flow patterns with minimal evidence of erosion; however, these features are indicative of reduced hydrologic function. |
| 3. Pedestals and/or Terracettes | Increased occurrence of pedestals and/or terracettes is indicative of reduced hydrologic function. Pedestals caused by water erosion and terracettes are indicators of reduced infiltration resulting in greater overland water flow, sediment transport, and deposition. Pedestals may also be caused by wind erosion, but the resultant soil loss may subsequently impact hydrologic function. Soil surface loss and degradation is likely to be observed around erosional pedestals. |
| 4. Bare Ground | When soils lack protective cover of vegetation, biological soil crusts, litter, and rocks, water is more likely to move across the soil surface prior to infiltration, affecting hydrologic function due to accelerated water loss from a site. Increases in bare ground and bare ground patch size and connectivity can also increase a site's vulnerability to erosion and promote further declines in hydrologic function. |
| 5. Gullies | Gullies are indicative of loss of hydrologic function because they can channel large amounts of water offsite. The amount of loss of water through a gully is generally greater than through water flow patterns or rills, and the effects are more concentrated. Gullies can also affect water table levels at a site (Poesen et al. 2003). |
| 8. Soil Surface Resistance to Erosion | Reduced soil surface resistance to erosion is associated with reduced infiltration rate, increased runoff, and increased erosion. Reductions in soil stability values indicate that soil particles are more likely to be dispersed in water. Dispersed particles may form physical crusts, which limit infiltration and thus impact hydrologic function. Soil surface resistance to erosion may have a spatial relationship with other indicators such as bare ground, which also influences hydrologic function. |

| Indicator | Relationship to the Hydrologic Function Attribute Rating |
|---|---|
| 9. Soil Surface Loss and Degradation | Potential infiltration rates are controlled by soil texture, while the actual infiltration rate is controlled by soil surface structure and porosity. Hydrologic function is impacted when loss of soil organic matter or degradation of surface horizon structure decrease infiltration rates and water holding capacity. Soil surface loss and degradation is an indicator of long-term change in rangeland health and often persists after vegetation cover has recovered. The degree of soil surface loss and degradation may help determine whether a site has the capability to recover ecosystem function or whether a physical threshold has been crossed. |
| 10. Effects of Plant Community Composition and Distribution on Infiltration | Plant community composition and distribution relative to infiltration reflects the unique contributions of functional/structural groups and their associated species in modifying infiltration. Plant rooting patterns, litter production and associated decomposition processes, height, basal area, and spatial distribution can all affect infiltration. Changes in vegetation composition and distribution can also affect hydrologic function by modifying evapotranspiration, soil water storage, and snow entrapment. |
| 11. Compaction Layer | Compaction layers may negatively impact hydrologic function by restricting water infiltration through the soil profile. In some cases, the compaction layer reduces infiltration to the point that surface runoff increases. |
| 14. Litter Cover and Depth | Litter influences hydrologic function by intercepting raindrops, obstructing overland flow, promoting infiltration, reducing evapotranspiration, and reducing erosion (Hester et al. 1997; Pierson et al. 2007; Thurow et al. 1988a, 1988b). Reductions in litter cover may be associated with increases in bare ground. Thick, contiguous litter mats may intercept moisture from small precipitation events, reducing infiltration. |

**Table E-28.** Interrelationships of the indicators associated with the biotic integrity attribute rating.

| Indicator | Relationship to the Biotic Integrity Attribute Rating |
|---|---|
| 8. Soil Surface Resistance to Erosion | Biotic factors, including biological soil crust and vegetation composition and cover, litter composition and decomposition, and root growth, all influence soil aggregate stability. Reduced soil surface stability usually reflects lower soil biotic integrity because soil biological processes depend on organic matter inputs and biological decomposition processes to form and maintain stable soil aggregates. These changes, in turn, affect biotic integrity because a stable soil surface provides the environment necessary for most germination and establishment of plant species. |
| 9. Soil Surface Loss and Degradation | Soil surface loss and degradation reflect changes in biotic integrity because of the role of soil biotic activity in creating and maintaining soil structure. These changes, in turn, affect biotic integrity because the soil surface provides the environment for most germination and establishment of plant species. It also provides the environment for soil microorganisms that enhance soil fertility, water holding capacity, and stability. In most sites, the soil at and near the surface has the highest organic matter and nutrient content. Soil organic matter generally controls the maximum rate of water infiltration into the soil and is essential for successful seedling establishment (Wood et al. 1997). Soil surface loss and degradation is an indicator of long-term change in rangeland health and often persists after vegetation cover has recovered. The degree of soil surface loss and degradation may help determine whether a site has the capability to recover ecosystem function or whether a physical threshold has been crossed. The loss or degradation of part or all of the soil surface layer or horizon is an indication of a loss in site potential (Dormaar and Willms 1998; Davenport et al. 1998). |
| 11. Compaction Layer | Compaction layers can restrict the distribution of plant roots, especially fibrous roots, through the soil, limiting the ability of vegetation to extract nutrients and moisture from the soil profile. Compaction layers can also reduce soil water holding capacity, decreasing moisture availability for plant growth. Compaction can also reflect a reduction in biotic integrity because it indicates that the factors that cause compaction are not balanced by recovery processes, including plant root growth. |

| Indicator | Relationship to the Biotic Integrity Attribute Rating |
|---|---|
| 12. Functional/ Structural Groups | A mixture of plant functional and structural groups appropriate to a site can promote community resistance to plant invasions and resilience to disturbances (Pokorny et al. 2005; Chambers et al. 2014). A change in the relative dominance or number of species in functional/structural groups may have a negative effect on ecosystem processes and overall biotic integrity. Both the presence of functional/structural groups and the number of species (or life forms for biological soil crusts) within these groups have a significant positive effect on ecosystem processes (Tilman et al. 1997). |
| 13. Dead or Dying Plants or Plant Parts | Plant mortality and recruitment are two processes that drive changes in plant populations and communities. This indicator addresses mortality, while indicator 17 indirectly addresses recruitment. If plant mortality exceeds recruitment, biotic integrity of the stand may decline and undesirable plants (e.g., invasive plants) may increase. |
| 14. Litter Cover and Depth | Litter provides a source of soil organic material and raw materials for onsite nutrient cycling (Whitford 1988, 1996), helps moderate the soil microclimate, provides food for microorganisms, and plays a role in enhancing erosion resistance by dissipating the energy of raindrops and obstructing overland flow (Hester et al. 1997; Thurow et al. 1988a, 1988b). Increased litter accumulation may influence biotic integrity by reducing sites for seed germination and may be an indicator of reduced decomposition rates. Litter accumulation may be correlated with indicator 15 (annual production). |
| 15. Annual Production | This is the only indicator that is directly linked to the ecological process of energy flow. Solar energy is converted into chemical energy by photosynthesis. The amount of solar energy captured in primary production (e.g., energy flow) represents the total amount of energy available for utilization by animals. Reduced annual production may be linked with reduced plant vigor, reduced litter, or changes in functional/ structural groups. |
| 16. Invasive Plants | Invasive plants impact an ecosystem's type and abundance of species, their interrelationships, and the processes by which energy and nutrients move through an ecosystem. These impacts can influence both biological organisms and physical properties of a site (Olson 1999) and may range from slight to severe depending on the species involved and their degree of dominance. Invasive species may adversely affect a site by increased water usage (e.g., salt cedar/tamarisk in riparian areas) or modifying disturbance regimes (e.g., shortened fire return intervals in annual grass-invaded sites). |
| 17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants | Plant vigor and reproductive capability are key components in ensuring that, when favorable recent weather conditions are present, recruitment can occur to balance plant mortality (indicator 13). Plant community composition and therefore resiliency are dependent on the availability of plants with the capability to reproduce and for recruitment to occur (Svejcar et al. 2014). |

X. After Completing the Assessment

Managers may use the final ratings of attributes of rangeland health to identify where to focus monitoring efforts or where management opportunities may exist. Areas with a "moderate" departure rating are often ideal for implementing monitoring studies or for making management changes since they should be the most responsive to management actions. Prior to implementing management actions, it is important to review other available relevant information to understand the cause of resource problems and monitor trends in vegetation and soils condition. Additional monitoring may be useful regardless of the departure rating, dependent on future changes in uses or management of an area. More IIRH Forms can be found in the Technical Reference.

## 645.0515 Pasture Condition Scoring for Health Assessments

A. Two pasture assessment tools are available in NRCS and provide for "quick assessment" of current conditions and management. Both tools are qualitative and semi-quantitative if field data are needed.

(1) **Pasture Condition Scoresheet II (PCSS II)** (USDA-NRCS 2020 Guide to Pasture Condition Scoring) provides the visual evaluation of 10 indicators, which rate pasture

vegetation and soils. Each indicator or factor has five possible ratings, ranging from lowest (poorest) condition (1) to highest (best) condition (5). The indicators are tallied into an overall score (50) for the pasture unit or utilized as individual scores and compared with the other nine indicators. Indicators receiving the lowest scores can be targeted for corrective action.

(2) **Determining Indicators of Pasture Health (DIPH)** is a detailed assessment tool and includes a matrix of indicators that can be used to determine the preponderance of evidence for three separate pastureland ecosystem attributes: biotic integrity, soil/site stability, and hydrologic function. DIPH is a similar methodology to IIRH V5 (Pellant et al. 2020), although there are specific indicators that are relevant to pastureland systems in DIPH. DIPH may be used as a standardized approach similar to IIRH to conduct a more comprehensive pasture assessment of hydrologic function, soil and surface stability, and biotic integrity.

B. Pasture Condition Score. Introduction—Pasture condition scoring (PCS) is a systematic way to assess how well a pasture is being managed and resources protected. The National Pasture Condition Scoring Guide and Score Sheet provides a systematic way to check how well a pasture is managed and can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/pasture/?cid=stelprdb1045215. Forms can be found in the PCS Guide and in this subpart.

(1) A pasture rated with a high score is well-managed with productivity (plant and animal) being sustained or enhanced. By rating the key indicators common to all pastures, pasture condition can be evaluated, and the primary reasons for a low condition score can be identified. A low rating typically means the pasture has one or more challenges or resource concerns, such as poor plant growth, weedy species invasion, poor animal performance (low forage quantity and quality), visible soil loss, increased runoff, and impaired water quality in or adjacent to the pasture.

(2) The PCS should be performed several times a year during critical management periods throughout the grazing season. The revised "Pasture Condition Score Sheet" (PCSS) (see tables E-29 and E-30) should be used to rate individual pastures. Regardless of the time of year selected to do the PCS, the best time to score a pasture is just before it is grazed. The PCS should be performed.

(i) As a benchmark condition of the pasture.
(ii) Early in the growing season before grazing events occur.
(iii) At peak forage supply periods.
(iv) At low forage supply periods.
(v) At plant stress periods such as drought or very wet conditions.
(vi) When conservation practices (management) have been fully applied.

(3) For best results, the livestock manager and conservation planners should evaluate the pastures the same time each year to note changes in the condition of the pasture. PCS results can be useful in deciding when to move livestock or planning other management actions. It assists in identifying which improvements are most likely to improve pasture condition or livestock performance.

(4) The PCS is not a replacement for doing a forage inventory or forage production estimates. The pasture planner should consider other available data such as pasture state information in an ecological site description (ESD) or pasture and hay suitability groups.

(5) PCS involves the visual evaluation of 10 indicators, listed and described below, which rate the pasture vegetation and soils. Rating subjectivity can be reduced by incorporating quantitative measures. For example, using the step-point method for evaluation (figure E-45) can provide measured results for five of the indicators (percent desirable plants, percent legume, live plant cover, plant diversity, and plant residue). Also, by pacing to measure the livestock concentration areas and using a shovel to quickly evaluate the soil compaction and soil regenerative indicator, the user of the PCSS and the guide can have confidence in each indicator rating and the total score.

**Figure E-45**. The step-point method can provide data for five indicators.

(6) On the PCSS, each indicator or factor has five possible ratings, ranging from lowest (poorest) condition "1" to highest (best) condition "5." This objectively identifies the extent of any pasture challenges and helps determine the likely causes. Evaluate each indicator separately. The indicators can then be combined into an overall score for the pasture unit or utilized as individual scores and compared with the other nine indicators. Indicators receiving the lowest scores can be targeted for corrective action. The plant vigor indicator is one of the last ones rated because previous indicators in the assessment give insight into the plant health and productivity of the pasture.

C. Indicator Descriptions: Percent Desirable Plants

(1) These are the key species that provide most of the quality forage ingested by the grazing animal being fed. The percent is calculated by dry matter weight. In this indicator assessment, determine the type and amount of plants within the pasture that the livestock will readily graze that are desirable and intermediate (figure E-46).

(i) Desirable species—Desirable species are well-adapted to the site, are readily consumed, show persistence, and provide high tonnage and quality, with sufficient fertility for a significant part of the growing season. The most desirable species may be grazed first and close to the ground in poorly managed systems, and therefore may decline in prevalence. Meanwhile, other less palatable species that can avoid grazing impacts may increase. These less-desirable species can eventually displace the desirable ones since they are grazed less, if at all. This replacement is important to this indicator and should not be overlooked when the desirability score is low. Some examples of desirable species are orchardgrass, white clover, Kentucky bluegrass, and big bluestem. Refer to your State or regional desirable plant list, and ideally, by grazing livestock type (cattle, sheep, goats) for scoring this indicator. Desirable, intermediate, and undesirable species will depend upon geographic region and livestock type.

(ii) Intermediate Species—Intermediate species are adapted to the prevailing site conditions; just as desirable species are. Intermediate species are those which, while eaten, provide low production or lose quality fast, are only eaten by certain livestock species, and often have a short-lived grazing-use period. Intermediates increase as desirable species are selectively grazed out but will be the next set of species to decrease if grazing management doesn't intervene. When adequate forage allotments are presented to livestock, the utilization rate of these species will be less than that of the desirable species. Examples of intermediates are dandelions, wild plantains, barnyard grass, and hop clover.

(iii) Undesirable Species—Undesirable species are those that typically are not eaten (rejected) by most livestock, cause undesirable side effects when eaten, or have little or no forage value. They include some woody invaders, noxious weeds, toxic plants, and plants that crowd out more desirable species. A few forages are undesirable during a specific growth stage when they produce toxins. On severely overstocked sites, such as exercise lots, undesirable species will become the only surviving plants. Examples of undesirable species are nimblewill, wild garlic, horsenettle, and buttercup. Record notes in the comment section of the scoresheet for invasive species creating plant pest pressure concerns. Some woody plants such as brush species may be present in the ratings of 1, 2, or 3 on this indicator in amounts economically impacting the herbaceous desirable species and should be noted in the rating.

**Figure E-46.** Cattle grazing desirable species.

(2) Estimate visually the proportion (percent) of desirable species present in the entire sward by dry matter weight and score accordingly. The technique of estimating dry weight through visual assessment requires training and knowledge of plant identification. The use of the step-point method is highly recommended for this indicator (figure E-45).

D. Indicator Descriptions: Percent Legume

(1) This indicator measures the average amount (percent) of legume present in a forage stand during the growing season, expressed as dry matter weight. The percent legumes present at a given time during the growing season can vary considerably, depending upon climate (especially heat), stability, and seasonal growth cycle of the legumes being assessed, the timing and severity or laxity of grazing events, and the timing and level of agronomic inputs.

(2) Legumes are important sources of nitrogen for pastures and improve the forage quality of the pasture mix when they comprise at least 20 percent of total air-dry weight of forage. Deep-rooted legumes also provide grazing during hot, dry periods in midsummer.

(3) Pastures can sometimes be limited in nitrogen, especially ones lacking enough legumes and low in organic matter. Nitrogen excreted by animals often is not distributed well due to lack of pasture management or the location of water, mineral, or shade except in some types of grazing systems such as high-density short-duration grazing. Pastures with few or no legumes will need added nitrogen for increased forage production. Legumes growing along with grasses in pastures have been shown to improve animal intake and performance.

(4) If the proportion of legumes is too high, especially legumes with bloat potential, forage consumption can cause bloat and thus be detrimental to ruminant livestock health. Legume cells rupture easily after ingestion, causing a high fermentation rate to occur in the rumen. This causes the formation of gas bubbles in a stable foam, which can lead to the rumen distending and causing lung malfunction. When bloating legumes, such as clovers and alfalfa (see your State's plant list for additional species), are greater than 40 percent of total forage dry weight, bloat incidence in ruminants is likely without preventative steps.

(5) To perform this indicator, visually estimate the percentage of legume present in the total forage biomass (figure E-47). When conducting the visual assessment on most introduced cool-season legumes – except red clover which has a higher dry weight (90 percent) and alfalfa (100 percent) – the estimate will need to be reduced by approximately 50 percent of the visual estimate when converting to a dry matter weight basis. Most legumes have their leaves in the upper part of the plant with only stems below. Thus, the upper part of the plant appears denser visually when compared to grasses which are denser at the base of the plants. For rare cases where legume percentages are greater than 40 percent of the stand, but still are less than 40 percent bloat-type legumes, rate as a 5.

**Figure E-47.** Visually estimating the percentage of legumes present.

Legumes at 6% by dry weight (approximately 10% visual wet).

Legumes at 15% by dry weight (approximately 30% visual wet).

Legumes at 27% by dry weight (approximately 50% visual wet).

E. Live Plant Cover (includes dormant)

(1) The percentage of the soil surface covered by live plants is important for pasture production and soil and water protection. This indicator rates how well the plant solar panel is working. The higher the leaf area, the higher the photosynthetic activity. A dense stand (high-stem count) of live leaf area ensures, when properly grazed, high animal intake and high sunlight interception for best forage growth. Bare, open spots allow for weed encroachment, increased water runoff during intense rains, soil erosion, and lost production. Attached, standing dead plant material can reduce forage quality, photosynthesis, and new tillering depending on the amount and height (see figure E-48).

(2) Live cover assessment can be determined at any time on continuously grazed pastures but is best done closer to optimal grazing heights. On rotational pastures, ideally estimate canopy cover of the paddock the day prior to livestock entry. This will represent the best possible condition. If cover rates fair or lower at this growth stage, management changes

are recommended. It can also be used to assess post-grazing events to determine if adequate residual is left or not.

**Figure E-48.** How good is my solar panel?

(3) Several things can influence live plant cover, especially time of year, rest period prior to review, forage present, weather conditions, and management. Forages can be easily placed into three different stages.
   (i) Stage one plants are short and immature, having high quality but low production. Stage one plants are good for being a solar panel, but they lack the surface area of stage two, which generally ends right at the early boot stage for grasses.
   (ii) Stage two has the greatest live leaf surface area and normally the best forage quality.
   (iii) The third stage has maturing vegetation of lower quality and dormant vegetation. Although this stage has the greatest volume of forage available, mature and dormant plants are performing less photosynthesis, and forage quality is less.

(4) The management factor in live plant cover is very important. Frequency of grazing, length of grazing period, stop-grazing height, stocking rates and density, length of rest period, and nutrient management are factors to be managed to achieve the highest production of quality forage for animal growth.

(5) There are times when letting the forage mature longer can certainly be a positive move, especially to grow deeper roots and potentially build soil organic matter. Dormant forage and stockpiled forage may not be the best collector of sunlight but should not be scored as the 5-point category, but could still score moderately well on the PCS scoresheet if everything else is met.

(6) Accordingly, forage stands with dead or dying intact material should be rated lower. This includes attached standing dead plant material. This material is not collecting sunlight, and it is not desirable for the livestock, although some fiber benefits occur early in the season. Too much standing dead material may cause the forage to be rejected by the grazing animal or lead to other forages being selectively grazed. Note that when forage is dormant, consider stockpile for future use.

(7) Visually estimate percent live cover of all species. Assign a value based on live green leaf canopy. If the estimate is inconclusive, or difficult to complete because of the complexity of species or stage of growth, then use the step-point method to estimate; or use a camera-based, accurate green canopy cover measurement tool.

F. Plant Diversity

(1) This indicator is done by dry matter weight. Forage production varies throughout the grazing season because of changing weather, growing degree days, management, and insect or disease pressures. Increasing diversity can help moderate negative changes. Having multiple dominant desirable forage species in a pasture offers some “insurance,” and it is more likely that something can be productive under a wide range of conditions. Warm season grasses, for example, can provide quality forage during hot, dry summer

periods for areas where adapted, when most cool-season forage tend to go dormant. Low species diversity makes pastures more vulnerable to stress and to changing conditions (see figure E-49).

(2) The plant diversity score describes the number and abundance of well-represented forage plants and functional groups. For the PCS scoresheet rating, desirable forage species must comprise more than 50 percent of the total biomass to score above a 1. Any time undesirable species outnumber desirable plant species, the score will be 1. Refer to the State or regional desirable plant list and ideally by grazing livestock type (species).

**Figure E-49.** Warm-season grasses are a functional group that when present in the system can ease summer slump periods.

(3) The PCSS considers a dominant species to be one that makes up at least 15 percent of the pasture biomass by dry weight. Dominant species contribute substantially to the total forage biomass, and having several similar dominant desirable species helps to spread the production and lower the risk.

(4) A functional group includes plant species that have similar management requirements, biological contributions, and attributes. For most of the United States, the four basic functional groups for improved pastures are cool-season grasses, warm season grasses, legumes, other grazable non-leguminous forbs (e.g., brassicas, forage chicory, dandelion) or a functional group designated by the State. A functional group is counted even if it has non-dominant species, if the group collectively makes up 15 percent of the pasture biomass.

(5) Plants from different functional groups are most compatible when they can be successfully managed together. Mixed species pastures with at least two functional groups and three or more well-represented forage species are generally the most productive. Higher total diversity within a functional group does not ensure higher productivity and may cause animals to avoid some species and graze others heavily, as species differences in palatability and maturity are more likely. The greatest benefit for the grazing system is often achieved by the addition of another functional group.

(6) Adding legumes to the stand increases protein and energy, improves forage quality, boosts production, fixes nitrogen for the grasses in the stand, are agronomically sound, environmentally friendly, and economically advantageous. The addition of forbs can provide plants with deeper roots that can bring up nutrients from deeper in the soil profile, provide some additional drought tolerance to the pasture, and often provide highly preferred species that livestock desire.

(7) Some climates may have other functional groups to assess to accomplish the desired outcomes of this indicator.

(8) The PCS scoresheet rating for diversity balances the number of dominant desirable species within a functional group and the number of functional groups to provide a score that indicates general forage productivity and manageability.

G. Plant Residue and Litter as Soil Cover

(1) Soil cover is important to slow evaporation, maintain and stabilize ideal soil temperatures, be a carbon and food source for soil life, deter erosion, and to help with water infiltration (Figure E-50). Residue is dead plant material in varying states of decay.

**Figure E-50.** Moving the cover to examine the surface for residue.

(2) Decomposing surface residue is detached plant material that typically creates a light duff layer directly on the soil surface. It is highly subject to microbial activity and is in constant flux. Litter is generally the uppermost layer of detached residue on the soil surface including freshly fallen or slightly decomposed vegetative material. This can include flattened plant material from a recent grazing event with high stock densities that may still be attached. Litter is slightly more stable for a longer period depending on the presence and amount of biological activity.

(3) In a well-managed system, some plant residue and litter should always be present. Extremely active biological systems, such as an intensely grazed dairy or beef finishing operations, where vegetation is consistently grazed in the vegetative stage, often lack enough residue and litter during much of the season. This can be resolved if needed by increasing the rest period and thus allows more trampling of mature forages onto the soil surface.

(4) Excessively high amounts of residue, especially litter, can interfere and slow down new tiller growth, and tie up nitrogen. These systems often lack enough biological activity. This can be resolved if needed by shortening the rest period, adding more diversity, especially legumes, and increasing stock density.

(5) Grazing events, grazing systems, soil biology and life, weather, and management are constantly changing and often quite fluid. The percentage of ideal cover is not exact but should be in most cases a minimum of 60 percent with good soil biological activity. The higher the requirements of microbial life, the higher amount of residue and litter is needed to support it.

(6) First assess the amount of bare soil. Cover is easily assessed during the step-point method by gently moving the aboveground plant cover to one side with your hand or foot if needed to see if soil cover is provided between plants and under the canopy (figures E-50 and E-51). The soil should be covered by either live plants and tillers or residue. Visually estimate the percent cover between live plants in the stand. The step-point method is a good quantitative way to do this.

H. Grazing Utilization and Severity

(1) The proper amount and frequency of grazing are critical in maintaining productive pastures. Close and frequent grazing causes loss of vigor, reduces density of desired species and yield, can promote erosion, and have impact on bite size and intake. Differences in species, plant maturity, stocking rate, location and distance to water, shade, and mineral availability may cause uneven grazing to occur.

**Figure E-51.** Estimate the amount of bare soil. When bare soil is easily seen it is rated a "1." This should not be common.

(2) Grazing utilization and severity are directly related to uniformity of grazing by livestock, except when continually overgrazing. Though an overgrazed pasture may look uniform, the impact of this severity places such pastures in the lowest rating. Uniform grazing results in almost all desirable and intermediate species being grazed to a targeted residual or "stop-grazing" height or slightly higher. Uniform grazing, without overgrazing, usually only exists when proper grazing management techniques are employed and especially where smaller allocations are made.

(3) Nonuniformity is spotty or patterned grazing that appears uneven throughout a pasture, with some plants or parts of paddocks grazed heavily and others grazed lightly or not at all. Individual forage species are being selected by the livestock based on their palatability, nutritional value, amounts of other forages available, and location in the pasture.

(4) Selectivity is also affected by differences in stage of maturity among species, amount of forage offered to livestock, their length of stay in the paddock, and the livestock stocking density. In most instances, livestock will readily select younger plants over more mature ones. Livestock will also usually refuse to graze where manure and urine have recently been deposited. This leads to a continuing cycle of uneven grazing patterns and reduced efficiency.

(5) Zone grazing occurs when one end of the pasture is heavily grazed, and the other end is lightly grazed or ungrazed. It often occurs on pastures with long walking distances from one end to the other, especially when shady areas, windbreaks, hay, creep, or mineral feeding and watering sites are a long distance from some parts of the field. Pastures with abrupt topography changes can also cause zone grazing.

(6) For this indicator solely visually assess. When zone grazing is occurring, along with some uneven grazing throughout, rate it a 3. Rate the pasture a 4 if the pasture is uniformly grazed to target residual heights but there is some zone grazing occurring.

(7) While understocking will lead to more selectivity and the potential for uneven grazing, continual overstocking can result in pastures being uniformly grazed (mowed lawn appearance) but to heights that are too low to maintain all the desirable species. These uniformly overgrazed pastures should be rated low on the score sheet.

I. Livestock Concentration Areas

(1) Concentration areas are places in pastures where livestock return frequently and linger near feeding areas, gates, water, mineral or salt, or shade. These areas may have reduced vegetative cover, increased bare ground, and have concentrated animal waste. Livestock trails to and from these preferred areas can create pathways that may increase erosion and become conduits for sediment, nutrients, and pathogens to nearby water bodies.

(2) This indicator addresses the potential impacts on water quality by assessing the size of the disturbed areas and the connectivity to adjacent water bodies through trailing and

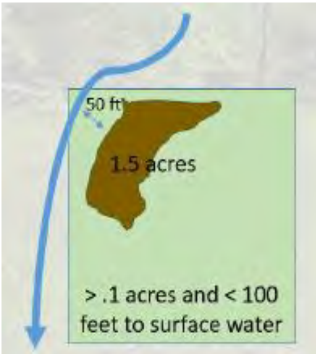
location. Livestock concentration areas near water sources or with direct conveyance to surface water can create resource concerns. Additionally, these areas on pervious soils over shallow ground water can also create water quality problems from introduced contaminants when close to adjacent waterbodies.

(3) For estimates and comparisons, one square acre is 208 feet by 208 feet, and 10 percent of that or 0.1 of an acre is 66 feet by 66 feet. When assessing pastures that are less than one acre, use 10 percent of grazing unit area as an alternative to 0.1 acres, to determine score. See examples in figure E-52.

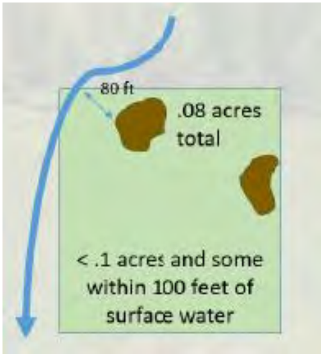
(4) Pace unknown distances and assess the amount of concentration area for this indicator.

**Figure E-52.** Examples of point ratings.

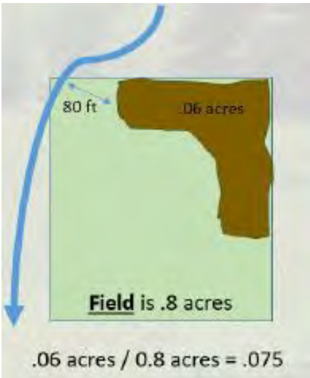
Example of a 1-point rating. Concentration areas are within 100 feet of water body and more than .1 acre in size.



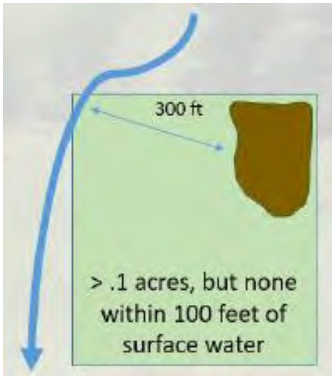

Example of a 2-point rating. Concentration areas are within 100 feet of water body and less than .1 acre in size.




Example of a 2-point rating where the field is less than 1 acre. It receives a rating of a 2.




Example of a 3-point rating. Concentration areas are greater than 100 feet of water body and more than .1 acre in size.




Example of a 4-point rating. Concentration areas are greater than 100 feet of water body and less than .1 acre in size.

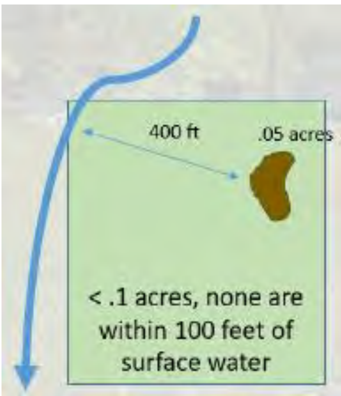


**Figure E-53.** Compaction is one of the most detrimental resource concerns.

J. Soil Compaction and Soil Regenerative Features

(1) Soil compaction is the diminished pore space between soil aggregates that hold air and water (figure E-53). Compaction reduces a pasture's ability to infiltrate water by minimizing pore space and increasing bulk density of the soils, negatively affecting hydrologic function, nutrient cycling, and the energy flow throughout the pasture ecosystem. Compaction affects the ability of plant roots to access water and nutrients. Increased runoff resulting from soil compaction creates the potential to transport contaminants such as sediment, nutrients, and pathogens to surface water, degrading water quality.

(2) Roots can be diminished by not only compacted layers, but also from overgrazing and haying. Shallow or sparse roots that do not move deeper in the soil profile, especially when there are no limiting layers, are good indicators these possible management activities are occurring.

(3) Soil regenerative features focus on the condition of plant roots and the abundance of soil life, both of which can improve important soil attributes like structure and organic matter. Soils with roots growing deep and downward have the potential to feed a large and diverse population of soil life. See figure E-54. These soil organisms can improve water-holding capacity, nutrient cycling, plant productivity, plant health and nutrient density.

(4) To evaluate, use a shovel to dig a hole in the pasture, large enough to see the indicator features.

(5) If a comparison is needed or desired, locate one hole in a protected area, such as a fence line where grazing can occur, but soil is not adversely affected by hoof action, and the other within the pasture away from the protected area and on the same soil type to compare differences in soil features. Soil features to observe and or to compare in the soil of each hole are:

**Figure E-54.** Healthy pasture soils should have good aggregates, vertical roots, and soil life.

(i) Ease of getting the shovel into the soil.
(ii) Soil structure – look for platiness and aggregates in the top twelve inches.
(iii) Rooting depth.
(iv) Root morphology and direction of growth, roots should be growing downward through the soil profile.
(v) Color-contrasting color changes in the soil with darker soil in the more biotically active upper layer.
(vi) Worms, tunnels, or other biotic presence and activity.

(6) When rating this indicator, begin with the primary sub indicators (compaction layer, then root characteristics) and use these two sub indicators as the main scoring factors, with the most adverse factor of the two sub indicators determining the score. Soil color and soil life sub indicators are secondary indicators and can be considered where applicable but used primarily for discussion with the manager and planning for improving soil health. When rating the compacted or platy layer, consider if the layer is within a zone where primary forage roots would typically extend to (not potentially).

K. Plant Vigor

(1) In simplest terms, plant vigor refers to the health of a plant. Another interpretation is the plant's robustness in comparison to others of the same species, relative to the size and age of the plant within the environment and weather where it is growing. A loss of plant vigor can cause a loss in desirable species and plant cover. Primary things to consider when rating plant vigor are color and rate of regrowth (recovery) following a grazing event, but also taking into consideration the grazing height of plants, size (density) of plants, and productivity. This indicator is purposely placed as one of the last indicators to score doing this PCS. The scorer can then use the earlier indicator scores information to better score plant vigor.

(2) Color is a major indicator of plant vigor. See figure E-55. Yellowing plants indicate drought, insect damage, or prolonged heavy usage (continuous grazing). Pale green grass plants can be indicative of low fertility or cool, wet, and poor soils and growing conditions. Fields where nitrogen-starved grasses exist will be obvious and have dark green spots under dung or urine patches with the rest of the pasture area or unit being pale in comparison. Frost-damaged plants will turn yellow or to a blue-gray cast depending on the severity of the cold damage.

(3) Leaf color can also change due to age. Older, lower leaves of plants turn yellow as they become more shaded, and nutrients are translocated from them to the younger leaves higher in the canopy. This type of progressive vigor decline on a single plant is critical to the producer timing the rotation of livestock from one pasture to the next. In general, color is a visual indicator of either mineral deficiencies or, occasionally, of over-fertilization.

**Figure E-55.** Recovery and forage color are good indicators of plant health.

(4) Over-fertilization is not separated out in this indicator but should be annotated in the notes when observed and rated a 1 if an issue. Excess applications of nitrogen can cause some major nitrate toxicity issues. A lush, lodged, very dark green-to-bluish-green grass can be indicative of over-fertilization especially by nitrogen. It can also occur where livestock have concentrated on a pasture such as at a permanent water trough or feed bunk. These spot areas are often ungrazed by livestock due to taste, smell, or post-ingestive feedback caused by low level nitrate poisoning indicators of plant health.

(5) Growth rate is a key trait of plant vigor, which is greatly affected by the management of the plant community. Plant recovery should be evaluated based on average growth rates for the plant community involved at the time of the season being rated. This is easier to evaluate on rotational pastures, because the last time an individual plant was grazed is likely to be known.

(6) Too often, the recovery period for the plants is too short. Ideally, when growth is slow, longer recovery is needed, and when growth is fast, shorter recovery is needed. Recovery is influenced by the time of year, the type of plants, and even manager goals, such as if it is planned to be used for stockpiled forage or not. It is highly influenced by how severely the pasture was used the last time it was grazed. The more severe the grazing (below recommended stop-grazing heights), the longer the recovery required. Most severe grazing occurs when a pasture is overstocked. Pasture plants when continuously grazed have little or no recovery. In contrast are pastures that are rarely grazed below stop-grazing heights and management is initiated at prime plant recovery and intake amounts. Make notes on any disease or insect stresses (pressure) on the plants. Using color as a plant vigor indicator may be difficult during a plant’s dormant season. Under such conditions, use the ratings of all indicators along with overall plant health and remaining leaf area to assist in a vigor score.

L. Erosion. Soil erosion involves the detachment, transport and redistribution of soil particles by forces of water, wind, or gravity. The types of erosion evaluated for pasture condition score are below.

(1) Sheet and Rill—Soil loss caused by water drop impact, drip splash from water dropping off plant leaves and stems onto bare soil, and a thin sheet of runoff water flowing across the soil surface. Sheet and rill erosion increase as cover decreases. Evidence of sheet erosion appears as small debris dams of plant residue that build up at obstructions or span between obstructions. Some soil aggregates or worm castings may also be washed into the debris’ dams. Rills are small, incised channels in the soil that run parallel to each other downslope. When rills appear, serious soil loss is occurring. This erosion type includes most irrigation-induced erosion.

(2) Streambank, Shoreline—When in pastures, channels or shorelines can have heightened erosion problems and loss of vegetative cover that typically grows on them. These accelerated damages can result from grazing animal traffic in or on them. Open channels may be intermittent or perennial flowing streams or dry washes. The factors that affect the extent of disturbance livestock cause to streambanks, shorelines, and their associated vegetation include:

  (i) Livestock traffic patterns.
  (ii) Frequency, duration, and intensity of use.
  (iii) Attractiveness of these channels or banks as sunning, dusting, travel lanes, watering, grazing, or rubbing areas.
  (iv) Channel shape and steepness of banks.
  (v) Water flow characteristics (frequency, depth, sediment load, velocity, and turbulence).
  (vi) Only consider erosion caused or influenced by livestock use.

(3) Wind—Wind erosion is the transport and deposition of soil from one location to another, occurring when heavier, windblown soil particles abrade, exposing soil and causing particles to become airborne. Deposition of the heavier soil particles occurs downwind of obstructions, such as fence lines, buildings, and vegetation. Often vegetative debris is

windrowed against obstructions and in extreme cases soil will abrade and smother vegetation.

(4) Gullies

(i) There are at least two type of erosion on this field. Circle both on the PCSS. The lowest rating score which accounts for the worst erosion present should be given.

**Figure E-56.** Gullies in a field.

(ii) Gullies are an advanced stage of water erosion, developing in situations where rill erosion has not been addressed. See figure E-56. Concentrated, fast-moving water can cause gully expansion through both mass soil caving along sides and head-cutting upslope, creating deep channels in the ground. Both ephemeral and advanced classic gullies should be addressed under this sub indicator. Circle or mark all erosion types found within the planning unit. Rate the indicator with the score for overall erosion as the lowest scoring point value of the erosion types.

**Table E-29.** Pasture Condition Score Sheet.

| | | | |
|---|---|---|---|
| **Operator:** | | **Date:** | |
| **Evaluator:** | | **Pasture ID:** | |
| **Soil(s), ESD(s) and or FSG(s):** | | **Livestock type:** | |
| **Current Season's Precipitation (check one)** | **Above Normal** **Normal** | **Below Normal** | |
| **Seasonal Temperature Trend (check one)** | **Above Normal** **Normal** | **Below Normal** | |
| **Evaluate the site and rate each indicator based upon your observations. Scores for each indicator may range from 1 to 5. Sum the indicator scores to determine overall pasture condition score.** | | | **Score** |

| Indicator | 1 Point | 2 Points | 3 Points | 4 Points | 5 Points | Points |
|---|---|---|---|---|---|---|
| Percent Desirable Plants* (Dry Weight; for Livestock Type) | Desirable species <20% of stand. | Desirable species 20 – 40% of stand. | Desirable species 41 – 60% of stand. | Desirable species 61 – 80% of stand. | Desirable species exceed 80% of stand. | |
| Percent Legume by Dry Weight | <5%<br>OR<br>>50% bloating legumes. | 5–10% legumes<br>OR<br>>40% bloating legume. | 11–20% legumes. | 21–30% legumes. | 31–40% legumes. No grass loss; grass may be increasing. | |
| Live (includes dormant) Plant Cover | Less than 40% is live leaf canopy. Remaining is either dead standing material, or bare ground. | 40–65% is live leaf canopy. Remaining is either dead standing material, or bare ground. | 66–80% live leaf canopy. Remaining is either dead standing material, or bare ground. | 81–95% live leaf canopy. Remaining is either dead standing material, or bare ground. | More than 95% live (non–dormant) leaf canopy. Remaining is either dead standing material, or bare ground. | |
| Plant Diversity by Dry Weight (see * footnote at end of table) | Diversity: Very low | Diversity: Low | Diversity: Moderate | Diversity: High | Diversity: Very high | |
| | <50% desirable species | 2 dominant desirable species in 1 functional group | 3 dominant desirable species in 1 functional group | 4 dominant desirable species in 2 functional groups | 4 dominant desirable species in 3 functional groups | |
| | OR | OR | OR | OR | OR | |
| | 1 dominant desirable species in 1 functional group | 2 functional groups each represented by minor species totaling ≥15% | 2–3 dominant desirable species in 2 functional groups | 3 dominant desirable species in 3 functional groups | 4 dominant desirable species in 2 functional groups AND 1 additional functional | |
| | OR | | OR | OR | | |

| Indicator | 1 Point | 2 Points | 3 Points | 4 Points | 5 Points | Points |
|---|---|---|---|---|---|---|
| | No dominant desirable species and all minor species in each functional group totaling <15% | | 3 functional groups each represented by minor species totaling ≥15% | 3 dominant desirable species in 2 functional groups AND 1 additional functional group represented by minor species totaling ≥15% | group represented by minor species totaling ≥15% | |
| Plant Residue and Litter as Soil Cover (pull back canopy) | Bare soil is very easily seen; | Openings of bare soil can be seen fairly easily; | Small openings of bare soil can be seen, but minimal; | No bare soil is easily seen; | No bare soil is seen; | |
| | There is <20% cover on the soil surface or it is excessive, and slow to break down. | Soil cover is 21–40%. | Soil cover is 41–60%. | Soil cover is 61–80%. | Soil cover is >80% with good biological activity and decomposition of older residue. | |
| Grazing Utilization and Severity | Pasture is overgrazed throughout. | Pasture consists primarily of overgrazed and/or refused areas (former dung areas, older plants, undesired plants). | Pastures show uneven grazing throughout with heavier grazing near water or feeding areas, or distinct zone grazing. | Pasture grazed evenly throughout with minimal overgrazing with some under grazed small areas and heavier use near water sources. | Pasture grazed evenly throughout with no overgrazing. | |
| Livestock Concentration Areas (if field <1 acre, see ** footnote at end of table) | Livestock concentration areas are within 100 feet of, or are a direct conveyance to surface water, and cover more than 0.1 acre, including trails. | Livestock concentration areas are within 100 feet of, or are a direct conveyance to surface water, and cover less than 0.1 acre, including trails. | Livestock concentration areas are farther than 100 feet from and are not a direct conveyance to surface water, and cover more than 0.1 acre, including trails. | Livestock concentration areas are farther than 100 feet and are not a direct conveyance to surface water, and cover less than 0.1 acre, including trails. | Livestock concentration areas, including trails, not present. | |
| Soil Compaction and Soil Regenerative Features (see *** footnote at end of table) | Compaction: Dense or thick platy layer very distinct; | Compaction: Dense or moderate platy layer noticeable; | Compaction: Thin dense or platy layer still present; | Compaction: Minor dense or platy layer; good aggregates common (crumbly soil); | Compaction: No dense or platy layers; crumbly soil throughout; | |

| Indicator | 1 Point | 2 Points | 3 Points | 4 Points | 5 Points | Points |
|---|---|---|---|---|---|---|
| Soil Compaction and Soil Regenerative Features (see *** footnote at end of table) | Roots: Dominantly horizontal; most shallow/sparse; | Roots: Numerous horizontal; moderate amount shallow/sparse; | Roots: Some horizontal with increasing downward; | Roots: Few horizontal, more downward through the soil profile; | Roots: Abundant growth primarily downward through the soil profile; | w |
| | Color: Surface horizon same as subsoil; | | Color: Surface horizon moderately darker than subsoil; | | Color: Surface horizon dramatically darker than subsoil; | |
| | Soil Life: Few or no signs. | Soil Life: Signs scattered in surface layer. | Soil Life: Signs scattered throughout. | Soil Life: Signs numerous throughout. | Soil Life: Signs abundant throughout. | |
| Plant Vigor | No plant recovery after grazing/harvest. Pale, yellow or brown, or severe stunting of desirable forage. | Some recovery. Yellowish green forage, or moderately or slight stunting of desirable forage. | Adequate recovery of desirable forage. Yellowish and dark green areas due to manure and urine patches. | Good recovery of desirable forage. Light green and dark green forage present. | Rapid recovery of desirable forage. All healthy green forage. | |
| Erosion (circle all that apply; the overall indicator score will be the lowest rating indicated) | Sheet and Rill: Plant density is insufficient to stop runoff, with poor infiltration. Erosion easily visible throughout pasture; | Sheet and Rill: Plant density slows runoff. Erosion present and easily seen on steeper terrain; | Sheet and Rill: Plant density good and runoff moderate. If present, erosion concentrated on heavily used areas; | Sheet and Rill: Plant density high, runoff low, good infiltration. May have evidence of past erosion if present; | Sheet and Rill: Plant density high, no runoff, good infiltration. No evidence of present or past erosion; | |
| Erosion (circle all that apply; the overall indicator score will be the lowest rating indicated) | Wind: Severe scoured areas and deposition throughout; | Wind: Scoured areas common, deposition effecting plants; | Wind: Occasional scoured areas, litter windrolled; | Wind: Minimal soil exposed, some detatched vegetation windrolled, minor plant damage; | Wind: No exposed soil; | |
| | Streambank and/or Shoreline: Banks bare, major sloughing, no bank vegetation; | Streambank and/or Shoreline: More than half the bank vegetation trampled; sloughing. | Streambank and/or Shoreline: Less than half the bank vegetation trampled; eroding at crossing/entrances. | Streambank and/or Shoreline: Eroding at crossings, entrances; all the bank vegetation is intact and banks are stable. | Streambank and/or Shoreline: Vegetation intact and stable, hardened crossings and alternative water sources used; | |

| Indicator | 1 Point | 2 Points | 3 Points | 4 Points | 5 Points | Points |
|---|---|---|---|---|---|---|
| | Gully: Very large mass movement, caving sides. | Gully: Advancing upslope, increasing fingering extensions. | Gully: Not all active but extensions present. | Gully: Stable with vegetative cover. | Gully: None, drainage ways vegetative. | |
| | | | | | Total points | |

* Use NRCS plant list for livestock species. Functional groups are as appropriate for your state (cool-season grasses, legumes, warm-season grasses, non-leguminous forbs). Any time there are more undesirables than desirables, it will be 1 point. Desirable species must total more than 50 percent of the total biomass. Dominant species are ≥15 percent. Functional groups must be ≥15 percent of stand to be counted.

** If field size is less than 1 ac. Use 10 percent of field size in place of 0.1 acre.

*** Use a shovel. Root and Compaction sub indicators are primary and should be considered first. Soil color and soil life are secondary sub indicators which can be considered where applicable

**Table E-30.** Overall Pasture Condition Score.

| Overall Pasture Condition Score | Individual Indicator Score | Management Change Suggested |
|---|---|---|
| 45 to 50 | 5 | No changes in management needed at this time. |
| 35 to 45 | 4 | Minor changes would enhance, do most beneficial first. |
| 25 to 35 | 3 | Improvements would benefit productivity and/or environment. |
| 15 to 25 | 2 | Needs immediate management changes, high return likely. |
| 10 to 15 | 1 | Major effort required in time, management, and expense. |

**Overall Pasture Condition Score =** ☐

## 645.0516 Determining Indicators of Pasture Health (DIPH): Technical Introduction

A. Introduction

Determining Indicators of Pasture Health (DIPH) is a detailed assessment tool and includes a matrix of indicators that can be used to determine the preponderance of evidence for three separate pastureland ecosystem attributes: biotic integrity, soil/site stability, and hydrologic function. DIPH is a similar methodology to IIRH V5 (Pellant et al. 2020), although there are specific indicators that are relevant to pastureland systems in DIPH. DIPH may be used as a standardized approach similar to IIRH to conduct a more comprehensive pasture assessment of hydrologic function, soil and surface stability, and biotic integrity.

B. Three health attributes are evaluated in both IIRH and DIPH and are designed to provide information about how well ecological processes – such as the water cycle, energy flow, and nutrient cycling – are functioning at a site. The three ecosystem attributes (soil and site stability, hydrologic function, and biotic integrity) are determined from specific indicators (some indicators are used for one or more of the three assessments) (table E-31). The methodology, DIPH, is more centric to the dynamics of the ecological site (ES). Various soil and plant variables may be different across the continuum of pasturelands in the U.S. Some pasture environments are capable of sustaining high species diversity and many different adapted forage species (including legumes) and soil biota such as earthworms, etc., while some pasture systems are limited in these respects by various environmental constraints. For example, a wide variety of cool season grasses and legumes may be grown and maintained successfully in humid cold temperate climates in New England, whereas a semiarid subtropical climate in Louisiana may only support a maximum diversity of two warm season pasture grasses (bermudagrass and Bahia grass), with no inherent introduced long-term sustainability of non-toxic legumes (which act as annuals). Therefore, rating these indicators should be evaluated with the ecological constraints associated with the ecological site.

C. Ecological site descriptions (if available) can provide valuable information about environmental parameters and reference conditions for specific indicators related to adaptability of certain forage species, legumes, invasive plants, as well as hydrology and erosion properties such as drainage, flooding, water flow paths, and propensity for rills, gullies, and erosion. Although ESD can be valuable documents that provide reference information related to climate-soils-plants-hydrology-management, both IIRH (section 7.1.4; Pellant et al. 2020) and DIPH can be used when ecological site information is not available.

D. The premise associated with IIRH and DIPH is that many unique site-specific effects and non-linear environmental relationships exist in grazingland ecosystems, and these methodologies provide a means of detecting changes in ecological attributes relative to a site's ecological potential. Toledo et al. (2016) compared the concepts of PCSS and IIRH and stated that there is a "need for an improved grazingland assessment tool that merges the relevant elements of both rangeland and pastureland assessment methods, while taking into account the differing ecosystem attributes and management objectives of the grazing lands where these methods are usually applied." Standardized grazingland assessment protocols based on ecological and land management principles would also ultimately improve national-level assessments (NRI) and would provide a valuable and efficient tool for assessing and managing grazing lands.

E. Assessment definitions:

(1) Soil/Site Stability—The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

(2) Hydrologic Function—The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

(3) Biotic Integrity—The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below the ground.

F. Table E-31 shows the commonality between IIRH and DIPH. There are common and unique indicators for DIPH as they represent specific characteristics of pasture environments. Seven livestock management factors are in DIPH to focus on issues that are specific to livestock management. Certain indicators may not have issues, such as rill, wind, gully, and streambank erosion, and percent legumes. Therefore, the field assessment process can proceed quickly. Unlike a number score used in PCSS II, the "preponderance of evidence" (Pellant et al. 2005, 2020) is used to determine the functional status of the three rangeland health attributes in DIPH. The preponderance of evidence approach is used to select the appropriate departure category for each attribute and the overall decision for each of the three attributes. This assessment is based, in part, on where the majority of the indicators for each attribute fall under the five categories (none to slight, slight to moderate, moderate, moderate to extreme, and extreme to total).

**Table E-31.** Proposed Matrix for Determining Indicators of Pasture Health (DIPH). Comparison of indicators in rangeland health matrix and proposed matrix for Determining Indicators of Pasture Health. LMQF=Livestock Management Quality Factor.

| Interpreting Indicators of Rangeland Health V 5 | Attribute | Determining Indicators of Pastureland Health | Attribute |
|---|---|---|---|
| 1. Rills | SSS, HF | Erosion (sheet and rill) | SSS, HF |
| 2. Water-flow patterns | SSS, HF | Water-flow patterns | SSS, HF |
| 3. Pedestals and/or terracettes | SSS, HF | Pedestals and/or terracettes | |
| 4. Bare ground | SSS, HF | Bare ground % | SSS, HF |
| 5. Gullies | SSS, HF | Erosion (gullies) | SSS, HF |
| 6. Wind-scoured, blowouts, and/or deposition areas | SSS | Erosion (wind) | SSS |
| | | Erosion (shoreline) if present | SSS, HF |
| 7. Litter movement | SSS | Litter movement | SSS, HF |
| 8. Soil surface resistance to erosion | SSS, HF, BI | | |
| | | Live plant foliar cover (hydrologic and erosion benefits) | SSS, HF |
| 9. Soil surface loss and degradation | SSS, HF, BI | Soil surface loss and degradation | SSS, HF, BI |
| 10. Effects of plant community composition and distribution on infiltration and runoff | HF | Effects of plant community composition and distribution on Infiltration and runoff | HF |
| 11. Compaction layer | SSS, HF, BI | Compaction layer | SSS, HF, BI |
| 12. Functional/structural groups | BI | | |
| | | Forage plant diversity | BI, LMQF |
| | | Percent desirable forage plants (for identified livestock class) | LMQF |
| 13. Dead or dying plants or plant parts | BI | Dead or dying plants or plant parts | BI |
| 14. Litter cover and depth | HF, BI | Litter cover and depth | HF, BI |
| 15. Annual production | BI | Annual production | BI, LMQF |
| 16. Invasive plants | BI | Invasive plants | BI |

| Interpreting Indicators of Rangeland Health V 5 | Attribute | Determining Indicators of Pastureland Health | Attribute |
|---|---|---|---|
| 17. Vigor with an emphasis on reproductive capability of perennial plants | BI | Plant vigor with an emphasis on reproductive capability of perennial Plants | BI |
| | | Percent non-toxic legumes (based on adaptability with ecol. site and/or what is expected stand and longevity for the site) | BI, LMQF |
| | | Uniformity of use | HF, BI, LMQF |
| | | Grazing and utilization | BI, SSS, HF, LMQF |

G. If an ES does not exist, or the pasture state narrative is not complete, the DIPH matrix can be used as a “stand-alone” document to determine indicator status. If repeated DIPH assessments are made on a specific ES, data can be collected to help develop the narrative for pasture groups and the ESD converted pasture state. In table E-31, several indicators can be evaluated with ecological aspects inherent with the ecological site. For example:

(1) Annual production capacity
(2) percent non-toxic legumes (based on adaptability associated with ES or what is the expected stand for the site)
(3) Forage plant adaptability and projected diversity
(4) Litter amount and plant residue
(5) Erosion (sheet and rill)
(6) Erosion (gullies)
(7) Erosion (wind)
(8) Water flow patterns
(9) percent bare ground
(10) Soil health attributes
(11) Dynamics of weeds and invasive plants

H. Determining Indicators of Pastureland Health Matrix (DIPH)

(1) Complete evaluation sheet (table E-32) and proceed to the DIPH evaluation matrix (table E-33). This table includes five generic descriptors for each indicator, which reflect the range of departure from expected conditions for the site: none to slight, slight to moderate, moderate, moderate to extreme, and extreme to total. Since many ESs have not developed pasture state narratives to establish reference conditions for pasture stands, the DIPH evaluation matrix is used with generic descriptors.
(2) DIPH is conducted in the field, and each indicator is evaluated based on the scale in the matrix (table E-33). Determination of preponderance of evidence would follow the same approach as used in Pellant et al. (2005, 2020). The 22 indicators are rated individually to determine the attribute ratings. The five departure categories (table E-33) reflect the collective degree of departure of the appropriate indicators as described in the DIPH matrix. Degree of departure for each attribute is then rated from the preponderance of evidence of the appropriate indicators using the worksheet for DIPH (table E-34). This assessment provides an initial rating for the three attributes (soil and site stability, hydrologic function, and biotic integrity), which may be used with other applicable quantitative monitoring and inventory data (if available). Notes can be included to support observations in the field to assist in determining ratings for soil and site stability, hydrologic function, biotic integrity, and livestock management quality factor. Table E-35 is an example of indicator ratings with evaluation and notes.

I. Review for Preponderance of Evidence (tables E-36 and E-37, example of field notes)

(1) Soil and Site Stability

Slight-to-Moderate with two Moderate Concerns. The critical indicators related to erosion are rated slight-to-moderate; however, bare ground was rated moderate-moderately higher than expected with patches sporadically connected. Many of the problems related to soil stability can be largely corrected with prescribed grazing and improvement of biotic integrity factors with pest management practices of weedy and woody species invasion.

(2) Hydrologic Function

(i) Some of the key indicators such as bare ground, annual production, litter cover and depth, invasive plants, and grazing and utilization were rated moderate. The first three indicators above are important in proving protective cover to the soil surface, which is directly correlated with rainfall interception and reducing raindrop soil splash and sheet and rill erosion. Invasive plants such as shrubs can result in loss of understory cover, but this is not a problem on this site as invasive plants were largely Canada thistles. The main concern with bare ground, annual production, and litter cover and depth at moderate rating is that evaporation rates are higher than expected, and the result is depleted water-holding capacity which will affect plant growth and production. Overall water balance is now compromised but can be remedied with the planned rest schedule.

(ii) Uniformity of use was rated mod. To extreme (little-grazed or ungrazed patches where forage species are rejected cover 26–50 percent of the area). Patches are occasionally connected, and grazing and utilization were rated moderate (pasture utilization 60–65 percent; current utilization is temporary and not representative of continual management). The pasture will be rested from July 15 to end of August, so there is no real concern about over-grazing at the present time.

(3) Biotic Integrity

(i) Biotic integrity indicators ranged from slight to moderate to moderate-to-extreme. The overall attribute rating is moderate. Where indicators are rated moderate or worse, there is cause for concern. Since plant community shifts affect the quality of forage availability, species changes also affect soil surface stability and hydrology; e.g., shifts from bunchgrass to sodgrass result in lower infiltration capacity and the prevalence of higher runoff. Improvement is needed regarding the indicators rated as moderate for BI.

(ii) Annual productivity was moderate as was litter cover and depth. Uniformity of use was rated moderate-to-extreme (little-grazed or ungrazed patches where forage species are rejected cover 26–50 percent of the area). Patches are occasionally connected because of stands of undesirable weedy species (Canada thistle and yellow mustard).

(iii) Forage plant diversity, invasive species, plant vigor, dead or dying plants or plant parts, litter cover and depth, and uniformity of use were rated moderate or worse. Legumes are not adapted, based on Ecological site. Two dominant grass spp. And Canada thistles in overgrazed areas with yellow mustard. Overall plant diversity is low, compared to site potential and species that are adapted to this site. Invasive weed management is needed.

**Table E-32.** Determining Indicators of Pasture Health Evaluation Sheet.

| **Determining Indicators of Pasture Health Evaluation Sheet** | | | |
|---|---|---|---|
| Evaluation Sheet ID (Landowner, Farm, Ranch etc.) | | Date: | |
| Management Unit: | Office: | | |
| Observers: | | | |
| Ecological site ID and Code: | | | |
| Pasture State Narrative (Y/N): | | | |
| Soil Survey: | Map Unit: | Soil Component: | |
| Surface Soil Texture: | | | |
| Position by GPS? Y/N: | Photos taken? Y/N: | | |
| GPS Location: | | | |
| | | | |
| Location Description: | | | |
| Township: | Range: | Section: | ¼ Section: |
| Pasture Size (ac): | How many DIPH samples needed? | | |
| Size (ac) represented by DIPH sample: | | | |
| Criteria used to select evaluation area: | | | |
| Natural Disturbances (list): | | | |
| Land treatments or conservation practices applied: | | | |
| | | | |
| Resource Concerns: | | | |
| | | | |
| | | | |
| Historic Grazing Intensity (Low, Mod, High): | Current Grazing Intensity (Low, Mod, High): | | |
| Grazing System: | | | |
| Haying History: | | | |
| Offsite Influences on Pasture: | | | |
| | | | |
| | | | |
| Evaluation Area description Data | | | |
| Slope | Slope Shape (concave, convex, linear) | Aspect | |
| Elevation: | | | |
| Avg. Annual Precipitation (in or cm) | Precipitation Range (in or cm): | | |
| Precipitation to Date: (Below, Normal, Above) | Pct. Of normal precipitation received to date: | | |
| Seasonal Climate Notes: | | | |
| | | | |
| | | | |
| Dominant forage species and estimated composition: | | | |
| | | | |
| | | | |
| Supporting Data for Range and Pasture Hydrology Model | | | |
| Representative Climate Station: | Bare ground (%): | | |
| Foliar Cover (% composition): Bunchgrasses ( ); Sodgrasses ( ); Annual Grasses/Forbs ( ); | | | |
| Perennial Forbs ( ); Shrubs ( ); Trees ( ); Other Vines ( ) | | | |
| Ground Cover (%) litter ( ); rock ( ); biotic crusts ( ); basal plant cover ( ) | | | |
| Remarks and Notes: | | | |

**Table E-33.** Evaluation matrix used to rate the 22 indicators and five departure categories of the three attributes of pastureland health.

| Indicators | Extreme-to-Total | Moderate-to-Extreme | Moderate | Slight-to-Moderate | None-to-Slight |
|---|---|---|---|---|---|
| 1. Erosion (sheet and rill) | Numerous and frequent throughout. Nearly all rills are wide, deep and long. Occur in exposed and vegetated areas. | Moderate in number at frequent intervals. Many rills are wide, deep, and long. Occur in exposed areas and in some adjacent vegetated areas. | Moderate in number at infrequent intervals. Moderate rill width, depth, and length. Occur mostly in exposed areas, and steeper slopes. | Scarce and scattered. Minimal rill width, depth, and length. Occur in exposed areas, and steeper slopes. | Current or past formation of rills – none. |
| 2. Erosion (gullies) | Sporadic or no vegetation on gully banks and/or bottom. Numerous nick points. Significant active bank and bottom erosion, including downcutting. Substantial depth and/or width. Active headcuts may be present. | Intermittent vegetation on gully banks and/or bottom. Nick points common. Moderate active bank and bottom erosion, including downcutting. Significant width and/or depth. Active headcuts may be present. | Occasional vegetation on gully banks and/or bottom. Occasional nickpoints and/or slight downcutting. Moderate depth and/or width. Active headcuts absent. | Vegetation on most gully banks and/or bottom. Few nickpoints and/or minimal downcutting. Minimal gully depth and/or width. Headcuts absent. | None |
| 3. Erosion, Wind-Scoured and/or Depositional Areas | Extensive. Wind blowouts/scours usually connected. Large soil depositions around obstructions. | Common. Wind scours frequently connected. Moderate soil depositions around obstructions. | Occasionally present. Wind scours infrequently connected. Minor soil deposition around obstructions. | Infrequent and few. Wind scours rarely connected. Trace amounts of soil deposition around obstructions. | None or as expected in reference ESD |
| 4. Erosion (streambank or shoreline) | Banks bare, major vertical down cutting, major sloughing, little or no bank vegetation. Hydrology of riparian system severely altered. | More than half the expected bank vegetation absent, veg. trampled; sloughing and vert. banks active erosion. Hydrology of riparian system highly altered. | About half the bank vegetation trampled; active sloughing and downcutting. Hydrology of riparian system moderately altered. | Some indication of trampled bank vegetation, active sloughing downcutting, or vertical slopes are minimal. Hydrology of riparian system slightly altered. | Bank vegetation intact, minimal trampling and/or sloughing. |
| 5. Water Flow Patterns | Extensive. Long and wide. Erosional and/or depositional areas widespread. Usually connected. | More numerous and widespread. Longer and wider than expected. Erosional and/or depositional areas common. Occasionally | Lengths and/or widths slightly to moderately higher than expected. Minor to moderate erosional and/or depositional areas. | Length and width nearly match expected. Some minor erosional and/or depositional areas. Rarely connected. | Natural, well vegetated, or as described in ESD |

| Indicators | Extreme-to-Total | Moderate-to-Extreme | Moderate | Slight-to-Moderate | None-to-Slight |
|---|---|---|---|---|---|
| | | connected. | Infrequently connected. | | |
| 6. Bare Ground (%) | Substantially higher than expected. Bare ground patches are large and frequently connected. | Much higher than expected. Major bare ground patches throughout stand, large and occasionally connected. | Moderately higher than expected. Bare ground patches are moderate in size and sporadically connected. | Slightly higher than expected. Bare ground patches are small and rarely connected. | Amount and size of bare areas match that expected for the site. Else, no bare ground in stand. |
| 7. Pedestals and/or Terracettes | Pedestals extensive; roots frequently exposed. Terracettes, if present, are widespread. | Pedestals widespread; roots commonly exposed. Terracettes, if present, are common. | Pedestals common; roots occasionally exposed. Terracettes, if present, are uncommon. | Pedestals uncommon; roots rarely exposed. Terracettes scarce. | None<br>Terracettes, none |
| 8. Litter Movement (wind or water) | Extreme movement of all size classes (including large). Significant accumulations around obstructions or in depressions. | Moderate to extreme movement of small to moderate size classes. Moderate accumulations around obstructions or in depressions. | Moderate movement of mostly small size classes. Small accumulations around obstructions or in depressions. | Slight movement of small size classes. Minimal or no accumulations around obstructions or in depressions. | None or as described in ESD |
| 9, Effects of Plant Community Composition and Distribution on Infiltration and Runoff<br>* Assume that decreased infiltration causes a corresponding increase in runoff. Indicator 9 is correlated with Indicator 10 | Changes in plant community (functional/structural groups) composition and/or distribution are associated with severe reduction in infiltration and a significant increase in runoff. | Changes in plant community (functional/ structural groups) composition and/or distribution are associated with significantly or greatly decreased infiltration and a large increase in runoff. | Changes in plant community (functional/structural groups) composition and/or distribution are associated with moderate reduction in infiltration and a moderate increase in runoff | Community (functional/ structural groups) composition and/or plant distribution are associated with moderate reduction in infiltration and slight to moderate increase in runoff. | Infiltration and runoff are as expected for pasture state in S&T model. Plant composition and corresponding soil physical properties are not impeding infiltration |
| 10. Soil Surface Loss or Degradation | Soil surface horizon very thin to absent throughout. Soil surface structure similar to or more degraded than subsurface. No distinguishable difference between | Severe soil loss and/or degradation throughout. Minor differences in soil organic matter content and structure between surface and subsurface layers. | Moderate soil loss and/or degradation in plant interspaces with some degradation beneath plant canopies. Soil organic matter content is markedly | Slight soil loss and/or soil structure shows slight signs of degradation, especially in plant interspaces. Minor change in soil organic matter content. | No apparent soil loss or degradation (Reference ESD narrative) |

| Indicators | Extreme-to-Total | Moderate-to-Extreme | Moderate | Slight-to-Moderate | None-to-Slight |
|---|---|---|---|---|---|
| | surface and subsurface organic matter content. | | reduced. | | |
| 11. Compaction Layer | Extensive and/or strongly developed (thickness and density); may severely restrict root penetration and infiltrability. | Widespread and/or moderately to strongly developed (thickness and density); may greatly restrict root penetration and infiltrability. | Moderately widespread and/or moderately developed (thickness and density); may moderately restrict root penetration and infiltrability. | Not widespread and/or weakly developed (thickness and density); may weakly restrict root penetration and infiltrability. | No apparent compaction. |
| 12. Live Plant Foliar Cover (hydrologic and erosion benefits)[1] | Less than 40% live foliar cover. Remaining is either dead standing material or bare ground. | 40–60% live foliar cover. Remaining is either dead standing material or bare ground. | 60–75% live foliar cover. Remaining is either dead standing material or bare ground. | 75–95% live foliar cover. Remaining is either dead standing material or bare ground. | More than 95% live foliar cover. Remaining is either dead standing material or bare ground. |
| 13. Forage Plant Diversity Note: (Legumes' adaptability based on what is expected for site in ESD) | Diversity severely lacking in comparison with site potential and/or with management objectives. | Low diversity in comparison with site potential and/or plant diversity not in accordance with management objectives. | Moderate diversity in comparison with site potential and/or plant diversity is not optimum with management objectives. | Diversity slightly decreased in comparison with site potential and/or plant diversity is somewhat lacking with management objectives. | High diversity of desirable forage plants in stand and/or plant diversity in full accordance with management objectives. |
| 14. Percent Desirable Forage Plants (for identified livestock class) | Desirable forage species <20% dry weight. | Desirable forage species 20–40% dry weight. | Desirable forage species 40–60% dry weight. | Desirable forage species 60–80% dry weight. | Desirable forage species exceed 80% dry weight. |
| 15. Invasive Plants | Invasive species dominate the site. | Invasive species common throughout the site. | Invasive species scattered throughout the site. | Invasive species present in infrequent disturbed areas within the site. | Invasive species rare, except in very infrequently disturbed areas. |
| 16. Annual Production | Less than 20% of potential production. Considering recent | 21–40% of potential production. Considering recent | 41–60% of potential production. Considering recent | 61–80% of potential production. Considering recent | Annual production >80% of potential. Considering recent |

[1] To define all possible undesirables (invasives, shrubs, and other weedy herbaceous forbs would be difficult). 60 percent cover has been shown to be the breakpoint of foliar cover where soil surface is relatively protected (Gifford 1985; Thurow 1986).

| Indicators | Extreme-to-Total | Moderate-to-Extreme | Moderate | Slight-to-Moderate | None-to-Slight |
|---|---|---|---|---|---|
| | weather conditions | weather conditions | weather conditions | weather conditions | weather conditions |
| 17. Plant Vigor with an Emphasis on Reproductive Capability of Perennials | Plant reproduction and/or recovery after use is extremely reduced.<br>Pale, yellow or brown, or severely stunted plants. | Plant reproduction and/or recovery after use is greatly reduced.<br>Yellowish green forage, or moderately or slightly stunted plants. | Plant reproduction and/or recovery after use is moderately reduced.<br>Adequate recovery.<br>Yellowish and dark green areas due to manure and urine patches. | Plant reproduction and/or recovery is slightly-to-moderately reduced after use.<br>Good recovery. Light green and dark green plants present | Plant reproduction and/or recovery is what is expected for the site.<br>Rapid recovery. All healthy green plants. |
| 18. Dead or Dying Plants or Plant Parts | Extensive mortality and/or dying plants/plant parts concentrated in one or more functional groups. | Widespread mortality and/or dying plants/plant parts concentrated in one or more functional groups. | Moderate mortality and/or dying plants/plant parts concentrated in one or more functional groups. | Occasional mortality and/or dying plants/plant parts concentrated in one or more functional groups. | No apparent mortality and/or dying plants/plant or plant parts. |
| 19. Litter Cover and Depth | Accumulation of litter cover and depth, and decomposition extremely out of balance with current weather conditions. | Accumulation of litter cover and depth, and decomposition mod-to-extremely out of balance with current weather conditions. | Accumulation of litter cover and depth, and decomposition moderately out of balance with current weather conditions. | Accumulation of litter cover and depth, and decomposition slightly out of balance with current weather conditions. | Accumulation of litter cover and depth, and decomposition as expected for the site, and with current weather conditions. |
| 20. Percentage Nontoxic Legumes[2]<br>Note: if bloating legumes dominate the stand-by weight, rating = Extreme to Total. Substantial risk to livestock with and without bloat prevention protocols. Fields with high legume composition should be considered | If ES Altered Pasture State supports legumes, stands have less than 2% by weight<br>and/or<br>legume composition extremely out of balance with management objectives. | If ES Altered Pasture State supports legumes, stands have 2–5% by weight<br>and/or<br>legume composition mod-to-extremely out of balance with management objectives. | If ES Altered Pasture State supports legumes, stands have 5–15% by weight<br>and/or<br>legume composition moderately out of balance with management objectives. | If ES Altered Pasture State supports legumes, stands have 15–30% by weight<br>and/or<br>legume composition slightly out of balance with management objectives. | If ES Altered Pasture State supports legumes, stands have 30–35% by weight<br>and/or<br>legume use in accordance with management objectives. |

[2] Note: some literature mentions maximum legume comp. at 40-50 percent to minimize bloat potential.

| **Indicators** | **Extreme-to-Total** | **Moderate-to-Extreme** | **Moderate** | **Slight-to-Moderate** | **None-to-Slight** |
|---|---|---|---|---|---|
| for hayland. | | | | | |
| 21. Uniformity of Use | Little-grazed or ungrazed patches where forage species are rejected cover over 50% of the area. Rejected patches are generally connected.<br>Or<br>Uniform use due to overutilization. | Little-grazed or ungrazed patches where forage species are rejected cover 26 to 50% of the area. Patches are occasionally connected. | Little-grazed or ungrazed patches where forage species are rejected cover 10 to 25% of the area. Patches sporadically connected. | Light-grazed or ungrazed and unconnected patches where forage species are rejected are small and isolated (<10% cover). Urine and dung patches avoided. | Uniform grazing throughout pasture. Areas where forage species are rejected only present at urine and dung patches. |
| 22. Grazing and Utilization<br>Note: Utilization percentages can be temporarily adjusted in grazing rotation systems given that rest and/or deferment are planned. | Pasture severely overgrazed (>70% utilization), plant height continually below recommended graz. Ht. for spp.<br>Livestock concentration areas > 10% of the pasture and transport contaminated runoff can directly into water channels unbuffered. | Pasture utilization 65–70%, plant height is continually below recommended graz. Ht. for spp.<br>Livestock concentration areas and trails cover 5–10% of the area and drain into water channels unbuffered. | Pasture utilization 60–65%; current utilization is temporary and not representative of continual management.<br>Isolated and unconnected livestock concentration areas and trails (<5% of area); can potentially drain into water channels unbuffered. | Pasture utilization 50–60%; plant height generally meets recommended graz. Ht. for spp.<br>Some livestock trails and one or two small unconnected concentration areas. | Pasture utilization =<50%; plant ht. meets recommended graz.ht. for spp.<br>No presence of livestock concentration areas or heavy use areas. |

**Table E-34.** DIPH evaluation sheet (Part A) for preponderance of evidence with notes on field observations.

| Preponderance of Evidence | Attribute | Rating | Field Obs., Notes and Comments |
|---|---|---|---|
| Erosion (Sheet and Rill) | SSS, HF | | |
| | | | |
| Erosion (Gullies) if present | SSS, HF | | |
| Erosion (Wind) if present | SSS, HF | | |
| Erosion (Streambank/shoreline) if present | SSS, HF | | |
| Water-flow Patterns | SSS, HF | | |
| Bare ground % | SSS, HF | | |
| Pedestals and Terracettes | SSS, HF | | |
| Litter Movement | SSS, HF | | |
| Effects of Plant Community Composition and Distribution on Infiltration and Runoff | HF | | |
| Soil Surface Loss or Degradation | SSS, HF, BI | | |
| Compaction Layer | SSS, HF, BI | | |
| Live Plant Foliar Cover (hydrologic and erosion benefits) | SSS, HF | | |
| Forage Plant Diversity | BI, LMQF | | |
| Percent Desirable Forage Plants (for identified livestock class) | LMQF | | |
| Invasive Plants | HF, BI, LMQF | | |
| Annual production | BI, LMQF | | |
| Plant Vigor with an Emphasis on Reproductive Capability of Perennial Plants | BI | | |
| Dead or Dying Plants or Plant Parts | BI | | |
| Litter Cover and Depth | HF, BI | | |
| Percent non-toxic Legumes (based on adaptability of Ecol. Site and/or what is expected stand for the site) | BI, LMQF | | |
| Uniformity of Use | HF, BI, LMQF | | |
| Grazing and Utilization | BI, SSS, HF, LMQF | | |

**Table E-35.** DIPH evaluation sheet (Part B) for determination of preponderance of evidence.

| Preponderance of Evidence | Attribute | E to T | M to E | Mod | S to M | N to S |
|---|---|---|---|---|---|---|
| Erosion (Sheet and Rill) | SSS, HF | | | | | |
| Erosion (Gullies) if present | SSS, HF | | | | | |
| Erosion (Wind) if present | SSS, HF | | | | | |
| Erosion (Streambank/shoreline) if present | SSS, HF | | | | | |
| Water-flow Patterns | SSS, HF | | | | | |
| Bare ground % | SSS, HF | | | | | |
| Pedestals and Terracettes | SSS, HF | | | | | |
| Litter Movement | SSS, HF | | | | | |
| Effects of Plant Community Composition and Distribution on Infiltration and Runoff | HF | | | | | |
| Soil Surface Loss or Degradation | SSS, HF, BI | | | | | |
| Compaction Layer | SSS, HF, BI | | | | | |
| Live Plant Foliar Cover (hydrologic and erosion benefits) | SSS, HF | | | | | |
| Forage Plant Diversity | BI, LMQF | | | | | |
| Percent Desirable Forage Plants (for identified livestock class) | LMQF | | | | | |
| Invasive Plants | HF, BI, LMQF | | | | | |
| Annual production | BI, LMQF | | | | | |
| Plant Vigor with an Emphasis on Reproductive Capability of Perennial Plants | BI | | | | | |
| Dead or Dying Plants or Plant Parts | BI | | | | | |
| Litter Cover and Depth | HF, BI | | | | | |
| Percent non-toxic Legumes (based on adaptability of Ecol. Site and/or what is expected stand for the site) | BI, LMQF | | | | | |
| Uniformity of Use | HF, BI, LMQF | | | | | |
| Grazing and Utilization | BI, SSS, HF, LMQF | | | | | |

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
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| Soil & Site Stability Attribute Rating | | | | |
| | | | | |

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
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| Hydrologic Function Attribute Rating | | | | |
| | | | | |

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
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| | | | | |
| Biotic Integrity Attribute Rating | | | | |
| | | | | |

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | | |
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| | | | | |
| Livestock Management Quality Factor (LQMF Rating) | | | | |
| | | | | |

| Notes |
|---|
| |

**Table E-36.** Example DIPH evaluation sheet (Part A) for preponderance of evidence with notes on field observations.

| Preponderance of Evidence | Attribute | Rating | Field Obs., Notes and Comments |
|---|---|---|---|
| Erosion (Sheet and Rill) | SSS, HF | SM | Evidence of past rills and gullies but vegetated and healed at present. Some rilling in livestock trails and along vehicle trail. |
| Erosion (Gullies) if present | SSS, HF | SM | Observed old past gullies, vegetated with graminoids and woody plants |
| Erosion (Wind) if present | SSS, HF | NS | No wind erosion observed |
| Erosion (Streambank/shoreline) if present | SSS, HF | N/A | No shorelines associated with field |
| Water-flow Patterns | SSS, HF | SM | Some water flow patterns have merged due to a high runoff event, signs of litter movement and debris dams against shrub bases |
| Bare ground % | SSS, HF | M | Expected bare ground <5%. Estimated bare ground 10–15%. Some bare ground patches connected |
| Pedestals and Terracettes | SSS, HF | SM | Some pedestals observed in water flow channels, some debris dams formed by recent runoff event |
| Litter Movement | SSS, HF | SM | Some litter and mulch movement in water flow channels observed |
| Effects of Plant Community Composition and Distribution on Infiltration and Runoff | HF | SM | Trend appears to be moving toward Kentucky bluegrass in overgrazed areas, replacing bunchgrass, primarily orchardgrass. Sod forming species are associated with decreased infiltrability (See Subpart G) |
| Soil Surface Loss or Degradation | SSS, HF, BI | SM | Some surface soil loss associated with history of cultivation in the past. Organic matter was undoubtedly lost during cultivation |
| Compaction Layer | SSS, HF, BI | SM | Compaction observed, mostly along livestock trails, fencelines, gate areas |
| Live Plant Foliar Cover (hydrologic and erosion benefits) | SSS, HF | SM | Plant foliar cover 85–90%, not optimum, but adequate for interception of raindrops |
| Forage Plant Diversity | BI, LMQF | ME | Forage diversity has declined from desirable bunchgrasses to sod forming K. bluegrass dominating site. Some Canadian thistles in overgrazed areas, and scattered Multiflora rose |
| Percent Desirable Forage Plants (for identified livestock class) | LMQF | ME | A transition is in progress and shifting from bunchgrasses to sodgrass. Weedy forbs such as mustards, sowthistle, prickly lettuce common, with multiflora rose and Canadian thistle patches |
| Invasive Plants | HF, BI, LMQF | M | Invasive species increasing such as Canadian thistle, multiflora rose in areas, and undesirable weedy forbs. Can be controlled, but action needed before threshold crosses to Mod to Ex. |
| Annual production | BI, LMQF | M | Annual production has decreased to about 50% of potential production due to increasing composition of Kentucky bluegrass and weedy forbs |
| Plant Vigor with an Emphasis on Reproductive Capability of Perennial Plants | BI | M | Vigor and composition of orchardgrass has diminished, and K. bluegrass gaining dominance in pasture. |

| Preponderance of Evidence | Attribute | Rating | Field Obs., Notes and Comments |
|---|---|---|---|
| Dead or Dying Plants or Plant Parts | BI | M | Observations conclude that orchardgrass plants are yellowing and dying due to moisture stress. K. bluegrass is very efficient at usurping available water with dense surface fibrous roots (see Subpart E) |
| Litter Cover and Depth | HF, BI | M | No litter cover in bare ground areas, overall ground cover of litter is < 2% |
| Percent non-toxic Legumes (based on adaptability of Ecol. Site and/or what is expected stand for the site) | BI, LMQF | ME | Legume composition <5%. Legumes' diversity reduced; dominant remaining legume is white clover. Area outside fence has higher legume composition and red clover. |
| Uniformity of Use | HF, BI, LMQF | M | Grazing distribution uneven, high use around pond area, uneven use extending from water source. Pond banks are experiencing sloughing due to high use. |
| Grazing and Utilization | BI, SSS, HF, LMQF | ME | Pasture grazing levels have exceeded moderate grazing. Heavy use around pond and extending from water source. Utilization about 70% in grazed areas. |

**Table E-37.** Example DIPH evaluation sheet (Part B) for determination of preponderance of evidence.

| Preponderance of Evidence | Attribute | E to T | M to E | Mod | S to M | N to S |
|---|---|---|---|---|---|---|
| Erosion (Sheet and Rill) | SSS, HF | | | | ✓ | |
| Erosion (Gullies) if present | SSS, HF | | | | ✓ | |
| Erosion (Wind) if present | SSS, HF | | | | | ✓ |
| Erosion (Streambank/shoreline) if present | SSS, HF | | | | | N/A |
| Water-flow Patterns | SSS, HF | | | | ✓ | |
| Bare ground % | SSS, HF | | | ✓ | | |
| Pedestals and Terracettes | SSS, HF | | | | ✓ | |
| Litter Movement | SSS, HF | | | | ✓ | |
| Effects of Plant Community Composition and Distribution on Infiltration and Runoff | HF | | | | ✓ | |
| Soil Surface Loss or Degradation | SSS, HF, BI | | | | ✓ | |
| Compaction Layer | SSS, HF, BI | | | | ✓ | |
| Live Plant Foliar Cover (hydrologic and erosion benefits) | SSS, HF | | | | ✓ | |
| Forage Plant Diversity | BI, LMQF | | ✓ | | | |
| Percent Desirable Forage Plants (for identified livestock class) | LMQF | | ✓ | | | |
| Invasive Plants | HF, BI, LMQF | | | ✓ | | |
| Annual production | BI, LMQF | | | ✓ | | |
| Plant Vigor with an Emphasis on Reproductive Capability of Perennial Plants | BI | | | ✓ | | |
| Dead or Dying Plants or Plant Parts | BI | | | ✓ | | |
| Litter Cover and Depth | HF, BI | | | ✓ | | |
| Percent non-toxic Legumes (based on adaptability of Ecol. Site and/or what is expected stand for the site) | BI, LMQF | | ✓ | | | |
| Uniformity of Use | HF, BI, LMQF | | | ✓ | | |
| Grazing and Utilization | BI, SSS, HF, LMQF | | ✓ | | | |

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 1 | |
| | | | 2 | |
| | | | | 3 |
| | | | | |
| | | | 5 | |
| | | 6 | | |
| | | | 7 | |
| | 22 | | 8 | |
| | | | 10 | |
| | | | 11 | |
| | | | 12 | |

Soil & Site Stability Attribute Rating
S-M with some M-ME concerns

Evidence of past rills and gullies but vegetated at present. #14 community comp. shifting from bunch to sod forming grasses

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 1 | |
| | | | 2 | 3 |
| | | | | |
| | | 6 | 5 | |
| | | 15 | 7 | |
| | | 16 | 8 | |
| | | 19 | 9 | |
| | | 21 | 10 | |
| | 22 | | 11 | |
| | | | 12 | |
| | | | | |

Hydrologic Function Attribute Rating
M

Bare ground patches connected, grazing dist. Heavy near watering area and fencelines. Some rilling in livestock trails and along vehicle trail.

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | | | 10 | |
| | | | 11 | |
| | 13 | | | |
| | | 15 | | |
| | | 16 | | |
| | | 17 | | |
| | | 18 | | |
| | | 19 | | |
| | 20 | | | |
| | | 21 | | |
| | 22 | | | |

Biotic Integrity Attribute Rating
M with ME concerns

Legumes' diversity reduced; dominant legume is white clover. Some Canadian thistles in overgrazed areas, and scattered Multiflora rose, diversity low. Shifting grass comp. from bunchgrasses to sodgrasses.

Notes: Salt placement by watering area. Livestock use, trails to pond and along fence lines. Forage plant diversity could be improved by controlling Undesirable weedy plants. Bunchgrasses are decreasing in stand, invasive shrubs scattered throughout pasture. SOM somewhat depleted from past cropping history and water erosion events. About 50% of Soil aggregates dispersed in water.

| E-T | M-E | M | S-M | N-S |
|---|---|---|---|---|
| | 13 | 15 | | |
| | 14 | 16 | | |
| | 20 | | | |
| | | 21 | | |
| | 22 | | | |
| | | | | |
| Livestock Management Quality Factor<br>LQMF Rating M to ME | | | | |

## 645.0517 Monitoring

A. Introduction

(1) Monitoring is the orderly repeated collection, analysis, and interpretation of resource information data. It can be used to make both short- and long-term management decisions (Perryman et al. 2004). Short term monitoring, for example, could be conducted to quantify the amount of forage used during a grazing event, whereas long term monitoring can be conducted to quantify the extent and direction of change within a plant community on an ecological site.

(2) Monitoring is important to evaluate changes over time in ecological process, in evaluating management actions or the effectiveness of a conservation plan. It is a part of Step 9 of the NRCS nine steps of conservation planning. Monitoring is part of a broader process in which data is used to test and refine management decisions and allow the collective knowledge of scientists and land managers to improve resource management (Herrick et al. 2009).

(3) Determining what and where to monitor are probably the most time-consuming components of developing a monitoring program (Allison et al. 1951, 1961). Some purposes to monitor can include:
(i) To determine the effectiveness of management practices.
(ii) Determining if forage supply and demand are in balance.
(iii) Documenting the effect of livestock grazing on natural resources.
(iv) Documenting effectiveness of movement toward a desired condition.
(v) Documenting reasons for range and pasture conditions.
(vi) Gaining a better understanding of resources and their management.
(vii) Using the information gathered to provide for adaptive management strategies.

(4) Some agencies have been transitioning toward implementing monitoring methods that are quantitative, repeatable, and statistically rigorous which involves training and calibrating observers (Burkett 2021). Factors that may dictate measurement of different attributes and/or different methods include vegetation type, management objectives and concerns, time and money available, qualifications of personnel, and other factors (Smith et al. 2012).

B. Uses on all grazing lands

(1) The Monitoring Manual for Grassland, Shrubland and Savannah Ecosystems, Core Methods Volume 1 Second edition and Design, supplementary methods and interpretations Volume 2 (Herrick et al. 2017) will be used as the standard reference for inventory and monitoring methods on rangeland, pastureland and grazed forestland which are also used in the NRCS National Resources Inventory (NRI). https://jornada.nmsu.edu/monit-assess/manuals/monitoring.

(2) The Utilization Studies and Residual Measurements, Interagency Technical Reference 1999, is a guide to provide the basis for consistent, uniform, and standard utilization studies and residual measurements that are economical, repeatable, statistically reliable, and technically adequate. https://www.blm.gov/sites/blm.gov/files/documents/files/Library_BLMTechnicalReference1734-03.pdf.

(3) *Riparian Area Management-Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation* (Technical Reference 1737-23) is a reference to provide information necessary for land managers to adaptively manage riparian resources. The MIM protocol is designed to be objective, efficient and effective for monitoring streambanks, stream channels, and streamside riparian vegetation primarily from impacts of livestock and other large herbivores on wadable streams. MIM protocol integrates annual grazing use and long-term trend indicators allowing for evaluation of livestock grazing management, with the long-term indicators being useful for monitoring changes occurring on the streambank and in the channel as a result of management activities other

than grazing. For more information see https://www.blm.gov/documents/national-office/blm-library/technical-reference/multiple-indicator-monitoring-mim-stream.

(4) Some of the remote sensing resources listed in this subpart [NRPH Subpart E 645.0501 D (4)] can be used for monitoring purposes. They can be used in combination with on-site vegetation measurements to provide perspective and context for rangeland monitoring across entire grazing units or ranches. Examination of trends in vegetation on watershed, county, or landscape scales is relatively easy with the remote sensing products that have recently become widely accessible. Remote sensing can be used to monitor and evaluate the effects of current or past disturbances and management practices.

When incorporating remote sensing into monitoring plans, remember that:

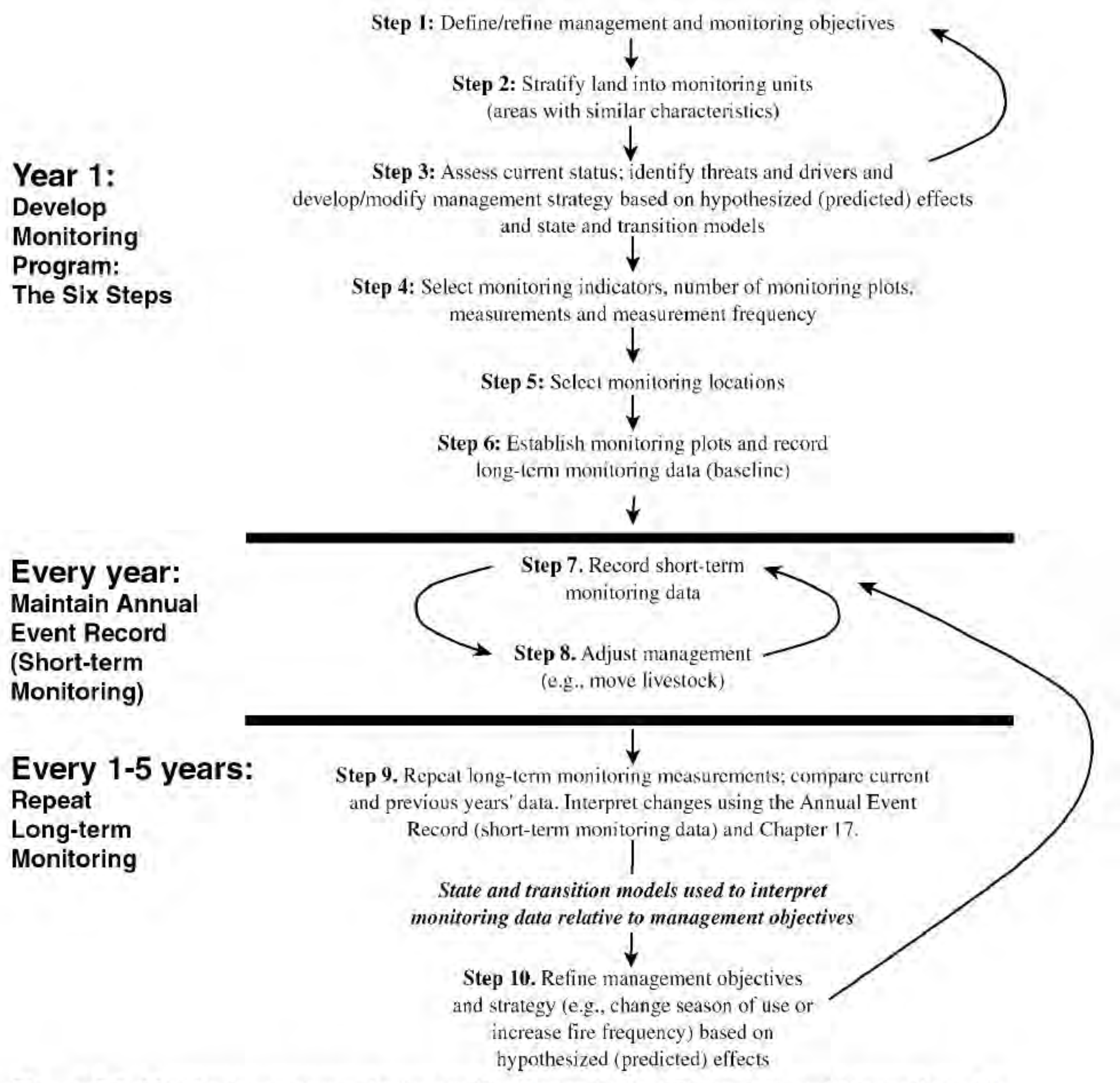
- Remote sensing does not identify plant species, only plant groups (i.e., perennial grasses and forbs, annuals, shrubs, trees, etc.).
- The trends shown by remote sensing are reliable, even though absolute values of percent cover or reported production may not always be accurate.
- Remote sensing is very effective for displaying the spatial variability of cover and production across a grazing unit, which is very useful when interpreting and extrapolating on-site vegetation measurements.

C. Developing a Monitoring Program—The Six Steps

Six steps are generally needed to design and implement a long-term ecosystem-based monitoring program. Each of the six steps are illustrated in the flow chart (figure E-57) and listed in their own chapters in Volume II of the Monitoring Manual (Herrick 2017). The steps are listed in the order they are normally completed, but because there is no single way to design a monitoring program, revisiting earlier steps is often helpful.

For example, the assessments completed in Step 3 often reveal issues that lead to new management and monitoring objectives (Step 1). State-and-transition models can be helpful here by focusing attention on areas that are at risk or have a high potential for recovery. It is also helpful to redefine management and monitoring objectives (Step 1).

**Figure E-57.** Gullies in a field monitoring program design and implementation (Steps 1–6) and integration with management (Steps 7–10) (Herrick et al. 2005).



## 645.0518 Monitoring Methods

Several materials, procedure, and calculation instructions for the methods listed in this section are described in the *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, Volumes I and II* (Herrick et al. 2005). Follow the recommendations in the manual for plot size, sampling size, transect length and shape, and data interpretations if one of these methods are selected. Sampling sites should be geospatially located and mapped on the conservation plan map.

(i) Line-Point Intercept:

- Line-point intercept is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biological crusts. See tables E-62 and E-63 for the Line-Point Intercept Data Sheet and Data Sheet Example. These measurements are related to wind and water erosion, water infiltration, and the ability of the site to resist and recover from disturbance. Line-point intercept can be measured together with vegetation height, which describes vertical vegetation structure.
- Line-point intercept is a common method used in monitoring so the instructions on using the Line-point intercept are found here (tables E-38, E-39, E-40, E-41, and figures E-58, E-59, E-61) but full instructions with helpful tips can be found in Jornada Core Methods Volume 1, 2nd edition 2017 publication at: https://jornada.nmsu.edu/files/Core_Methods.pdf.
- Materials
  - – Measuring tape (length of transect). If using a tape measure in feet, use one marked in tenths of feet.
  - – Two steel stakes for anchoring tape.
  - – One pointer – a straight piece of wire or rod, such as a long pin flag, at least 75 cm (2.5 ft) long and 1 mm (0.04 in) or less in diameter.
  - – Electronic device for paperless data collection (preferred) OR clipboard, Line-point Intercept Data Sheet and pencil(s).

(ii) Gap intercept

Gap intercept measurements provide information about the proportion of the line covered by large gaps between plants (Herrick et al. 2005). The size and frequency of gaps in plant canopies (canopy gap intercept) reflects the potential for wind erosion on a site. Basal gap intercept measures the gaps between plant bases. The higher the proportion of a plot in large basal gaps, the greater the risk of water erosion. Larger gaps also correlate to a higher risk of invasion by weeds or woody species. Gap intercept and vegetation height together can be used to characterize vegetation.

(iii) Photograph Monitoring

- Use photo points to qualitatively monitor how vegetation changes over time. Permanent photographs of a landscape are useful for detecting changes in vegetation structure and for visually documenting measured changes.
- The Sampling Vegetative Attributes Interagency Technical Reference includes a section on how to conduct photo monitoring. That procedure is included here:
  - – General description-photographs and videotapes can be valuable sources of information in portraying resource values and conditions. Therefore, pictures should be taken of all study areas when feasible. Both photographs and videos can be taken at photo plots or photo points. A photo point is a panoramic view landscape photo of the study area where a phot plot is a closeup photograph of a permanently marked plot on the ground. Use close-up and/or general view pictures with all of the study methods. Comparing pictures of the same site taken over a period of years furnishes visual evidence of vegetation and soil changes. In some situations, photo points could be the primary monitoring tool. All pictures should be in color, regardless of whether they are the primary or secondary monitoring tool (ITR 1734-4).

– Equipment—The following equipment is suggested for the establishment of photo plots:

- Study Location and Documentation Data form (see ITR Appendix A)
  -- Photo Identification Label (see ITR Appendix C)
  -- Frame to delineate the 3- x 3-foot, 5- x 5-foot, or 1- x 1-meter photo plots (see Illustrations 1 and 2)
  -- Four rods to divide the 3- x 3-foot and 1- x 1-meter photo plot into nine square segments
  -- Stakes of 3/4- or 1-inch angle iron not less than 16 inches long (request approval from client before placing angle iron on private land)
  -- Hammer
  -- 35-mm camera with a 28-mm wide-angle lens and film
  -- Small step ladder (for 5- x 5-foot photo plots)
  -- Felt tip pen with waterproof ink
- Study Identification Number studies for proper identification to ensure that the data collected can be positively associated with specific studies on the ground (see ITR Appendix B).
- Close-up Pictures Close-up pictures show the soil surface characteristics and the amount of ground surface covered by vegetation and litter. Close-up pictures are generally taken of permanently located photo plots.
- The location of photo plots is determined at the time the studies are established. Document the location of photo plots on the Study Location and Documentation Data form to expedite relocation (see ITR Appendix A).
- Generally, a 3 x 3-foot square frame is used for photo plots; however, a different size and shape frame may be used. Where new studies are being established, a 1-meter x 1-meter photo plot is recommended. Frames can be made of PVC pipe, steel rods, or any similar material. Illustration 1 of the Interagency Technical Reference shows a diagram of a typical photo plot frame constructed of steel rod.
- Angle iron stakes are driven into the ground at two diagonal corners of the frame to permanently mark a photo plot (see ITR Illustration 3). Paint the stakes with bright-colored permanent spray paint (yellow or orange) to aid in relocation. Repaint these stakes when subsequent pictures are taken.
- The Photo ID Label is placed flat on the ground immediately adjacent to the photo frame. Photo label should include date, location (pasture), name of ranch, and study site number.
- The camera point, or the location from which the close-up picture is taken should be on the north side of the phot plot so that repeat pictures can be taken at any time during the day without casting a shadow across the plot.
- To take the close-up pictures, stand over the photo plot with toes touching the edge of the frame.
- A step ladder may be needed to take close up pictures of plots larger than 3 x 3 feet.
- General View Pictures. General view pictures are photo points and present a broad view of a study site. These pictures are often helpful in relocating study sites.

– If a linear design is used, general view pictures may be taken from either or both ends of the transect. The points from which these pictures are taken are determined at the time the studies are established. Document the location of these points on the Study Location and Documentation Data form to expedite relocation (see ITR Appendix C).

– The Photo Identification Label is placed in an upright position so that it will appear in the foreground of the photograph (see ITR Appendix C).

– To take general view pictures, stand at the selected points and include the photo label, a general view of the site, and some sky in the pictures.

  - A picture of a study site taken from the nearest road at the time of establishment of the study facilitates relocation.
- Photo Points. General view photographs taken from a permanent reference point are often adequate to visually portray dominant landscape vegetation. It is important that the photo point location be documented in writing and that the photo include a reference point in the foreground (fencepost, fence line, etc.), along with a distinct landmark on the skyline. Photographs taken from photo points should be brought to the field to assist in finding the photo point and to ensure that the same photograph (bearing, amount of skyline, etc.) is retaken. The photograph should be taken at roughly the same time each year to assist in interpreting changes in vegetation. As always, recording field notes to supplement the photographs is a good idea. See figure E-64.
- Video Images. Video cameras (i.e., camcorders) are able to record multiple images of landscapes for monitoring. While video images provide ways to record landscape images, limitations in their use should also be considered. Video tapes, especially the quality of the image, may begin to deteriorate within 5 years. These images can be protected by conversion to digital computer images or rerecording the original tape onto a new blank tape. Comparing repeat video images is difficult, especially if the same landscape sequences are not repeated in the same way on subsequent video recordings. Advantages and disadvantages of video cameras should be carefully considered prior to implementing a video monitoring system.
- Repeat Pictures. When repeat pictures are taken, follow the same process used in taking the initial pictures. Include the same area and landmarks in the repeat general view pictures that were included in the initial pictures. Take repeat pictures at approximately the same time of year as the original pictures.
- General Observations. General observations concerning the sites on which photographs are taken can be important in interpreting the photos. Such factors as rodent use, insect infestation, animal concentration, fire, vandalism, and other site uses can have considerable impact on vegetation and soil resources. This information can be recorded on note paper or on study method forms themselves if the photographs are taken while collecting other monitoring data.
- The Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems Second Edition, Volume 1 Core Methods also provides instructions for setting up and conducting photo monitoring.

**Table E-38.** Line-point intercept (rule set).

| | |
|---|---|
| 1. | Pull out the tape and anchor each end with a steel stake. |
| | Keep the measuring tape taut and straight. |
| | Keep the measuring tape as close to the ground as possible (thread under shrubs using a steel stake or PVC pipe as a “needle” being careful to not disturb the soil surface or natural lay of the vegetation). |
| | In shrubby areas, it may be helpful to reverse-string the tape by anchoring the reel at the endpoint and working backwards toward the “0” end of the tape. |
| 2. | As you move from one end of the tape to the other, always stand on the same side (the south side for NRI) of the transect for all methods and measurements. Move to the first point (0 mark) on the tape. |
| 3. | Drop a pin flag to the ground from a standard height next to the tape. |
| 3.1 | Keep the pin vertical. |
| 3.2 | Make a “controlled drop” of the pin from the same height each time. Position the pin so its lower end is several centimeters above the vegetation, release it and allow it to slip through the hand until it hits the ground. A low drop height minimizes “bounces” off of vegetation but increases the possibility for bias. |
| 3.3 | Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the transect tape mark. |
| 3.4 | A laser with a bubble level can be used instead of the pin. This tool is useful in ecosystems where plant layers may be above eye level. |
| 4. | Once the pin flag is flush with the ground, record every plant species it intercepts (table E-39 and figure E-60). |
| 4.1 | Record the species of the uppermost or first stem, leaf or plant base intercepted in the “Top layer” column, using the PLANTS Database species code (https://plants.usda.gov), a code based on the first two letters of the genus and species, or the common name. |
| 4.2 | If no leaf, stem or plant base is intercepted or touches the pin, record “N” for none in the “Top layer” column. |
| 4.3 | Record all additional species intercepted by the pin, in the order that they are intercepted, from top to bottom. |
| 4.4 | Record herbaceous litter as “HL,” if present. Herbaceous litter is defined as detached stems, roots, leaves, haybales, and dung. Record “WL” for detached woody or succulent litter that is greater than 5 mm (or ~1/4 in) in diameter. Record “NL” for non-vegetative litter (e.g., plastic, metal, decomposing animal matter). |
| 4.5 | Record each plant species only once, the first time it is intercepted, even if it is intercepted several times. |
| 4.6 | If a plant species is not known, use the following codes, adding sequential numbers as necessary: AF# = Annual forb (also includes biennials). |
| | If necessary, collect a sample of unknown plants off the transect for later identification (see page 14 of the Monitoring Manual, 2nd edition for voucher specimen collection protocols). |
| 4.7 | If the genus is known, but not the species, either use the PLANTS Database genus code (https://plants.usda.gov) or record an unknown plant code as described above and note the genus at the bottom of the data sheet. |
| 4.8 | Foliage can be live or dead (see figures E-59 and E-60), but only record each species once at each pin drop. If both live and dead canopy for the same species is hit on the same point, record the live canopy. |
| 4.9 | Record vagrant lichen as “VL” or by its species in the lower layer columns. |
| 4.10 | In environments where deposited soil over a plant base occurs push the pin below the soil surface. Gently move the pin from side to side to feel for buried plant bases. If resistance from the plant base is encountered, record deposited soil as “DS” in the lower canopy and record the species basal hit in the “Soil Surface” column. |
| 5. | Record a species code (if the pin flag intercepts a plant base, figure E-60) or another soil surface code in the “Soil surface” column). |
| 5.1 | For unidentified plant bases, use the codes listed under Rule 4.6. |
| 5.2 | An intercept with a plant base is defined as when the end of the pin rests either on, or immediately adjacent to and touching, living or dead plant material that is rooted in the soil. Carefully scrutinize if the pin rests either on, or immediately adjacent to and touching, living or dead plant material that is rooted in the soil. Carefully scrutinize if the pin is touching small, single-stemmed plants. See figure E-60. |
| 6.0 | Optional: Add more specific soil surface categories. |

| | |
|---|---|
| 6.1 | Record “CY” or dark cyanobacterial crust. |
| 6.2 | If mosses and lichens are identified to species, record the species code in the “Soil surface” column. |
| 7. | Repeat Steps 3–6 at regular intervals along the transect. |
| | R = Rock (> 5 mm or ~1/4 inch in diameter) (a category for coarse fragments functionally resistant to movement raindrop impact). |

The following specific size classes be used in place of “R”. This is required where data will be used to develop classification systems, such as ecological sites.

GR = Gravel (5 – 76 mm)
CB = Cobble (> 76 – 250 mm)
ST = Stone (> 250 – 600 mm)
BY = Boulder (> 600 mm)
BR = Bedrock
D = Duff
M = Moss
LC = Visible lichen on soil crust (do not record if it is attached to a rock substrate)
W = Water
S = Soil that is visibly unprotected by any of the above

PF# = Perennial forb
AG#= Annual graminoid
PG#= Perennial graminoid
SH#= Shrub
TR#= Tree

**Figure E-58.** Correct Pin flag position dropping on bare soil (N/S reading) (Herrick et al. 2005).

**Figure E-59.** Recording Dead vs. Live.

**RECORDING DEAD VS. LIVE**

Distinguishing dead vs. live plant parts is important for many objectives. A pin intercept is a standing dead hit if the pin touches a dead plant part.

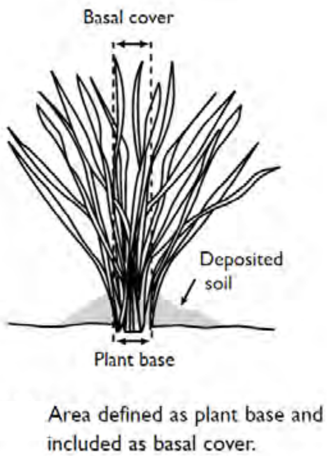
- Vegetation which grew in the current growing season is alive while rooted vegetation from the previous growing season is dead.
- Perennial and woody plant parts which support live vegetation are alive.
- Points where only dead plants or plant parts are intercepted can be recorded on paper by circling the species on paper data sheets, or electronically (by using the optional checkbox in the DIMA Line-point intercept form (https://jornada.nmsu.edu/monit-assess/).

**Table E-39.** A list of columns that can be populated as part of Line-point intercept, along with a list of permitted options for each Column. Following these protocols facilitates simple calculations on paper data sheets, and consistent calculations with Electronically recorded data.

| LPI COLUMN | PERMITTED OPTIONS | SOURCE/CODE | | DESCRIPTION |
|---|---|---|---|---|
| Top layer codes | N | | | Indicates no foliar cover. |
| | Plant code | From PLANTS Database | | Foliar cover. |
| | Unknown plant code | User assigned code | | |
| Lower codes | Plant code | From PLANTS Database | | Foliar cover. |
| | Unknown plant code | User assigned code | | |
| | Litter | L or HL - herbaceous litter (including dung and haybales) | | Litter cannot be entered above the first plant code or in the Top layer. |
| | | WL - woody or succulent litter > 5 mm diameter | | |
| | | NL - other litter such as plastic, metal, and decomposing animal matter | | |
| | Optional | | Otherwise record: | |
| | Deposited soil | DS | S on Soil surface | Soil deposition overlying a plant base. |
| | Water | W | W on Soil surface | Water or ice present at the time of measurement. May be permanent or ephemeral. |
| | Vagrant lichen | VL | Litter | Lichens that are loose, never attached to any substrate. |
| | Rock fragment | GR - gravel | GR or R on soil sur face | Rock fragments 5 - 76 mm, but only when overlying a buried plant base. |
| | | CB - cobble | CB or R on soil surface | Rock fragments 76 - 250 mm, but only when overlying a buried plant base. |
| | | ST- stone | ST or R on soil surface | Rock fragments 250 - 600 mm, but only when overlying a buried plant base. |
| Soil surface codes | Plant code | From PLANTS Database | | Indicates pin on hit a plant base. Plant bases have no minimum height, record a foliar hit of the same species above any plant basal hit even when no apparent pin contact is made with a leaf or stem. |
| | Unknown plant | User assigned code | | |
| | Soil | S | | Indicates bare soil, mineral soil, or soil with no detectable biological crust. |
| | Lichen | LC (or species code if known*) | | Visible lichen crust attached to soil surface. Record if attached to soil, but not if on rock. |
| | Moss | M (or species code if known*) | | |
| | Duff | D | | Partially decomposed plant litter with no recognizable plant parts. |
| | Water | W | | Permanent water |
| | Rock fragment | R | | All rock fragments > 5 mm (do not use GR,CB, ST, or BY because R represents all of these). |
| | Optional | | Otherwise, record: | |
| | Cyanobacteria | CY | S | For consistency with NRI bare ground calculations, both "N/S" and "N/CY" pin hits constitute bare ground. |
| | Embedded litter | EL | L in lower canopy and S on the Soil surface | Embedded woody litter > 5 mm in diameter |
| | | GR - gravel | R | Rock fragments 5 - 76 mm. |
| | | CB - cobble | R | Rock fragments 76 - 250 mm. |
| | | ST - stone | R | Rock fragments 250 - 600 mm. |
| | | BY- boulder | R | Rock fragments > 600 mm. |
| | | BR - bedrock | R | |

**Figure E-60.** Sample data sheet for examples illustrated below. Points 1 and 2 show the first two points on a transect. In Point 1, the pin flag is touching dead fescue (FERU2), live bluegrass (POPR). Clover (TRRE3), live fescue, litter, and a rock. Record fescue only once, even though it intercepts the pin twice. In Point 2, the flag touches fescue, then touches litter, and finally the fescue plant base.

| PT. | TOP LAYER | LOWER LAYERS | | | SOIL SURFACE |
|---|---|---|---|---|---|
| | | CODE 1 | CODE 2 | CODE 3 | |
| 1 | FERU2 | POPR | TRRE3 | HL | R |
| 2 | FERU2 | HL | | | FERU2 |
| 3 | FERU2 | HL | | | S |
| 4 | N | | | | S |
| etc. | | | | | |



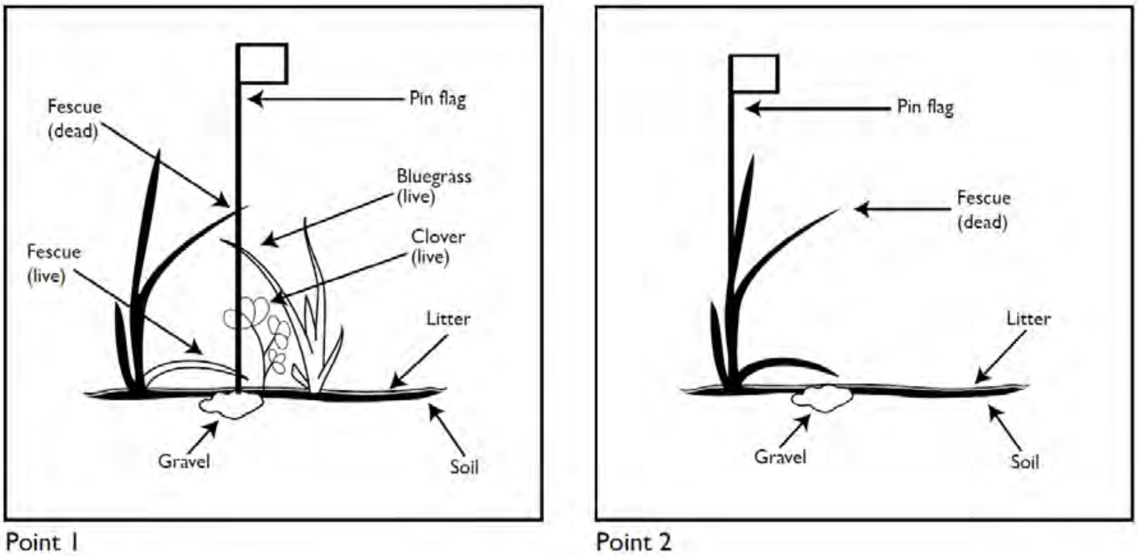




**Table E-40**. Quality Assurance.

| Quality Assurance | |
|---|---|
| ☐ | Each data sheet is complete. All points, observer, recorder, date, line, and plot name are recorded. Scan every entry to make sure they are legible. |
| ☐ | Each pin drop is made as close to vertical as possible, and observers avoid leaning too far over the line in either direction in order to avoid parallax. Parallax issues can increase variability year-to-year because different amounts of plant canopy are measured among years. |
| ☐ | Every Top layer and Soil surface cell has an entry. Each species may occur a maximum of once in the first four columns. |
| ☐ | Fill every cell with its appropriate data; do not draw vertical lines down through multiple cells or columns to indicate repeating values. |
| ☐ | % bare ground + % foliar cover + % between plant ground cover = 100%. |
| ☐ | Cover values are consistent with plot observations. |

**Table E-41.** Line-Point Intercept Indicator Calculations.

| | |
|---|---|
| | Foliar cover (as calculated here) does not include bare spaces within a plant's canopy. |
| 1. | Percent foliar cover. |
| 1.1 | Count the total number of plant intercepts in the "Top layer" column and record this number in the blank provided. |
| 1.2 | Plant intercepts include all points where a plant is recorded in the "Top layer" column. Do not include points that have a "N" in the "Top layer" column. |
| 1.3 | Divide the number of plant intercepts by the total number of pin drops and record % foliar cover in the blank provided. |
| 2. | Percent bare ground. |
| 2.1 | Count the total number of points along the line that have bare ground and record this number in the blank provided. |
| 2.2 | Bare ground occurs only when: |
| | A. There are no plant intercepts (N is recorded in the "Top layer" column). |
| | B. There are no litter intercepts ("Lower layers" columns are empty). |
| | C. The pin only intercepts bare soil ("S" recorded in the "Soil surface" column). |
| 2.3 | Divide the total number of bare ground hits by the total number of pin drops and record % bare ground in the blank provided. |
| 3. | Percent basal cover. |
| 3.1 | Count the total number of plant basal intercepts in the "Soil surface" column and record this number in the blank provided. |
| 3.2 | Plant basal intercepts occur anytime the pin intercepts a live or dead plant base (species code recorded in "Soil surface"). |
| 3.3 | Divide the total number of basal intercepts by the total number of pin drops and record % basal cover in the blank column) provided. |
| 4. | Vegetation composition. |
| 4.1 | Count the total number of intercepts where rooted vegetation occurs in at least one layer (Top, Lower, or Soil Surface layers). |
| 4.2 | Count the total number of intercepts where Species A occurs in at least one layer. |
| 4.3 | Divide the count from 4.2 by the count from. |
| 4.1 | Multiply by 100% and record this as the composition of Species A. |
| 4.4 | Repeat for Species B, C, D, N. |
| 4.5 | Sum the percent composition of each species. |

**Figure E-61.** Line-point intercept basic interpretation.

## LINE-POINT INTERCEPT BASIC INTERPRETATION

Increases in **foliar cover** are correlated with increased resistance to degradation. **Basal cover** is a more reliable long-term indicator. Basal cover is less sensitive to seasonal and annual differences in precipitation and use. Increases in **bare ground** nearly always indicate a higher risk of runoff and erosion.

Where species composition* changes may be occurring, calculate basal and foliar cover for each major species. Foliar cover usually is used for shrubs, trees and sometimes grasses. Basal cover is used for perennial grasses. When calculating foliar cover of a single species, count each time the species is intercepted, regardless of whether it is in the top or lower layer (only count it once in cases where it occurs in an upper layer and the soil surface for the same pin drop). Use these indicators together with the indicators from **Gap intercept** and **Soil stability tests** to help determine whether observed erosion changes are due to loss of cover, changes in vegetation spatial distribution, or reduced soil stability. Use these indicators together with **Plant density** data to track changes in species composition. For more information about how to interpret these indicators, please see Chapter 21, Volume II.

*Foliar cover is often used to estimate species composition. It must be recognized, however, that in dense, complex vegetation systems, foliar cover estimates of species composition based on only the first hit on each species (as described in this manual), are less strongly correlated with biomass-based species composition than estimates where multiple pin intercepts are recorded.

TYPICAL EFFECT ON EACH ATTRIBUTE OF AN INCREASE IN THE LINE-POINT INTERCEPT INDICATOR VALUE

| Indicator | Attributes | | |
|---|---|---|---|
| | Soil and site stability* | Hydrologic function** | Biotic integrity |
| Foliar cover % | ↑ | ↑ | ↑ |
| Bare ground % | ↓ | ↓ | ↓ |
| Basal cover % | ↑ | ↑ | ↑ |

The Line-Point Intercept Data Sheet is below with an example of a correctly populated sheet.

**Figure E-62.** Line-point intercept data sheet (blank).

## LINE-POINT INTERCEPT DATA SHEET

Page ______ of ______ 　　　　Shaded cells for calculations

Plot: ____________________ Line: _____ Observer: ________________ Recorder: ________________

Azimuth: _______ Date: ____________ 　　Intercept (Point) Spacing Interval: _____ ☐ cm ☐ in

| PT. | TOP LAYER | LOWER LAYERS | | | SOIL SURFACE | PT. | TOP LAYER | LOWER LAYERS | | | SOIL SURFACE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CODE 1 | CODE 2 | CODE 3 | | | | CODE 1 | CODE 2 | CODE 3 | |
| 1 | | | | | | 26 | | | | | |
| 2 | | | | | | 27 | | | | | |
| 3 | | | | | | 28 | | | | | |
| 4 | | | | | | 29 | | | | | |
| 5 | | | | | | 30 | | | | | |
| 6 | | | | | | 31 | | | | | |
| 7 | | | | | | 32 | | | | | |
| 8 | | | | | | 33 | | | | | |
| 9 | | | | | | 34 | | | | | |
| 10 | | | | | | 35 | | | | | |
| 11 | | | | | | 36 | | | | | |
| 12 | | | | | | 37 | | | | | |
| 13 | | | | | | 38 | | | | | |
| 14 | | | | | | 39 | | | | | |
| 15 | | | | | | 40 | | | | | |
| 16 | | | | | | 41 | | | | | |
| 17 | | | | | | 42 | | | | | |
| 18 | | | | | | 43 | | | | | |
| 19 | | | | | | 44 | | | | | |
| 20 | | | | | | 45 | | | | | |
| 21 | | | | | | 46 | | | | | |
| 22 | | | | | | 47 | | | | | |
| 23 | | | | | | 48 | | | | | |
| 24 | | | | | | 49 | | | | | |
| 25 | | | | | | 50 | | | | | |

% foliar cover = ____ top layer pts (1st col) x 2 = _____%
% bare ground* = ____pts (w/N over S) x 2 = _____%
% basal cover = ____ plant base pts (last col) x 2 = _____%

* For NRI, bare ground occurs ONLY when Top layer = N, Lower layers are empty (no litter), and Soil surface = S or CY.

Top layer codes: Species code or N (no cover).
Lower layers codes: Species code or
HL (herbaceous litter), WL (woody litter, > 5 mm (~1/4 in) diameter), NL (non-vegetative litter), VL (vagrant lichen).

UNKNOWN SPECIES CODES:
- AF# = annual forb
- PF# = perennial forb
- AG# = annual graminoid
- PG# = perennial graminoid
- SH# = shrub
- TR# = tree

SOIL SURFACE (DO NOT USE LITTER):
- R = Rock** (≥ 5 mm or ~ 1/4 in diameter)
- BR = Bedrock
- D = Duff
- M = Moss
- LC = Visible lichen on soil
- S = Soil

** Optional: use rock fragment classes in place of "R": GR (5-76 mm), CB (76-250 mm), ST (250 mm-600 mm), BY (>600 mm)

Data entry ________ Date ___________ Error check ________ Date ___________

**Figure E-63.** Line-point intercept data sheet (example).

## LINE-POINT INTERCEPT DATA SHEET

Shaded cells for calculations

Page 1 of 1

Plot: 3 Line: 2 Observer: Jane Mendez Recorder: David Stein

Azimuth: 120 Date: 10/15/2002 Intercept (Point) Spacing Interval: 100 ☑ cm ☐ in

| PT. | TOP LAYER | LOWER LAYERS CODE 1 | CODE 2 | CODE 3 | SOIL SURFACE | PT. | TOP LAYER | LOWER LAYERS CODE 1 | CODE 2 | CODE 3 | SOIL SURFACE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BOER4 | | | | BOER4 | 26 | PRGL | BOER4 | | | S |
| 2 | BOER4 | | | | S | 27 | N | HL | | | S |
| 3 | AFO1 | BOER4 | | | S | 28 | BOER4 | | | | LC |
| 4 | BOER4 | | | | S | 29 | AFO1 | BOER4 | | | S |
| 5 | N | | | | S | 30 | YUEL | HL | | | S |
| 6 | BOER4 | | | | LC | 31 | BOER4 | | | | S |
| 7 | N | HL | | | S | 32 | N | | | | R |
| 8 | N | | | | S | 33 | BOER4 | PGO2 | | | S |
| 9 | BOER4 | | | | S | 34 | N | HL | | | S |
| 10 | BOER4 | HL | | | S | 35 | BOER4 | | | | S |
| 11 | BOER4 | HL | | | S | 36 | BOER4 | HL | | | BOER4 |
| 12 | BOER4 | | | | S | 37 | BOER4 | HL | | | S |
| 13 | N | | | | S | 38 | BOER4 | HL | | | S |
| 14 | BOER4 | | | | S | 39 | N | | | | S |
| 15 | N | HL | | | S | 40 | N | HL | | | S |
| 16 | N | | | | R | 41 | BOER4 | | | | S |
| 17 | BOER4 | | | | S | 42 | PRGL | AFO1 | | | S |
| 18 | BOER4 | | | | BOER4 | 43 | PRGL | | | | S |
| 19 | N | | | | R | 44 | AFO1 | | | | S |
| 20 | BOER4 | | | | S | 45 | N | | | | S |
| 21 | BOER4 | | | | S | 46 | BOER4 | | | | S |
| 22 | AFO1 | | | | S | 47 | BOER4 | | | | BOER4 |
| 23 | BOER4 | HL | | | S | 48 | BOER4 | HL | | | S |
| 24 | N | HL | | | S | 49 | N | HL | | | S |
| 25 | N | HL | | | S | 50 | BOER4 | GUSA | | | S |

% foliar cover = 34 top layer pts (1st col) x 2 = 68 %
% bare ground* = 5 pts (w/N over S) x 2 = 10 %
% basal cover = 4 plant base pts (last col) x 2 = 8 %

* For NRI, bare ground occurs ONLY when Top layer = N, Lower layers are empty (no litter), and Soil surface = S or CY.

Top layer codes: Species code or N (no cover).
Lower layers codes: Species code or HL (herbaceous litter), WL (woody litter, > 5 mm (~1/4 in) diameter), NL (non-vegetative litter), VL (vagrant lichen).

UNKNOWN SPECIES CODES:
- AF# = annual forb
- PF# = perennial forb
- AG# = annual graminoid
- PG# = perennial graminoid
- SH# = shrub
- TR# = tree

SOIL SURFACE (DO NOT USE LITTER):
- R = Rock** (≥ 5 mm or ~ 1/4 in diameter)
- BR = Bedrock
- D = Duff
- M = Moss
- LC = Visible lichen on soil
- S = Soil

** Optional: use rock fragment classes in place of "R": GR (5-76 mm), CB (76-250 mm), ST (250 mm-600 mm), BY (>600 mm)

Data entry SAS Date 10/17/2002 Error check JMP Date 10/18/2002

**Figure E-64.** Photo point.


E. Other Uses of NRCS Grazing Land Inventory, Monitoring and Assessment Data

(1) Inventory, assessment, and monitoring data can be used to study conservation treatment effects, to establish the baseline data for monitoring and determine resource concerns, and for other uses including:
   (i) coordinating grazing history, stocking rate, and animal performance records in determining guides to initial stocking rates
   (ii) development of ecological site description and preparing soil survey manuscripts
   (iii) studies of conservation practice treatment effects
   (iv) analyzing wildlife habitat values
   (v) planning watershed and river basin projects
   (vi) assisting and training landowners and operators in monitoring vegetation trends and the impact of applied conservation practices and programs
   (vii) exchanging information with research institutions and agencies
   (viii) preparing guides and specifications for recreation developments, beautification, natural landscaping, roadside planting, and other developments or practices
   (ix) directing Plant Material Center program activities
   (x) developing modeling tools and identifying potential climate smart grazing practices
   (xi) helping direct policy

(2) Data collected during inventories, assessments and monitoring activities can be used for ecological site description development. However, data collected for ecological site descriptions is more extensive than data for conservation planning inventories. Ecological site development requires collection of biomass data, a review of local history related to a reference plant community and are correlated to a specific soil component. The National Ecological Site Handbook describes the tiers of data required for provisional, approved and correlated ecological site products.

(3) The Conservation Effects Assessment Project (CEAP) quantifies the environmental effects of conservation practices and programs. The process includes research, modelling, assessment, monitoring and data collection.

(4) The National Resources Inventory (NRI) Grazingland On-site Study collects and produces scientifically credible information on the status, condition, and trends of land, soil, water, and related resources on the Nation's non-federal lands in support of efforts to protect, restore, and enhance the lands and waters of the United States.

(5) Through the National Environmental Protection Act (NEPA) requirements. NRCS data is used to determine and document the environmental effects of conservation decisions through the NRCS Environmental Effects policy.
(6) Hydrologic model development is an important activity in NRCS that requires data collection from a unique set of variables including plant cover and slope. The Rangeland Hydrology and Erosion Model (RHEM) is used to assess erosion risk on rangeland.

## 645.0519 References

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## 645.0520 Appendices

Appendix E-A – Forest Land Evaluations

Appendix E-B – Example Ecological Site Description

Appendix E-C – Study and Photograph Identification

Appendix E-D – NRCS Oregon Range Technical Note No. 27

## APPENDIX E-A – Forest Land Evaluations

**EXHIBIT E-A-1. Grazable Forest Land Evaluation**

ECS-4

U.S. Department of Agriculture ECS-4
Natural Resources Conservation Service
GRAZABLE FOREST LAND EVALUATION

Date: Recorded By: Map Unit: Photo No.: Location:

Ecological Site (Habitat Type, etc.):

Soil Group: ______ Canopy: ______

Slope %: 0.00%______ Distance to Water:______

No. Roads & Trails Through: ______ No. Water Developments: ______

Mechanical Barriers: ______ Aspect: ______

Use History:

Weed Infestations:

Critical Erosion or Sediment Sources:

Wildlife:

| TREE REGENERATION | | PLOT SIZE: | | |
|---|---|---|---|---|
| **SPECIES** | **DBH 0–1"** | **DBH 1–2"** | **DBH 2–3"** | **DBH 3–4"** |
| | | | | |
| | | | | |
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| | | | | |
| | | | | |

Ecological Status Rating: ______ Forage Value Rating:______

Initial Stocking Rate:______ Grazability Factor (%): 0.00%______

Adjusted Stocking Rate:______

**Exhibit E-A-2.** Forest Land Status and Condition Record

ECS-4 Page 2
U.S. Department of Agriculture ECS-4
Natural Resources Conservation Service

| SPECIES | % Composition by Weight | % Counted as Climax | GRAZING PREFERENCE C S D E | | | % Counted for FVR | Cover % | Average Height |
|---|---|---|---|---|---|---|---|---|
| | | | P | D | N | | | |
| GRASSES AND GRASSLIKE: (PLANT GROUP WT. %) | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
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| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| FORBS: (PLANT GROUP WT. %) | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
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| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| WOODY PLANTS: (PLANT GROUP WT. %) | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| | 0.00% | 0.00% | | | | 0.00% | 0.00% | |
| Percent Composition | 0.00% | 0.00% | | | | 0.00% | 0.00% | |

## **EXHIBIT E-A-3.** Soil-Woodland Correlation Field Data Sheet

Vigor________________________________ % Bare Soil________________________________
Topography (pick one)___________________ Horizontal Configuration_____________________

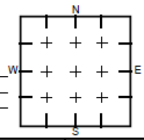
| Topography | | Horizontal Configuration | |
|---|---|---|---|
| | 1- Ridge | | 1- Convex (dry) |
| | 2 Upper Slope | | 2 Straight |
| | 3 Mid Slope | | 3 Concave (wet) |
| | 4 Lower Slope | | 4 Undulating |
| | 5 Bench or Flat | | |

ECS-5 page 1

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

**SOIL--WOODLAND CORRELATION FIELD DATA SHEET**

ECS-5
08-07




Sec. ____
Twp. ____
Rge. ____

Date ____________ County ______________ State ________ Location ______________________________

Date By ______________________________

| | PLOT NUMBER | | | | COVER TYPE NO. (SAF) | MAJOR LAND RESOURCE AREA | | STATE PLANE COORDINATES OR SECTION, TOWNSHIP, RANGE | | | | | ELEVATION | CARD IDENTIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site | Yr. | St. | Cnty | | Number | Subdiv. | Zone No. / Sec. | East (X) / Town-ship | | North (Y) / Range | | (feet) | |
| LOCATION | | | | | | | | | | | | | | |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

| | PRECIPITATION (INCHES) | | LAND-FORM | SLOPE | | | | | | POSITION ON SLOPE | CARD IDENTIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Annual | Summer | (code) | Percent | Kind (code) | Shape (code) | Micro-Relief (code) | Aspect Degr. of Azimuth | Approximate Length (feet) | (code) | |
| PHYSICAL | | | | | | | | | | | |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

| | DETAILED PROFILE DESCR. | DETAILED UNDER-STORY | MENSUR. INFORM. | SOIL SERIES NAME | TEXTURE | | PAST EROSION | DRAINAGE CLASS | ALTERED WATER RELA-TIONS | CARD IDENTIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|
| | (Y or N) | (Y or N) | (Y or N) | (Print name in full) | Modifier (code) | Type (code) | (code) | (No.) | | |
| SOIL | | | | | | | | | | |

SOIL PROFILE DESCRIPTION by Soil Scientist: ______________________________

| Hori-zon | Depth | Color | | Texture | Structure | Consistence | | | Reac-tion | Boundary |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Dry | Moist | | | Dry | Moist | Dry | | |
| | | | | | | | | | | |
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NOTES:

Underlying material: ______________________________

Clear Form

ECS-5 page 2

| SITE | YEAR | STATE | COUNTY | PLOT NUMBER (Identification only) | 0 1" 2" |
|---|---|---|---|---|---|
| | | | | | |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

| | Scientific Plant Name Symbol | Crown Class. | Tree Origin | Tree Diameter | In. Rad. Last 10 Yr. | Rings, Pith to 1.5 in. | AGE ESTIMATION Ht. Ring Ct. | No. of Rings | Mea.Pt. Age | Total Age | Total Height | CARD IDENTIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TREE 1 | | | | | | | | | | | | |
| TREE 2 | | | | | | | | | | | | |
| TREE 3 | | | | | | | | | | | | |
| TREE 4 | | | | | | | | | | | | |
| TREE 5 | | | | | | | | | | | | |
| TREE 6 | | | | | | | | | | | | |
| TREE 7 | | | | | | | | | | | | |
| TREE 8 | | | | | | | | | | | | |
| TREE 9 | | | | | | | | | | | | |
| TREE 10 | | | | | | | | | | | | |
| TREE 11 | | | | | | | | | | | | |
| TREE 12 | | | | | | | | | | | | |
| (two woodcrops per line) | Scientific Plant Name Symbol | Number of Trees | Site Index Curve Number | | Aver. Plot Site Index | Scientific Plant Name Symbol | | Number of Trees | Site Index Curve Number | | Aver. Plot Site Index | |
| INDEX | | | | | | | | | | | | |
| INDEX | | | | | | | | | | | | |
| | UNDERSTORY ABUNDANCE Rate Each by Code | | | | STAND DENSITY (CANOPY) | | BASAL AREA Sq. Ft. per Acre | CROWN COMPETITION FACTOR | | | | |
| | Reprod. | All Woody | Grasses, Forbs | Mosses, Lichens | M. or E. | Percent | M. or E. | Sq. Ft. | (applies only to lodgepole pine) | | | |
| DENSITY | | | | | | | | | | | | |
| (four species per line) | Scientific Plant Name Symbol | Percent | Scientific Plant Name Symbol | | Percent | Scientific Plant Name Symbol | | Percent | Scientific Plant Name Symbol | | Percent | |
| CANOPY | | | | | | | | | | | | |
| CANOPY | | | | | | | | | | | | |
| CANOPY | | | | | | | | | | | | |
| (four species per line) | Scientific Plant Name Symbol | Rating | Scientific Plant Name Symbol | | Rating | Scientific Plant Name Symbol | | Rating | Scientific Plant Name Symbol | | Rating | |
| GROUND | | | | | | | | | | | | |
| GROUND | | | | | | | | | | | | |
| GROUND | | | | | | | | | | | | |
| | Essential remarks only. If detailed understory or mensurational information recorded, identify the cooperating agency or plot number. Print letters between tick marks. | | | | | | | | | | | |
| REMARKS | | | | | | | | | | | | |
| REMARKS | | | | | | | | | | | | |
| REMARKS | | | | | | | | | | | | |

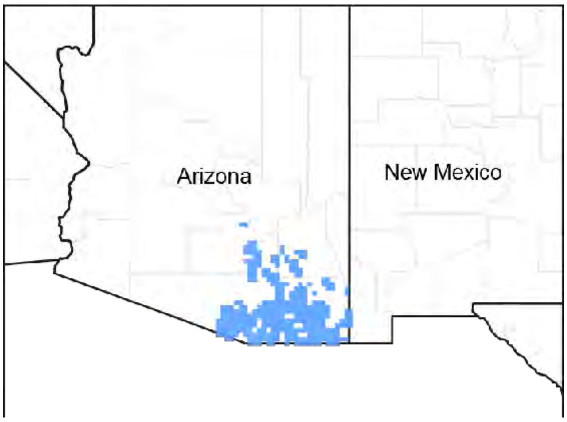
## Appendix E-B. Example Ecological Site Description: Loamy Upland 12"–16" p.z. 041XC313AZ

Ecological site 041XC313AZ
Loamy Upland 12"–16" p.z.
Last update: 4/12/2021
Accessed: 07/14/2021

### General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state-and-transition model and enough information to identify the ecological site.

**Figure E-B-1.** Mapped extent.




Areas shown in blue indicate the maximum mapped extent of this ecological site. Other ecological sites likely occur within the highlighted areas. It is also possible for this ecological site to occur outside of highlighted areas if detailed soil survey has not been completed or recently updated.

### MLRA notes

Major Land Resource Area (MLRA): 041X–Southeastern Arizona Basin and Range

Major Land Resource Area (MLRA) 41 represents the most northern extent of the Sierra Madre Occidental, or in English, the "mother mountains of the west." The Sierra Madre Occidental is a massive, rugged mountain system that runs northwest from the Rio Grande de Santiago, in the state of Jalisco, Mexico, through the states of Sonora and Chihuahua, and ending in Arizona and New Mexico. Through Mexico, this mountain system runs parallel to the Pacific coast and, as it crosses into the United States and confronts the tectonic folding and rifting of the Basin and Range Physiographic Province, the land mass geographically breaks into smaller, isolated mountain ranges, called "sky islands." The centralizing theme for this MLRA can be summed up as a series of inland islands extending from their mainland, the Sierra Madre Occidental, surrounded by a sea of desert grassland. To the west, the Madrean Archipelago bounds the Sonoran Basin and Range where several sky islands in southern Arizona grade into Sonoran Desert basins; to the north it bounds the contiguous mountains and geology of the Mogollon Transition area; and to the east, in New Mexico, it bounds the geology of the Rio Grande Rift. MLRA 41 is primarily a rangeland subdivision with small amounts of irrigated cropland. It encompasses approximately 13M acres.

### LRU notes

Land Resource Unit 41-3, Chihuahuan – Sonoran Semidesert Grasslands. Elevations range from 3200 to 5000 feet and precipitation ranges from 12 to 16 inches per year. Vegetation includes mesquite, catclaw acacia, netleaf hackberry, palo verde, false mesquite, range ratany, fourwing saltbush, tarbush, littleleaf sumac, sideoats grama, black grama, plains lovegrass, cane beardgrass, tobosa, vine mesquite, threeawns, Arizona cottontop and bush muhly. The soil temperature regime is thermic and the soil moisture regime is ustic aridic.

### Classification relationships

USDA-NRCS Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin: Western Range and Irrigated Region D; Major Land Resource Area 41, Southeastern Arizona Basin and Range; Land Resource Unit 41-3, Semi-Desert Grassland; Ecological Site Loamy Upland, 12"–16" p.z.

U.S. Environmental Protection Agency, Ecological Regions of North America: Level I, Region 12, Southern Semi-Arid Highlands; Level II, 12.1 Western Sierra Madre Piedmont, Level III, Ecoregion 79 Madrean Archipelago, 79a, Apachian Valleys and Low Hills.

USDA-USFS Ecological Subregions: Sections of the Conterminous United States: Section 321 Basin and Range; Section 321A, Basin and Range Section.

### Ecological site concept

Loamy Upland, 12"–16" p.z., is found on upland landscapes with deep soils with an argillic horizon underlying loam textured soil or, when the soil above the argillic is sandy loam textured, it is less than 4" thick.

Associated sites

| | |
|---|---|
| R041XC318AZ | Sandy Loam 12–16" p.z. Deep<br>gently sloping areas with thicker sandy loam surface over argillic subsurface |
| R041XC314AZ | Loamy Slopes 12–16" p.z.<br>adjacent slopes with deep, non-calcareous soils |

Similar sites

| | |
|---|---|
| R041XA108AZ | Loamy Upland 16–20" p.z.<br>elevation range 4,500–6,500 ft.; precipitation zone 16–20" |
| R041XB210AZ | Loamy Upland 8–12" p.z.<br>elevation range 2,600–4,500 ft.; precipitation zone 8–12" |

**Table E-B-1.** Dominant plant species.

| | |
|---|---|
| Tree | Not specified |
| Shrub | *calliandra eriophylla*<br>*krameria erecta* |
| Herbaceous | *bouteloua curtipendula*<br>*bouteloua chondrosioides* |

### Physiographic features

This site occurs in the middle elevations of the Madrean Basin and Range province in southeastern Arizona. It occurs on old fan terraces and old stream terraces.

### Climatic features

Precipitation in this common resource area ranges from 12–16 inches yearly in the eastern part with elevations from 3600–5000 feet, and 13–17 inches in the western part where elevations are 3300–4500 feet. Winter-Summer rainfall ratios are 40–60 percent in the west and 30–70 percent in the east. Summer rains fall July-September, originate in the Gulf of Mexico and are convective, usually brief, intense thunderstorms. Cool season moisture tends to be frontal, originates in the Pacific and Gulf of California, and falls in widespread storms with long duration and low intensity. Snow rarely lasts more than one day. May and June are the driest months of the year. Humidity is generally very low.

**Table E-B-2.** Representative physiographic features.

| | |
|---|---|
| Landforms | Fan piedmont<br>Stream terrace<br>Plain |
| Flooding frequency | None |
| Ponding frequency | None |
| Elevation | 3,200–5,000 ft |
| Slope | 1–15% |
| Aspect | Aspect is not a significant factor |

Temperatures are mild. Freezing temperatures are common at night from December-April; however, temperatures during the day are frequently above 50°F. Occasionally in December–February, brief 0°F temperatures may be experienced some nights. During June, July and August, some days may exceed 100°F.

Cool season plants start growth in early spring and mature in early summer. Warm season plants take advantage of summer rains and are growing and nutritious July–September. Warm season grasses may remain green throughout the year.

**Table E-B-3.** Representative climatic features.

| | |
|---|---|
| Frost-free period (characteristic range) | 164–189 days |
| Freeze-free period (characteristic range) | 193–213 days |
| Precipitation total (characteristic range) | 13–15 in |
| Frost-free period (actual range) | 163–199 days |
| Freeze-free period (actual range) | 192–237 days |
| Precipitation total (actual range) | 13–17 in |
| Frost-free period (average) | 178 days |
| Freeze-free period (average) | 207 days |
| Precipitation total (average) | 15 in |

### Climate stations used

DOUGLAS [USC00022659], Douglas, AZ
TOMBSTONE [USC00028619], Tombstone, AZ
WILLCOX [USC00029334], Willcox, AZ
NOGALES 6 N [USC00025924], Rio Rico, AZ
PEARCE - SUNSITES [USC00026353], Pearce, AZ

### Influencing water features

There are no water features associated with this site.

### Soil features

These soils are deep soils which have formed in loamy alluvium of mixed origin. Soil surfaces range from very gravelly sandy loam to loam. Sandy loam surfaces can be no thicker than four inches (eight inches for GRV-SL) and not less than one inch. They are not calcareous in the upper 20 inches. These soils have argillic horizons near the surface. They may have calcic horizons at moderate depths (20 to 40 inches). Plant-soil moisture relationships are fair to good. Soil surfaces are dark colored. Soil series representative of this ecological site are Whitehouse and McAllister; several other series have been correlated to 41-3 Loamy Upland, 12–16" p.z., including among others, Sasabe, Wampoo, Chiricahua, Continental, and Whitehouse GrL.

**Table E-B-4.** Representative soil features.

| | |
|---|---|
| Parent material | (1) Alluvium–igneous, metamorphic and sedimentary rock |
| Family particle size | (1) Clayey |
| Drainage class | Moderately well drained to well drained |
| Permeability class | Moderately slow to moderate |
| Soil depth | 60 in |
| Surface fragment cover <=3" | 5–40% |
| Surface fragment cover >3" | 0–15% |
| Available water capacity (0–40in) | 4.8–9.6 in |
| Calcium carbonate equivalent (0–40in) | 1–25% |
| Electrical conductivity (0–40in) | 0–2 mmhos/cm |
| Sodium adsorption ratio (0–40in) | 0–2 |
| Soil reaction (1:1 water) (0–40in) | 6.6–8.4 |
| Subsurface fragment volume <=3" (Depth not specified) | 5–40% |
| Subsurface fragment volume >3" (Depth not specified) | 0–15% |

### Ecological dynamics

Loamy Upland, 12"–16" p.z., ecological site is a desert grassland. Plant community variation occurs along the precipitation gradient and with depth to argillic horizon. Perennial grass composition, basal cover, and distribution are affected. At the lower end of the precipitation gradient (and with thin surface horizon over argillic), patches of short-grasses dominate over mid-grasses; while at the high end of the precipitation gradient (and with increased depth to argillic), mid-grasses dominate and bare areas diminish. Fire dynamically maintains the grassland aspect by killing seedling mesquite, other small shrubs, and half shrubs. Larger mesquite and other re-sprouting species are top-killed. Fire effects on perennial grasses will be variable with species, season of burning, and fire intensity. Alternate states arise from removal of fuel and introduction of non-native lovegrasses. Aspect is open grassland.

### Land use 1 Rangeland

Rangeland uses of Loamy Upland, 12"–16" p.z., are most commonly livestock grazing, wildlife management and recreation; environmental services are many. Natural disturbances are fire, weather events, natural climatic cycling, and wildlife.

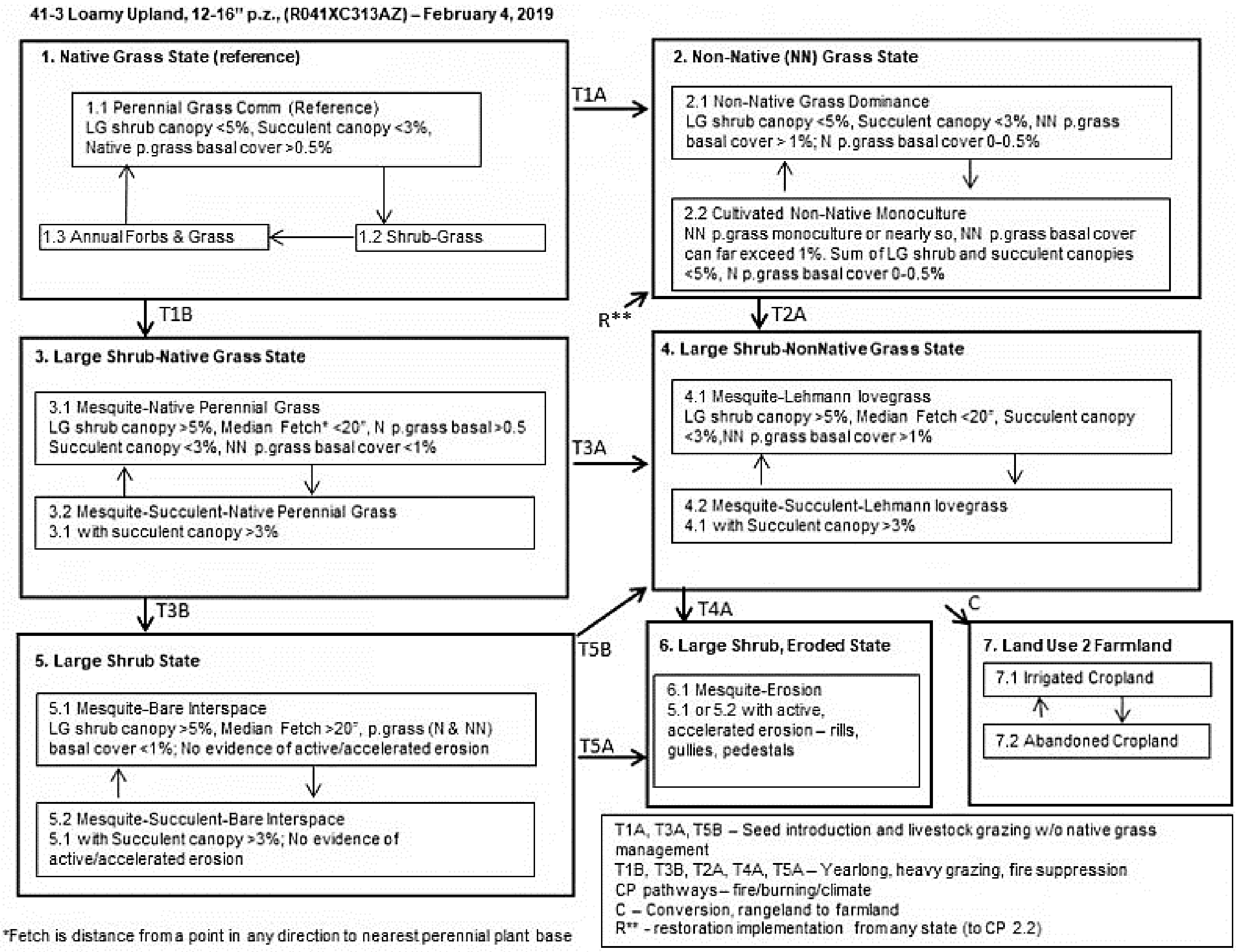
### State 1.1

#### Native Grass (Reference)

The Native Grass (Reference) State is characterized by the open grassland aspect, with a wide variety of native perennial grasses dominating the plant community.

Characteristics and indicators. Native perennial grass basal cover ≥ 0.5 percent, large shrub (mesquite) canopy <5 percent, and succulent canopy <3 percent.

## State-and-transition model




**Dominant plant species**

| | | |
|---|---|---|
| Velvet mesquite | *Prosopis velutina* | shrub |
| fairyduster | *Calliandra eriophylla* | shrub |
| ratany | *Krameria* | shrub |
| broom snakeweed | *Gutierrezia sarothrae* | shrub |

| Community 1.1.1<br>Native Perennial Grass (Reference) | | |
|---|---|---|
| Blue grama | *Bouteloua gracilis* | grass |
| Sideoats grama | *Bouteloua curtipendula* | grass |
| curly-mesquite | *Hilaria belangeri* | grass |

**Figure E-B-3.** Loamy Upland 12"–16" p.z. Dos Cabezas Cemetery.

The potential plant community on this site is dominated by warm season perennial grasses. All the major perennial grass species on the site are well dispersed throughout the plant community. Perennial forbs and a few species of low shrubs are well represented on the site. The aspect is open grassland.

With continuous heavy grazing, palatable perennial grasses like blue, hairy, sprucetop and sideoats gramas decrease. Increasers under such circumstances include curly mesquite, threeawns and, in places, false mesquite. With severe deterioration, shrubby species increase to dominate. Loss of porous surface soil causes a reduction in the site’s ability to effectively use intense summer rainfall. Natural fire was important in the development of the potential plant community. Stable areas of the site can produce effective herbaceous covers with up to 5 percent canopy cover of mesquite. In areas where half-shrubs dominate the under-story, the potential production of perennial grass is about the same as the present production of half-shrubs once they are removed from the plant community by fire or brush management.

**Table E-B-5.** Annual production by plant type.

| Plant Type | Low (Lb/Acre) | Representative Value (Lb/Acre) | High (Lb/Acre) |
|---|---|---|---|
| Grass/Grasslike | 546 | 850 | 1350 |
| Forb | 20 | 45 | 225 |
| Shrub/Vine | 53 | 100 | 210 |
| Tree | 0 | 5 | 15 |
| Total | 619 | 1000 | 1800 |

**Table E-B-6.** Soil surface cover.

| Surface Cover | Percent |
|---|---|
| Tree basal cover | 0–1 |
| Shrub/vine/liana basal cover | 1–5 |
| Grass/grasslike basal cover | 6–25 |
| Forb basal cover | 0–1 |
| Non-vascular plants | 0–1 |
| Biological crusts | 1–10 |
| Litter | 10–60 |
| Surface fragments >0.25" and <=3" | 5–40 |
| Surface fragments >3" | 0–15 |
| Bedrock | 0 |
| Water | 0 |
| Bare ground | 15–25 |

**Table E-B-7.** Canopy structure (percent cover).

| Height Above Ground (Ft) | Tree | Shrub/Vine | Grass/ Grasslike | Forb |
|---|---|---|---|---|
| <0.5 | – | 1–10% | 10–25% | 0–5% |
| >0.5 <= 1 | – | 1–10% | 10–25% | 0–2% |
| >1 <= 2 | – | 0–5% | 10–15% | 0–2% |
| >2 <= 4.5 | – | 0–1% | 1–5% | – |
| >4.5 <= 13 | 0–1% | – | – | – |
| >13 <= 40 | – | – | – | – |
| >40 <= 80 | – | – | – | – |
| >80 <= 120 | – | – | – | – |
| >120 | – | – | – | – |

**Figure E-B-4.** Plant community growth curve (percent production by month). AZ4134, 41.3 12"–16" p.z. other sites. Growth begins in the spring, semi-dormancy occurs during the May through June drought, most growth occurs during the summer rains.

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 5 | 10 | 0 | 0 | 30 | 35 | 15 | 5 | 0 | 0 |

**Community 1.1.2**
Small Shrub-Native Grass

The small shrub, decadent grass community phase occurs after several fire-free years and average or above average rainfall period. Perennial grass litter accumulates, and live basal cover may contract. Small shrub population reflects winter moisture dynamics with a flourish of germination and increase canopy cover following wet winters.

**Community 1.1.3**
Annual Forbs and Grasses

Annual forbs and annual grasses dominate this plant community phase while perennial grasses and half shrubs are diminished after fire or extended drought. This CP is extremely vulnerable to non-native perennial grass germination from a latent soil seedbank.

Pathway P1.1a Community 1.1.1 to 1.1.2

Disturbance free plant growth and decadence.

Pathway P1.2a Community 1.1.2 to 1.1.3

Fire

Pathway P1.3a Community 1.1.3 to 1.1.1

Post-fire regrowth

**State 1.2**

Non-Native Grass

Non-native lovegrass basal cover is more than 1 percent within the plant community; native perennial grass basal cover is diminished. Large shrubs are scattered with less than 5 percent canopy cover. Fire may act to increase exotic lovegrass at the expense of native perennial grasses but may allow native annual species a chance to make seed and persist in the seedbank. Some soil compaction has occurred due to livestock traffic, but hydrologic relationships have not been impaired

Characteristics and indicators. Large shrub canopy <5 percent; succulent canopy <3 percent; Non-native perennial grass basal cover >1 percent; native perennial grass basal cover 0–5 percent

Dominant plant species

| | | |
|---|---|---|
| Fairyduster | *Calliandra eriophylla* | shrub |
| littleleaf ratany | *Krameria erecta* | shrub |
| Lehmann lovegrass | *Eragrostis lehmanniana* | grass |
| weeping lovegrass | *Eragrostis curvula* | grass |

Dominant resource concerns

Plant productivity and health Plant structure and composition Feed and forage imbalance
Inadequate livestock shelter
Inadequate livestock water quantity, quality, and distribution

**Community 1.2.1 Lehmann Lovegrass**

A suite of African lovegrasses can become entrenched on this ecological site; Lehmann lovegrass is the most common and has been seen to persist in the plant community once its basal cover exceeds 1 percent. The native perennial grasses can remain until a disturbance, such as drought, fire, yearlong or heavy growing season grazing, depletes vigor or causes perennial grass mortality. Large shrub and succulent canopy percentages are similar to State 1.

**Community 1.2.2**
Cultivated non-native grass monoculture

Non-native perennial grasses prevail across this LRU, with a seedbank that may or may not be readily apparent on site. A non-native perennial grass monoculture results from application several restoration practices applied to any of Loamy Upland States. Most commonly, brush management or mechanical land treatment (ripping) is applied to remove mesquite dominance and reduce erosion (from States 4 or 5, for example). While species like Lehmann, Boer, Wilman and Cochise lovegrass may be seeded, non-native perennial grasses will likely invade the site regardless because of their overwhelming presence across this LRU. With good grazing management, hydrologic relationships are good and non-native grass productivity remains high (although protein and nutrient values of LL are negligible). Treated areas typically have reduced runoff for long periods of time, depending on grazing management. Mesquite and other shrubs will re-invade these areas making brush management maintenance treatment necessary within 10–15 years.

**State 1.3**

Large Shrub, Native Grass

**Figure E-B-5.**

The open aspect is interrupted by large shrubs. The perennial grass community is diminished in diversity and basal cover.

Characteristics and indicators. Large shrub canopy >5 percent, median fetch* <20”, native perennial grass basal cover 0.5 percent, NN p. grass basal cover <1 percent; succulents may or may not be dominant, see CPs.

*Fetch is distance from a point in any direction to nearest perennial plant base

Dominant plant species

| | | |
|---|---|---|
| velvet mesquite | *Prosopis velutina* | shrub |
| blue grama | *Bouteloua gracilis* | grass |
| curly-mesquite | *Hilaria belangeri* | grass |

Dominant resource concerns

Feed and forage imbalance

Inadequate livestock water quantity, quality, and distribution

**Community 1.3.1**

Mesquite, Native Perennial Grass

Mesquite increases in the absence of fire for long periods of time. Native perennial grasses maintain dominance with good grazing management; mesquite canopy levels are from 5 to 10 percent. Short gramas and curly mesquite are dominant and the site remains stable as long as their basal cover does not drop below 6 or 7 percent. Snakeweed and burroweed cycle with climate but never gain dominance. Some soil compaction has occurred due to livestock traffic, but hydrologic relationships are not impaired.

**Community 1.3.2**

Mesquite, Succulent, Native Perennial Grass

Succulents, once established within the plant community, expand in canopy coverage until removed by fire.

Pathway P3.1a Community 1.3.1 to 1.3.2

Fire-free period

Pathway P3.2a Community 1.3.2 to 1.3.1

Prescribed burning and prescribed grazing.

**State 1.4**

Large Shrub, Non-native Grass

Large shrubs and non-native lovegrasses are co-dominant. Native perennial grasses may remain intact, generally under large shrub canopies. Non-native perennial grasses include African lovegrasses (most commonly Lehmann and Cochise lovegrasses) and, at the low and high elevations of this LRU, bufflegrass and yellow bluestem, respectively. The large shrubs are resistant to fire mortality and burning will not affect their removal from the plant community. Repeated burning or heavy grazing negatively affects the perennial grasses and puts the site at risk of excessive soil erosion. In these areas, mechanical brush management will likely result in transitioning the site to State 2, with a loss of native grasses, both their productivity and diversity.

Characteristics and indicators. Large shrub canopy >5 percent, median fetch* <20”, NN p. grass basal cover >1 percent; succulent canopy fluctuates, see CPs. Native perennial grass basal cover 0–5 percent.

*Fetch is distance from a point in any direction to nearest perennial plant base

Dominant plant species

| | | |
|---|---|---|
| velvet mesquite | *Prosopis velutina* | shrub |
| Lehmann lovegrass | *Eragrostis lehmanniana* | grass |
| weeping lovegrass | *Eragrostis curvula* | grass |
| yellow bluestem | *Bothriochloa ischaemum* | grass |

**Community 1.4.1**

Mesquite, Lehmann lovegrass

**Community 1.4.2**

Mesquite, Succulents, Lehmann lovegrass

**State 1.5 Large Shrub**

**Figure E-B-6.**


Mesquite and other large shrubs have increased and are dominant with canopies greater than 5 percent. Native and non-native annual forbs and grasses, both cool and warm season, dominate the under-story. Snakeweed and burroweed cycle with climate, but both remain important in the plant community. Native perennial grasses are largely gone, due to the interactions of drought, fire and continuous, heavy grazing. Areas located close to mountains usually have higher soil cover of cobbles and gravel, thus, exhibit inherent soil and site stability. Hydrologic relationships have changed to increase the amount of runoff. Loamy upland in this State is at risk to transition to State 6 (Large Shrub, Eroded).

Characteristics and indicators. Large shrub canopy >5 percent, Median Fetch* >20”, perennial grass basal cover <1 percent, no evidence of active, accelerated erosion

*Fetch is distance from a point in any direction to nearest perennial plant base

Dominant plant species

| | | |
|---|---|---|
| velvet mesquite | *Prosopis velutina* | shrub |
| burroweed | *Isocoma tenuisecta* | shrub |
| broom snakeweed | *Gutierrezia sarothrae* | shrub |

Dominant resource concerns

Plant productivity and health Plant structure and composition Feed and forage imbalance Inadequate livestock water quantity, quality, and distribution

**Community 1.5.1** Mesquite, bare interspace

The Mesquite-Bare Interspace Plant community is dominated by mesquite and other large shrubs with and understory of half-shrubs, snakeweed and burroweed; miscellaneous perennial forbs and annuals occur within the confines of the shrubs. Interspaces are open, herbaceous litter is moved by wind and water until obstructed.

Remnant perennial grasses, such as bush muhly and plains bristlegrass, may occur well within protection of shrubs and indicate a seed source. Succulents are not dominant in this community phase.

**Community 1.5.2** Mesquite, succulent, bare

The Mesquite-Succulent-Bare Interspace Plant community is dominated by mesquite and other large shrubs with and understory of half-shrubs and succulents (prickly pear and cane cholla). Interspaces are open, herbaceous litter is moved by wind and water until obstructed. Remnant perennial grasses, such as bush muhly and plains bristlegrass, may occur well within protection of shrubs and indicate a seed source. Succulents will continue growth until fine fuels accumulate to carry fire, such as after extremely wet spring flourish of annual forbs.

**State 1.6**

Large Shrub, Eroded

The Large Shrub, Eroded State is very similar in structure to States 4 and 5 (mesquite dominated, half-shrub understory), however, the soil erosion threshold has been crossed; active, extreme soil loss (exposed argillic horizon, rills, pedestals, gullies) is occurring. Snakeweed and burroweed cycle with climate, but both remain important in the plant community. Native perennial grasses are largely gone, due to the interactions of drought, fire and continuous, heavy grazing. Remnant non-native lovegrasses may be present. Hydrologic relationships are permanently altered. Restoration practices can be applied to slow erosion rates and trap sediments; paired with prescribed grazing, non-native lovegrasses will colonize the site resulting in Plant Community 2.2, Cultivated Lehmann lovegrass Community.

Characteristics and indicators. Large shrub canopy >5 percent, Median Fetch* >20”, perennial grass basal cover <1 percent, active, accelerated erosion as indicted by water flow patterns, litter dams, and rills

*Fetch is distance from a point in any direction to nearest perennial plant base

Dominant resource concerns

- Sheet and rill erosion
- Plant productivity and health Plant structure and composition Feed and forage imbalance
- Inadequate livestock water quantity, quality, and distribution

**Community 1.6.1** Mesquite, erosion

Mesquite dominates with active soil erosion in most interspaces (rills, exposed argillic horizon, gullies). Soil surface horizon is largely absent. Annual forbs and grasses are confined to shrubs. This plant community will not produce continuous fine fuels to carry fire.

Transition T1A State 1.1 to 1.2

Seed introduction and livestock grazing w/o native grass management or spontaneous flourish of Lehmann lovegrass establishing from unknown seedbank following fire/drought.

Transition T1B State 1.1 to 1.3

Extended fire-free interval (removal of fire fuel) and community composition changes by heavy, repeated or yearlong livestock grazing.

Transition T2A State 1.2 to 1.4

Extended fire-free interval (removal of fire fuel) and community composition changes by yearlong or heavy livestock grazing.

Restoration pathway R** State 1.3 to 1.2

From any Loamy Upland State, restoration practices applied to remove large shrub dominance or arrest accelerated erosion result in non-native perennial grass (Lehmann lovegrass) dominance.

Conservation practices

**Table E-B-7.** Conservation practices.

| Practice Name |
|---|
| Trails and Walkways |
| Brush Management |
| Fence |
| Grazing Land Mechanical Treatment |
| Livestock Pipeline |
| Livestock Use Area Protection |
| Pond |
| Pond Sealing or Lining, Bentonite Sealant |
| Pond Sealing or Lining, Flexible Membrane |
| Pond Sealing or Lining, Soil Dispersant |
| Prescribed Burning |
| Prescribed Grazing |
| Prescribed Grazing |
| Pumping Plant |
| Range Planting |
| Spring Development |
| Trails and Walkways |
| Upland Wildlife Habitat Management |
| Vegetated Treatment Area |
| Water Harvesting Catchment |
| Water Well |
| Watering Facility |

Transition T3A State 1.3 to 1.4

Seed introduction and livestock grazing w/o native grass management.

Transition T4A State 1.4 to 1.6

Yearlong, heavy grazing, fire suppression

Transition T5B State 1.5 to 1.4

Seed introduction and livestock grazing w/o native grass management

Transition T5A State 1.5 to 1.6

Yearlong, heavy grazing, fire suppression

### Land use 2 Cropland

Cropland includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and non-cultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, for example, hay land or pastureland that is in a rotation with row or close-grown crops. Non-cultivated cropland includes permanent hay land and horticultural cropland. In this MLRA-LRU, cultivated cropland is the more common category of use; all cropland is irrigated. Several row crops and close-grown crops are grown including cotton, corn, chili, and small grains. Hay land crops, alfalfa and bermudagrass, are rotated on a 3 to 5-year cycle.

When cropping and irrigation are suspended, annual forbs and annual grasses will dominate the newly barren field. Common annuals first to come in include Russian thistle, careless weed, and brome. Over time, shrubs and sub-shrubs will establish, initially in low-lying areas and eventually may come to dominate. Native perennial grasses will be largely absent; bermudagrass patches may establish in low-lying areas. Farm field maintenance, periodic tillage, will sustain the barren field with annual forbs and grasses.

After farming, the site may be restored to an area suitable to a grazing use. However, long-lasting changes in soil structure, hydrology, and nutrient availability prevent the site from returning to the Rangeland State-and-transition model. Restoration practices may be implemented to attain achieve land use goals such as increased forage availability. A desired plant community that will persist without continued watering may seeded before cessation of irrigation.

**Table E-B-8.** Dominant resource concerns.

| | **Dominant resource concerns** |
|---|---|
| | Sheet and rill erosion |
| | Wind erosion |
| | Ephemeral gully erosion |
| | Classic gully erosion |
| | Bank erosion from streams, shorelines, or water conveyance channels |
| | Subsidence |
| | Compaction |
| | Organic matter depletion |
| | Concentration of salts or other chemicals |
| | Aggregate instability |
| | Ponding and flooding |
| | Seasonal high water table |
| | Ground water depletion |
| | Naturally available moisture use |
| | Inefficient irrigation water use |
| | Nutrients transported to surface water |
| | Nutrients transported to ground water |
| | Pesticides transported to surface water |
| | Pesticides transported to ground water |
| | Pathogens and chemicals from manure, biosolids, or compost applications transported to surface water Pathogens and chemicals from manure, biosolids, or compost applications transported to ground water |
| | Salts transported to surface water |
| | Salts transported to ground water |
| | Petroleum, heavy metals, and other pollutants transported to surface water |
| | Petroleum, heavy metals, and other pollutants transported to ground water |
| | Sediment transported to surface water |
| | Elevated water temperature |
| | Emissions of particulate matter (PM) and PM precursors |
| | Emissions of greenhouse gases (GHGs) |
| | Emissions of ozone precursors |
| | Plant productivity and health |
| | Plant structure and composition |
| | Plant pest pressure |
| | Terrestrial habitat for wildlife and invertebrates |
| | Feed and forage imbalance |
| | Inadequate livestock shelter |
| | Inadequate livestock water quantity, quality, and distribution |
| | Energy efficiency of equipment and facilities |
| | Energy efficiency of farming/ranching practices and field operations |

Conversion C Land use 1 to 2
Conversion from rangeland to cropland, requires extensive input into field and irrigation development.

Additional community tables

**Table E-B-9.** Community 1.1 plant community composition.

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| **Grass/Grasslike** | | | | | |
| **1** | **Dominant Mid Grasses** | **300–500** | | | |
| | sideoats grama | BOCU | *Bouteloua curtipendula* | 200–500 | |
| | plains lovegrass | ERIN | *Eragrostis intermedia* | 50–200 | |
| | cane bluestem | BOBA3 | *Bothriochloa barbinodis* | 50–200 | |
| **2** | **Dominant Short Grasses** | **150–300** | | | |
| | blue grama | BOGR2 | *Bouteloua gracilis* | 50–250 | |
| | sprucetop grama | BOCH | *Bouteloua chondrosioides* | 50–100 | |
| | black grama | BOER4 | *Bouteloua eriopoda* | 50–100 | |
| | hairy grama | BOHI2 | *Bouteloua hirsuta* | 0–50 | |
| | slender grama | BORE2 | *Bouteloua repens* | 0–50 | |
| | common wolfstail | LYPH | *Lycurus phleoides* | 0–50 | |
| **3** | **Shortlived Grasses** | **20–150** | | | |
| | Rothrock's grama | BORO2 | *Bouteloua rothrockii* | 10–50 | |
| | curly-mesquite | HIBE | *Hilaria belangeri* | 10–50 | |
| | sand dropseed | SPCR | *Sporobolus cryptandrus* | 0–50 | |
| | Arizona muhly | MUAR3 | *Muhlenbergia arizonica* | 0–25 | |
| **4** | **Subdominant Mid Grasses** | **10–150** | | | |
| | Arizona cottontop | DICA8 | *Digitaria californica* | 5–50 | |
| | bush muhly | MUPO2 | *Muhlenbergia porteri* | 0–50 | |
| | plains bristlegrass | SEVU2 | *Setaria vulpiseta* | 5–50 | |
| | tanglehead | HECO10 | *Heteropogon contortus* | 0–40 | |
| **5** | **Perennial Threeawns** | **50–100** | | | |
| | spidergrass | ARTE3 | *Aristida ternipes* | 5–50 | |
| | spidergrass | ARTEG | *Aristida ternipes var. gentilis* | 5–50 | |
| | Fendler threeawn | ARPUL | *Aristida purpurea var. longiseta* | 5–50 | |
| | poverty threeawn | ARDI5 | *Aristida divaricata* | 5–30 | |
| | purple threeawn | ARPU9 | *Aristida purpurea* | 0–25 | |
| | Parish's threeawn | ARPUP5 | *Aristida purpurea var. parishii* | 0–25 | |
| | Santa Rita threeawn | ARCAG | *Aristida californica var. glabrata* | 0–15 | |
| | Havard's threeawn | ARHA3 | *Aristida havardii* | 0–10 | |
| | Wooton's threeawn | ARPA9 | *Aristida pansa* | 0–10 | |
| | Wright's threeawn | ARPUW | *Aristida purpurea var. wrightii* | 0–10 | |
| **6** | **Miscellaneous Grasses** | **6–50** | | | |
| | squirreltail | ELEL5 | *Elymus elymoides* | 5–50 | |
| | tobosagrass | PLMU3 | *Pleuraphis mutica* | 0–25 | |
| | green sprangletop | LEDU | *Leptochloa dubia* | 0–20 | |
| | vine mesquite | PAOB | *Panicum obtusum* | 0–20 | |
| | whiplash pappusgrass | PAVA2 | *Pappophorum vaginatum* | 0–20 | |
| | purple grama | BORA | *Bouteloua radicosa* | 0–20 | |
| | fall witchgrass | DICO6 | *Digitaria cognata* | 1–20 | |
| | red grama | BOTR2 | *Bouteloua trifida* | 0–10 | |
| | burrograss | SCBR2 | *Scleropogon brevifolius* | 0–10 | |
| | spike dropseed | SPCO4 | *Sporobolus contractus* | 0–5 | |
| | slim tridens | TRMU | *Tridens muticus* | 0–5 | |
| | Hall's panicgrass | PAHA | *Panicum hallii* | 0–5 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | low woollygrass | DAPU7 | *Dasyochloa pulchella* | 0–5 | |
| | nineawn pappusgrass | ENDE | *Enneapogon desvauxii* | 0–5 | |
| **7** | **Annual Grasses** | **10–100** | | | |
| | sixweeks threeawn | ARAD | *Aristida adscensionis* | 1–50 | |
| | feather fingergrass | CHVI4 | *Chloris virgata* | 0–50 | |
| | needle grama | BOAR | *Bouteloua aristidoides* | 1–50 | |
| | Mexican panicgrass | PAHI5 | *Panicum hirticaule* | 0–50 | |
| | sixweeks fescue | VUOC | *Vulpia octoflora* | 1–50 | |
| | mucronate sprangeltop | LEPAB | *Leptochloa panicea ssp. brachiata* | 0–25 | |
| | sixweeks grama | BOBA2 | *Bouteloua barbata* | 1–25 | |
| | tapertip cupgrass | ERACA | *Eriochloa acuminata var. acuminata* | 0–25 | |
| | prairie threeawn | AROL | *Aristida oligantha* | 1–20 | |
| | tufted lovegrass | ERPE | *Eragrostis pectinacea* | 0–20 | |
| | desert lovegrass | ERPEM | *Eragrostis pectinacea var. miserrima* | 0–20 | |
| | Mexican sprangletop | LEFUU | *Leptochloa fusca ssp. uninervia* | 0–20 | |
| | Arizona signalgrass | URAR | *Urochloa arizonica* | 0–20 | |
| | Mexican lovegrass | ERME | *Eragrostis mexicana* | 0–15 | |
| | littleseed muhly | MUMI | *Muhlenbergia microsperma* | 0–10 | |
| | witchgrass | PACA6 | *Panicum capillare* | 0–10 | |
| | Parry's grama | BOPA2 | *Bouteloua parryi* | 0–10 | |
| | Arizona brome | BRAR4 | *Bromus arizonicus* | 0–5 | |
| | Bigelow's bluegrass | POBI | *Poa bigelovii* | 0–5 | |
| | delicate muhly | MUFR | *Muhlenbergia fragilis* | 0–5 | |
| **Forb** | | | | | |
| **8** | **Perennial Forbs** | **5–75** | | | |
| | weakleaf bur ragweed | AMCO3 | *Ambrosia confertiflora* | 1–25 | |
| | bluedicks | DICA14 | *Dichelostemma capitatum* | 1–20 | |
| | spreading fleabane | ERDI4 | *Erigeron divergens* | 1–20 | |
| | lacy tansyaster | MAPI | *Machaeranthera pinnatifida* | 1–20 | |
| | desert globemallow | SPAM2 | *Sphaeralcea ambigua* | 1–20 | |
| | brownplume wirelettuce | STPA4 | *Stephanomeria pauciflora* | 1–20 | |
| | New Mexico fanpetals | SINE | *Sida neomexicana* | 0–10 | |
| | Rocky Mountain zinnia | ZIGR | *Zinnia grandiflora* | 1–10 | |
| | Wright's deervetch | LOWR | *Lotus wrightii* | 1–10 | |
| | Indian rushpea | HOGL2 | *Hoffmannseggia glauca* | 0–10 | |
| | slender janusia | JAGR | *Janusia gracilis* | 0–10 | |
| | wild dwarf morning-glory | EVAR | *Evolvulus arizonicus* | 1–10 | |
| | spreading snakeherb | DYSCD | *Dyschoriste schiedeana var. decumbens* | 0–10 | |
| | dense ayenia | AYMI | *Ayenia microphylla* | 0–10 | |
| | leatherweed | CRPO5 | *Croton pottsii* | 0–10 | |
| | Cooley's bundleflower | DECO2 | *Desmanthus cooleyi* | 0–5 | |
| | trailing windmills | ALIN | *Allionia incarnata* | 0–5 | |
| | Arizona wrightwort | CAAR7 | *Carlowrightia arizonica* | 0–5 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | hairyseed bahia | BAAB | *Bahia absinthifolia* | 0–5 | |
| | desert marigold | BAMU | *Baileya multiradiata* | 0–5 | |
| | dwarf desertpeony | ACNA2 | *Acourtia nana* | 0–5 | |
| | brownfoot | ACWR5 | *Acourtia wrightii* | 0–5 | |
| | fetid marigold | DYPA | *Dyssodia papposa* | 0–5 | |
| | Arizona snakecotton | FRAR2 | *Froelichia arizonica* | 0–5 | |
| | beeblossom | GAURA | *Gaura* | 0–5 | |
| | small matweed | GUDE | *Guilleminea densa* | 0–5 | |
| | ragged nettlespurge | JAMA | *Jatropha macrorhiza* | 0–5 | |
| | Greene's bird's-foot trefoil | LOGR4 | *Lotus greenei* | 0–5 | |
| | Gila manroot | MAGI | *Marah gilensis* | 0–5 | |
| | variableleaf bushbean | MAGI2 | *Macroptilium gibbosifolium* | 0–5 | |
| | American vetch | VIAM | *Vicia americana* | 0–5 | |
| | Louisiana vetch | VILU | *Vicia ludoviciana* | 0–5 | |
| | silverleaf nightshade | SOEL | *Solanum elaeagnifolium* | 0–5 | |
| | Coulter's wrinklefruit | TECO | *Tetraclea coulteri* | 0–5 | |
| | pricklyleaf dogweed | THAC | *Thymophylla acerosa* | 0–5 | |
| | tufted evening primrose | OECA10 | *Oenothera caespitosa* | 0–5 | |
| | orange fameflower | PHAU13 | *Phemeranthus aurantiacus* | 0–5 | |
| | slender poreleaf | POGR5 | *Porophyllum gracile* | 0–5 | |
| | velvetseed milkwort | POOB | *Polygala obscura* | 0–5 | |
| | Arizona cudweed | PSAR12 | *Pseudognaphalium arizonicum* | 0–5 | |
| | Wright's cudweed | PSCAC2 | *Pseudognaphalium canescens ssp. canescens* | 0–5 | |
| | twinleaf senna | SEBA3 | *Senna bauhinioides* | 0–5 | |
| | Leiberg stonecrop | SELE | *Sedum leibergii* | 0–5 | |
| | Lemmon's ragwort | SELE8 | *Senecio lemmonii* | 0–5 | |
| | anoda | ANODA | *Anoda* | 0–5 | |
| | tuber anemone | ANTU | *Anemone tuberosa* | 0–5 | |
| | rockcress | ARABI2 | *Arabis* | 0–5 | |
| | New Mexico silverbush | ARNE2 | *Argythamnia neomexicana* | 0–5 | |
| | pioneer rockcress | ARPL | *Arabis platysperma* | 0–5 | |
| | southwestern pricklypoppy | ARPL3 | *Argemone pleiacantha* | 0–5 | |
| | Watson's dutchman's pipe | ARWA | *Aristolochia watsonii* | 0–5 | |
| | spiny milkwort | POSU2 | *Polygala subspinosa* | 0–2 | |
| | shrubby purslane | POSU3 | *Portulaca suffrutescens* | 0–2 | |
| | branched noseburn | TRRA5 | *Tragia ramosa* | 0–2 | |
| | jewels of Opar | TAPA2 | *Talinum paniculatum* | 0–2 | |
| | gooseberryleaf globemallow | SPGR2 | *Sphaeralcea grossulariifolia* | 0–2 | |
| | canaigre dock | RUHY | *Rumex hymenosepalus* | 0–2 | |
| | rose heath | CHER2 | *Chaetopappa ericoides* | 0–2 | |
| | San Felipe dogweed | ADPO | *Adenophyllum porophylloides* | 0–2 | |
| | lyreleaf greeneyes | BELY | *Berlandiera lyrata* | 0–2 | |
| | climbing wartclub | BOSC | *Boerhavia scandens* | 0–2 | |
| | fingerleaf gourd | CUDI | *Cucurbita digitata* | 0–2 | |
| | coyote gourd | CUPA | *Cucurbita palmata* | 0–2 | |
| | desert larkspur | DEPA | *Delphinium parishii* | 0–1 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | Indian paintbrush | CASTI2 | *Castilleja* | 0–1 | |
| | desert tobacco | NIOB | *Nicotiana obtusifolia* | 0–1 | |
| | copper zephyrlily | ZELO | *Zephyranthes longifolia* | 0–1 | |
| | slimflower scurfpea | PSTE5 | *Psoralidium tenuiflorum* | 0–1 | |
| **9** | **Annual forbs** | **15–150** | | | |
| | sensitive partridge pea | CHNI2 | *Chamaecrista nictitans* | 1–50 | |
| | longleaf false goldeneye | HELOA2 | *Heliomeris longifolia var. annua* | 1–50 | |
| | camphorweed | HESU3 | *Heterotheca subaxillaris* | 0–25 | |
| | Arizona poppy | KAGR | *Kallstroemia grandiflora* | 0–25 | |
| | slender goldenweed | MAGR10 | *Machaeranthera gracilis* | 1–25 | |
| | tanseyleaf tansyaster | MATA2 | *Machaeranthera tanacetifolia* | 1–25 | |
| | woolly plantain | PLPA2 | *Plantago patagonica* | 1–25 | |
| | Arizona popcornflower | PLAR | *Plagiobothrys arizonicus* | 1–25 | |
| | desert Indianwheat | PLOV | *Plantago ovata* | 1–20 | |
| | hollowleaf annual lupine | LUSU3 | *Lupinus succulentus* | 0–20 | |
| | crestrib morning-glory | IPCO2 | *Ipomoea costellata* | 1–20 | |
| | western tansymustard | DEPI | *Descurainia pinnata* | 1–20 | |
| | lambsquarters | CHAL7 | *Chenopodium album* | 1–20 | |
| | Coulter's spiderling | BOCO2 | *Boerhavia coulteri* | 1–20 | |
| | carelessweed | AMPA | *Amaranthus palmeri* | 1–20 | |
| | milkvetch | ASTRA | *Astragalus* | 1–20 | |
| | wheelscale saltbush | ATEL | *Atriplex elegans* | 0–15 | |
| | New Mexico thistle | CINE | *Cirsium neomexicanum* | 1–15 | |
| | California poppy | ESCAM | *Eschscholzia californica ssp. mexicana* | 0–15 | |
| | shaggyfruit pepperweed | LELA | *Lepidium lasiocarpum* | 0–15 | |
| | foothill deervetch | LOHU2 | *Lotus humistratus* | 0–15 | |
| | coastal bird's-foot trefoil | LOSAB | *Lotus salsuginosus var. brevivexillus* | 0–15 | |
| | spreading fanpetals | SIAB | *Sida abutifolia* | 1–15 | |
| | woolly tidestromia | TILA2 | *Tidestromia lanuginosa* | 0–10 | |
| | purslane | PORTU | *Portulaca* | 0–10 | |
| | manybristle chinchweed | PEPA2 | *Pectis papposa* | 0–10 | |
| | tepary bean | PHAC | *Phaseolus acutifolius* | 0–10 | |
| | sorrel buckwheat | ERPO4 | *Eriogonum polycladon* | 1–10 | |
| | scrambled eggs | COAU2 | *Corydalis aurea* | 0–10 | |
| | fringed redmaids | CACI2 | *Calandrinia ciliata* | 0–10 | |
| | suncup | CAMIS | *Camissonia* | 0–5 | |
| | hoary bowlesia | BOIN3 | *Bowlesia incana* | 0–5 | |
| | miner's lettuce | CLPEP | *Claytonia perfoliata ssp. perfoliata* | 0–5 | |
| | bristly fiddleneck | AMTE3 | *Amsinckia tessellata* | 0–5 | |
| | New Mexico copperleaf | ACNE | *Acalypha neomexicana* | 0–5 | |
| | cryptantha | CRYPT | *Cryptantha* | 0–5 | |
| | American wild carrot | DAPU3 | *Daucus pusillus* | 1–5 | |
| | Wright's prairie | DAWR | *Dalea wrightii* | 0–5 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | clover | | | | |
| | sacred thorn-apple | DAWR2 | *Datura wrightii* | 0–5 | |
| | Texas stork's bill | ERTE13 | *Erodium texanum* | 0–5 | |
| | wedgeleaf draba | DRCU | *Draba cuneifolia* | 0–5 | |
| | spurge | EUPHO | *Euphorbia* | 0–5 | |
| | Arizona blanketflower | GAAR2 | *Gaillardia arizonica* | 0–5 | |
| | star gilia | GIST | *Gilia stellata* | 0–5 | |
| | southwestern mock vervain | GLGO | *Glandularia gooddingii* | 0–5 | |
| | pearly globe amaranth | GONI | *Gomphrena nitida* | 0–5 | |
| | Arizona gumweed | GRAR2 | *Grindelia arizonica* | 0–5 | |
| | Arizona lupine | LUAR4 | *Lupinus arizonicus* | 0–5 | |
| | Coulter's lupine | LUSP2 | *Lupinus sparsiflorus* | 0–5 | |
| | miniature woollystar | ERDI2 | *Eriastrum diffusum* | 0–5 | |
| | Thurber's morning-glory | IPTH | *Ipomoea thurberi* | 0–5 | |
| | intermediate pepperweed | LEVIM | *Lepidium virginicum var. medium* | 0–5 | |
| | Lewis flax | LILE3 | *Linum lewisii* | 0–5 | |
| | whitestem blazingstar | MEAL6 | *Mentzelia albicaulis* | 0–5 | |
| | Nuttall's povertyweed | MONU | *Monolepis nuttalliana* | 0–5 | |
| | combseed | PECTO | *Pectocarya* | 0–5 | |
| | phacelia | PHACE | *Phacelia* | 0–5 | |
| | phlox | PHLOX | *Phlox* | 0–5 | |
| | groundcherry | PHYSA | *Physalis* | 0–5 | |
| | desert unicorn-plant | PRAL4 | *Proboscidea althaeifolia* | 0–5 | |
| | doubleclaw | PRPA2 | *Proboscidea parviflora* | 0–5 | |
| | New Mexico plumeseed | RANE | *Rafinesquia neomexicana* | 0–5 | |
| | golden crownbeard | VEEN | *Verbesina encelioides* | 0–5 | |
| | sleepy silene | SIAN2 | *Silene antirrhina* | 0–5 | |
| | Gordon's bladderpod | LEGO | *Lesquerella gordonii* | 0–5 | |
| | sawtooth sage | SASU7 | *Salvia subincisa* | 1–5 | |
| | chia | SACO6 | *Salvia columbariae* | 0–2 | |
| | Fendler's desertdandelion | MAFE | *Malacothrix fendleri* | 0–2 | |
| | warty caltrop | KAPA | *Kallstroemia parviflora* | 0–2 | |
| | redstar | IPCO3 | *Ipomoea coccinea* | 0–2 | |
| | sanddune wallflower | ERCA14 | *Erysimum capitatum* | 0–2 | |
| | southwestern pricklypoppy | ARPL3 | *Argemone pleiacantha* | 0–2 | |
| | fewflower beggarticks | BILE | *Bidens leptocephala* | 0–2 | |
| | sego lily | CANU3 | *Calochortus nuttallii* | 1–2 | |
| **Shrub/Vine** | | | | | |
| **10** | **Dominant Half-shrubs** | **50–100** | | | |
| | fairyduster | CAER | *Calliandra eriophylla* | 20–100 | |
| | bastardsage | ERWR | *Eriogonum wrightii* | 10–50 | |
| | littleleaf ratany | KRER | *Krameria erecta* | 20–50 | |
| | trailing krameria | KRLA | *Krameria lanceolata* | 0–50 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | desert zinnia | ZIAC | *Zinnia acerosa* | 0–50 | |
| **11** | **Increaser Half-shrubs** | **1–40** | | | |
| | broom snakeweed | GUSA2 | *Gutierrezia sarothrae* | 1–30 | |
| | burroweed | ISTE2 | *Isocoma tenuisecta* | 0–30 | |
| | threadleaf snakeweed | GUMI | *Gutierrezia microcephala* | 0–20 | |
| | turpentine bush | ERLA12 | *Ericameria laricifolia* | 0–10 | |
| **12** | **Miscellaneous Shrubs** | **0–20** | | | |
| | Fourwing saltbush | ATCA 2 | *Atriplex canenscens* | 0–10 | |
| | velvet mesquite | PRVE | *Prosopis velutina* | 0–5 | |
| | oneseed juniper | JUMO | *Juniperus monosperma* | 0–2 | |
| | Jerusalem thorn | PAAC3 | *Parkinsonia aculeata* | 0–2 | |
| | blue paloverde | PAFL6 | *Parkinsonia florida* | 0–2 | |
| | spiny hackberry | CEEH | *Celtis ehrenbergiana* | 0–10 | |
| | knifeleaf condalia | COSP3 | *Condalia spathulata* | 0–5 | |
| | whitethorn acacia | ACCOP9 | *Acacia constricta var. paucispina* | 0–5 | |
| | catclaw acacia | ACGRG3 | *Acacia greggii var. greggii* | 0–5 | |
| | rough menodora | MESC | *Menodora scabra* | 0–5 | |
| | catclaw mimosa | MIACB | *Mimosa aculeaticarpa var. biuncifera* | 0–5 | |
| | sacahuista | NOMI | *Nolina microcarpa* | 0–5 | |
| | velvetpod mimosa | MIDY | *Mimosa dysocarpa* | 0–2 | |
| | longleaf jointfir | EPTR | *Ephedra trifurca* | 0–2 | |
| | American tarwort | FLCE | *Flourensia cernua* | 0–2 | |
| | ocotillo | FOSP2 | *Fouquieria splendens* | 0–2 | |
| | desert-thorn | LYCIU | *Lycium* | 0–2 | |
| | yerba de pasmo | BAPT | *Baccharis pteronioides* | 0–2 | |
| | Warnock's snakewood | COWA | *Condalia warnockii* | 0–2 | |
| | Kearney's snakewood | COWAK | *Condalia warnockii var. kearneyana* | 0–2 | |
| | whitethorn acacia | ACCO2 | *Acacia constricta* | 0–2 | |
| | lotebush | ZIOB | *Ziziphus obtusifolia* | 0–2 | |
| | button brittlebush | ENFR | *Encelia frutescens* | 0–1 | |
| | whitestem paperflower | PSCO2 | *Psilostrophe cooperi* | 0–1 | |
| | threadleaf ragwort | SEFL3 | *Senecio flaccidus* | 0–1 | |
| **13** | **Succulents** | **2–50** | | | |
| | Palmer's century plant | AGPA3 | *Agave palmeri* | 0–5 | |
| | beehive cactus | CORYP | *Coryphantha* | 0–5 | |
| | Christmas cactus | CYLE8 | *Cylindropuntia leptocaulis* | 0–5 | |
| | walkingstick cactus | CYSP8 | *Cylindropuntia spinosior* | 0–5 | |
| | staghorn cholla | CYVE3 | *Cylindropuntia versicolor* | 0–5 | |
| | hedgehog cactus | ECHIN3 | *Echinocereus* | 0–5 | |
| | candy barrelcactus | FEWI | *Ferocactus wislizeni* | 1–5 | |
| | globe cactus | MAMMI | *Mammillaria* | 0–5 | |
| | cactus apple | OPEN3 | *Opuntia engelmannii* | 1–5 | |
| | purple pricklypear | OPMAM | *Opuntia macrocentra var. macrocentra* | 0–5 | |
| | tulip pricklypear | OPPH | *Opuntia phaeacantha* | 0–5 | |

| Group | Common Name | Symbol | Scientific Name | Annual Production (Lb/Acre) | Foliar Cover (%) |
|---|---|---|---|---|---|
| | banana yucca | YUBA | *Yucca baccata* | 0–5 | |
| | soaptree yucca | YUEL | *Yucca elata* | 0–5 | |
| | jumping cholla | CYFU10 | *Cylindropuntia fulgida* | 0–5 | |
| | candle cholla | CYKL | *Cylindropuntia kleiniae* | 0–2 | |
| | Santa Rita pricklypear | OPSA | *Opuntia santa-rita* | 0–2 | |
| | Arizona pencil cholla | CYAR14 | *Cylindropuntia arbuscula* | 0–2 | |
| | rainbow cactus | ECPEP | *Echinocereus pectinatus var. pectinatus* | 0–1 | |
| | spinystar | ESVI2 | *Escobaria vivipara* | 0–1 | |
| **Tree** | | | | | |
| **14** | **Trees** | **0–15** | | | |
| | western honey mesquite | PRGLT | *Prosopis glandulosa var. torreyana* | 0–5 | |

### Animal community

With continuous heavy grazing, palatable perennial grasses like blue, hairy, sprucetop and sideoats grammas and plains lovegrass decrease. Increasers under such circumstances include curly mesquite, threeawns and, in some areas, false mesquite. With severe deterioration, shrubby species increase to dominate. Mesquite forms the over-story with snakeweed and lesser amounts of burroweed in the under-story. Cholla and prickly pear can also increase on the site. Water developments are very important to wildlife on the site. Being open grassland, this site is home to a variety of small herbivores, birds and their associated predators. With the exception of the antelope, the site is mainly a forage area for larger wildlife species.

### Hydrological functions

Thin, coarse textured, soil surfaces capture some of the intense summer rainfall on the site. Natural rates of runoff are as high as 30 percent for this site. Very shallow argillic (clayey) horizons keep soil moisture high in the soil profile and available to shallow rooted plants. Rainfall simulator studies, conducted by ARS in southern Arizona, offer some insight into how the ratio of infiltration to runoff changes under different ecological conditions and with different thickness of soil surface horizon. Two inches of rain was applied to wet soils, in a one-hour time period. A site with vegetation in high ecological condition and 4 inches of A horizon, had a ratio of 27/73 percent, runoff to infiltration. A site with vegetation in fair ecological condition and 1 and 1/2 inches of A horizon, had a ratio of 44/56 percent, runoff to infiltration. And the last site with vegetation in poor ecological condition and with only 1/2 inch of A horizon had a ratio of 85/15 percent, runoff to infiltration.

### Recreational uses

Hunting, hiking, horseback riding, photography, bird-watching.

### Wood products

Mesquite remains shrubby on this site due to very thin soil surfaces over clayey sub-soils. Established mesquite offers little more than fuel-wood for campfires, and nothing large enough for post or stay.

### Inventory data references

Range 417s include 10 in excellent condition, 15 in good condition and 15 in fair condition.

**Type locality**

**Table E-B-10.** Type localities.

| | |
|---|---|
| Location 1: Pinal County, AZ | |
| Township/Range/Section | T10S R13E S2 |
| General legal description | Tom Mix Hwy ROW |
| Location 2: Cochise County, AZ | |
| Township/Range/Section | T18S R28E S2 |
| General legal description | Oak Ranch |
| Location 3: Cochise County, AZ | |
| Township/Range/Section | T21S R19E S17 |
| General legal description | Un-surveyed. Ft. Huachuca |
| Location 4: Pima County, AZ | |
| Township/Range/Section | T19S R14E S16 |
| General legal description | Enclosure # 41 on the Santa Rita Experimental Range. On the Whitehouse fan at 3575 feet elevation |

**Other references**

Griffith, G.E., J.M. Omernik, C.B. Johnson, and D.S. Turner, 2014, Ecoregions of Arizona (poster): U.S. Geological Survey Open-File Report 2014-1141, with map, scale 1:1,325,000, https://dx.doi.org/10.3133/ofr20141141. ISSN 2331-1258 (online)

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296.

McNab, W.H.; D.T. Cleland, J.A. Freeouf, J.E. Keys, Jr., G.J. Nowacki, C.A. Carpenter, comps. 2007. Description of ecological subregions: sections of the conterminous United States [CD-ROM]. Gen. Tech. Report WO-76B. Washington, DC: U.S. Department of Agriculture, Forest Service. 80 p.

Contributors: Dan Robinett, Larry D. Ellicott

Approval: Curtis Talbot, 4/12/2021

**Rangeland health reference sheet**

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

**Table E-B-11.**

| | |
|---|---|
| Author(s)/participant(s) | Robinett, Carrillo, Womack, Decker, Roberts, McReynolds, Buono |
| Contact for lead author | 3241 N Romero Rd, Tucson, AZ 85705 520-292-2999x105 |
| Date | 12/01/2007 |
| Approved by | Curtis Talbot |
| Approval date | |
| Composition (Indicators 10 and 12) based on | Annual Production |

**Table E-B-12**. Indicators.

| No. | Description |
|---|---|
| 1 | Number and extent of rills: None, these sites generally occur on low slopes not prone to rill formation |
| 2 | Presence of water flow patterns: They cover about 15 percent of the area, are discontinuous, sinuous, uniformly distributed and range in length from 2 to 20 feet and width is generally < 1ft |
| 3 | Number and height of erosional pedestals or terracettes: Very slight pedastalling on longer-lived plants. Terracettes are infrequent, 5 to 20 feet apart and with elevation differences of 1 – 2 in. |
| 4 | Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground): 20–25 percent bare ground (20–30 percent gravel on some soil series), bare patch size averages 1–3 ft, connectivity is very low |
| 5 | Number of gullies and erosion associated with gullies: None, these sites generally occur on low slopes not prone to gully formation |
| 6 | Extent of wind scoured, blowouts and/or depositional areas: None present |
| 7 | Amount of litter movement (describe size and distance expected to travel): Litter is all fine, herbaceous and litter movement in steeper areas is from 1 to 2 feet. Litter is not moving in flatter areas. No loss of litter from the site |
| 8 | Soil surface (top few mm) resistance to erosion (stability values are averages -- most sites will show a range of values): Soil surface is 3 to 4 inches of dark colored gravelly sandyloam over clayloam and clay. Soil surface resistance to erosion is good across the site with little variability, aggregate stability test averages > 5 |
| 9 | Soil surface structure and SOM content (include type of structure and A-horizon color and thickness): Soil surface has moderate to strong fine granular structure, with common to many fine roots. Surface horizon is 3 to 4 inches thick and dark colored and OM present throughout site |
| 10 | Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff: Perennial mid-grasses have a canopy of 30 percent, half-shrubs a canopy of 5 percent, shor grasses a canopy of 5 percent, and large shrubs and succulents a canopy of 2 percent. All species are uniformly dispersed with no reduction in basal area affecting infiltration and runoff (basal area: >12–15 percent) |
| 11 | Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site): No surface soil compaction. Soil surface is loose as you walk across it in some areas. An abrupt textural change at 3 to 4 inches from sandyloam to heavy clayloam or clay has the feel of being compacted but is not. |
| 12 | Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to): |
| | Dominant: Warm season perennial mid-grasses >> half-shrubs > warm season perennial short grasses = annual forbs > perennial forbs = succulents > large shrubs and trees |
| | Sub-dominant: Other: |
| | Additional: |
| 13 | Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence): Good age class distribution of dominant perennial grasses. Some mortality and loss of live basal meristem during severe drought conditions. Litter and senescent vegetation comprise a large amount of the total biomass |
| 14 | Average percent litter cover ( percent) and depth (in): Litter is roughly 20–25 percent of ground cover (predominantly from mid-grasses) and is uniformly distributed throughout site, depth (1/8 to 1 in) |
| 15 | Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production): Production in lbs/acre based on annual rainfall: High- >1150 lbs/ac, Norm- >1040 lbs/ac, Low- >930 lbs/ac |
| 16 | Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site: Mesquite, whitethorn, burroweed, prickly pear, Lehmann lovegrass |
| 17 | Perennial plant reproductive capability: Not impaired in any way; good age class distribution of perennial grasses, recruitment is evident throughout site |

## APPENDIX E-C. Study and Photograph Identification

A. Numbering Studies—Studies should be numbered to assure positive identification. These numbers can also be used to identify photographs. Following are three alternative schemes for numbering studies

(1) Number Scheme 1. Consecutive numbers may be assigned to study within an allotment. For example, Mooncreek #1 and Mooncreek #2 would be studies Number 1 and 2 within the Mooncreek Allotment. A disadvantage to using the name of allotments in a numbering scheme is that names can and often do change.

(2) Number Scheme 2 may be numbered based on their location within a township, range and section. A 10-character number can be assigned in the following manner.

(i) The first three characters are the township (03S), the second three are the range (27W), the next two are the section (08), and the last two are simply a series number assigned to a study based on the number of studies located within a section.

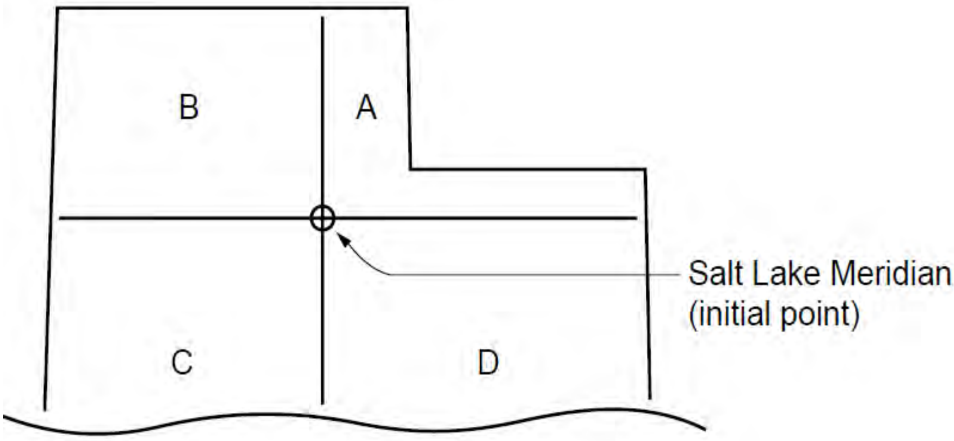
(ii) The numbers for studies located in Section 8 would be 03S-27W-08-01, 03S-27W-08-02, and so forth.

(iii) Depending on the local situation, this scheme can be modified by adding characters to the code where there are fractional townships or ranges, where there are more than 99 sections/tracts within a township, and/or where there is more than one public land survey principal meridian and baseline within the area of jurisdiction.

(3) Numbering Scheme 3. Studies may be numbered based on their location relative to the initial point of survey (principal meridian and baseline governing public land survey).

(i) Under this scheme, the first character is a letter assigned to a principal meridian and baseline quadrat. Using the initial point of the survey as the center point, the northeast quadrat (townships located to the north and east of the initial point) is coded "A." The northwest, southwest, and southeast quadrats are coded "B," "C," and "D," respectively. For Example:

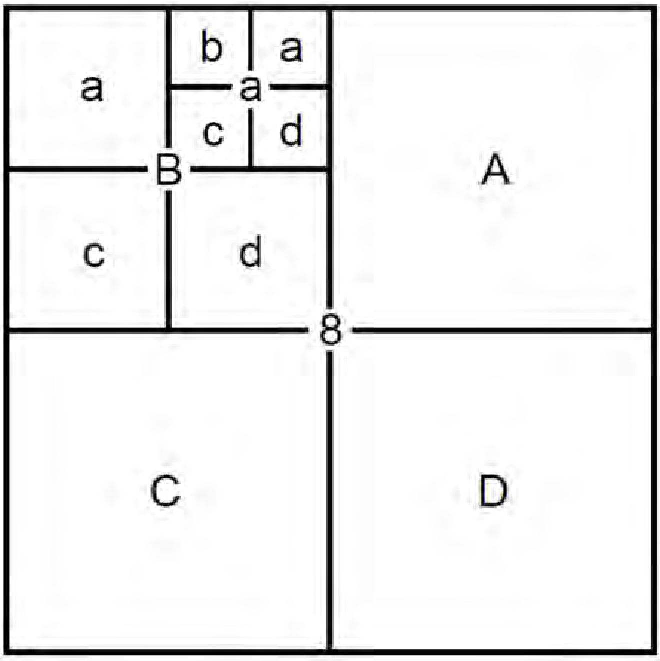
**Figure E-C-1.**




(ii) The next characters are the township number (3.16, etc. followed by the range number (7, 32, etc.) and the section number (8, 21, etc.)).

(iii) The next three characters are used to identify the subdivisions within a section (down to 10 acres) in which a study is located. These subdivisions have letter designations as follows:

**Figure E-C-2.** Numbering Scheme.




(iv) The last character(s) is (are) simply a series of numbers (1,2,3 etc.) assigned to a study based on the number of studies located within the smallest subdivision.
(v) For example, Studies 1 and 2 located in the SE1/4NE1/4NW1/4 of Section 8, T3S, R21E would be numbered (D-3-21)8Bad-1 and (D-3-21)8Bad-2.
(vi) Depending on the local situation, this scheme can be modified by adding characters to the code where there are fractional townships or ranges, where there are more than 99 sections/tracts within a township. And/or where there is more than one public land survey principal meridian and baseline within the area of jurisdiction.

B. Identifying Photographs—In most cases, the number that has been assigned to a study is the number used to identify the photographs associated with that study. Following is a description of the three labels that can be used to include the study number in the photographs:

(1) Label 1 The Photo Identification Label below can be copied and used to identify photographs. This label provides space for documenting the date, number, and location (Resource Area, allotment, and pasture) of study. A large black felt tip marking pen should be used to print the information on the label.
(2) Label 2 A common white board with dry erase markers can be used as a inexpensive label. The whiteboard should be large enough to have all specific identifying information at a scale that is readable in the photo (1½” lettering). After one photo site is complete, the white board can be wiped clean and the whiteboard reused for the next photo site. Caution must be used with markers that are not dark enough to be clearly visible (black is recommended) and the white board should be placed at an angle that prevents sunlight glare.

Photo Identification Label

DATE:____________
No.______________
R.A._____________
Allot.____________
Pasture:__________

## APPENDIX E-D. – NRCS Oregon Range Technical Note No. 27

# TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
PORTLAND, OREGON JULY 2014

**RANGE TECHNICAL NOTE NO. 27**

**Dry Weight Percentages of Selected Oregon Grasses, Grass-likes, Forbs, Vines, Shrubs, and Trees**

This technical note is based on information contained in a WNTSC technical note.

INTRODUCTION:

The green weight of field clipped vegetation needs to be converted to air-dry weight for immediate stocking recommendations, Ecological Site Descriptions, and Forage Suitability Groups.

Air-dry weight in pounds per acre (lbs./acre) or in kilograms per hectare (kg/ha) differentiate Ecological Site Description's characteristic vegetation of the reference state, the plant association tables, and the production data found in Forage Suitability Groups. The field green-weight must be converted to air-dry weight. Air-dry weight can be determined by using these conversion tables based on species and phenological stage of growth. The air-dry weight of all plant species are documented and inventoried during the conservation planning process and development of Ecological Site Descriptions.

The relationship of green weight to air-dry weight varies according to such factors as exposure, amount of shading, time since last rain, unseasonable dry periods, and the phenological stage of the plant. Thus, ranges of dry-weight are common in the tables.

Prescribed Grazing (528) requires a Forage-Animal Balance developed for the grazing plan. This balance ensures forage produced or available meets forage demand of livestock and/or wildlife. Air-dry forage consumed in one month is estimated to be 912.5 pounds per 1.000 pounds of grazing animal equivalent. This amount is known as an Animal Unit Month (AUM).

Usable production is a method of determining stocking rates based on measuring the total amount of forage (standing crop) per acre and converting green weight to air dry weights and into AUM's. The only production to be considered in determining stocking rate is the current year's forage growth below 4.5 feet vertical height. Forage from plant species that are undesirable, non-consumed, or toxic to the kind and class of livestock intended to graze the area should be excluded. The air dry weight is summarized for the entire area to be grazed after any necessary adjustments are made. Read Chapter 5 Management of Grazing Lands in the National Range and Pasture Handbook for information on adjustments.

HOW TO USE THE TABLES:

The tables contain the Plant Code; Phenological Stage Classification (occurrence of natural events in their annual cycle). The phenological classifications for grasses, forbs, and tree/shrubs are described separately; the present Scientific Name; Historic or Archived Scientific Name; Common Name, and a Notes column.

Example 1: During a high precipitation year, Russian wildrye is clipped while in stage 3. The field measured green weight is 200 pounds/acre.

PSJU3 = 200 pounds X .40 = 80 pounds air-dry weight.

Example 2: During a low precipitation year, Russian wildrye is clipped while in stage 3. The field measured green weight is 125 pounds/acre.

PSJU3 = 125 pounds X .50 = 62.5 air-dry pounds/acre.

Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees

## GRASS AND GRASSLIKES

**GRASS PHENOLOGICAL STAGE CLASSIFICATION:**

1 -GREEN LEAVES BEFORE BOOT
2- BOOT STAGE
3- SEED SOFT DOUGH TO RIPE
4- SEED DISSEMINATION
5- WINTER DORMANCY CURED

### INTRODUCED COOL-SEASON PERENNIAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| AGCR | 25-30 | 40-45 | 50-55 | 60 | 75-90 | Agropyron cristatum | Agropyron cristatum | Fairway crested wheatgras | |
| AGDE2 | 25-30 | 40-45 | 50-55 | 60 | 75-90 | Agropyron desertorum | Agropyron desertorum | Standard crested wheatgra | |
| AGCRxAGDE2 | 25-30 | 40-45 | 50-55 | 60 | 75-90 | A. cristatum x A. desertorum | | Crested wheatgrass cross | |
| AGFR | 25-30 | 40-45 | 50-55 | 60-65 | 75-90 | Agropyron fragile | Agropyron sibiricum | Siberian wheatgrass | |
| ALAR | 25 | 35-40 | 45-50 | 55-60 | 70 | Alopecurus arundinaceus | Alopecurus arundinaceus | Creeping foxtail | strong rhizomes |
| ARELE | 25 | 35-40 | 40-45 | 50-55 | 65-85 | Arrhenatherum elatius var. elatius | Arrhenatherum elatius | Tall oatgrass | |
| BRER3 | 20-25 | 35-40 | 40-45 | 50-55 | 75-85 | Bromus erectus | Bromus riparius | Meadow brome | short rhizomes |
| BRIN2 | 20-25 | 35-40 | 40-45 | 50-55 | 75-85 | Bromus inermis | Bromus inermis | Smooth brome | sod-forming |
| DAGL | 20-25 | 30-35 | 40-45 | 50-55 | 60-80 | Dactylis glomerata | Dactylus glomerata | Orchardgrass | |
| FEBR7 | 25-35 | 40-45 | 45-50 | 55-60 | 75-85 | Festuca brevipila | Festuca ovina duriuscula | Hard fescue | |
| FEOV | 25-35 | 40-45 | 45-50 | 55-60 | 75-85 | Festuca ovina | Festuca ovina | Sheep fescue | |
| LOPE | 25-30 | 40-45 | 45-55 | 55-60 | 70-85 | Lolium perenne | Lolium perenne | Perennial ryegrass | |
| PHAR3 | 25 | 40-45 | 50-55 | 60 | 75 | Phalaris arundinacea | Phalaris arundinacea | Reed canarygrass | sod- forming |
| PHPR3 | 25 | 35-40 | 45-55 | 55-65 | 70-90 | Phleum pratensis | Phleum pratensis | Timothy | |
| POPR | 20-25 | 35-40 | 45-50 | 55-60 | 65-70+ | Poa pratensis | Poa pratensis | Kentucky bluegrass | sod-forming |
| SCAR7 | 25 | 35-40 | 45-50 | 55-60 | 70 | Schedonorus arundinaceus | Festuca arundinacea | Tall fescue | |
| THIN6 | 25 | 40-45 | 45-50 | 55-60 | 75-85 | Thinopyrum intermedium | Agropyron intermedium | Intermediate wheatgrass | short rhizomes |
| THIN6 | 25-30 | 38-43 | 45-50 | 55-60 | 70-85 | Thinopyrum intermedium | Agropyron trichophorum | Pubescent wheatgrass | short rhizomes |
| THPO7 | 25 | 40-45 | 48-55 | 55-65 | 80-90 | Thinopyrum ponticum | Agropyron elongatum | Tall wheatgrass | |
| PSJU3 | 25 | 35-40 | 40-50 | 55-65 | 70-85 | Psathyrostachys juncea | Elymus junceus | Russian wildrye | |

**Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees**

**GRASS PHENOLOGICAL STAGE CLASSIFICATION:**

1 -GREEN LEAVES BEFORE BOOT
2- BOOT STAGE
3- SEED SOFT DOUGH TO RIPE
4- SEED DISSEMINATION
5- WINTER DORMANCY CURED

**NATIVE COOL-SEASON PERENNIAL GRASS**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| ACHY | 30-35 | 45-50 | 50-55 | 60-75 | 80 | Achnatherum hymenoides | Oryzopsis hymenoides | Indian ricegrass | |
| ACLE9 | 25-30 | 40-45 | 50-55 | 60-65 | 70+ | Achnatherum lettermanii | Stipa lettermani | Letterman needlegrass | |
| ACNEN2 | 25-30 | 40-45 | 50 | 55-60 | 75+ | Achnatherum nelsonii ssp. nelsonii | Stipa columbiana | Columbia needlegrass | |
| ACNEN2 | 25-30 | 40-45 | 50 | 55-60 | 70+ | Achnatherum nelsonii ssp. nelsonii | Stipa williamsi | Williams needlegrass | |
| ACTH7 | 25-30 | 40-45 | 50-55 | 60-65 | 80+ | Achnatherum thurberianum | Stipa thurberiana | Thurber needlegrass | |
| BRMA4 | 20-25 | 35-40 | 40-45 | 50-75 | 65-85 | Bromus marginatus | Bromus marginatus | Mountain brome | short-lived |
| BRVU | | 44 | | | | Bromus vulgaris | Bromus vulgaris | Columbia brome | |
| ELEL5 | 25-35 | 45-50 | 55-60 | 65-70 | 85-90 | Elymus elymoides | Sitanion hystrix | Bottlebrush squirreltail | |
| ELGL | 25 | 35 | 40 | 75 | 75-85 | Elymus glaucus | Elymus glaucus | Blue wildrye | short-lived |
| ELLA3 | 25-30 | 45-50 | 53-56 | 60-65 | 80-90 | Elymus lanceolatus ssp. lanceolatus | Agropyron riparium | Streambank wheatgrass | rhizomatous |
| ELLAL | 25 | 45-50 | 55-60 | 60-65 | 85-90 | Elymus lanceolatus ssp. lanceolatus | Agropyron dasystachyum | Thickspike wheatgrass | rhizomes |
| ELTRT | 25-30 | 40-45 | 50-55 | 60-65 | 75-90 | Elymus trachycaulus ssp. trachycaulus | Agropyron trachycaulum | Slender wheatgrass | short-lived |
| ELWA2 | 25-30 | 40-50 | 50-55 | 55-65 | 80-90 | Elymus wawawaiensis | Agropyron spicatum | Snake River wheatgrass | |
| FEID | 25-35 | 40 | 45-50 | 50-60 | 75-85 | Festuca idahoensis | Festuca idahoensis | Idaho fescue | |
| HECO26 | 25-35 | 40-50 | 50-55 | 60-65 | 70+ | Hesperostipa comata | Stipa comata | Needle & Thread | |
| KOMA | 20-35 | 38-50 | 50-55 | 60-65 | 75-85 | Koeleria macrantha | Koeleria cristata | Prairie junegrass | |
| LECI4 | 25-30 | 45-50 | 50-55 | 60-65 | 65-80 | Leymus cinereus | Elymus cinereus | Basin wildrye | |
| MEBU | 20-30 | 40-45 | 45-50 | 50-55 | 80-85 | Melica bulbosa | Melica bulbosa | Oniongrass | |
| PASM | 25-35 | 45-55 | 53-58 | 60-65 | 70-90 | Pascopyrum smithii | Agropyron smithii | Western wheatgrass | rhizomes |
| POFE | 25-35 | 45 | | 50-60 | 90-95 | Poa fendleriana | Poa fendleriana | Muttongrass | |
| POSE | 25-30 | 38-45 | 50-55 | 60-65 | 70+ | Poa secunda | Poa ampla | Sandberg (big) bluegrass | |
| POSE | 20-30 | 38-50 | 50-55 | 60-65 | 70+ | Poa secunda | Poa nevadensis | Sandberg (Nevada) bluegrass | |
| POSE | | 69 | | | 63 | Poa secunda | Poa sandbergii | Sandberg bluegrass | |
| POSE | 25-30 | 40-45 | 50-55 | 55-60 | 65-90 | Poa secunda | Poa secunda | Sandberg bluegrass | |
| PSSPI | 25-30 | 35-40 | 45 | 50-60 | 80-90 | Pseudoroegneria spicata spp.inermis | Agropyron inerme | Beardless wheatgrass | strong tillers |
| PSSPS | 25-30 | 40-50 | 50-55 | 55-65 | 80-90 | Pseudoroegneria spicata ssp. spicata | Agropyron spicatum | Bluebunch wheatgrass | |



Developed from WNTSC Technical Note

Prepared by Bob Gillaspy, 6/30/2014

Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees

| GRASS PHENOLOGICAL STAGE CLASSIFICATION: |
|---|
| 1 -GREEN LEAVES BEFORE BOOT |
| 2- BOOT STAGE |
| 3- SEED SOFT DOUGH TO RIPE |
| 4- SEED DISSEMINATION |
| 5- WINTER DORMANCY CURED |

NATIVE WARM-SEASON PERENNIAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| ARPUL | 28-35 | 40-45 | 50-55 | 60-65 | 85-90 | Aristida purpurea var. longiseta | Aristida longiseta | Red threeawn | |
| CARU | 25-30 | 35-40 | 40-45 | 45-50 | | Calamagrostis rubescens | Calamagrostis rubescens | Pinegrass | rhizomatous |
| SPCR | 30-45 | 40-50 | 50 | 60-70 | 90 | Sporobolus cryptandrus | Sporobolus cryptandrus | Sand dropseed | |
| SPAI | 30-40 | 45-60 | 55 | 65 | 80 | Sporobolus airoides | Sporobolus airoides | Alkali sacaton | |

INTRODUCED COOL-SEASON ANNUAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| BRAR5 | | | | 56 | | Bromus arvensis | Bromus japonicus | Japanese brome | tillers |
| BRRU2 | | | | 70 | | Bromus rubens | Bromus rubrum | Red brome | |
| BRTE | 20-30 | 35-50 | 50-55 | 60-65 | 85-90 | Bromus tectorum | Bromus tectorum | Cheatgrass | |

NATIVE COOL-SEASON ANNUAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| VUOCG | | | | 80 | | Vulpia octoflora | Festuca octoflora | Sixweeks fescue | |

GRASSLIKE

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| CAFI | 30 | 49 | 55 | 60-67 | 80 | Carex filifolia | Carex filifolia | Threadleaf sedge | |
| CAGE2 | 40 | 50 | 55 | 60 | 75 | Carex geyeri | Carex geyeri | Elk sedge | rhizomatus |
| ELEOC | | | | 38 | | Eleocharis sp. | Eleocharis sp. | Spikerush | |
| JUNCO | 20 | 40-45 | 55-60 | | | Juncus balticus | Juncus spp | Wiregrass, Baltic rush | |



Developed from WNTSC Technical Note

Prepared by Bob Gillaspy, 6/30/201

**Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees**

## FORBS and VINES

**FORB PHENOLOGICAL STAGE CLASSIFICATION:**

1- GREEN BEFORE FLOWERING
2 - FULL BLOOM PETALS FALLING
3 - FRUIT RIPENING
4 - FRUIT RIPE OR FALL DORMANCY
5 - SEED DISSEMINATION OR WINTER DORMANCY

### NATIVE PERENNIAL FORBS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| ACMI2 | | 31-49 | | | | Achillea millefolium | Achillea millefolium | Common yarrow | |
| AGUR | 25 | 30-40 | 45 | | | Agastache urticifolia | Agastache urticifolia | Horsemint/hyssop | rhizomatous |
| AGGL | 17-20 | 45 | | | | Agoseris glauca | Agoseris pumila | Mountain dandelion | |
| ALAC4 | 15 | 20-40 | | 70 | 70-90 | Allium acuminatum | Allium acuminatum | Onion | |
| ANRO2 | 35 | 55 | | 85 | | Antennaria rosea | Antennaria rosea | Pussytoes | |
| ARLU | 18 | | | 43-45 | 65+ | Artemisia ludoviciana | Artemisia ludoviciana | Louisiana sagewort & cudweed | rhizomatous |
| ASCO9 | | | 47 | | | Astragalus columbianus | Astragalus columbia | Columbia vetch | |
| ASSP4 | 31 | | | | | Astragalus spaldingii | Astrogalus spaldingii | Milkvetch, spalding's | |
| BASA3 | 17-32 | 27-36 | 35-45 | 45-50 | 65+ | Balsamorhiza sagittata | Balsamorhiza sagittata | Arrowleaf balsamroot | |
| CAAN7 | | 27 | 30 | 35 | 50+ | Castilleja angustifolia | Castilleja spp. | Indian paintbrush | |
| COUMP | 20 | 50 | | | | Comandra umbellata ssp. pallida | Comandra palida | Bastard toadflax | |
| CRCA2 | 20-25 | 30-40 | 35 | 40 | 50 | Crepis acuminata | Crepis acuminata | Tapertip hawksbeard | |
| DEOC | 22 | 28 | 30 | 35 | 50 | Delphinium ×occidentale | Delphinium spp. | Tall larkspur | |
| DENU2 | 25 | 30 | 35 | 40 | 50 | Delphinium nuttallianum | Delphinium spp. | Low larkspur | |
| DICA14 | | | | 70 | | Dichelostemma capitatum | Dicheloatemma spp | Bluedicks | corm |
| ERCH4 | | | | | 60-100 | Erigeron chrysopsidis | Erigeron chrysopsidis | Dwarf yellow fleabane | |
| ERSP4 | 22 | 25 | 33 | 35 | 55 | Erigeron speciosus | Erigeron speciosus | Daisies | |
| ERHE2 | 45-50 | | 67-70 | 90 | | Eriogonum heracleoides | Erigonum heraculoides | Wyeth buckwheat | |
| ERUM | 20-25 | 30-40 | 46 | 50-55 | 65+ | Eriogonum umbellatum | Eriogonum umbellatum | Sulphur-flower buckwheat | |
| FRSP | | 20 | 20 | | | Frasera speciosa | Fraseria speciosa | Elkweed | |
| GABO2 | 17-20 | | | 45-50 | 85 | Galium boreale | Galium boreale | Bedstraw | |
| GEMA4 | 20 | | | | | Geum macrophyllum | Geum macrophyllum | Largeleaf avens | |
| GETR | | 39 | | | | Geum triflorum | Geum triflorum | Old Man's Whiskers | |
| HEUN | 20 | 30-35 | 38-45 | 50-55 | 65+ | Helianthella uniflora | Helianthella uniflora | Oneflower sunflower | |
| HEMA80 | 20 | 20 | 20 | 22 | 30 | Heracleum maximum | Heracleum lanatum | Cow parsnip | |
| HECH | 40 | | | | | Heuchera chlorantha | Heuchera spp. | Alumroot | |
| HISCA | 15-20 | 25-30 | | 35-40 | 65+ | Hieracium scouleri var. albertinum | Hieracium albertinum | Hawkweed | |
| LIPU11 | | | | 60 | | Leptodactylon pungens | Leptodactylon pungens | Granite gilia | |
| LUARM4 | | | | | 57 | Lupinus arbustus | Lupinus laxiflorus | Spur Lupine | |

**Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees**

| FORB PHENOLOGICAL STAGE CLASSIFICATION: |
|---|
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| 3 - FRUIT RIPENING |
| 4 - FRUIT RIPE OR FALL DORMANCY |
| 5 - SEED DISSEMINATION OR WINTER DORMANCY |

**NATIVE PERENNIAL FORBS continued**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| LUSE4 | | | 32 | | 39 | Lupinus sericeus | Lupinus sericeus | Silky Lupine | |
| LUPIN | 18-25 | 25-30 | 30-35 | 40-45 | 50-90 | Lupinus | Lupinus spp. | Lupine | |
| MEAR6 | 15-18 | 20-25 | 22 | 30 | 50-75 | Mertensia arizonica | Mertensia leonardi | Bluebells | |
| OSOC | 15-18 | 21 | 25 | 30 | 50-70 | Osmorhiza occidentalis | Osmorhiza occidentalis | Sweet anise | |
| PABR | | | 30-38 | 40 | | Paeonia brownii | Paeonia brownii | Peony | |
| PHHO | 35 | 50 | | 75 | | Phlox hoodii | Phlox hoodii | Hoods phlox | |
| PHLO2 | 20-25 | 35-40 | 50 | | 70-80 | Phlox longifolia | Phlox longifolia | Longleaf phlox | |
| POAR7 | 50 | | | | | Potentilla arguta | Potentilla arguta | Galley cinquefoil | |
| POGR9 | 44 | 50 | | | | Potentilla gracilis | Potentilla gracilis | Northwest cinquefoil | |
| POTEN | 15-20 | 25 | 30-35 | 38-45 | 55+ | Potentilla | Potentilla spp. | Cinquefoil | |
| RUOC2 | 20 | 25-35 | | 30-40 | 55-70 | Rudbeckia occidentalis | Rudbeckia occidentalis | Coneflower | |
| PACA15 | | 24 | | | | Packera cana | Senecio canus | Wooly groundsel | |
| SESE2 | 15-20 | 25-30 | 35 | 40 | 55+ | Senecio serra | Senecio serre | Butterweed | |
| SOMI2 | 30 | | | | | Solidago Missouriensis | Solidago Missouriensis | Missouri goldenrod | |
| PSJA2 | 23 | 25 | 30 | 31 | 90 | Pseudostellaria jamesiana | Stellaria jamesiana | Starwort | |
| TAOF | 20 | 25 | | | | Taraxacum officinale | Taraxacum officinale | Dandelion | |
| THFE | 23 | 30 | 36 | 40 | 70 | Thalictrum fendleri | Thalictrum fendleri | Meadow rue | |
| VAOC2 | | 20 | | 25 | | Valeriana occidentalis | Valeriana occidentalis | Valerian | |
| VIOLA | 15-20 | 20-25 | 30 | 38 | | Viola | Viola spp. | Violet | |
| WYAM | 20-25 | 25-30 | 35 | 40 | 55+ | Wyethia amplexicaulis | Wyethia amplexicaulis | Mulesear | |
| LESQU | | | | 65 | | Lesquerella | Lesquerella spp | Tallow weed | |
| ARCA12 | 30-35 | 65 | | 80-85 | | Artemisia campestris ssp. borealis | Artemisia spp. | Sageworts | biennial |
| CHAL7 | 29 | | | | | Chenopodium album | Chenopodium spp | Lambsquarters | |
| CRSE11 | 50 | | | | | Croton setigerus | Croton spp | Dove seed | |
| GEVI2 | 20 | 38 | 30-35 | 40-45 | 55-70 | Geranium viscosissimum | Geranium viscosissimum | Sticky geranium | |
| HEAN3 | 25 | 50 | | 95 | | Helianthus annuus | Helianthus annuus | Annual sunflower | |
| LAOCO | 25 | 45 | | 95 | | Lappula occidentalis var. occidentalis | Lappula redowskii | Stickseed | biennial |
| ORLU2 | 15 | 20 | 25 | 35 | 45+ | Orthocarpus luteus | Orthocarpus spp. | Owl-clover | |
| PODO4 | 25 | 40 | | 85 | | Polygonum douglasi | Polygonum douglasi | Knotweed | |
| SEIN2 | 15-20 | 23-30 | 30-40 | 40-45 | 55+ | Senecio integerrimus | Senecio integerrimus | Lambstongue | biennial |
| SOAM | 20 | | | | | Solanum americanum | Solanum nigrum | Black nightshade | |
| SPCO | 40-45 | 55 | | 80-90 | | Sphaeralcea coccinea | Sphaeralcea coccinea | Scarlet globemallow | biennial |
| THIN | | | 50 | | | Thelypodium integrifolium | thelypodium integrifolium | Entire leaved thelypod | biennia |
| AMRE | | 20 | | | | Amaranthus retroflexus | Amaranthus spp | Red root | |
| AMTE3 | | | | 80 | | Amsinckia tessellata | Amsinckia spp | Fiddle neck | |
| LAPPU | | | | 85 | | Lappula | Lappula spp | Stick seed | biennial |
| PLOV | | | | 75 | | Plantago ovata | Plantago spp | Indian wheat | |

Developed from WNTSC Technical Note — Page 7 — Prepared by Bob Gillaspy, 6/30/2014

Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees

| FORB PHENOLOGICAL STAGE CLASSIFICATION: |
|---|
| 1- GREEN BEFORE FLOWERING |
| 2 - FULL BLOOM PETALS FALLING |
| 3 - FRUIT RIPENING |
| 4 - FRUIT RIPE OR FALL DORMANCY |
| 5 - SEED DISSEMINATION OR WINTER DORMANCY |

NATIVE VINE

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| LABR | 15-20 | | 25-40 | | 50-80 | Lathyrus brachycalyx | Lathyrus spp. | Peavine, Bonneville pea | |
| VIAM | 20 | 25-30 | | 75 | | Vicia americana | Vicia americana | American vetch | rhizomatous |
| HULU | 30 | | | 80 | | Humulus lupulus | Humulus spp | Hop | |

INTRODUCED FORBS/VINE

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| COAR4 | | 35 | | | | Convolvulus arvensis | Convolvulus spp | Field bindweed | perennial, vine |
| CYOF | 20 | 35 | | 90 | | Cynoglossum officinale | Cynoglossum officinale | Houndstonque | biennial |
| SAKA | 30 | 50 | | 100 | | Salsola kali | Salsola kali | Russian thistle | annual |
| SATR12 | 25 | 30 | 45 | 50 | 65 | Salsola tragus | Salsola tenuifolia | Prickly Russian thistle | annual |
| TRDU | 33 | | | | | Tragopogon dubius | Tragopogon dubius | Salsify | annual/biennial |
| TRLA30 | 30 | 50 | | 75 | | Tragopogon lamottei | Tragopogon pratensis | Goatsbeard | biennial |
| ASCI4 | 20 | 30 | | | | Astragalus cicer | Astragalus cicer | Cicer milkvetch | perennial |
| ERCI6 | | 40 | | 60 | | Erodium cicutarium | Erodium spp | Alfilaria | annual/biennial |
| MESA | 20 | 30 | | 39-42 | | Medicago sativa | Medicago sativa | Alfalfa | annual/perennial |
| MELIL | 20 | 30 | | | | Melilotus | Melilotus spp. | Sweetclover | biennial |
| ONVI | 20 | 30 | | | | Onobrychis sativa | Onobrychis sativa | Sainfoin | perennial, forb |

Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees

TREE/SHRUB/SUBSHRUB

SHRUB PHENOLOGICAL STAGE CLASSIFICATION:

1 - GREEN LEAVES ONLY OR FULL LEAF STAGE
2 - FLOWERS IN BUD, GREEN FLOWERING STAGE
3 - FLOWERS OPEN OR FRUIT DROP
4 - SEED MATURITY OR FALL DORMANCY * = GREEN FRUIT WT
5 - WINTER DORMANCY OR CURED LEAVES ** = DRY FRUIT WEIGHT

NATIVE TREE/SHRUB

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| ACGL | 30 | | | | | Acer glabrum | Acer glabrum | Rocky Mtn. maple | |
| AMAL2 | 35 | 45 | 85 | 30* | 85** | Amelanchier alnifolia | Amelanchier alnifolia | Serviceberry | |
| ARTR2 | 35-55 | 40-65 | 50 | 55-75 | 60-90 | Artemisia tridentata | Artemisia tridentata | Big sagebrush | |
| CEVE | 35 | 45 | 50 | 65 | | Ceanothus velutinus | Ceanothus velutinus | Snowbrush | thicket forming |
| JUOS | | | 58 | | | Juniperus osteosperma | Juniperus osteosperma | Utah Juniper | single stem |
| JUSC2 | 45 | 55 | 60 | 35* | 85** | Juniperus scopulorum | Juniperus scopulorum | Juniper | stoloniferous |
| POTR5 | 20 | 20 | 37-50 | 52-56 | | Populus tremuloides | Populus tremuloides | Quaking aspen | single stem |
| PREM | | | 43 | 69 | | Prunus emarginata | Prunus emarginata | Bitter-cherry | thicket forming |
| PRVI | 30 | 40-46 | 65 | 40* | 90** | Prunus virginiana | Prunus virginiana | Chokecherry | |
| SALIX | | 30 | | | | Salix | Salix spp. | Willow | |
| SANIC6 | 15 | 45 | 60 | 30* | 80** | Sambucus cerulea | Sambucus cerulea | Elderberry | |

Developed from WNTSC Technical Note



Prepared by Bob Gillaspy, 6/30/2014

Dry Weight Percentages of Selected Oregon Grasses, Grasslikes, Forbs, Shrubs, and Trees

| SHRUB PHENOLOGICAL STAGE CLASSIFICATION: |
|---|
| 1 - GREEN LEAVES ONLY OR FULL LEAF STAGE |
| 2 - FLOWERS IN BUD, GREEN FLOWERING STAGE |
| 3 - FLOWERS OPEN OR FRUIT DROP |
| 4 - SEED MATURITY OR FALL DORMANCY * = GREEN FRUIT WT |
| 5 - WINTER DORMANCY OR CURED LEAVES ** = DRY FRUIT WEIGHT |

NATIVE SHRUB

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME | NOTES |
|---|---|---|---|---|---|---|---|---|---|
| ARPA6 | | | | 60 | | Arctostaphylos patula | Arctostaphylos spp | Greenleaf manzanita | |
| ARAR8 | 45 | 60 | 54-70 | 60-75 | | Artemisia arbuscula | Artemisia arbuscula | Low sagebrush | single stem |
| ARNO4 | 40 | 55 | 50-75 | 60-75 | | Artemisia nova | Artemisia nova | Black sagebrush | |
| ARTR4 | 40 | | 38-50 | | | Artemisia tripartita | Artemisia tripartita | Threetip sagebrush | |
| ARCA13 | 35 | 50 | 70 | | | Artemisia cana | Artemisia cana | Silver sagebrush | rhizomatous |
| ATCA2 | 58 | | | 60 | | Atriplex canescens | Atriplex canescens | Fourwing saltbush | |
| ATCO | 40 | 60 | 75 | | | Atriplex confertifolia | Atriplex confertifolia | Shadscale | |
| ATCO | | | | 40 | | Atriplex confertifolia | Atriplex jonesii | Mound saltbush | |
| MARE11 | | 37-67 | | | | Mahonia repens | Berberis repens | Oregongrape | stoloniferous |
| MATR3 | 50 | 65 | | | | Mahonia trifoliolata | Berberis spp | Algerita | |
| CEGR | | | | 70 | | Ceanothus greggii | Ceanothus greggii | Buckbrush | |
| ERNAO | 30-40 | 45-50 | 55-60 | 65 | 70+ | Ericameria nauseosa ssp. consimilis | Chrysothamnus nauseosus | Rubber rabbitbrush | |
| CHVI8 | 30 | 37-45 | 50-60 | 65 | 70+ | Chrysothamnus viscidiflorus | Chrysothamnus viscidiflorus | Green rabbitbrush | |
| EPVI | 10 | | | 55 | | Ephedra viridis | Ephedra spp | Mormontea | |
| KRLA2 | 20-25 | 60-67 | 65 | | | Krascheninnikovia lanata | Eurotia lanata | Winterfat | |
| GUSA2 | 30 | 50 | 75 | | | Gutierrezia sarothrae | Gutierrezia sarothrae | Broom snakeweed | |
| HODI | 50 | | | | | Holodiscus discolor | Holodiscus discolor | Oceanspray | |
| OPUNT | | | | 30 | | Opuntia | Opuntia spp | Pricklypear (fruit only) | succulent |
| OPUNT | 10 | 15 | 13-20 | 10* | 70** | Opuntia | Opuntia spp. | Pricklypear | succulent |
| PHLE4 | 33 | | | | | Philadelphus lewisii | Philadelphus lewisii | Mockorange | |
| PHMA5 | | | | 74 | | Physocarpus malvaceus | Physocarpus malvaceus | Ninebark | |
| PUTR2 | 30-35 | 40-45 | 55-65 | 65 | | Purshia tridentata | Purshia tridentata | Bitterbrush | |
| RHTR | | | | 50 | | Rhus trilobata | Rhus trilobata | Skunkbush sumac, Squaw | rhizomatous |
| RIBES | | | 45 | | | Ribes | Ribes | Currant | |
| ROWO | 20-25 | 35 | 35-50 | 50* | 85** | Rosa woodsii | Rosa spp. | Rose | rhizomatous |
| SAVE4 | 35 | 38-45 | 60 | | | Sarcobatus vermiculatus | Sarcobatus vermiculatus | Greasewood | |
| SEFLF | | | | 20* | | Senecio flaccidus | Senecio longilobus | Woolly groundsel | |
| SYAL | 25-30 | 35-40 | 65 | 30-40* | 85** | Symphoricarpos albus | Symphoricarpos spp | Snowberry | rhizomatus |
| TECA2 | | | 55 | 70 | | Tetradymia canescens | Tetradymia canescens | Horsebrush | |

# Part 645 – National Range and Pasture Handbook

## Subpart F – Management of Grazing Lands

### 645.0601 Introduction

A. This subpart contains guidance for planning grazing management on the various kinds of grazing lands. Section 645.0602, Managing Native Grazing lands, provides general guidance on all grazing lands, but provides specific information on rangelands, grazed forest lands, and native and naturalized pasture. Section 645.0603 provides information on managing forage crops and pasturelands. Section 645.0604 provides guidance on procedures and worksheets for planning grazing management. This section includes information for completing livestock inventory and forage balance, determining forage composition and value ratings, determining stocking rates, and completing grazing schedules.

B. Understanding plant communities, ecological processes, and plant-herbivore interactions are key to successful management of grazing lands. Knowing the present condition of a grazing unit helps to set the direction and guide management when changes are needed to meet objectives.

C. Sound grazing management ensures the health of plant communities and all Soil, Water, Air, Plant, Animal, Human and Energy resources (SWAPA+H+E). Therefore, managed grazing (NRCS National Conservation Practice Standard CPS 528) is a basic requirement for achieving desired results for all conservation plans on grazing lands. Furthermore, livestock may be used as management tools to manipulate vegetation structure and composition to achieve specific goals and objectives for forage production, wildlife habitat, recreation, air, water, and soil resource concerns.

D. In some cases, land managers may have trouble understanding that grazing management may provide a solution to the resource concerns that exist. If management changes are not made in those cases, then the implementation of primary or supporting practices will have marginal effects at best to solve problems on the land. Plant communities will remain weakened, and the cascading effects of the resource concerns, both economic and environmental, will remain in place.

E. Grazing management attempts to manage the intensity, frequency, duration, and timing of grazing. In managing these elements, many items must be considered including:

(1) Land manager's willingness to adopt or alter management
(2) Ecological Site and current state
(3) Grazing intensity and stocking rate
(4) Forage nutritive value relative to desired animal performance
(5) Forage seasonal availability
(6) Distribution of grazing on the landscape

F. Each ecological site or state has inherent characteristics that influence adapted forage species, productivity of the site, and ease of implementing grazing management. Understanding these characteristics as they relate to a particular operation will assist in planning and implementing supporting and accelerating practices and developing grazing units that have similar characteristics and management considerations.

G. NRCS staff work with land managers through the nine steps of conservation planning to provide assistance in inventorying, assessing, and monitoring grazing lands and in developing a conservation plan that addresses resource concerns. See the following subparts of this handbook for more information: Subpart D, Conservation Planning on Grazing lands; and Subpart E, Inventory, Assessment, and Monitoring of Grazing lands.

## 645.0602 Managing Native Grazing lands

A. When working with landowners on rangeland, many considerations must be included in the planning process. Dynamic ecological sites, complexities of large acreages, arid and variable weather conditions, multi-use habitats, checker-boarded land statuses, landowner goals, and financial and management capabilities are just a few.

(1) Dynamics of ecological sites

(i) The natural plant communities for an ecological site are dynamic [Ecosystem Dynamics Interpretive Tool website (EDIT)]. They respond to changes in the environment, to various uses, and to stresses by adjusting the kinds, proportions, and amounts of species in the plant community. Climatic cycles, fire, insects, grazing, and physical disturbances are factors that can cause plant communities to change. Some changes, such as those resulting from seasonal drought or short-term heavy grazing, are temporary, while others may be longer lasting. In some cases, the degree of influence or disturbance can be significant enough to cross a threshold and cause a permanent change in the ecological site potential.

(ii) Individual species or groups of species in a plant community respond differently to the same use or stress, such as fire, changes in climate, and grazing or browsing pressure. It is normal for some plants to be grazed more closely and frequently than others by livestock or wildlife. Most plants are sensitive to stress during some stage of growth. However, they may be affected by improper use or stress during critical growth periods, but tolerant at other times.

(iii) Many plants respond to changes in the microenvironment in a unique manner that may be different from their associated species. For example, some species are destroyed by fire, while neighboring plants thrive following fire or are dependent on fire to complete life cycle stages. Just as the same weather conditions may be favorable for the growth of one species, it may be unfavorable for another species in the same plant community. For example, a growing season in which frequent light rainfall occurs may be ideal for some species, while other species may be dependent upon deep soil moisture, making frequent light rainfall ineffective, even though the total rainfall may be above average. Thus, many complex factors contribute to changes in the composition, structure, health and productivity, and trend of plant communities. Many changes may be caused by climatic fluctuations, fire, and extreme episodic events, while some changes are related to livestock grazing.

(iv) The inventory process provides the opportunity to gather information and data on the present plant community. Once data can be described and quantified, then a comparison of the current community to a desired community will help identify the differences and resource concerns that need to be addressed. Ecological site descriptions (ESDs) are a tool to assist in this process.

(v) On rangeland, Ecological Site Descriptions (ESDs) provide land managers a guide for describing the plant community on rangeland ecological sites (ES). The potential for the site is called the Reference Plant Community and attempts to describe what the plant community was prior to European influence (pre-European >200 years ago). State-and-transition models within ESDs describe changes in the plant communities and associated dynamic soil properties that can occur on a site. The causes of change, the constraints to reversibility of the change, and the management interventions needed to prevent or initiate change are described in ESDs (jornada.nmsu.edu/esd).

(vi) State-and-transition models include restoration pathways between States to help land managers consider what conservation practices or management actions are needed to direct the plant community towards a desired condition (Bestelmeyer 2017). A goal for manipulating and managing the plant community on most operations is to increase forage production and diversify the existing plant community. In many cases, years of domestic livestock grazing can reduce the amount of preferred forage species and diminish the diversity due to selective grazing. Benefits to increase useable production are generally apparent as they relate to higher carrying capacities; but increasing diversity to provide greater resilience, improve wildlife habitat, increase soil health, and extend the growing seasons may not be as well known. For more information on Inventory, Assessment and Monitoring of grazing lands, see Subpart E of this handbook.

(vii) Common resource concerns on native grazing lands include degraded plant conditions such as plant structure and composition, health and productivity, plant pest pressure, and animal concerns such as feed and forage imbalance. Other resource concerns can also occur and conducting an infield inventory and running appropriate assessment tools as outlined in NRCS Planning Criteria (USDA-NRCS 2020) and described in Subpart E are encouraged. For the full list of resource concerns and planning criteria requirements, see the NRCS Resource Concern List and Planning Criteria (USDA-NRCS 2020). The resource concern fact sheets can be found in NRCS National Instruction 450-309 as Exhibit 309.22.

(viii) Many native grazing land operations include large acreages. Therefore, meeting all resource concerns or the full extent of one resource concern may not be feasible with one application of a conservation practice or treatment. Economics and the ability of the landowner must be included in the process of determining realistic and attainable goals and objectives and reaching desired conservation levels. For these operations, prioritizing grazing units and resource concerns should be considered. NRCS employees should discuss the benefit of Resource Management System (RMS) level planning with the land manager and work to develop a complete conservation plan with the land manager, while applying a progressive planning strategy, or step-by-step process to reach the RMS goal. An RMS is a combination of conservation practices and resource management activities that treats all identified resource concerns for soil, water, air, plants, animals, human and energy to a level that meets or exceeds the planning criteria [USDA-NRCS National Planning Procedures Handbook (NPPH)]. For more on conservation planning on grazing lands see Subpart D of this handbook.

(ix) Another consideration on native rangelands should be the reality of time. In areas of low precipitation, the effects of some conservation practices or management changes may take longer to show. For example, the practice of range seeding may take several years before climate conditions are conducive for seed germination, or the full effect of a brush treatment may not be observed for several growing seasons. Even with proper planning and application through proven specifications, limited precipitation and large variability in weather patterns in arid regions create additional challenges that must be recognized.

(x) Further, considerations should also include the land manager's ability to meet all requirements of the practice. Restoration pathways in a state-and-transition model identify practices needed to move toward a more desired state or condition, but considerations for the ability of the landowner to meet all the requirements of the practice need to be assessed. In some cases, supporting practices (like cross-fence), additional water sources, and access control may need to occur before the primary practice can be applied.

(xi) Conservation planning on many native grazing lands require a multi-use approach. With the large expanse of many operations, watershed level planning may be appropriate. Besides livestock grazing, additional activities on these operations may include hunting, energy development and transmission infrastructure, mining operations, recreational and scenic areas, archeology sites, municipal water origins, and considerations for multiple wildlife habitat zones. Conservation planning must consider the additional requirements and parameters each of these and other activities present and include those factors in the operation's conservation plan.

(xii) Finally, many native grazing land operations include both private and Federal or State land parcels. While agencies like the U.S. Forest Service, Bureau of Land Management, and State Land Departments maintain oversight and management of public lands, all acreages should be included in the overall conservation plan for the operation. Agencies involved within the operating unit boundaries should collectively develop plans through a process called Coordinated Resource Management Plan (CRMPs)(USDA-NRCS 2020). The CRMP process outlines the opportunities to combine efforts and resources between the agencies to improve management and provide collaborative guidance for the operator. CRMPs have all the components of conventional conservation plans but also document decisions agreed upon by the agencies involved and generally require more time to develop during the planning phase (USDA-NRCS 2020).

(2) Establishing Management Objectives

Management objectives are developed and determined working with the landowner during the planning process. The management objective requires developing an understanding of the desired future condition of the grazing units with the client as compared to the existing condition. Objectives should be feasible and meet the needs of the landowner, the resources, and the grazing animals. NRCS will assist the land manager in making informed decisions by conducting inventories and assessments, consider on-site and off-site resource concerns, identifying opportunities for natural resource protection and management, and being informed of policies such as State and Federal laws or mandates that affect the operation. Figure F-1 shows NRCS infield assistance with landowners. Once resource concerns are identified, all treatment alternatives should be evaluated and discussed.

**Figure F-1.** New Mexico NRCS staff discussing management objectives with a rancher.

(3) Use of Inventory and Assessment Data

The NRCS conservationist will use information from the ecological site description, trend determinations, similarity index determinations, interpreting indicators of rangeland health determinations, and other inventory and assessment information to assist the land manager understand the current state. The goals and objectives of the land manager also help identify what inventory and assessment methods to run to provide the most helpful and relevant information. This stage of the conservation planning process involves the following steps:

- Inventory the present plant community and determine annual production for each species.
- Identify from the ecological site description, where available, the desired plant community that is achievable, meets the land manager's goals and the resource needs.
- Determine what changes may be occurring (determine trend).
- Compute similarity index or an approved inventory method to evaluate and compare the present community to the desired plant community.
- Determine how the ecological processes of the site are functioning [Interpreting Indicators of Rangeland Health assessment (Pellant 2020) or Describing Indicators of Pasture Health assessment (Ogles 2020)].
- Determine what conservation practice alternatives and resulting resource management system will achieve or maintain the desired plant community.
- Develop the grazing management plan within the Conservation Plan on the operation.
- Provide follow-up assistance to the land manager in plan implementation.
- Provide assistance to develop a monitoring plan. For more information on conservation planning, see Subpart D of this handbook.

(4) Conservation practices

Conservation practices applied on grazing lands are grouped into two categories to reflect their major purposes: primary practices and supporting practices.

- Primary Practices for grazed or hayed lands are Forage Harvest Management (511) and Managed Grazing (528). These are the most difficult and complex practices to plan and apply. These practices, respectively, are the proper application of hayland harvest and the proper manipulation of livestock number, kind, and class through pastures or rangeland in a time or manner that causes the plant community composition to move toward or maintain the desired community, while meeting the needs of the livestock and wildlife of concern.
- Supporting practices facilitate management or the function of another practice, or both, but does not achieve the desired effects on its own. For example: a fence is a supporting practice for managed grazing. Managed grazing helps improve forage for livestock. Supporting practices need to be installed according to a technical design to ensure success. NRCS personnel shall provide on-the-ground technical assistance needed for design and installation to ensure technical adequacy and that NRCS standards and specifications are met.
- Practices, such as brush management, herbaceous weed control, range planting, pasture and hay land planting, prescribed burning, and grazing land mechanical treatment, could be primary or supporting practices depending on how they are addressing the resource concerns. All need to be installed according to a technical design to ensure success. NRCS shall provide the technical assistance needed for design and installation. Figure F-2 shows Conservation Practice Standard 548 Grazing land Mechanical Treatment.
- A complete list of conservation practices, along with definitions and standards, are provided in the National Handbook of Conservation Practices and in each State's local Field Office Technical Guide (FOTG). The FOTG provides detailed information applicable to each conservation practice, including the practice standard and the State-specific practice specification and implementation requirements.

**Figure F-2.** Grazing Land Mechanical Treatment. Photo credit: Robert Crane, NRCS Area Rangeland Management Specialist.

(5) Determining conservation practice treatment alternatives

(i) For most grazing units, there are several management alternatives. These alternatives should promote the kind of plant community that supports and maintains a healthy ecosystem, meets the needs of the grazing manager, produces adequate available amounts of quality forage for grazing animals, and provides desirable wildlife habitat. Developing alternatives with the landowner or operator must also take into account not only the actions needed to address the identified resource concern or management objective, but must also consider the level of willingness and ability of the manager to accept and implement the actions needed.

(ii) Sometimes ranching operations follow grazing patterns developed or set over time or through traditions. In these cases, pastures or grazing units may be used during the same time and for the same length of time each year, as grazing strategies are continued from one family generation to the next or are influenced by infrastructure locations like working or shipping pens and water sources, livestock shelter, seasonal accessibility, and public land permits with set grazing periods during the year. If changes are needed to reach a desired plant community, changes in these grazing strategies may also be needed. NRCS conservationists can help landowners understand benefits to changing grazing and use patterns and explain how adaptive grazing strategies may be beneficial to help reach the new desired plant community.

(iii) Additionally, conservation practices may include multiple treatment options and methods. Matching those methods with the landowner's goals and objectives will provide the best opportunity for success on the operation. For example, if plant pest pressure has been identified as a concern due to increases in woody invasive species – but the operator has chemical hesitancy and prefers to not use herbicides – alternatives to meet the resource concern mechanically should be a treatment option for consideration. Figure F-3 shows Pinon mechanical extraction.

**Figure F-3.** Trac hoe extraction of Pinon and Juniper trees under CPS 314 mechanical brush management. Photo credit: Brenda Simpson, NGLT.

(6) Grazing Management Plan Development

(i) NRCS provides assistance to cooperators who wish to apply grazing management. The primary conservation practice used is 528 Managed Grazing (formerly called Prescribed Grazing). Managed Grazing is the vegetation management practice that is applied to all land where grazing is a planned use. The grazing may be from domestic livestock, semi-domestic animals (buffalo and reindeer), or wildlife. Managed grazing is managing vegetation with grazing and browsing animals with the intent to achieve specific ecological, economic, and management objectives. The 528 standard provides items that should be included in a Grazing Management Plan (GMP).

(ii) The objectives of the GMP are developed with the landowner during the planning process. The minimum level of planning for the managed grazing practice includes enough inventory and assessment information for the landowner to understand the proper amount of harvest of key species and other useable vegetation to maintain adequate cover to protect the soil and maintain or improve the quality and quantity of desired vegetation.

(iii) The available forage and the number of grazing and browsing animals must be in balance for effective management of grazing lands. A useful tool to understand this balance is developing a feed-forage balance sheet. This part of the inventory identifies the available forage from the land and the demand for forage by the livestock and wildlife. It identifies where and when shortages or surpluses in forage exist. Procedures and worksheets are in section 645.0604.

(iv) Once a feed and forage balance sheet is developed, a strategy should be designed on how to utilize the pasture including when to graze, how long to stay and how often to come back (intensity, timing, duration and frequency of grazing). Other factors besides livestock numbers will affect this strategy, such as existing resource conditions and concerns, existing infrastructure, planned infrastructure, and management goals. Once the plan is developed, a monitoring plan should be implemented that gauges the impact of grazing on the management objectives and resource concerns. Adjustments to the plan may be needed to meet these objectives, and a contingency plan should be designed in the event of potential problems (i.e., drought, flooding, insect damage, etc.) See CPS 528 or the National Range and Pasture Manual (NRPM)(USDA-NRCS 2021) for more details https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=46773.wba.

(v) Grazing can have a big impact on what plant species will dominate a site. Grazing pressures can vary by types of grazing and browsing animals and affect different plant species. If grazing is severe, undesirable plants can increase in the plant community.

(vi) Grazing management can be planned and applied that supports a particular plant community or species. This can be done to meet the objectives of the landowner and the needs of the resource. For instance, grazing management has been successfully planned and applied to encourage the re-establishment and increase of desirable woody plants along riparian areas, while still providing quality forage for the grazing animal in the understory and adjacent areas.

(vii) Alleviation of grazing pressures that have caused composition changes in a community does not immediately and solely end or reverse changes caused by these pressures. Many plants, both desirable and undesirable to grazing, are long-lived. If increase of undesirables is related only to the suppression of the desirable species, a change in grazing pressure and management sometimes allows the desirable species to regain their competitive status and suppress the invaders. Such a rapid recovery can occur only when prior grazing has been harmful for a comparatively short time. Where plants have died, recovery depends upon establishment of new plants. Re-establishment of seedlings of desirable species usually only happens under favorable growing conditions.

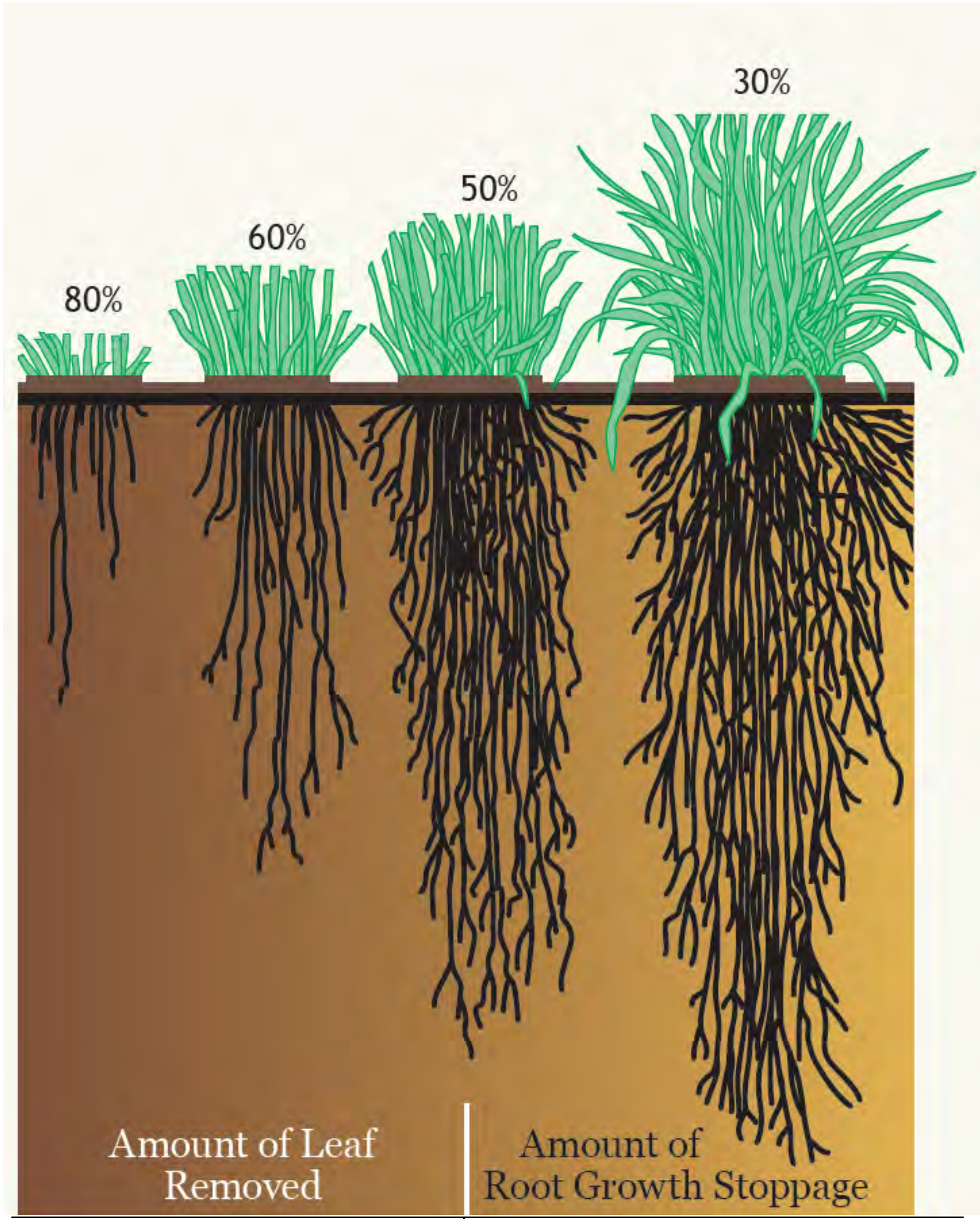
(viii) Defoliation of a plant by grazing reduces the photosynthetic capability of the plant. The leaves are the food factory. Rate of plant regrowth following grazing is dependent on the amount of leaf area remaining for photosynthesis and the availability of active growing areas to initiate new tillers and additional leaf area. Roots anchor the plants to the soil, take up water and nutrients, and if healthy, enable the plant to survive stress from drought, cold, heat, and grazing. Root growth is dependent upon the energy provided from photosynthesis. Figure F-4 illustrates the relationship between grazing and root growth. Healthy plant roots are essential for soil stability and erosion control.

(ix) Management of the grazing animal is one of the most economical methods to ensure the health and stability of the grazing land resource. For grazing management to be successful, it must help direct proper grazing use, meet the needs of the land, the landowner, and the livestock, and meet the NRCS Field Office Technical Guide planning criteria.

(viii) Key grazing areas and key species

- The term “grazing unit” is synonymous with terms such as pasture, paddock, range, and planning land unit (PLU) as the management unit on grazing land. For this subpart, all grazing management areas will be called grazing units for simplicity. They are typically enclosed by fences or natural barriers and may contain multiple ownerships and land status.

**Figure F-4.** Plant root response to grazing – percentage of leaf material removed (NRCS Soil Health Division 2016).




| | |
|---|---|
| 10–40% | 0% |
| 50% | 2–4% |
| 60% | 50% |
| 70% | 78% |
| 80–90% | 100% |

If 80% of plant leaf material is removed, plant root growth can cease for 12 full days, which slows plant regrowth considerably (Crider 1955, Dietz 1989, USDA-NRCS 2016. If only 10% to 40% of plant leaf material is removed, plant root growth doesn't stop, and the plant regrows faster and remains healthier; but this effect varies by species (USDA-NRCS 2016).

- Each grazing management unit has certain characteristics that influence the distribution of grazing. Among these characteristics are soil, topography, size of enclosure, location of water, fences, riparian areas, natural barriers, and the kinds and distribution of plants. In addition, weather conditions, insects, location of salt and minerals, type of grazing management being applied (timing, duration, frequency, and intensity of grazing), and habits of the grazing animals affect the pattern of grazing use. For these reasons, it is impractical to prescribe grazing use for every part of a large grazing unit or to prescribe identical use for all grazing units of a farm or ranch. Determining the key grazing area(s) in each unit and planning the grazing to meet the needs of the plants in the key area are more practical. If the key grazing area of a unit and the key grazing plants are properly grazed, the unit as a whole should not be considered excessively used.
- The key grazing area in a management unit is a relatively small area within the grazing unit. This key area(s) is used to represent the grazing unit as a whole. The key grazing area and key species concepts have proven highly useful to managers in evaluating grazing effects on useable vegetation (Holechek 1989, Holechek et al. 2011).
- Characteristics of a key grazing area:
  - Provides a significant amount, but not necessarily the greatest amount, of the available forage in the grazing unit.
  - Is easily grazed because of even topography, accessible water, and other favorable factors influencing grazing distribution. Small areas of natural concentration, such as those immediately adjacent to water, salt, or shade, are not key grazing areas, nor are remote areas far from water (generally over 1 ½ miles) or of limited accessibility.
  - Generally, consists of a single ecological site or the majority falls in one ESD.
  - Areas of special concern can be designated as key areas. Areas of special concern could include habitat for threatened or endangered species, cultural or archeological resources, areas around impaired waterbodies, and critically eroding areas.
  - Usually limited to one per grazing unit. In cases where the grazing units are small, the entire acreage many be considered the key area. In other cases, more than one key grazing area may be needed when:
    - -- units are large with diverse ecological sites and topography
    - -- units have riparian areas
    - -- units have very rough topography or widely spaced water where animals tend to locate
    - -- different kinds of animals graze the unit, or when the unit is grazed at different seasons
  - Riparian areas are of special concern when establishing key grazing areas. Riparian areas are of generally small extent in relation to the surrounding landscape. These areas represent a significant resource in terms of forage production, buffering surface water flows, controlling accelerated erosion and sedimentation, capturing and transforming subsurface pollutants, and providing essential wildlife habitat and local biodiversity. From an ecological basis, their designation as a key grazing area is therefore an important consideration. See figure F-5 Bear Creek riparian area, functioning well and providing forage production, buffering surface water, controlling erosion, capturing pollutants, and providing diverse wildlife habitat.
  - Table F-1 is an example of how and when to consider using a riparian area as a key grazing area.

**Figure F-5.** Bear Creek riparian area, Iowa NRCS. Photo credit Lynn Betts.

**Table F-1.** Decision support for consideration of riparian areas as key grazing areas:

| **Factors** | **Riparian area characteristics** | | |
|---|---|---|---|
| **Proportion of unit** | **< 5%** | **5–10%** | **> 10%** |
| Livestock accessibility | Difficult because of surface rock, steep slopes, debris, etc. | Some difficulty, but consistently used by livestock classes able to deal with limitations (e.g., yearlings). | Readily accessed and consistently used by all classes of livestock. |
| Habitat/forage for livestock | Livestock do not congregate for protection or forage based on season of grazing, geographic location. | Livestock congregate for water, protection, or forage based on season of grazing, geographic location. | Livestock congregate for water, protection, and forage based on season of grazing, geographic location. |
| Ecological site | Similar to associated upland sites. | Different from associated sites; e.g., woody versus herbaceous species. | Different from associated sites; e.g., woody versus herbaceous species. |
| Ecological rating | No less than associated sites. | Less than associated sites. | N/A |
| Decision-support riparian area key grazing area status | Consider area as an integral part of the associated sites, but not necessarily as a key grazing area. | Consider area an integral part of the associated sites, and possibly as a key grazing area. | Consider area separate from associated sites; identify a key grazing area within. |

(ix) Key grazing species

- Key grazing species are forage species whose utilization serves as an indicator of the degree of use of associated species. They are species that must, because of their importance, be considered in the management program (Society for Range

Management 1989, Holechek 2011). Most plant communities in a grazing unit consist of several plant species in varying amounts. Even though the entire plant community is of concern to management, attempting to reach the desired use of every species would be impractical. It is more practical to identify a single species (or in some situations two or three) as a key species to serve as a guide to the use of the entire plant community. If the key species within the key grazing area is properly grazed, the concept is that the entire plant community will not be excessively used or overgrazed.

- Considerations when selecting a key species include:
  - Selected only after careful evaluation of the current pattern of grazing use in the grazing unit.
  - Selected to meet the objectives and needs of the resources, livestock, and landowner. Objectives and needs must meet NRCS planning criteria.
  - Changed when the pattern of grazing use is significantly modified because of changes in season of use, kinds or classes of grazing animals, grazing unit size, water supplies, or other factors that affect grazing distribution.

(x) Characteristics of key species (USDA-NRCS NGLT 1997):

- Palatability – A relatively higher grazing preference is exhibited for it by the kind of grazing animal and for the planned season of use than for associated species in the key grazing area. Very palatable plants that have a negligible production potential should not be selected as key species, except as needed to meet management objectives or resource goals, like restoring a missing functional group in a plant community or ensuring that important species remain in a riparian area.
- Provides more than 15 percent of the readily available forage in the key grazing area. A species providing less than 15 percent of the available forage can be selected as the key species if it has a potential for greater production, like a species that should be more dominant but has been "grazed out" or is critical to the needs of the specified grazing animals [15 percent is a statistical result from research on pastures (USDA-NRCS NGLT 1997)]. A choice browse species on deer winter range or in a riparian area are examples of such a species. Selection of this kind of species usually necessitates a change in management such as a reduction in the stocking rate, timing or season of use, or duration and intensity of use. Additional measures may be needed to facilitate an increase in the desired species.
- Is consistent with the management objectives for the plant community. If the objective is to maintain or improve the plant community to a near-reference state, the key species should be one that is a major component of the reference state or community phases within the reference state. For more on reference states and community phases in ecological site descriptions, see Subpart B of this handbook.
- Is a perennial except where the grazing land is managed specifically for annual vegetation or where the grazing unit has only annual species or a mixture of annuals of good forage value and perennial species of little or no grazing value.

(xi) Key species should be selected in consultation with the land manager or decisionmaker who should be involved in choosing the key grazing area and evaluating the present plant community. This will help them in determining the kind of plant community that will be the goal of the operation and management, thinking about the kinds and classes of grazing animals and the season of use, and evaluating the factors affecting grazing distribution. Figure F-6 shows NRCS working with a landowner on a key grazing area.

**Figure F-6.** Virginia NRCS staff assisting cooperator at a key grazing area. Photo credit: Jeff Vanuga.

(xii) Defining proper degree of grazing use for key species

- The objective of grazing management is to maintain or develop the kind of plant community within the capability of the land that meets the goals of the land manager or decisionmaker. The trend, similarity index, and rangeland health of the rangeland ecological site are important to understand. Attaining a specified degree of use of key plant species in key areas is not an objective. The degree of use specified for key species is a planning tool and guideline or reference point by which the health of the plant community can be evaluated.
- The following should be considered in defining degree of grazing use:
  - Specifications for the degree of use of forage and browse species should be based on local experience of the conservationist and rancher and on the best available appropriate research data. Research and experience indicate that the amount of use that plants can tolerate varies greatly according to the kind of plant, season of use, soil, climate, recent weather conditions, vigor of the plants, and amount of use to which competing species are subjected. NRCS State supplemental guidance and Land Grant University publications are good sources for State-specific information.
  - If a grazing unit is grazed mainly during the dormant season, use may be greater than during the growing season, before damage to the plant occurs. However, considerations should be made to ensure that enough residual amounts remain to protect the soil surface from erosion and protect the plant crown from temperature fluctuations, including providing thermal protection and increase the potential for plant cover to catch and intercept precipitation and snow (Beckman 2021).
  - The planned or allowable degree of use for browse species differs from grass species. The degree of use applies only to the annual growth of twigs and leaves

within reach of animals. If deciduous browse species are used during the dormant season, the degree of use suggested applies to the annual twig growth.

– A significantly greater percentage of annual growth can be safely removed from many native plants if pastures are grazed at high intensity for short periods and completely rested for longer periods. This is particularly true if all plants growing in association are harvested somewhat equally. Extreme care must be exercised in applying such grazing management to ensure that vegetation and conditions are similar to those for which specifications are being established. Temporary heavy use must be compatible with the management objectives and must not contribute to site deterioration.
– If grazing units contain significant amounts of both warm- and cool-season forage plants, key species need to be changed when the grazing season and grazing periods are during that species' usage preference or growing season (warm or cool season). Key grazing areas may also need to be changed to areas where those species are present.
– If two or more kinds of animals make significant use of a grazing unit, and their forage preference or grazing patterns differ, specifications for season of use and proper grazing use should be determined for each kind of animal. This includes selecting appropriate key grazing areas and key species, as needed.
– The degree of use for most grazing units is expressed as the percentage removal, by weight, of the key species in the key grazing area(s). Estimates of the percentage removal are based on the total production of the key grazing plants for the growing season.
– The degree of use on annual ranges of the Mediterranean-type climatic zone can be expressed in pounds of current growth left as residue (Bartolome et al. 2020).
– For certain perennial plant communities, the appropriate degree of use can also be expressed in pounds per acre of annual growth residual remaining at the end of the grazing season if:
  -- The plant community is dominated by a single plant species of high forage value that is uniformly distributed in the grazing unit.
  -- The management objective is to perpetuate that species as dominant.
  -- The resulting cover provides adequate soil and moisture protection.
  -- Research or reliable data based on local experience are available for guidance.
– The amount of growth left on a perennial plant – not the amount removed – is important for the plant to function within its community. During an unfavorable growing season, a weakened plant may be severely damaged by use that would not otherwise adversely affect it during a normal or favorable growing season. Under these conditions, the residue procedure (above) can be applied. In many plant communities, however, species are neither equally abundant nor uniformly distributed, and they do not have the same ecological status. Thus, a specification based on weight per acre would be impractical. Supporting grazing use specifications are better suited to indicate the percentage of annual growth that can be removed from the key plant species in key grazing areas.
– The Percent Use of Grazing Species form (see Subpart E, figure E-23) is useful for recording planned utilization specifications for key species in key grazing areas. Data concerning actual grazing use for future comparisons can also be recorded. Methods for determining the degree of utilization of key plants are described in Subpart E, 645.0502.

(7) Degree of grazing use as related to stocking rates
   (i) Because of fluctuations in forage production or loss of forage other than by grazing use, arbitrarily assigning a stocking rate at the beginning of a grazing period does not ensure a specific degree of use. If the specified degree of use is to be reached and trend satisfactorily maintained, stocking rates must be adjusted as the amount of available forage fluctuates.
   (ii) When determining initial stocking rates, grazing distribution characteristics of the individual grazing unit must be considered. For example, a Stony Hills Range Site has steep areas adjacent to a relatively level Loamy Upland Range Site. The site generally receives less grazing use by cattle than the Loamy Upland Range Site due to the added energy cattle must exert grazing on the steeper slope areas. The Stony Hills Range Site may produce enough forage to permit a stocking rate of two acres per animal unit per month when it is the only site in a grazing unit. Its grazing use, however, is generally substantially less, in the example just described, by the time the Loamy Upland Range Site has been properly used. The reverse may be true if the grazing animal is sheep or goats. Therefore, initial stocking rates for a grazing unit should not be based directly on the initial stocking rate guides without a careful onsite evaluation of factors affecting grazing use of the entire grazing unit and the types of livestock that will be using those grazing units.
   (iii) Many methods are used to determine the initial stocking rate within a grazing unit. Often the past stocking history and the trend of the plant community are the best indicators of a proper stocking rate. New software programs can help calculate stocking rates when information like soils, plant community species and production, distance to water, slope, and other topographic information is known. For example, the NRCS Grazing land Resource Analysis System (GRAS) is a grazing management planning tool within Conservation Desktop to assist NRCS personnel in developing conservation treatment alternatives for land units where grazing or browsing occur. GRAS is a national grazing management tool integrated into the agency enterprise system. It leverages existing client geospatial and attribute information and provides consistency across the agency in developing forage animal balance reports.
   (iv) GRAS further supports the development of grazing plan components required for the conservation practice of grazing, CPS-528, and assists in the inventory and analysis of grazing lands, leading to the development of forage animal balance between animal demand and forage and roughage supply. This information provides documentation addressing the resource concern – inadequate feed and forage. Advanced features of GRAS will be included to assist clients who desire a more detailed forage and livestock inventory. See also Stocking Rate and Forage Value Rating Worksheet, directions and examples (figures F-7 and F-8).

**Figure F-7.** Stocking Rate and Forage Value Rating Worksheet

## Stocking Rate And Forage Value Rating

**Ecological Site:**_______________
**Pasture No:** ________
**Acres:** ________
**Date:** _________

**Operator:** ____________________
**Location:** ____________________
**Conservationist:** ______________
**Canopy:** _____________________

| | | | Potential consumed (lb/ac x HE) | | | | | | Actual consumed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Present composition | | Animal: | | | Animal: | | | Animal: | | | Animal: | | |
| Plant species | Weight lb/ac | % | P | D | UD | P | D | UD | P | D | UD | P | D | UD |
| | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | |
| Total forage consumed (Sum of P, D, UD): | | | | | | | | | | | | | | |
| Pounds per AUM: | | | | | | | | | | | | | | |
| AUM/ac (forage consumed / 790.8): | | | | | | | | | | | | | | |
| Ac/AU (12 / AUM/Ac): | | | | | | | | | | | | | | |
| % by Preference: | | | | | | | | | | | | | | |
| Forage value rating: | | | | | | | | | | | | | | |
| Harvest efficiency factors: P = .35, D = .25, UD = .15 | | | | | | | | | | | | | | |

**Notes** :

**Instructions for Stocking Rate Based on Preference and Forage Value Rating.**

This is a method to determine stocking rate based on consumption of forage allocated by preference of animal species. When wildlife are on the site, allocate feed to them first. Livestock stocking rate is based on the remaining forage. If more than one wildlife species is present, allocate to the larger animal first, then to the next smaller wildlife species. The remaining forage is then allocated to livestock. If more than one type of livestock is on the site, allocate feed to the larger animal first, then the smaller. This ensures that the area will not be overstocked with a combination of wildlife and livestock.

1. Record the name of the site being inventoried.
2. Record the management unit number.
3. Record the acreage of the area represented by the plant community being evaluated.
4. Record the date of the inventory.
5. Record the name of the client.
6. Record the field office name.
7. Record the name or initials of the person providing the technical assistance.
8. Record the canopy of the overstory of woody species.
9. Determine the present plant community composition by weight, then calculate the percentage composition. The composition is based on the forage within reach of the animal, normally below 4 ½ feet.
10. Compute the potential pounds consumed by multiplying the harvest efficiency times the pounds per acre of each plant listed in the community. Use the following harvest efficiencies:
11. Preferred =35%, Desirable= 25%, and Undesirable= 15%. Place the pounds consumed under the proper preference heading.
12. Total the pounds harvested for each preference heading. Then sum the production for total forage consumed.
13. Compute the AUM/AC by dividing the total forage consumed by 790 (the pounds allocated to an AUM).
14. Determine the AC/AU by dividing 12 by the AUM/AC.
15. Compute the forage value rating by determining the percent preferred, desirable and undesirable for the animal. Compare the percent preferred and desirable to the following table to determine the forage value rating.

| | |
|---|---|
| Very high | 50% P + D = 90% |
| High | 30% P + D = 60% |
| Moderate | 10% P + D = 30% |
| Low | Less than 10 P |

16. Compute AUM/AC and AC/AU and the forage value rating for the other animals following the above guidance. (Steps 10 through 14).
17. Compute the pounds per acre consumed by the different wildlife species presently on this site.

    **Example**:

    If site has one deer per 15 acres, divide 9,490 pounds (amount of forage allocated to an Animal Unit Year) by 15 = 632.6 pounds per acre total forage consumed by one AU of deer. Five Deer = one AU in this case. Divide 632.6 by 5 deer = 126.5 pound of forage per acre consumed by deer.

    Or

    9,490 divided by 5 deer = 1,898 pounds of forage consumed by one deer. 1,898 divided by 15 acres = 126.5 pounds per acre of forage consumed by deer when there is one deer per 15 acres.

18. Compute the forage consumed by wildlife (deer) by first recording the pounds consumed per acre (126.5) in the total forage consumed line and in the deer portion of actual consumed. Then, allocate preferred, desirable, and undesirable forages in that order until the deer are fed the computed forage consumed (126.5 pounds in example). When a forage plant is used to the maximum harvest efficiency level, then none is available to livestock or the next smaller wildlife species. If forage is left, then the remaining amount is allocated to the next smaller wildlife or livestock. Allocate the remaining plants to the livestock or next smaller wildlife in the same manner.
19. Then compute the livestock and wildlife AUM/AC and AC/AU based on the new total forage consumed for the livestock and wildlife. (Example: 48 AC/AU compared to the 35.3 AC/AU for livestock originally computed.) If wildlife populations are greater than what the "potential" computation show is advisable, then the plants will be overused, and then none of the wildlife plants will be available for the livestock.

**Figure F-8.** Stocking Rate and Forage Value Rating Worksheet Example

## Example – Stocking Rate And Forage Value Rating

(1) **Ecological Site:** Sandy Loam
(2) **Pasture No:** 12
(3) **Acres:** 100
(4) **Date:** 4/10/96

(5) **Operator:** I. B. Good
(6) **Location:** Happy Hollow
(7) **Conservationist:** RHJ
(8) **Canopy:** 45%

| (9) | (9) Present composition | | (10) Potential consumed (lb/ac x HE) | | | | | | (17) Actual consumed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Animal: Cattle | | | Animal: Deer | | | Animal: Deer | | | Animal: Cattle | | |
| Plant species | Weight lb/ac | % | P | D | UD | P | D | UD | P | D | UD | P | D | UD |
| Pine Hill Bluestem | 500 | 50 | 175 | | | | | | | | | 175 | | |
| Low Panic | 50 | 5 | | 12.5 | | | 12.5 | | | 1.5 | | | 11 | |
| Sweet Gum | 100 | 10 | | | 15 | | 25 | | | 25 | | | | |
| Amer. Beauty Berry | 100 | 10 | | 25 | | 35 | | | 35 | | | | | |
| Carpetgrass | 50 | 5 | | 12.5 | | | | | | | | | 12.5 | |
| St. Andrews Cross | 50 | 5 | | | 7.5 | | 12.5 | | | 12.5 | | | | |
| Sassafras | 150 | 15 | | | 22.5 | 52.5 | | | 52.5 | | | | | |
| Total | 1000 | 100 | (11) 175 | (11) 50 | (11) 45 | (11) 87.5 | (11) 50 | (11) 0 | 87.5 | 39 | | 175 | 23.5 | |
| Total forage consumed (Sum of P, D, UD): | | | (11) 270 lb/ac | | | (11) 137.5 lb/ac | | | (18) 126.5 | | | (18) 198.5 | | |
| Pounds per AUM: | | | 790.8 | | | 790.8 | | | 790.8 | | | 790.8 | | |
| AUM/ac (forage consumed / 790.8): | | | (12) .34 AUM/Ac | | | (15) .17 AUM/Ac | | | (18) .16 | | | (18) .25 | | |
| Ac/AU (12 / AUM/Ac): | | | (13) 35.3 Ac/AU | | | (15) 70.6 Ac/AU | | | (18) 75 Ac/AU | | | (18) 48 Ac/AU | | |
| % by Preference: | | | (14) 50 | (14) 20 | (14) 30 | 25 | 20 | 0 | ////////// | | | ////////// | | |
| Forage value rating: | | | (14) High | | | (15) Moderate | | | ////////// | | | ////////// | | |
| Harvest efficiency factors: P = .35, D = .25, UD = .15 | | | | | | | | | | | | | | |

**Notes**: (16)

Potential Site has 1 Deer / 15 Ac.
9,490 lb / 15 = 632.6 lb/Ac.
632.6 / 5 = 126.5 lb. Consumed by deer per acre, or
9,490 / 5 deer = 1,898 lb/deer.
1,898 / 15 Ac = 126.5 lb/Ac consumed by deer.

Estimated Stocking Rate:

Deer: 1 deer to 15 Ac = 6.6 deer
Cattle: 100 x .25 = 25AUM, or
2 AU year long

(8) Grazing Schedule (System, Strategy, Methods). A number of terms are commonly used to describe the way a livestock manager sets up a plan to graze and rotate livestock through their grazing units. Grazing systems vary with each operation based on climate, available plant species, soil types, and livestock species. Some operations utilize continuous grazing or season-long stocking where animals are in the grazing unit throughout the year or for that part of the year during which grazing is feasible. In cases where animals are continuously in a grazing unit, stocking rates must be carefully considered to avoid exceeding the recovery of the plant community and causing deterioration.

(i) How each type of grazing management system works, and the advantages and disadvantages of each type, must be understood. A land manager rarely adopts any grazing management system exactly as it is conceptualized in a handbook or textbook. The management that gets applied to the land is a combination of things that come closest to achieving the needs of the resources, landowner, and livestock. The NRCS conservationist must understand how livestock graze, the response of plants to grazing, and how rangelands in an area are impacted by different types of grazing management. Generally, the more extensive the grazing management, the slower the response of the forage resource; the more intensive the grazing management, the faster the forage response. However, risk of poor animal performance may be increased. All of these factors must be discussed with and understood by the land manager.

(ii) A grazing schedule is a system in which two or more grazing units are alternately deferred or rested and grazed in a planned sequence over time. The period of nongrazing can be throughout the year or during the growing season of the key plants. Generally, "deferment" implies a nongrazing period less than a calendar year, while "rest" implies nongrazing for a full year or longer. The period of deferment is set for a critical period for plant germination, establishment, growth, or other management objectives. While grazing management is defined as the manipulation of grazing and browsing animals to accomplish a desired result, it is a tool to balance the capture of energy by plants, the harvest of that energy by animals, and conversion of that energy into a product that is marketable, while maintaining or improving the natural resources. This is done primarily by balancing the supply of forage with the demand for that forage. Such systems help to

- Maintain or accelerate improvement in vegetation and facilitate proper use of the forage in the grazing units.
- Improve efficiency of grazing through uniform use of the grazing units.
- Stabilize the supply of forage throughout the grazing season.
- Enhance forage quality to meet livestock and wildlife needs.
- Improve the functioning of the ecological processes.
- Improve watershed protection.
- Enhance wildlife habitat.

(iii) Some grazing systems are better suited in some areas and in some operations due to many varying factors. These factors can include forage production potential, topography, water source availability, climate, accessibility, and availability of grazing units. Managed grazing is designed to fit the individual operating unit and to meet the operator's objectives, meet the conservation practice standards, and address resource concerns. Figures F-9 and F-10, NRCS's Grazing Schedule Worksheet, may be used in conservation planning. Other formats are available now through many grazing software programs.

**Figure F-9**. Grazing Schedule Worksheet

## Managed Grazing Schedule

Cooperator: ______________ Type of enterprise: (cow-calf, stock, or combination, stock & wildlife): ______________________

Technician: _____________ Animal units on hand: _______ Planned animal units: _____

Date: ___________ Kind and estimated number of wildlife: _____________

| Grazing units and kinds of forage | Acres | Total AUM's available | Record by month the planned number of animals in each grazing unit | | | | | | | | | | | | Total AUM's scheduled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | | | | | |

Notes:

**Instructions for Managed Grazing Schedule**

1. Enter client’s name.
2. Enter name of person providing technical assistance.
3. Enter date of technical assistance.
4. Enter type of livestock or wildlife enterprise.
5. Enter number of animal units of animals presently on land.
6. Enter number of animal units of animals for which the plan is being developed.
7. Record the kind and estimated number of grazing and browsing wildlife on the operating unit.
8. Record the number of the pasture or field and the pertinent information that affects the production, such as forage suitability group, fertilization rate, harvest efficiency.
9. Record the acreage in the pasture or field.
10. Record the total AUMs available in the field or pasture for the year.
11. Enter the months in a manner that matches the months listing on the forage inventory, or in a manner that best depicts the grazing period in relation to growth of forage.
12. Record by month the AUMs of animals scheduled to graze in each of the pastures or fields during the year. Also record mechanical forage harvest or the allocation of forage used in any other manner.
13. Record the total of AUMs scheduled in the pasture or field.
14. Record the total for all columns.
15. Record notes needed to explain any part of the worksheet or information needed for follow-up evaluations. Notes should include information about supplemental feeding plans of action in case of drought, future adjustments, desired trends, sales or shipping dates, hunting seasons, husbandry dates, (dates of breeding seasons), calving or lambing season, livestock working dates, type of grazing system, fertilizer rates and dates, and other information pertinent to the operation of the grazing schedule.

**Figure F-10.** Managed Grazing Schedule Worksheet

## Example – Managed Grazing Schedule

Cooperator: (1) Rancher

Type of enterprise: (cow-calf, stock, or combination, stock & wildlife): (4) Cow/calf

Technician: (2) Conservationist

Animal units on hand: (5) 64

Planned animal units: (6) 64

Date: (3) 4/10/96

Kind and estimated number of wildlife: (7) None

| (8) Grazing units and kinds of forage | (9) Acres | (10) Total AUM's available | (12) Record by month the planned number of animals in each grazing unit | | | | | | | | | | | | (13) Total AUM's scheduled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (11) A | M | J | J | A | S | O | N | D | J | F | M | |
| #1 Bermuda 3A High, 50 H.E. (500 AUM's) | 50 | | | | 64 | 64 | 64 | 64 | 64 | | | | | | |
| #2 Rangeland (294) AUM's) | 500 | | 33 | 33 | | | | | | 64 | 64 | 33 | 33 | 33 | |
| Hay feed on Rangeland (155 AUM's) | | | 31 | 31 | | | | | | | | 31 | 31 | 31 | |
| | | | | | | | | | | | | | | | |
| Hay Harvest from #1 (208 AUM's) | | | | (50) | (36) | (86) | (36) | | | | | | | | |
| | | 550 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | |
| | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | |
| (14) TOTAL | | | | | | | | | | | | | | | |

**Notes:** (15) Supplemental Feed
Drought Plans (When & How)
Future Adjustments
Trends
Sales or Shipping Dates
Husbandry
Type of Grazing System
Fertilizer Rates and Dates
Other Information

1. Protein supplement will be fed as needed in Dec., Jan., and Feb.
2. Inventory of Forage Production will be taken August 1st. Stocking will be adjusted based on on current forage inventory and projected production. At frost, an inventory of forage will be made and stock numbers balanced with forage available to carry animals through May.

(iv) Basic types of grazing management systems are as follow. Many others can be developed to fit specific objectives on specific lands.

- Deferred rotation
- Season-long deferred rotation
- Rest rotation
- High intensity – Low frequency
- Short duration
- Adaptive grazing

(v) Deferred rotation grazing

- Deferred rotation is any grazing system that provides for a systematic rotation of deferment among pastures. The time of the rest period generally changes in succeeding years. An example of a deferred grazing system is the four-pasture, three-herd Merrill System. This system grazes three herds of livestock in four grazing units, with one unit being deferred at all times. The number of livestock is balanced with the available forage in all four grazing units. Each grazing unit is deferred about four months. In this way the same grazing unit is not grazed the same time each year. This type of system will repeat itself every four years. Figure F-11 is an example of a deferred rotation system.
- The fifth year of this type of system is the same as the first year. Note that the actual length of time grazed and deferred depends on the size of the grazing units, the size of the herd, and the weather for the year. The model in Figure F-11 assumes equal size (in terms of forage supply) for the four grazing units in the system.

**Figure F-11.** Deferred rotation system model example

| Year one | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | | | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 2 | graze | graze | | | | | graze | graze | graze | graze | graze | graze |
| 3 | graze | graze | graze | graze | graze | graze | | | | | graze | graze |
| 4 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | | |

| Year two | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | | | | | graze | graze | graze | graze | graze | graze |
| 2 | graze | graze | graze | graze | graze | graze | | | | | graze | graze |
| 3 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | | |
| 4 | | | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |

| Year three | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | graze | graze | graze | graze | | | | | graze | graze |
| 2 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | | |
| 3 | | | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 4 | graze | graze | | | | | graze | graze | graze | graze | graze | graze |

| Year four | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | | |
| 2 | | | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 3 | graze | graze | | | | | graze | graze | graze | graze | graze | graze |
| 4 | graze | graze | graze | graze | graze | graze | | | | | graze | graze |

(vi) Season-long grazing

- In many parts of the United States, livestock cannot graze on the land the entire year. Where snow or other related conditions prevent yearlong grazing, the concepts of the grazing systems still apply. Figure F-12 is an example of a season-long deferred rotation grazing scheme where the livestock can only be on the grazing land from April through October.
- When livestock are grazed during the growing season, forage is usually at its highest nutritional level.
- Stocking rates should consider regrowth needs of forage.
- Excessive grazing of grasses during the growing season can reduce food-producing (photosynthesizing) parts of the plant, increase vulnerability to growing points, and reduce food reserves and growth.

**Figure F-12.** Season-long rotation grazing scheme (April-October)

| **Year one** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 2 | | | | | | | graze | graze | graze | graze | | |
| 3 | | | | graze | graze | graze | | | | | | |
| 4 | | | | graze | graze | graze | graze | graze | graze | graze | | |

| **Year two** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | | | | | | | graze | graze | graze | graze | | |
| 2 | | | | graze | graze | graze | | | | | | |
| 3 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 4 | | | | graze | graze | graze | graze | graze | graze | graze | | |

| **Year three** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | | | | graze | graze | graze | | | | | | |
| 2 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 3 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 4 | | | | | | | graze | graze | graze | graze | | |

| **Year four** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 2 | | | | graze | graze | graze | graze | graze | graze | graze | | |
| 3 | | | | | | | graze | graze | graze | graze | | |
| 4 | | | | graze | graze | graze | | | | | | |

(vii) Rest rotation grazing

- Allows for a full year of rest from grazing for the units on a rotating basis. For example, in year one, grazing units 2 and 4 are rested after March for over a year before being grazed again. The grazing units receiving rest will rotate different years through this system. See figure F-13 for the example.
- Rest rotation grazing consists of either multi-pasture, multi-herd, or multi-pasture-single herd systems.
- Grazing units are rested or deferred to
  − Restore plant vigor.
  − Allow for seed development and ripening.
  − Allow seedling establishment.

   - Livestock numbers should be based on the amount of forage that is produced in the pastures that are to be grazed each year.
- Figure F-13 is a model of one example of five grazing periods in which the growing season begins the first of April, and seed ripening occurs in July. Sequence of grazing treatments is an entire year of grazing followed by complete rest the second growing season. This rest period allows plants to regain vigor. During the third growing season, the grazing unit receives a deferment until seeds of the desired plants have ripened and then is grazed the remainder of the growing season. The fourth year is an entire growing season of rest to allow for seedling establishment. During the fifth growing season, grazing is deferred during the early of the growing season to further enhance seedling establishment, and then the unit is grazed the remainder of the growing season.

**Figure F-13.** Rest rotation system model example

| Year one | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. Unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 2 | graze | graze | graze | | | | | | | | | |
| 3 | | | | | | | | graze | graze | graze | graze | graze |
| 4 | graze | graze | graze | | | | | | | | | |
| 5 | | | | | | | graze | graze | graze | graze | graze | graze |

| Year two | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. Unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | graze | | | | | | | | | |
| 2 | | | | | | | | graze | graze | graze | graze | graze |
| 3 | graze | graze | graze | | | | | | | | | |
| 4 | | | | | | | graze | graze | graze | graze | graze | graze |
| 5 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |

| Year three | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. Unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | | | | | | | | graze | graze | graze | graze | graze |
| 2 | graze | graze | graze | | | | | | | | | |
| 3 | | | | | | | graze | graze | graze | graze | graze | graze |
| 4 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 5 | graze | graze | graze | | | | | | | | | |

| Year four | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. Unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | graze | graze | graze | | | | | | | | | |
| 2 | | | | | | | graze | graze | graze | graze | graze | graze |
| 3 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 4 | graze | graze | graze | | | | | | | | | |
| 5 | | | | | | | | graze | graze | graze | graze | graze |

| Year five | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. Unit** | **Jan.** | **Feb.** | **March** | **April** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| 1 | | | | | | | graze | graze | graze | graze | graze | graze |
| 2 | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze | graze |
| 3 | graze | graze | graze | | | | | | | | | |
| 4 | | | | | | | | graze | graze | graze | graze | graze |
| 5 | graze | graze | graze | | | | | | | | | |

(viii) High intensity – low frequency grazing

- High intensity – low frequency (HILF) systems are multi-pasture systems where livestock numbers are high, and grazing duration is short. These systems are generally single herd systems.
- Stock density is high to extremely high. Stock density is the relationship between number of animals and the specific unit of land being grazed at any one point in time. This may be expressed in animal units per unit of land area (animal units at a specific time or area of land)(Society for Range Management).
- The length of the grazing period is moderate to short, with a long rest period. Dates for moving livestock are set by the utilization of the forage.
- Grazing units are not grazed the same time of year each year.
- Figure F-14 is an example of a model of a HILF grazing system. In HILF, the number of grazing units and grazing capacity of each unit determine how often, if ever, the same grazing unit is grazed during the same period of the year.

**Figure F-14**. HILF grazing system model example

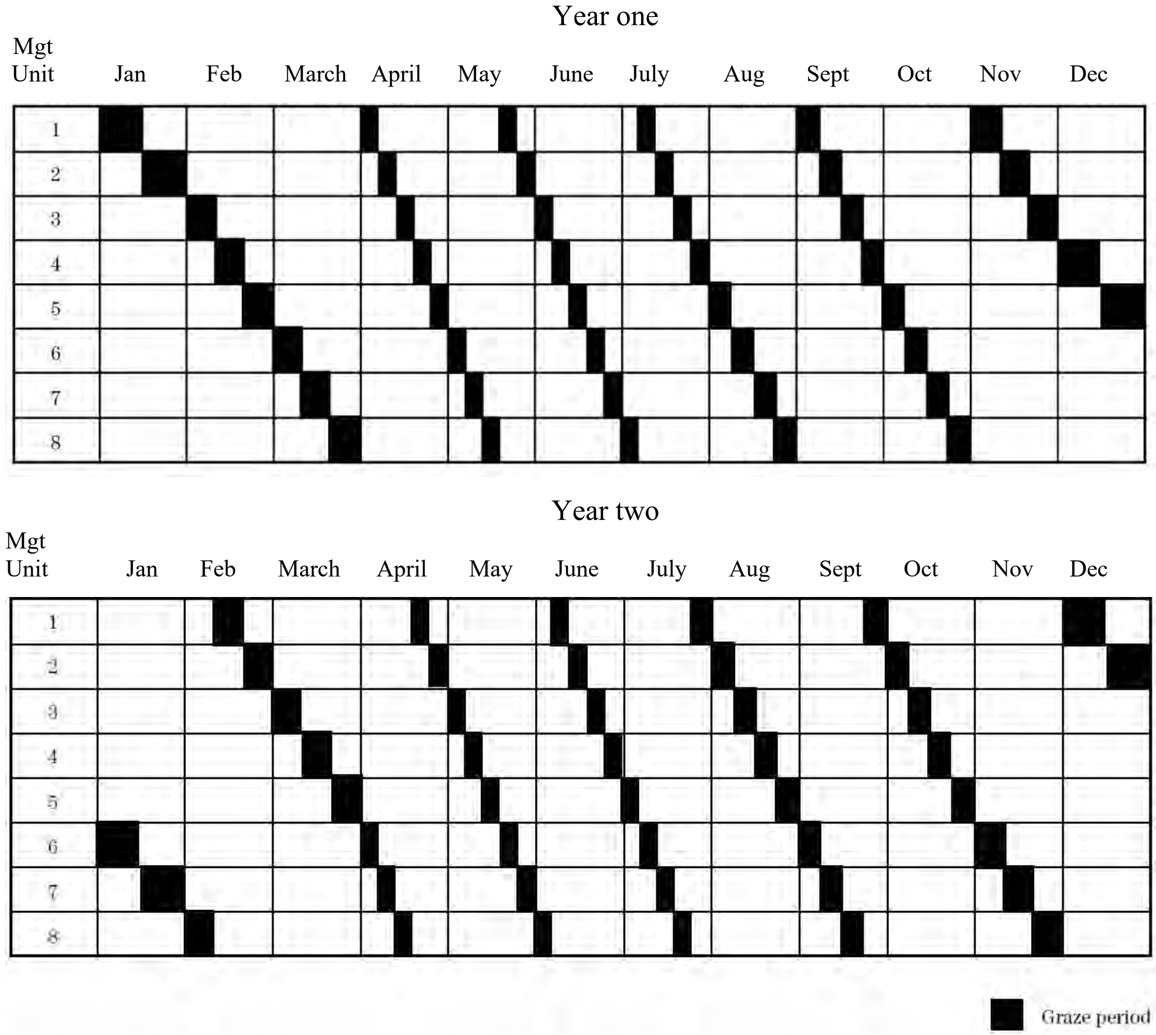
| Year one | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | graze | | | | | | | graze | | | | |
| 2 | | graze | | | | | | | graze | | | |
| 3 | | | graze | | | | | | | graze | | |
| 4 | | | | graze | | | | | | | graze | |
| 5 | | | | | graze | | | | | | | graze |
| 6 | | | | | | graze | | | | | | |
| 7 | | | | | | | graze | | | | | |

| Year two | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mgt. unit** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| 1 | | | graze | | | | | | | graze | | |
| 2 | | | | graze | | | | | | | graze | |
| 3 | | | | | graze | | | | | | | graze |
| 4 | | | | | | graze | | | | | | |
| 5 | | | | | | | graze | | | | | |
| 6 | graze | | | | | | | graze | | | | |
| 7 | | graze | | | | | | | graze | | | |

(ix) Short duration grazing

- Short duration grazing is similar to high intensity-low frequency except that the length of the grazing and rest periods are both shorter for the short duration strategy. Utilization, therefore, is less during any given grazing period. Stock densities are high. Figure F-15 is a conceptual model of a short duration grazing system.
- In the short duration model, the pattern may never repeat itself.

**Figure F-15.** Short duration grazing system model:




(x) Adaptive grazing

- Adaptive grazing management, or sometimes referred to as outcome-based grazing, uses current monitoring information, current precipitation data, forage production, and grazing intensity to keep grazing animal numbers in balance with forage supplies on a seasonal and annual basis for a particular grazing unit (Holechek et al. 2011).
- The concept of adaptive management is that the grazing strategy is adaptable and modifiable to accommodate changing conditions to ensure that the grazing unit condition is not adversely affected. Generally, multiple grazing units are used in this strategy.
- Application of supporting practices for grazing management (e.g., fencing and water development) are often necessary to facilitate necessary management changes, but they should not be the focus of planning efforts. The emphasis should be placed on integrating these practices with adaptive management decisions such as stocking rate, drought resiliency, and land health goals (Briske 2011).
- The quality of grazing management is on a continuum where it is always being evaluated for improvement. The plan should be to further the application of sound principles improving from the benchmark. Understanding these principles is central

for adaptive management. See Subpart E of this handbook for information on evaluating grazing management.

- Adaptive management requires constant vigilance with observation and analysis of ecological, economic, and logistic components of a ranching operation being flexible with objectives (actions), having a variety of choices available, and having clearly defined priorities and goals for conservation outcomes. Focused monitoring of ecological variables is crucial for adaptive grazing management (Briske 2011).
- Adaptive management allows for continual progress towards conservation goals. Rigid application of any "grazing system" will rarely be successful (Briske 2011), but adaptive grazing management allows incremental improvements to be rapidly applied. For example:
  - Basing grazing timing decisions on phenological growth stages to manage invasive annual grasses (Smith et al. 2012).
  - Assessing plant recovery from grazing (and readiness for grazing) based on phenological growth stages of perennial grasses (Grissom 2013).
  - Establishing a "forage bank" or stockpiling forage, in concert with patch burning, to increase drought resiliency and forage quality (Spiess et al. 2020).
  - Strengthening important forage plants in riparian areas with only short periods of use or moderate intensity use during the growing season, providing sufficient growing season recovery before next use, and grazing at a different time from one year to the next, with annual and seasonal decisions based on riparian vegetation monitoring (Swanson et al 2015).

B. Managing grazed woodlands

(1) Principles of woodland grazing

(i) Managing a wooded area to produce forage for livestock, desired wildlife habitat, quality water, quality fisheries, wood products, and many other desired outcomes requires an understanding of the wooded ecosystem and how it responds to the manager's decisions.

(ii) Not all sites capable of growing trees and forages are suitable for silvopasture establishment and management. Establishing these systems requires significant investments that need to be compensated with sufficient productive outputs. Marginal sites may be limited in productivity and may be more susceptible to negative grazing impacts, reducing production over time (Chedzoy et al. 2022).

(iii) Grazeable woodlands include grazed forests, silvopasture, and wooded lots used for holding livestock.

(2) Forest grazing (as depicted in figure F-16) is based on the ecological principles that drive a natural system to move toward or maintain a desired ecological site.

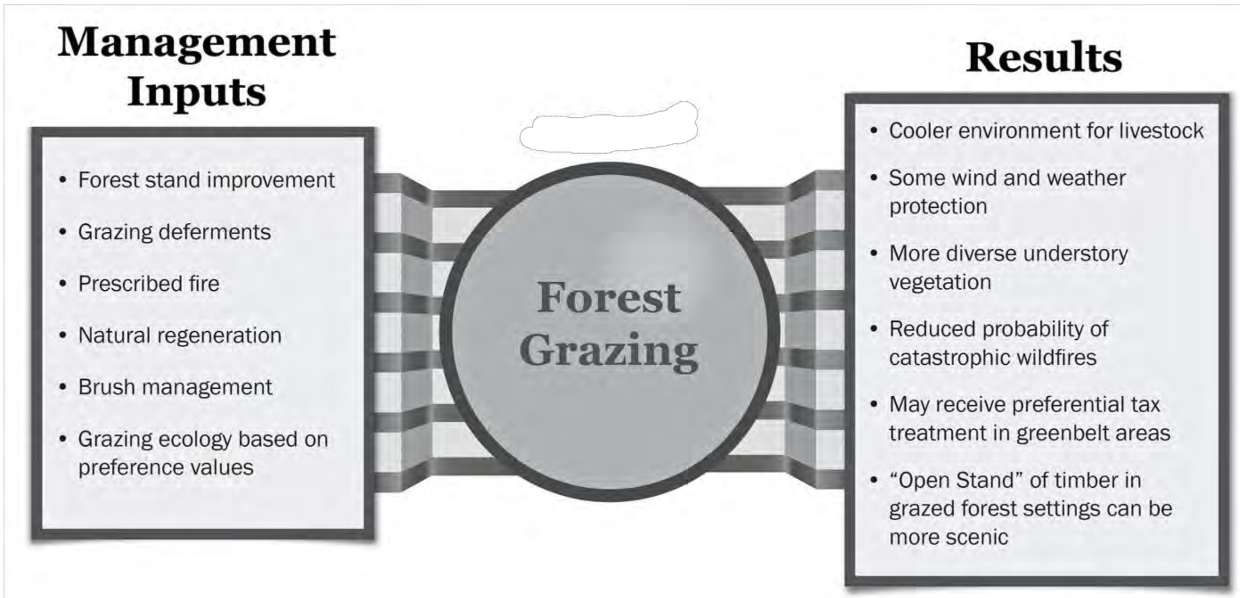
(i) Typical management practices may include (but are not limited to) grazing deferments based on selected forage and browse availability, prescribed fire, forest improvement that drives the forest ecologically toward a desired outcome, herbivory that doesn't detract from the desired natural regeneration or ecological site needs, biological or chemical brush management, and livestock grazing intensity based on key forage plant preferences for the grazing season.

(ii) The desired plants are only grazed to the degree that still allows for them to have the desired dominance level in the plant community. Forage preference values are currently derived from manager's experience, the USDA Ecological Site Information System (for some sites), or Extension Service experience and documentation (Brantly 2014).

(iii) Some forest ecosystems managed for forest products have limited capabilities for livestock grazing. Livestock grazing can cause detrimental effects, such as reduced regeneration of desired native woody and herbaceous species, merchantable tree damage, altered hydrology, adverse soil compaction, or soil erosion on steep, highly erodible sites.

(iv) With good management, the native or naturalized plant community is strategically grazed and browsed when the canopy is more open, with adequate light reaching the forest floor (Brantly 2014).

**Figure F-16.** Forest Grazing (Brantly 2014)

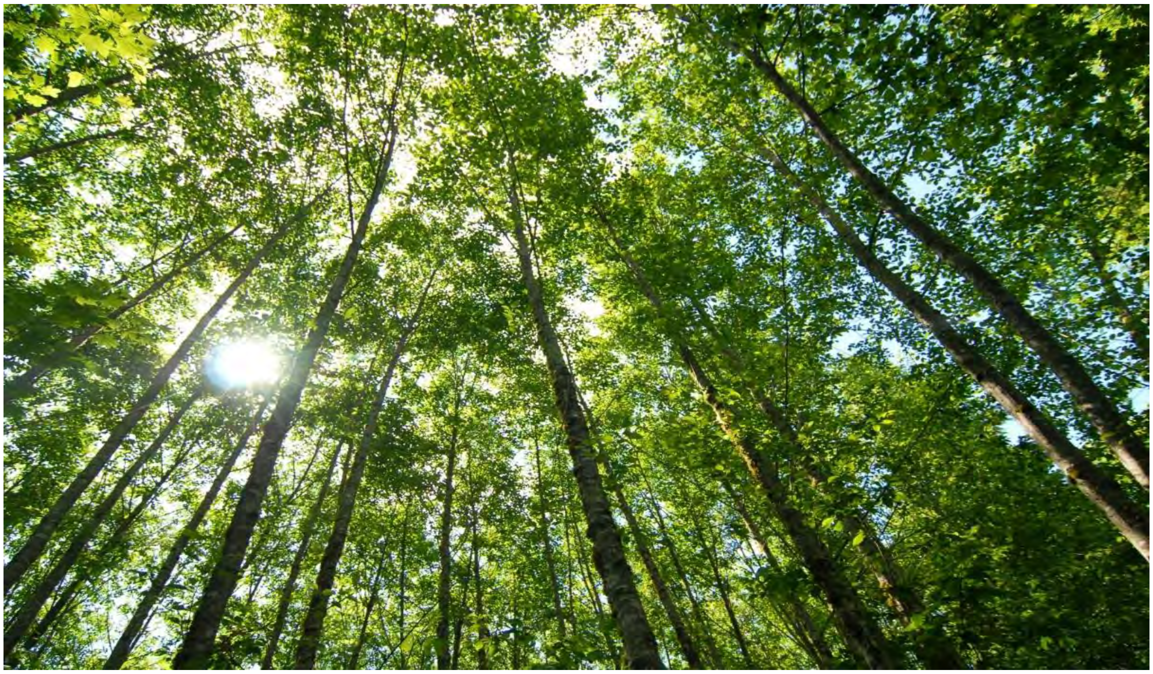



(v) In most forests, solar energy is the major ecological component affected in the management process. Solar energy is intercepted by the canopy of the tallest trees (figure F-17). This reduces solar energy as it penetrates to the next vegetation layer, the midstory of woody plants, or grasses and forbs growing on the forest floor. Managing the forest ecosystem for the desired plant community and the desired outcomes is, in a large part, accomplished by managing the plant populations in the different vegetation layers (overstory, midstory, and understory) to provide the most efficient use of solar energy by the desired plants.

(vi) As the forest matures, canopy closure reduces the understory herbaceous and shrubby components until grazing is no longer feasible. For most ecosystems, canopy cover exceeding 50 percent results in inadequate forage for forest grazing.

(vii) Managing forests for forage and wood products requires that the Forest Management Plan and the Managed Grazing Plan be coordinated to produce the desired effects on the plant community and all of the ecological components.

**Figure F-17.** Manage canopy for solar infiltration. Photo Credit: Ron Nichols.



(3) Principles of silvopasture management

(i) Silvopasture is the deliberate integration of trees and grazing livestock operations on the same land. These systems are intensively managed for both forest products and forage, providing both short- and long-term income sources (Smith et al. 2022).

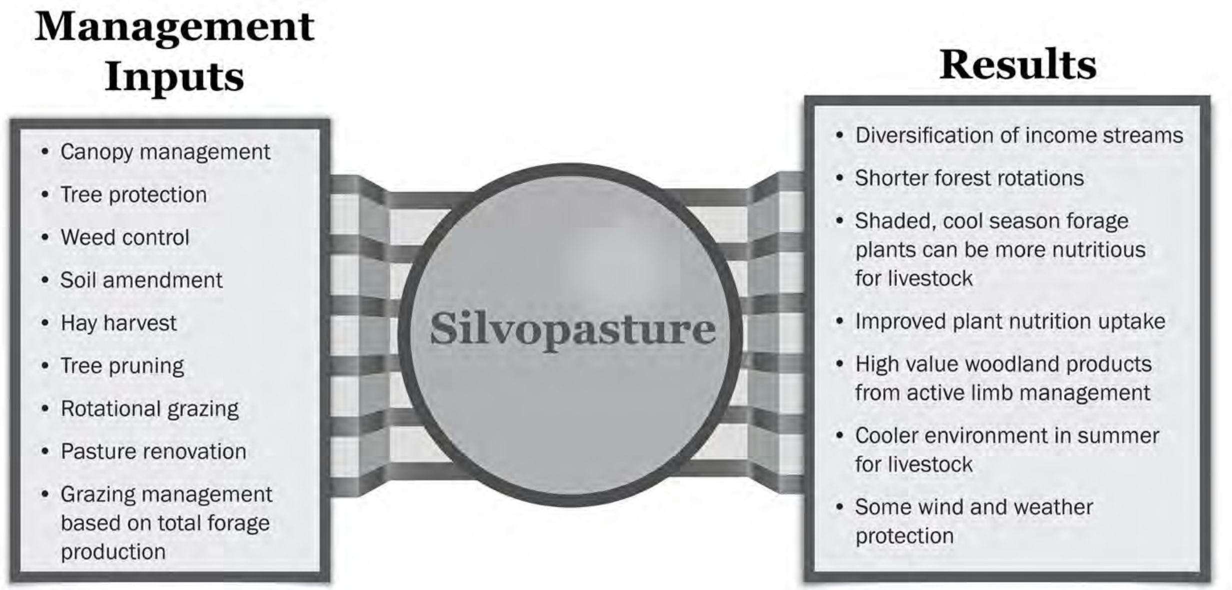
(ii) Because few individual producers or land managers have all the skills needed for establishing and managing a silvopasture, the best approach is to build a team. The team should include the land manager and all who are engaged in land management at the site, such as extension agents, foresters, and technical service providers (from the NRCS, conservation districts, or land management agencies), as well as those who routinely perform tasks on the farm or ranch, such as companies or professionals who spread fertilizer or spray chemicals (Chedzoy et al. 2022).

(iii) Silvopastures are most commonly created either by planting trees into pastures or thinning stands of trees and planting or encouraging forage. However, silvopasture can also be established in existing orchards or savannas. The addition of cross and boundary fencing and water infrastructure is usually a part of establishment. Regardless, silvopasture managers coordinate tree thinning and pruning practices to modify the canopy density in ways that complement sustained forage production throughout the majority of the rotation and meet the needs of canopy species.

(iv) Silvopasture systems are intensively managed and therefore require regular and consistent monitoring. A producer must understand each of the three components: trees, forage, and livestock, and how they interact to be successful (USDA-NAC 2008). Successful rotational or management intensive grazing is generally considered a prerequisite to silvopasture management. Smith et al. (2022) found that 98 percent of silvopasture adopters use rotational or management intensive grazing.

(v) Silvopasture management (as depicted in figure F-18) is based on the agronomic and forestry principles used to profitably produce and harvest forage and forest products, guided by the limitations and potential of the land. Typical management practices may include (but are not limited to) soil amendment applications (usually fertilizer and lime), pasture renovations, rotational grazing management based on total forage production, targeted grazing by livestock that will help control woody seedling and sampling regeneration, chemical and mechanical weed management, tree pruning, hay harvest, tree protection, and forest thinning for proper canopy management (Smith et al. 2022).

**Figure F-18.** Silvopasture (USDA-NAC 2013)




(vi) Tree species are often selected that have an economic potential and meet forage light requirements. However, tree species selection may be driven by other management objectives, such as wildlife habitat. Forages are selected that thrive in the range of sunlight penetration that is anticipated with the given canopy management and are typically introduced or native pasture grasses and nitrogen fixing legumes (USDA-NAC 2008).

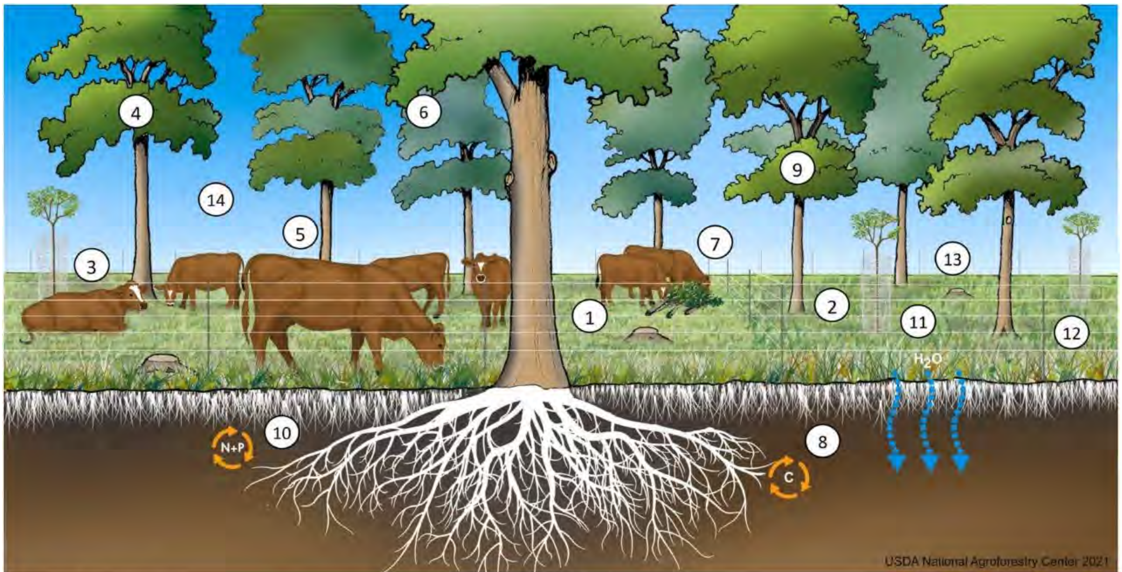
(vii) Livestock benefit in silvopasture systems from shade and reduced heat stress, which improves animal performance and well-being (Smith et al. 2022).

(viii) Wildlife habitat and populations of many wildlife species often increase with the addition of agroforestry systems in urban and agricultural areas (Mason et al. 2014).

(ix) Most silvopastures are used in rotation with open or more traditional pastures. Approximately 96 percent of silvopasture practitioners use a combination of both silvopastures and open pastures in rotation (Smith et al. 2022).

(x) Silvopasture requires that forest management, pasture management, and grazing management be coordinated and conducted together to ensure the production of multiple, harvestable components (Brantly 2014). See figure F-19 for a summary of primary effects of silvopastures (Smith et al. 2022). See Conservation Practice 381-Silvopasture for more information on establishment or management of desired trees and forages on the same land unit.

**Figure F-19.** Summary of primary effects of silvopastures (Smith et al. 2022).

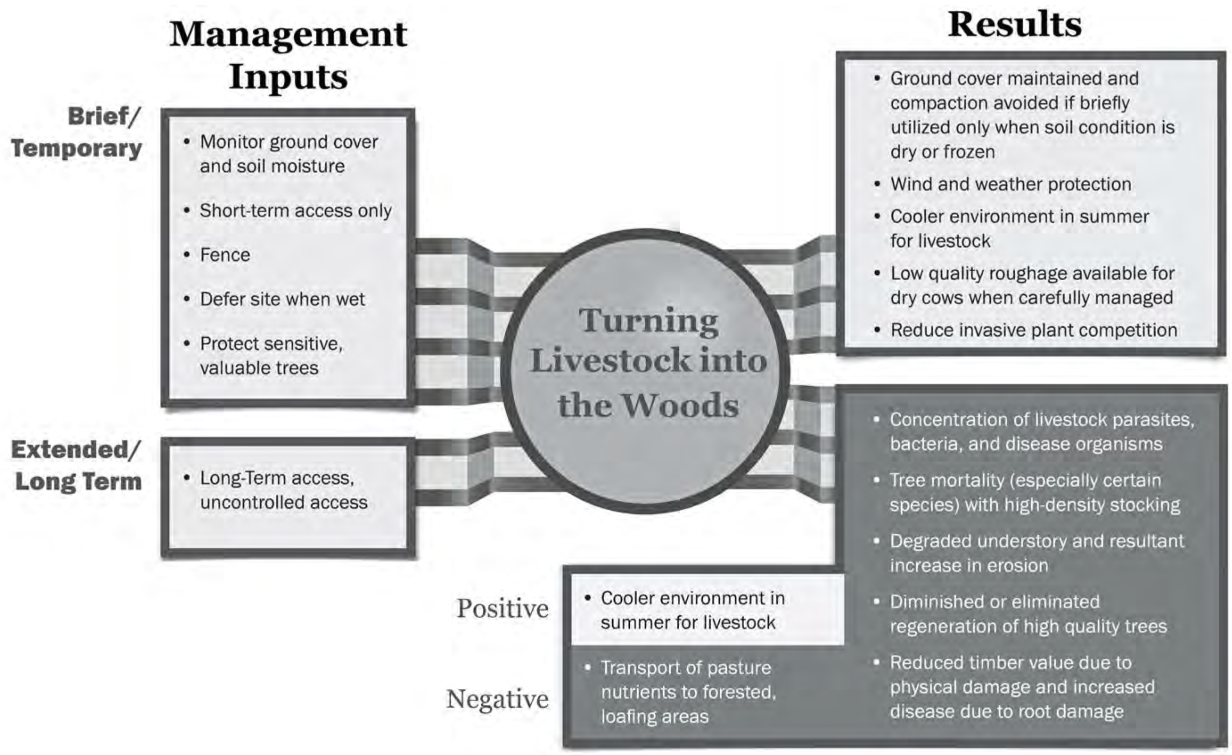



| Key | Component | Summarized primary effects | Key references |
|---|---|---|---|
| 1 | Forage | Microclimate modification can maintain or enhance forage yield and quality compared to open pasture depending on species and management. | Buergler et al. (2006), Ford et al. (2019b), Fannon et al. (2019), Orefice et al. (2019), Pang et al. (2019a, 2019b) |
| 2 | Forage | Potential for extending forage growing season and yields due to microclimatic modification in droughty summer months and reducing radiation frosts in early and late season. | Frost and McDougald (1989), Feldhake (2002), Kallenbach et al. (2006), Coble et al. (2020) |
| 3 | Livestock | Shade reduces solar radiation and heat stress which can enhance animal productivity. | Karki and Goodman (2010), Schütz et al. (2014), Van laer et al. (2014), Pent et al. (2020b, 2021) |
| 4 | Livestock | Shelter from trees can offer thermal protection for livestock during winter by reducing wind and precipitation reaching sheltering animals. | Van laer et al. (2014, 2015), He et al. (2017) |
| 5 | Livestock | Livestock weight gain in silvopastures can be comparable to that of livestock grazed in open pastures depending on species and management. | Kallenbach et al. (2006), Ford et al. (2019b), Pent et al. (2020a) |
| 6 | Tree | Trees in silvopasture can produce products to increase enterprise diversification. Tree growth can benefit from nutrient input but may be negatively impacted by livestock if not adequately managed. | Ares et al. (2006), Broughton et al. (2012), Bruck et al. (2019), Pent 2020 |
| 7 | Tree | Leaf fodder and mast (e.g., acorns, honey locust pods, apples) can augment livestock diets and offer nutritional value depending on species. | Moreno et al. (2018), Vandermeulen et al. (2018), Pent and Fike (2019), Hassan et al. (2020), Seidavi et al. (2020) |
| 8 | Ecosystem service | Soil carbon storage is increased at various soil horizons and depths when converting from open pasture to silvopasture but may decrease when converting from forest. | Haile et al. (2008, 2010), Baah-Acheamfour et al. (2014, 2015), De Stefano and Jacobson (2018) |
| 9 | Ecosystem service | Soil and biomass carbon sequestration is generally higher in silvopasture than open pasture but may be lower than forests. | De Stefano and Jacobson (2018), Lal et al. (2018) |
| 10 | Ecosystem service | Silvopasture can enhance nutrient recycling and reduce phosphorus loss and nitrate leaching when compared to open pasture. | Michel et al. (2007), Bambo et al. (2009), Boyer and Neel (2010), Nyakatawa et al. (2012 ) |
| 11 | Ecosystem service | Infiltration rates are similar or slightly higher in silvopasture than open pasture but lower than forests. | Sharrow (2007), Moreno et al. (2018) Stewart et al. (2020) |
| 12 | Ecosystem service | Silvopasture can increase biodiversity compared to open pastures but may be less than diverse natural forests. | Burgess (1999), Mcadam et al. (2007) Torralba et al. (2016), Moreno et al. (2018) |
| 13 | Ecosystem service | Grazing and woodland management in silvopasture systems may reduce fuel load and wildlife risk. | Ruiz-Mirazo and Robles et al. (2012), Palaiologou et al. (2020), Damianidis et al. (2021) |
| 14 | Ecosystem service | Silvopasture may provide cultural ecosystem services including sense of place, aesthetic value, recreation and ecotourism, and cultural heritage value. | Fagerholm et al. (2016), Moreno et al. (2018) |

(4) Turning livestock into the woods (Brantly 2014).

(i) Using wooded areas for supplemental grazing units (as depicted in figure F-20) is usually based on the need for additional forage or browse, to rest other pastures, and sometimes just the need to reduce environmental stress on animals. Livestock managers may choose to utilize woodlots or forests as loafing lots for animals that simply need some place to be for a short while.

**Figure F-20.** Turning Livestock into the Woods (Brantly 2014)




(ii) They may also choose to turn livestock into the woods for short durations to help control invasive plants.

(iii) These areas can sometimes provide temporary shade, winter and wind protection, or low-quality roughage for dry cows.

(iv) Depending on the geographical region, the species and stage of tree maturity, and soil characteristics, a forest may recover adequately from a single temporary grazing period. However, when a relatively large number of cattle have uncontrolled access to forest for long periods of time, production of wood products and forest attributes will almost always degrade.

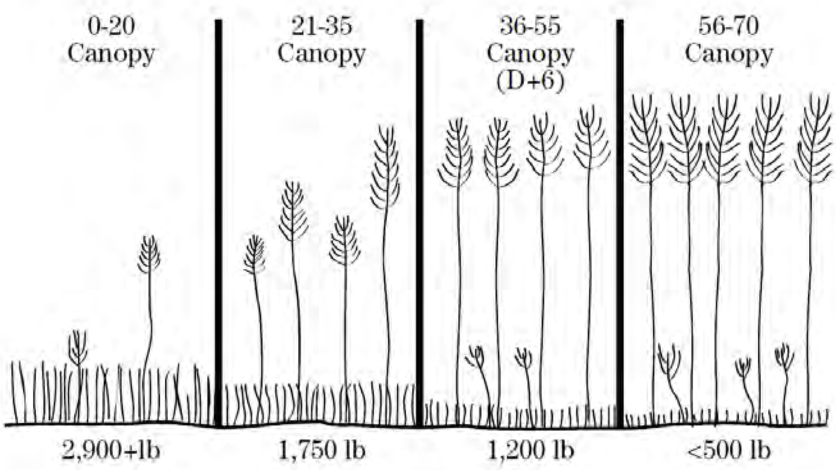
(5) Management of the overstory

(i) Ecological site descriptions for forest land are housed in the Ecosystem Dynamics Interpretive Tool (EDIT) at https://edit.jornada.nmsu.edu/. They provide information for each forestland ecological sites where they are developed. At this time, not all Forest ESDs are complete. Completed forest land ecological sites contain a description of the overstory canopy composition classes that are on the site. Plant species adapted to the site and the amount of sunlight that penetrates to the ground level are listed for each canopy class. The description of the understory composition includes the production (in pounds) of each plant or groups of plants and the total production for the canopy class.

(ii) Where forest ESDs are not developed, alternative information can be found in older woodland site descriptions, NRCS State Technical Notes, Land Grant publications, and from other forestry agencies. See Cornell University Silvopasture documents at https://blogs.cornell.edu/ccednrpublications/agroforestry-silvopasture/.

(iii) As canopy closes from totally open to totally closed (figure F-21, a southeast forest site), the understory species changes from shade-intolerant to more shade tolerant to very little understory vegetation. The gradual elimination of sunlight penetration leads to species composition changes and reduced forage production.

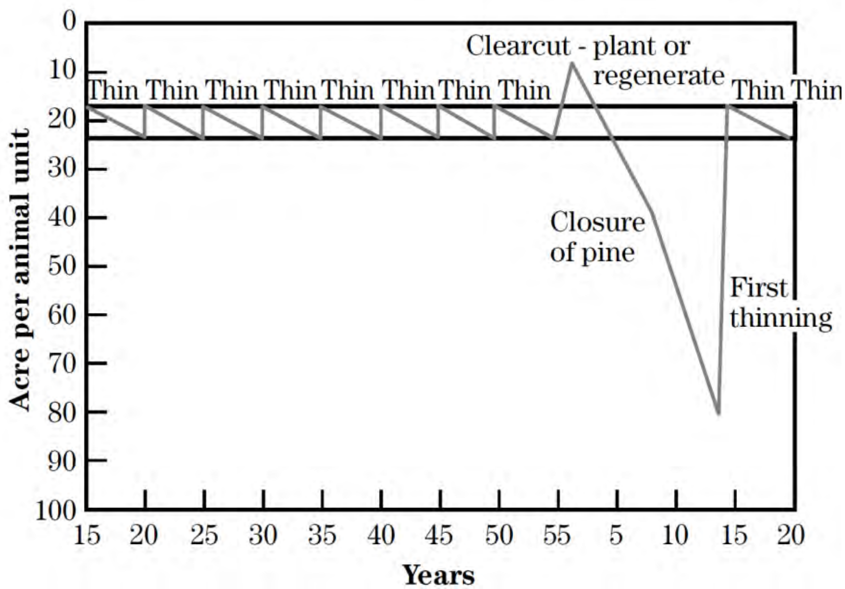
**Figure F-21.** Canopy classes in a southeast forest site




(iv) Management of the overstory canopy is essential to the desired production of forage and understory species. The mid-density of forest canopy of 21–35 percent and 36–55 percent (figure F-20) produce a mixture of the shade tolerant and shade intolerant plants, and in many instances can be managed to meet forest management objectives.

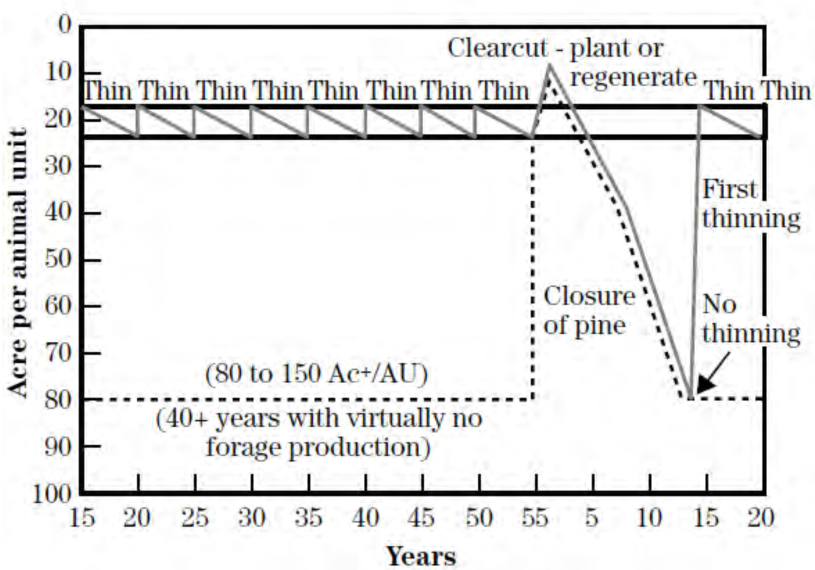
(v) For example, in some southern pine forests the practice of periodic thinning on a 5- to 6-year rotation can help maintain the desired canopy opening of trees to meet forest management objectives. This canopy allows substantial forage production for livestock and wildlife (figure F-22) This periodic thinning is continued until the forest matures. At that time, the forest is clear-cut and allowed to regenerate, or it is replanted to the desired tree species. The forage and browse production are usually excellent until the canopy of the regenerated or planted trees closes at about 10 years. Very little understory will be produced for about five years. The first thinning occurs when the stand has grown for 15 years. This starts the maintenance of the 35 to 55 percent overstory to meet forest management objectives and allows substantial understory forage production.

**Figure F-22.** Example forage production clear-cut for natural regeneration with periodic thinning




(vi) If, in the above example, the periodic cutting cycles are not made, the canopy will completely close and shade out the understory. Forage production will be limited, and the wildlife habitat for grazing or browsing wildlife will be undesirable (figure F-23). Pulp wood rotations, where plantings are made and not thinned until they are fully harvested, are examples of this type of management. Many privately owned forests are not managed due to a lack of understanding of forest management, grazing management, or other factors. This causes a canopy closure with the same results.

**Figure F-23.** Forage production clear-cut or natural regeneration with periodic thinning (compared to clear-cut or natural regeneration with no thinning).

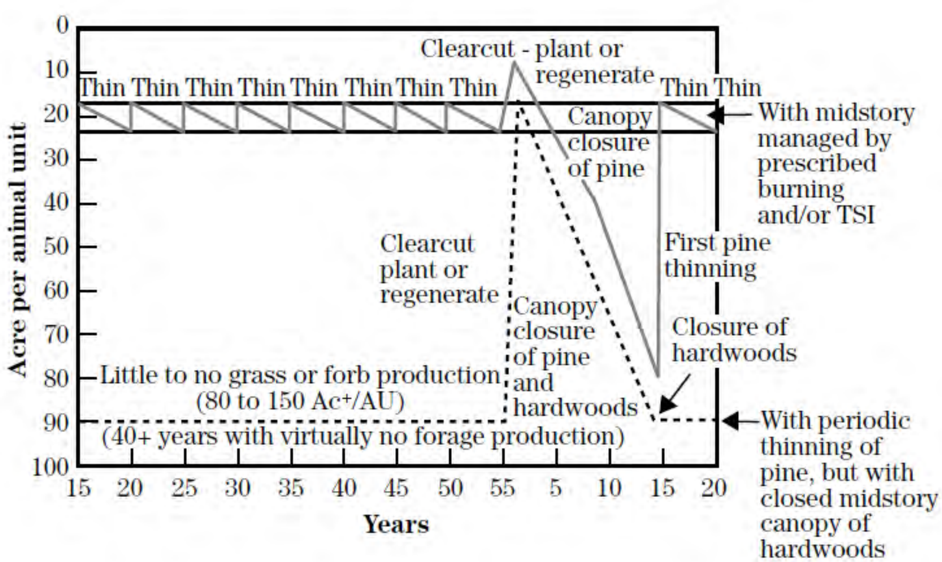


(6) Management of the midstory

(i) Many forests develop a midstory canopy that can completely shade the ground level understory (figure F-24). Even if the overstory is managed to maintain the desired canopy, a midstory can severely reduce the amount of sunlight reaching the ground level. The effects are the same as if the overstory is closed. The understory species composition changes to shade tolerant, and eventually forage production is severely reduced.

(ii) In this case, if understory production is desired, the manager must reduce the midstory. In some cases, prescribed burning can be used to control the midstory species. In other cases, forest stand improvement should be planned to manage the midstory to achieve the desired canopy density.

**Figure F-24.** Example forage production clear-cut or natural regeneration with periodic thinning (effects of hardwood midstory).




(7) Management of the understory

(i) The understory is made up of grasses, forbs, legumes, sedges, vines, shrubs, bryophytes, and lichens. When the overstory and the midstory are managed to allow the desired amount of light to reach the forest floor, a plant community develops that is adapted and supported by the amount of available light, water, and nutrients available on the site.

(ii) Livestock and wildlife graze their preferred plant species. If livestock are stocked too heavily, they overgraze the desired species. These species become weakened and possibly eliminated, while the less-preferred species increase in percentage composition. If the process is continued, both the preferred and secondary plant species will be severely reduced and replaced with nonpreferred species (figures F-25 and F-26).

(iii) To correct this grazing management problem, managed grazing must be applied with facilitating practices, like mechanical treatments such as mowing, firebreaks, fences, ponds, wells, pipelines, and troughs. Other practices, such as trails, walkways, and roads, may be needed. Sometimes a planting practice may be needed to provide a seed source of the desirable species.

(iv) Each conservation plan must be tailored to meet the needs of the soil, water, air, plants and animals, and objectives of the landowner.

**Figure F-25.** Example plant community response to grazing management (36 to 55% canopy).

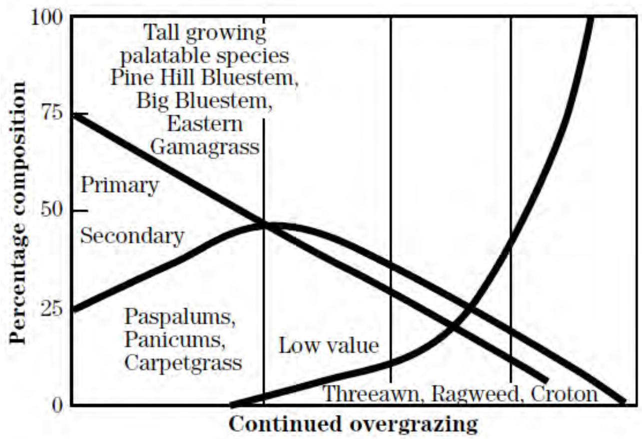
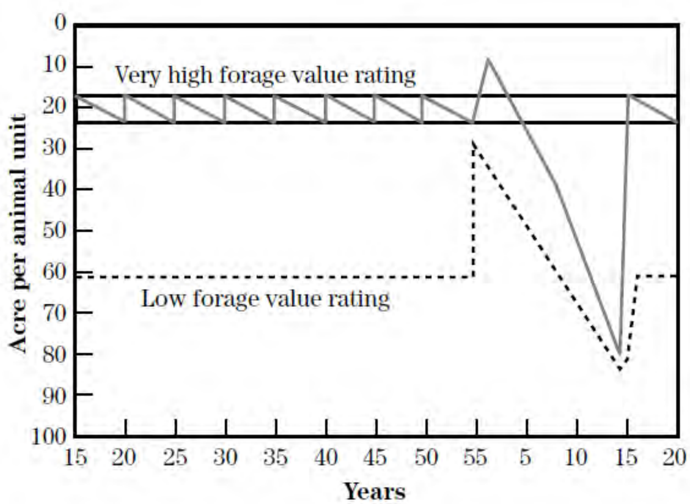


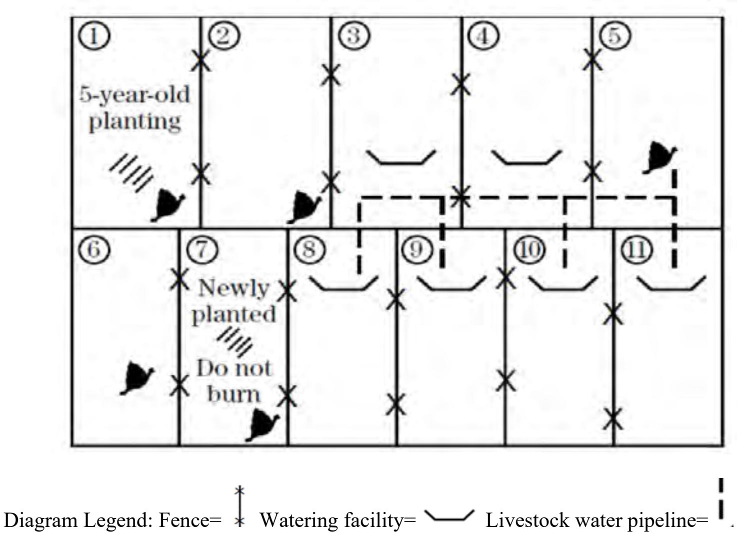

**Figure F-26.** Forage production clear-cut or natural regeneration with periodic thinning (very high forage value rating vs. low forage value rating).




(v) Figure F-27 is an example of a southern pine forest plan developed for a 50-year forest stand rotation, livestock production, and improved wildlife habitat.

(vi) Example F-1 describes a plan for a southern pine forest. Every 5th year, thin pastures as needed. In one pasture (1/11) clear-cut and plant or harvest to seed trees.

**Figure F-27.** Clear-cut or natural regeneration using a 55-year cutting cycle.




**Example F-1.** Plan for southern pine forest (refer to figure F-27)

1. Divide into 11 equal units. Eleven units allow the 50-year forest management cycle to have one unit cut every 5 years and replanted.
2. Install 30-foot-wide fertilized green firebreaks between units (20 acres per section in example). These also serve as roads for managing forest and livestock and for harvesting trees, clearing for fence lines, trails for livestock distribution, and wildlife habitat.
3. Install a 1- or 2-wire electric fence along each firebreak.
4. Install livestock water in each grazing unit.
5. Thin forest stands every 5 years in all units except those recently planted. First thinning will be at year 15.
6. Clear-cut and plant, or harvest to seed trees, one unit every 5 years. Rest new plantings as needed. Seed to native grasses, legumes, and forbs if a seed source is needed for establishment. (Severely over-grazed or old cropland fields may need a seed source).
7. Prescribe burn established stands on a 4-year cycle.
8. Rotate one herd of livestock through the grazeable units to meet the needs of the pine, forage plants, wildlife, and livestock.

(8) Western native forest lands

(i) Some western forests have naturally open or savanna-like aspects with highly productive understory plant communities. Others naturally develop dense canopies that eliminate nearly all understory vegetation. Savanna forest overstories are typically managed by removing a few trees for forest products on a periodic basis, while managing the understory community for wildlife habitat and forage.

(ii) Dense forest lands develop understory vegetation when the stand is thinned or clear-cut to allow sufficient light for understory vegetation or after a wildfire. After a fire, forests reseed or naturally regenerate allowing the plant community to transition back to dense forest. The 10- to 20-year transition period provides forage for livestock and wildlife. Forest management may involve periodical thinning or clear-cutting and varies based on species, markets, and landowner objectives. This ensures that a stable transitory forage resource is available for wildlife and livestock on the operation.

(iii) Conservation planning activities must consider both the forest resource and the wildlife and forage resources available to the landowner. Close coordination is needed to optimize the economic gain from these resources while protecting the ecological integrity and diversity of the management area.

(iv) Managing grazed forest lands for multiple benefits

- Many native forest lands in the Western United States provide forest products, forage for livestock, wildlife habitat, sustained summer stream flows, and clean water. Careful resource management is required to ensure a proper balance is achieved and that multiple resource values are sustained.
- Grazed forest lands range from high mountain spruce-fir ecosystems, to Douglas fir stands at middle elevations, to the dryer savanna-like mixed fir-pine and pure pine sites.
- An example of a typical grazed forest land ecosystem in the Western United States is a ponderosa pine, bitterbrush, Idaho fescue ecological site. This site is dominated by an overstory of ponderosa pine. Site indices (SI) can range from a low of less than 40 to more than 120. Forest products are harvested using uneven-aged management techniques. Trees are thinned from the stand based on the landowner's forest management plan and objectives. Younger trees get increased sunlight allowing them to rapidly grow and replace the thinned trees.
- Fire plays an important role in this community by periodically thinning some younger trees while causing little damage to the older ones because of their insulated, fire-resistant bark. This creates an open, savanna-like community, creating some of the most productive wildlife areas in the country, especially during the winter and spring.
- Understory vegetation is dominated by Idaho fescue and antelope bitterbrush. These species provide excellent forage and browse for deer and elk, as well as domestic cattle and sheep. Production in the understory is directly related to the density of the overstory tree canopy.
- Even though fire plays an important role and is a natural part of these communities, people have aggressively suppressed fire, causing major changes in the structure and health of many of these forest communities. Dog-hair thickets of young ponderosa pine, or forests where the trees have grown extremely thin and close together, now occupy the middle canopy layer, effectively shading out the understory vegetation while creating the potential for catastrophic, stand-replacing crown fires (figure F-28). See Subpart J Prescribed Burning in this handbook for more information on fire.

**Figure F-28**. Dog-hair thicket ponderosa pine stand burned in the Los Alamos wildfire in New Mexico.

- Management of these communities requires a knowledge of both the forest resource and the understory grazing resource. Forests may be thinned periodically while routinely harvesting the forage for the production of food and fiber through livestock grazing.
- The first step in managing the forest resource on a site is to develop a forest management plan that includes an inventory of the forest stands and a determination of the growth potential or Site Index (SI) for each stand. A rule-of-thumb for stand management is as follows:
  - SI > 100 – Thin trees to a D+3 to D+6 spacing. Remove trees as part of this thinning when feasible.
  - SI 80 to 100 – Thin trees to a D+5 to D+8 spacing. Remove trees as part of this thinning when feasible.
  - SI < 80 – Thin trees to a D+6 to D+9 spacing. Remove trees as part of this thinning when feasible.
- For optimum grazing in these stands, add one or two feet to the spacing.
- The D+ spacing is determined by measuring the diameter at breast height of each leave tree, then converting this number to feet and adding the + factor to establish total spacing for each individual tree's optimum growth. Select the next leave tree at the perimeter of this thinned area and repeat the process. As forest products are removed from the stand, additional thinning may be necessary to keep the stand well managed. Priority should be given for the removal of deformed and diseased trees during the thinning process.
- Grazing management of the understory vegetation follows the same principles as for rangeland management. A grazing management plan should be developed for each grazing unit. Managed grazing is the National Conservation Practice Standard (528) to be followed when designing practices for grazed forest lands.
- Wildlife use in these areas is often significant, and available forage must be allocated accordingly. Grazing plans should also take into account critical habitat requirements for threatened and endangered species and species of concern and consider significant life cycle events for wildlife life fawning and nesting areas and dates.

(9) Inventorying forage on grazed forests

(i) As described above, the amount and nature of the understory vegetation in forest are highly responsive to the amount and duration of shade provided by the overstory and midstory canopy. Significant changes in kinds and abundance of plants occur as the canopy changes – sometimes regardless of grazing use. Some changes occur slowly and gradually as a result of normal changes in tree size and spacing. Other changes occur dramatically and quickly, following intensive woodland harvest, thinning, or fire. However, significant changes can result from grazing use, and the understory can often be extensively modified positively or negatively through the manipulation of grazing animals.

(ii) Currently, the forest site descriptions in EDIT contain sections describing the forest overstory and understory, the canopy structure, ground cover, and soil surface cover; but typically, the total production of the site in pounds per acre is not available. In the past, woodland and forest sites contained information on forage value ratings. Some of those site descriptions may still be in circulation, so a description on how to use forage value rating is being retained in this version of the handbook for reference. Forage value ratings of grazeable forest are not an ecological evaluation of the understory. If a forage value rating table is available, it is a rating of potential utilization of the existing forage value of a specific tract of grazeable forest for specific livestock or wildlife. The landowner or manager needs to understand the current species composition and production in relation to their desired use of the land by specific animals. Table 5 in part 450.53 shows diet type by animal species. Also, many grass identification books, State technical notes, and Land Grant University publications may have forage value ratings and diet preference ratings by livestock class.

(ii) Procedure for determining forage value rating

- Forage value ratings are to be based on the percentage, by air-dry weight, of the existing understory plant community (below 4.5 feet) made up of preferred and desirable plant species. Four value ratings are recognized:

| Forage value rating | Minimum percentage |
|---|---|
| Very high | 50 preferred + desirable = 90 |
| High | 30 preferred + desirable = 60 |
| Moderate | 10 preferred + desirable = 30 |
| Low | Less than 10 preferred |

- Introduced species should be rated according to their preference by the animal species of concern and included in the determination of forage value rating. See Worksheet for Determining Forage Value Rating and example (figures F-29 and F-30).
- The production of understory plants can vary greatly, even within the same canopy class. Therefore, if the forage value rating obtained by considering only the percentage of preferred plants is very high or high, but the production is less than that expected for the existing canopy, reduce the final forage value rating one or more classes to reflect the correct value.

(10) Conclusions

(i) Before implementing silvopasture, forest grazing, or turning livestock into the woods, consider the site's topographical and site features that may limit its suitability. Features such as soils, slopes, and invasive and toxic plants should be assessed.

(ii) Pastures and woods are commonly associated with sub-prime soils. However, these soils can normally support adequate tree and forage growth under intensive rotational grazing (Chedzoy et al. 2022).

(iii) Avoid areas that have highly erosive or compaction-prone soil types, especially with excessive slope or frequent saturation (Chedzoy et al. 2022).

(iv) Grazing on slopes that have other factors such as gullies, springs, and poor paddock designs can contribute to unacceptable levels of erosion and site degradation (Chedzoy et al. 2022).

(v) In many locations that are suitable for woodland silvopasture, the starting condition is associated with agricultural abandonment, fire suppression, or historical overharvesting, and often exhibits an understory rife with invasive and nuisance species (Chedzoy et al. 2022).

(vi) Consider the potential for livestock poisoning when livestock enter a new foraging area. In addition to poisonous plants that animals may know to avoid in open pastures, there may be poisonous plants that occur predominantly in the forested portion of the landscape, such as bracken fern, hemlock, chokecherry, plants of the nightshade family, acorns (seasonal), snakeroot, black cherry and black locust. In addition to these plants, also be on the lookout for oleander, coral ardesia, coffee senna, marsh marigold, mountain laurel, and sheep laurel in the south and eastern parts of the country. The western forested areas have milkvetch, ponderosa pine needles, spring parsley, tansey ragwort, and some lupines that possess toxic properties. There are numerous other toxic plants that livestock may encounter. Other toxic plants that livestock consume in wooded areas may suddenly become toxic after an environmental event, such as wilted cherry leaves on broken branches after a windstorm. Livestock producers should always become familiar with potentially dangerous flora throughout the wooded areas (Brantly 2014). Most States' Land Grant universities have poisonous plant guides specific to that State. Here are a few online references for commonly found poisonous plants:

- https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022478.pdf
- https://www.ars.usda.gov/is/np/poisonousplants/poisonousplants.pdf
- https://extension.missouri.edu/publications/g4970

(vii) In addition to these livestock considerations, the impact that grazing management will have on the plant, soil, and water components of the ecosystem should be evaluated. Some ecological sites are highly productive and extremely resilient when impacted by disturbances such as intensive grazing, mechanical brush control, or even tillage. While other ecological sites can be fragile, sensitive to disturbances, they may never recover from even light grazing, or prescribed fire (Brantly 2014).

(viii) The nine steps of conservation planning should be used to manage forest grazing, silvopasture, and turning livestock into the woods systems. See Subpart D of this handbook for more information on conservation planning.

**Figure F-29**. Determining Forage Composition and Value Rating worksheet

## Worksheet for Determining Forage Compositon and Value Rating

**Ecological Site:** ________________ **Operator:** ________________

**Location:** ________________

**Pasture Number:** _______ **Conservationist:** ________________

**Date:** ________________ **Canopy:** ________________

| Plant species | Present compostion | | Animal: | | | Animal: | | | Animal: | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight | % | Forage value | P | D | Forage value | P | D | Forage value | P | D |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| Forage value rating 1/ | | | | | | | | | | | |
| Planned trend 2/ | | | | | | | | | | | |

Total estimated yield in very high forage value rating for cattle: _________

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

| | |
|---|---|
| Very high | 50% P + D = 90% |
| High | 30% P + D = 60% |
| Moderate | 10% P + D = 30% |
| Low | Less than 10% P |

2/ Planned trend symbols:

| | |
|---|---|
| Improving | + |
| Non-detectable | ❑ |
| Moving Away | – |

* Key grazing plant

Estimated initial stocking rate: ___________

Notes:

### Instructions for Worksheet for Determining Forage Composition and Value Rating

1. Record the name of the site that you are inventorying.
2. Record the management unit number.
3. Record the date of the inventory.
4. Record the name of the client.
5. Record the field office name.
6. Record the name or initials of the person providing the technical assistance.
7. Record the canopy of the overstory of woody species.
8. Record the plant species inventoried on the site.
9. Record the weight of each species in pounds per acre.
10. Record the percentage composition for each species.
11. Record the animal for which you are computing the forage value rating.
12. For each plant species, list the forage value (preferred or desirable) for the animal of concern.
13. For the plant species rated as preferred, list the percentage composition found in the present composition. (See item 10).
14. For the plant species rated as desirable, list the percentage composition found in the present composition. (See item 10).
15. Record the total weight in pounds per acre of the plants inventoried.

16. Record 100%.
17. Record the total percentage of the preferred plants.
18. Record the total percentage of the desirable plants.
19. Record the forage value rating for each animal as calculated using the chart provided.
20. Record the direction of plant community movement in relation to the desired plant community for each of the animals of concern. Is the forage value rating improving, not detectable, or moving away from the desired plant community for the animal of concern?
21. Record the total estimated yield for a very high value rating for livestock as a point of reference. This data should be recorded in the ecological site description for rangeland or forest land.
22. Identify the key grazing plant for each animal of concern.
23. Record the estimated safe starting stocking rate for the site. This may be taken from the ecological site description or calculated based on the production of preferred and desirable species.

    **Example:** Cattle
    500 pounds preferred times 35% harvest efficiency = 175 pounds
    200 pounds desirable times 25% harvest efficiency = 50 pounds
    Total harvested = 225 pounds
    9,490 (pounds in AUY) divided by 225 pounds = 42 acres required per animal unit of cattle.

24. Record notes needed to ensure understanding of inventory.

**Figure F-30.** Determining Forage Composition and Value Rating worksheet example.

## Example – Worksheet for Determining Forage Compositon and Value Rating

(1) **Ecological Site:** Sandy Loam

(2) **Pasture Number:** 12

(3) **Date:** 4/10/96

(4) **Operator:** Pat Stockton

(5) **Location:** Happy Hollow

(6) **Conservationist:** RHJ

(7) **Canopy** 45%

| (8) Plant species | Present compostion (9) Weight | (10) % | Animal: (11) Cattle Forage value (12) | (13) P | (14) D | Animal: (11) Deer Forage value (12) | (13) P | (14) D | Animal: (11) Turkey Forage value (12) | (13) P | (14) D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinehill Bluestem | 500 | 50 | P * | 50 | | UD | | | P * | 50 | |
| Low Panic | 50 | 5 | D | | 5 | D | | 5 | D | | 5 |
| Sweet Gum | 100 | 10 | UD | | | D | | 10 | UD | | |
| American Beauty Berry | 100 | 10 | D | | 10 | P | 10 | | D | | 10 |
| Carpet Grass | 50 | 5 | D | | 5 | UD | | | D | | 5 |
| St. Andrews Cross | 50 | 5 | UD | | | D | | 5 | D | | 5 |
| Sassafras | 150 | 15 | UD | | | P * | 15 | | UD | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| TOTAL | (15) 1000 | (16) 100 | | (17) 50 | (18) 20 | | (17) 25 | (18) 20 | | (17) 50 | (18) 25 |
| Forage value rating 1/ | | | (19) High | | | (19) Moderate | | | (19) High | | |
| Planned trend 2/ | | | | (20) + | | | (20) + | | | (20) + | |

(21) Total estimated yield in very high forage value rating for cattle: 1404 lb/Ac

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

| | |
|---|---|
| Very high | 50% P + D = 90% |
| High | 30% P + D = 60% |
| Moderate | 10% P + D = 30% |
| Low | Less than 10% P |

2/ Planned trend symbols:

| | |
|---|---|
| Improving | + |
| Non-detectable | ❑ |
| Moving Away | – |

(22) * Key grazing plant

(23) Estimated initial stocking rate: 1 AU to 42 Ac

(24) Notes:

C. Managing naturalized or native pasture

(1) Naturalized or native pasture is cleared, converted, past cultivation, “old-field” or “go-back land.” It is forestland and cropland that primarily contain introduced species that are largely adapted and have become established without agronomic and cultural inputs, persist under the current conditions of the local environment, and are stable over long time periods. In the case of forest land, the land was forest originally but is now being managed primarily for the production of forage rather than the production of wood products. It is managed with only the application of grazing management principles. The absence of the application of fertilizer, lime, and other agronomic type practices distinguish this land use from pasture.

(2) Because naturalized pasture was forest in its natural state, it will naturally evolve back to a forest-dominated plant community without management. For the site to be maintained as naturalized pasture, a form of brush management (CPS 314) is normally planned to suppress the tree and shrub component of the site. Prescribed burning and brush control using mechanical, herbicide, or biological brush need to be planned, designed, and applied to create the desired plant community to meet the resource criteria.

(3) Managed grazing is planned to meet the needs of the plant community, livestock, and wildlife of concern. The grazing management principles applicable to grazed range and pasture are applicable to naturalized pasture. The managed grazing plan must address solving all of the resource problems and concerns identified in the inventory and problem identification process, especially when livestock or wildlife are contributing to the concern.

(4) Range planting (CPS 550) is typically the conservation seeding practice to use on native grazing lands and may be needed to establish the desired plant community when a seed source of the desired species is not evident. Facilitating practices are planned as needed, such as firebreaks, fences, and livestock water development practices.

(5) NRCS assists cooperators to understand the ecology of their naturalized or native pasture. They assist them in inventorying and evaluating the naturalized pasture productivity and in determining the suitability of present and potential vegetation for the appropriate needs and uses. Where Forest Ecological Site Descriptions are developed, they are to be used as the naturalized or native pasture interpretative unit. The understory descriptions and interpretations, as described in the Forest Ecological Site Description, provide the needed information for inventory. Where ESDs are not developed, consult the NRCS State grazing specialist.

(6) Ecological site descriptions can be used to provide an index for the landowner and manager to understand the value of the present plant community in meeting the needs of their livestock and wildlife. In some cases, where Forest ESDs are not complete, previously developed forage value ratings from historic woodland site descriptions may be helpful when planning on these sites.

## 645.0603 Managing Pasture Lands and Forage Crops

A. Considerations in managing improved pasture

(1) Pasture is harvested principally by the grazing animal; therefore, it requires being managed differently than hayland and cropland harvests. Managing seasonal availability or distribution of forage growth is vital to allocating enough feed to the grazing animal without wasting it or overgrazing it.

(2) The benefits of livestock grazing standing forages are minimized loss of plant parts (no loss compared to cutting and baling) and minimized loss of vitamins and dry matter. Livestock can also selectively graze available forage to some degree, so managers who recognize and adjust their management to match cycles in forage quality and quantity, and growth and availability, can provide forages near optimum nutritional value.

(3) Grazing also recycles most of the nutrients consumed. Excess nutrients are excreted from the livestock through manure and urine. While these nutrients may not be evenly distributed over the pasture, they are continually returned to the grazing unit while it is occupied by the livestock.

(4) Grazing intensity is an important consideration and is a critical element in pasture management. Stocking rate (animal units per unit area) is the most common animal-based measure of grazing intensity (Thorne 2007). When combined with the amount of time livestock are allowed access to individual pastures (grazing period), grazing intensity has the greatest impact on forage, animal, soil, water, and wildlife responses on pastureland (Nelson 2012). Failure to achieve the proper stocking rate, and therefore the proper grazing intensity, cannot be overcome by any other grazing strategy. Grazing intensity must be a priority in conservation planning on pasturelands.

(i) Different forage species require different residual heights to maintain adequate leaf area to intercept full sunlight (see individual State guidance on recommended residual grazing heights). Forages grazed too intensely and too frequently lack adequate leaf area to optimally capture sunlight for optimal growth. This delays regrowth and uses stored carbohydrate reserves. If grazed too intensely and too frequently, the forage plant becomes weaker as carbohydrate reserves are depleted. This leads to reduced productivity and persistence, increases the percentage of bare ground, and opens the site to invasion from intermediate and undesirable species.

(ii) Forages differ greatly in their ability to withstand intense grazing. Forages that have growing points and some leaf area below the typical grazing height can withstand intense grazing (e.g., bermudagrass, bahia grass, Kentucky bluegrass, white clover), and if present in a frequently and intensely grazed pasture, will tend to be the dominant forage species.

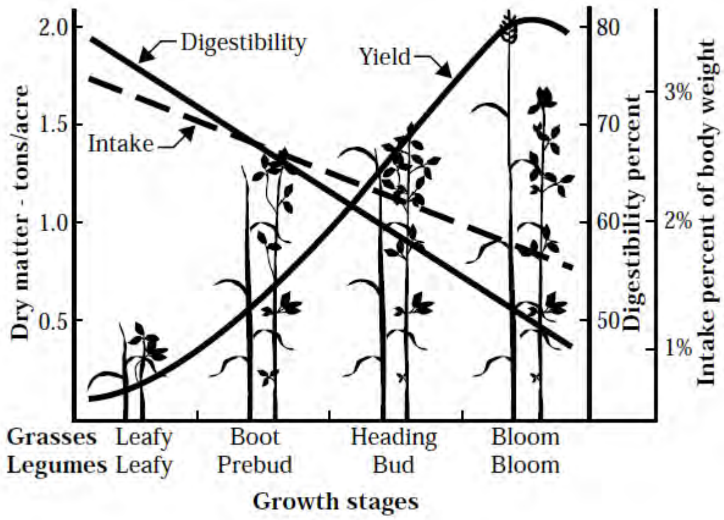
(iii) Spot (selective) grazing of pastures occurs when the intensity in combination with stock density (pounds of livestock per grazing area) and length of grazing period allow the animals to go back to previously grazed areas where the less mature (vegetative) plants are located. They will seek out these forages because they are more palatable than earlier refused plants. Spot grazing can occur whenever the forage supply is larger than animal demand.

(iv) Many other factors cause the potential for spot grazing, such as plant palatability differences. These differences can exist from species to species, within a species at stage of growth, or from anti-quality factors and based on soil conditions impacting plant nutrients. Spot grazing by livestock to avoid plants soiled by dung and urine is common. Shade and steep slopes also can cause spot grazing.

(5) Timing grazing events, such that availability and nutritive value of the forage meets the requirements of the type and class of livestock grazing, is also a consideration. Nutritive value fluctuates throughout the growing season and is influenced by several factors (Blaser et al. 1986). Primary among these are stage of maturity and species.

(i) As forages mature from the leafy vegetative stage of growth to the reproductive stage of growth with higher proportions of stem and fiber, nutritive value declines (see Figure F-31). See Appendix B: Relative Forage Preference of Plants for Grazing Use by Season in Idaho for an example of State supplemental guidance on plant palatability differences by season.

**Figure F-31.** Growth stages of grasses and legumes and their effect on intake, digestibility, and dry matter production (Blaser et al. 1986).




(ii) Species of forage influence nutritive value. Warm season forages have lower nutritive value potential than cool season forages, and legume species have the highest overall nutritive value potential. Grazing forages when they are in the vegetative growth stage and incorporating legumes, to the extent possible, into the forage system will provide the most nutritive value potential (observing the recommended residual grazing heights in State supplemental guidance).

(iii) Often the forage's growth curve does not dictate the forage's grazing availability, but rather management decisions do. For example, forages can be stockpiled. They are allowed to grow and accumulate mass and then grazed at a later date after the growing season has ended. Forages that retain their leaves and nutritional value are preferred for stockpiling (e.g., tall fescue).

(iv) Crop residues can also be grazed, with their availability as the important consideration rather than growth curves. For instance, cornstalk residue becomes available after harvest and has a useful life of about 60 to 90 days before weathering or trampling diminishes it as a feedstuff. This is, of course, dependent on rainfall and temperature. Low rainfall, coupled with very cold temperatures, prolongs its nutritional quality; and decomposition is arrested or slowed, and no mud is available to be trampled onto the residue.

(6) Understanding seasonal distribution of growth and availability of that growth is a consideration that helps manage and allocate pasture to livestock. Planners should understand and utilize growth curves for their regions. See figures F-32, F-33, and F-34 for example growth curves from various regions. Note how different forages have different growth curves for the year (i.e., warm season versus cool season production).

(i) Combining warm and cool season forages into complementary forage systems can lead to extended grazing seasons and less reliance on stored feed.

(ii) Growth curves effectively demonstrate periods of growth. They do not, however, indicate when the forage may be made available for grazing. It is the manager's decision to make the forage available.

**Figure F-32**. Gulf Coast seasonal distribution of growth and availability of pasture (Ball et al 1991).

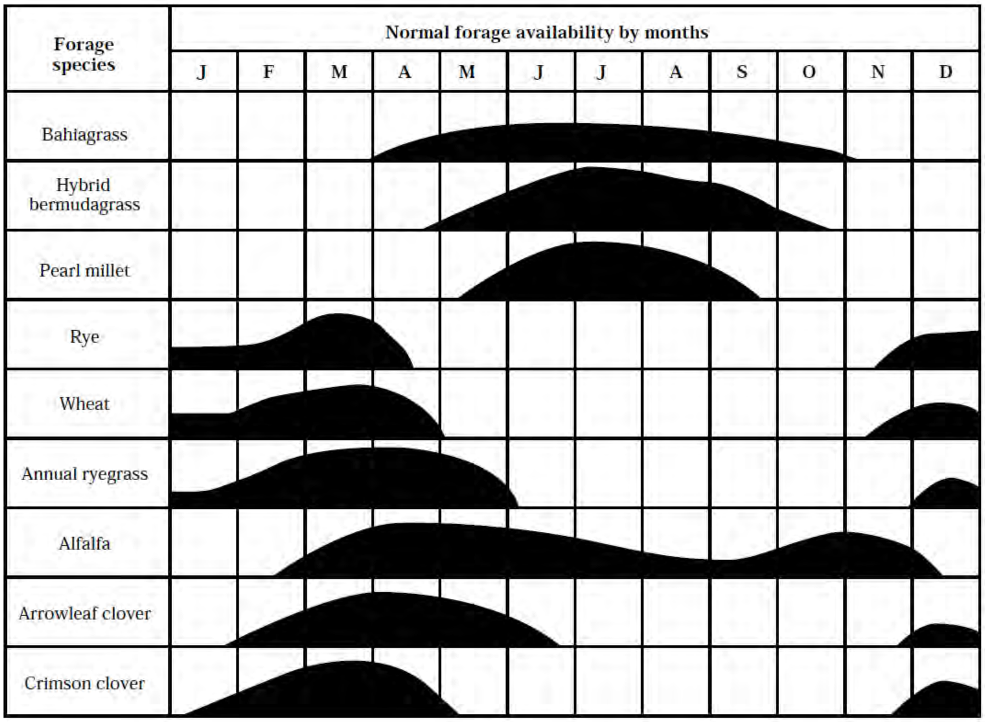



**Figure F-33**. Upper South seasonal distribution of growth and availability of pasture (Ball et al. 1991).

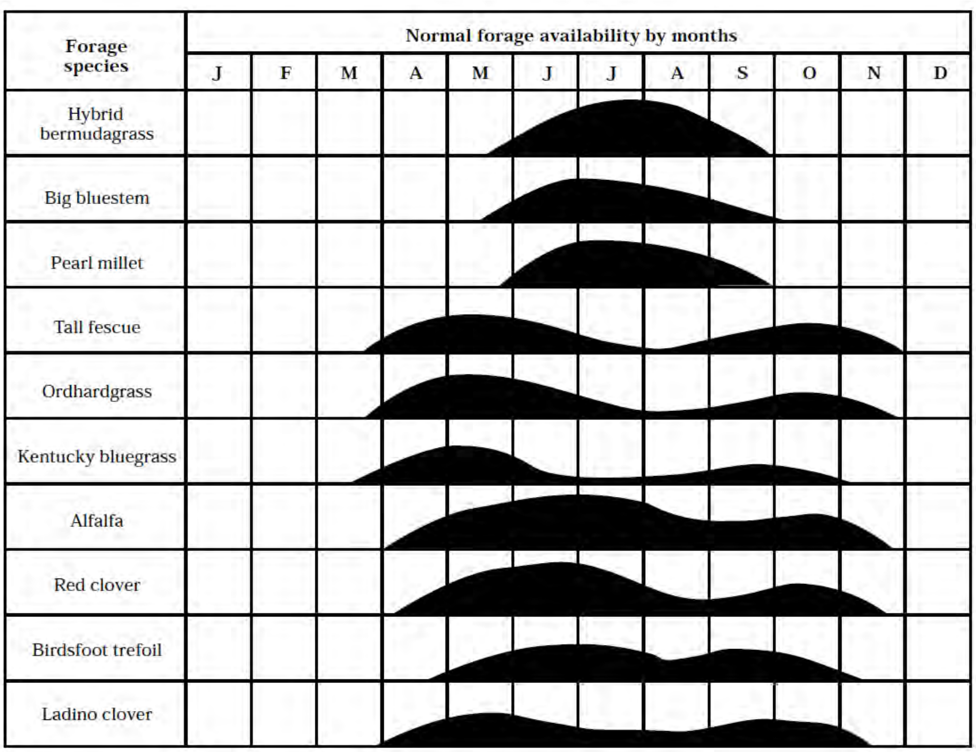
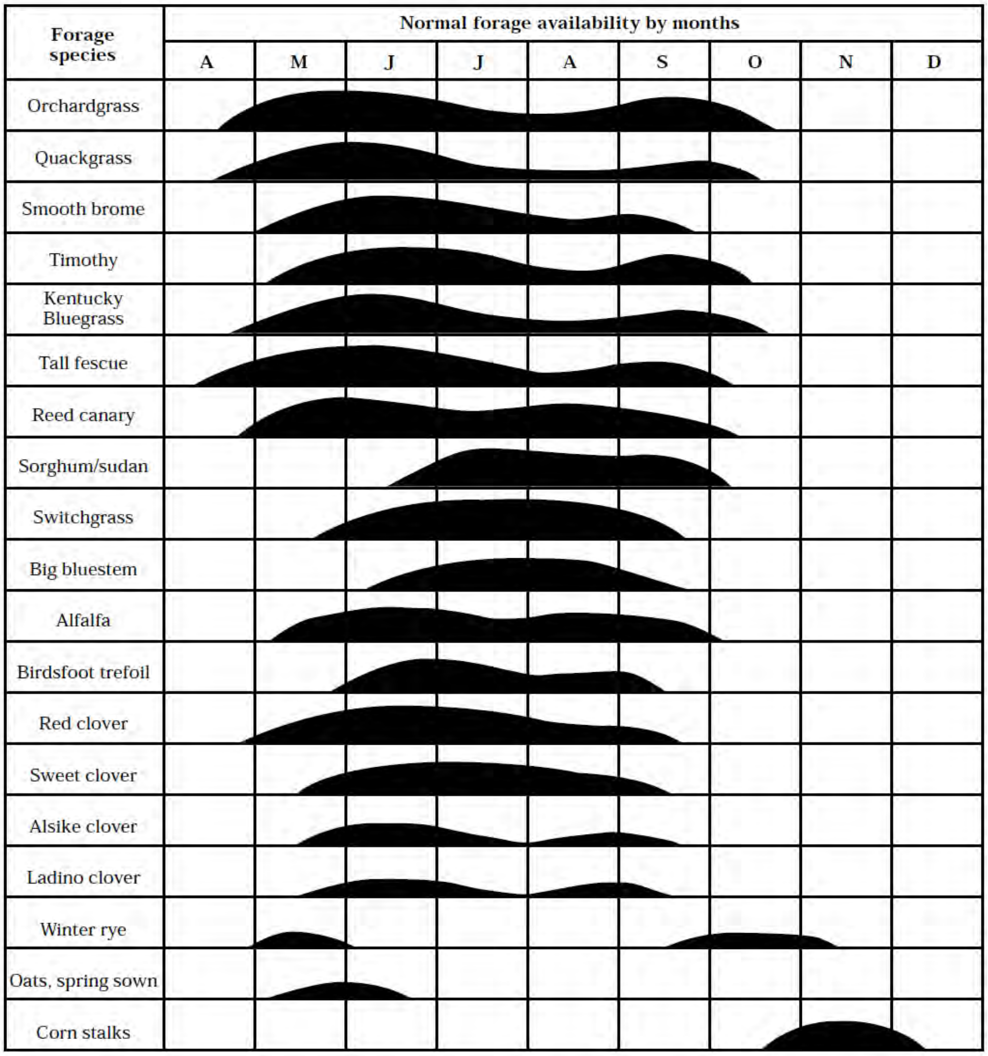


**Figure F-34.** Upper Midwest seasonal distribution of growth and availability of pasture (adapted from Undersander et al. 1991).




(7) Consideration of the site, its characteristics, and how livestock will be distributed or will distribute themselves on the landscape, are needed. Multiple factors will impact grazing intensity and nutrient distribution in the pasture including:
   (i) Slope
   (ii) Livestock water source
   (iii) Shade
   (iv) Barriers that affect livestock movement or behavior

(8) Generally, livestock will tend to prefer more level terrain and will minimize the amount of time they spend on slopes if adequate forage supplies are available on level areas. Additionally, slopes tend to be less productive, so livestock spend less time there due to reduced forage supply. Developing management units with similar slope characteristics can be beneficial in reducing ability of the livestock to choose what portion of the landscape they utilize. Fencing and herding can serve to force livestock into steeper terrain, but lures such as watering facilities, mineral supplements, and feed may also serve to attract livestock into steeper terrain.

(9) Livestock water sources serve as the center of grazing activity. Where they are placed in the grazing system heavily influences grazing distribution, with livestock typically utilizing areas closer to the watering source more heavily in both vertical and horizontal distance. The further livestock travel to a water source, the less likely they are to utilize that area. The lack of utilization essentially amounts to a loss in production, as the forage matures, and nutritive value drops, or the forage goes unutilized entirely. In humid and temperate environments, it is often recommended to keep travel distance to water between 700 to 900 feet, where possible. See table F-6 and table F-7 for more information on slope adjustments and general distance to water for grazing lands.

(10) In warm seasons or warm climates, shade may have more effect on livestock distribution than location of the watering source (Nelson 2012). When the only shade in a pasture is riparian shade, the riparian area may be overutilized with negative effects on soils, plant communities, wildlife populations, and water quality. Therefore, managing livestock access to riparian areas is effective in improving water quality and generally benefiting wildlife populations (Nelson 2012). Livestock also tend to prefer natural shade to artificial shade.

(11) Each of these factors not only affects the distribution of grazing, but also the distribution of nutrients within the pasture. Livestock return the vast majority of the nutrients that they take in back to the pasture environment through manure and urine. It is not an even distribution of nutrients but is usually a relocation of nutrients to areas with less slope, closer to water sources and shade. Approximately 70–90 percent of nitrogen, phosphorus, and potassium eaten are returned to the soil with urine, accounting for approximately 75 percent of the nitrogen and potassium and approximately 75 percent of phosphorus in the manure (USDA-NRCS 2016). Developing management units with similar slope characteristics, well distributed water sources, and taking into account utilization of shade can assist in more evenly returning nutrients to the pasture and lowering fertility costs for the land manager.

B. Conservation practices on grazing lands

(1) Managed Grazing-Conservation Practice Standard 528.

(i) The managed grazing conservation practice is used to provide adequate nutrition to animals, while maintaining or achieving the desired vegetative community on the grazed site, while protecting the natural resources. It is the foundational practice on all grazed lands.

(ii) The principal agent for vegetative manipulation is the grazing animal. If the controlled stocking of grazing animals alone cannot effectively change the vegetation toward the desired level of production or forage species composition in the time frame desired, then additional primary or supporting conservation practices are employed. See section 645.0602 in this subpart for more information on primary and supporting practices.

(iii) A complete list of conservation practices, along with definitions and standards, is provided in the National Handbook of Conservation Practices and in each State's local Field Office Technical Guide (FOTG). NRCS Field Offices also have Conservation Practice Standard information sheets, guide sheets, job sheets, or implementation requirements to assist conservation planners and livestock producers to successfully apply these practices.

(iv) Some examples of primary practices include:

- Managed Grazing (528)
- Nutrient Management (590)
- Pasture and Hay Planting (512)
- Range Planting (550)
- Prescribed Burning (338)
- Irrigation Water Management (449)

- Brush Management (314)
- Herbaceous Weed Control (315)
- Grazing land Mechanical Treatment (548)
- Forage Harvest Management (511)

(v) Some examples of supporting practices include:

- Fence (382)
- Trails and Walkways (575)
- Heavy Use Area Protection (561)
- Watering Facilities (614) and its various associated practices which could be:
  – Pipeline (516)
  – Spring Development (574)
  – Pond (378)
  – Pumping Plant (533)
  – Water Well (642)

(2) Several grazing methods can be used to accomplish the goals of the livestock producer while protecting the natural resources in implementing managed grazing. Several methods of stocking or grazing exist and can meet the producer's goals when observing the guidelines of the Managed Grazing practice. Herbivores graze, but livestock producers stock them on pasture, so the use of the term "stocking" is preferred over the term "grazing" here. However, when working with producers, it is important to understand their terms for these methods. Most producers will use the term, "grazing" system or method. For more details on grazing methods, see section 645.0602 of this subpart or contact the NRCS State grazing specialist for State-specific guidance. Other sources of information include the local Cooperative Extension office, Land Grant University publications, and the Environmental Effects of Conservation Practices on Grazing lands–A Conservation Effects Assessment Project (CEAP).

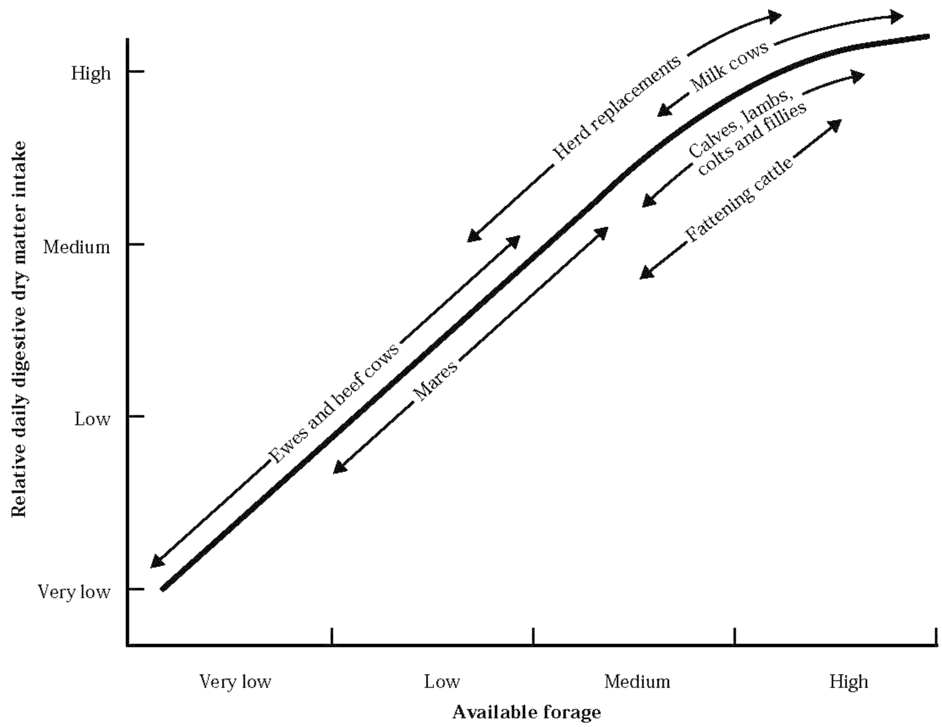
(3) For forages tolerant of continuous grazing and managed that way, it means leaving enough residual stubble height, or stop-grazing height, to maintain optimal leaf area for full sunlight interception while guarding against underutilized areas caused by spot grazing. Perennial forage pastures may need to be clipped (mowed) when areas of mature plants produce seed heads. This stimulates those plants to produce new vegetative growth.

(4) For forages suited to and utilized in rotational methods, it means leaving enough residual stubble height to allow recovery of the plants. It also means respecting the recovery period needed by these forages. Delaying or speeding up grazing rotations can do harm to the forage stand, as well as cause distortions in feed quality and quantity. Delays in implementing livestock movements can develop because of faster forage growth than expected, or the grazing period is extended to use pastures or paddocks better. When this occurs, some of the paddocks nearing seedhead emergence or bud flowering should be cut for stored feed, stockpiled for grazing later, or trampled onto the surface to improve soil health. If grazing rotations are sped up as a result of grazing periods being cut short for lack of enough available forage, stored feed or additional grazeable acres must be used to meet the animal demand.

(5) The manager using any of the grazing methods needs to know the amount of available forage in the pasture or paddock. "Available forage" is a critical term. As applied to pasture, it should be is defined as the consumable forage in pounds of digestible dry matter per acre between the allowable minimum stubble height, or stop-grazing height, for the preferred forage species being grazed and the plant height achieved before grazing. Harm can be done to the forage crop when grazed too close. As it is defined here, it is sometimes also called "usable forage."

(6) Available forage must meet each class of livestock's nutrient requirements at all times. When this cannot be met, supplemental feed, such as hay, must supply the remaining needed nutrients.
(7) Figure F-35 shows the relative amount of available forage that must be presented to different kinds and classes of livestock. Otherwise, a loss in livestock production occurs when availability falls below the minimum required.

**Figure F-35.** Available forage requirements for different classes and ages of livestock (Blaser 1986).




(8) "Forage utilization" is the estimated percent of available forage actually consumed or destroyed by the grazing animal based on annual net forage accumulation.
(9) Tables F-2 and F-3 give utilization rates versus grazing period length. The table values should be viewed as estimates only. The upper limit on high quality rotational pasture before intake by meat livestock becomes depressed enough to reduce gain per acre is 80 percent utilization. Forty percent utilization of available forage would maximize forage intake but leave much unutilized forage behind (figure F-33). This may meet some livestock producers' goals for a period of time but would usually not be the management system used in the long term.

**Table F-2.** Univ. of Missouri and Jim Gerrish Grazing Utilization Research (MU Extension 1999)

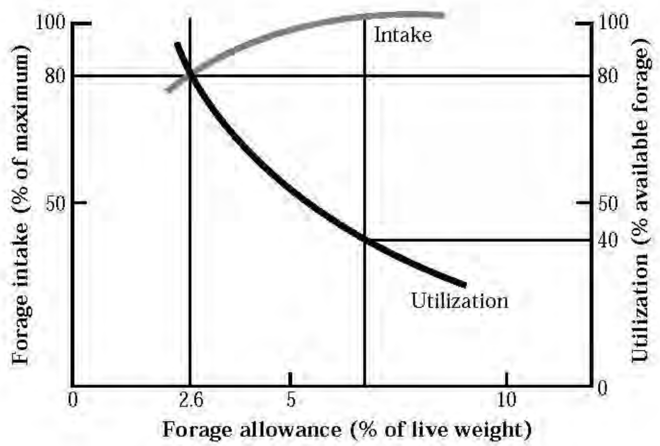
| Grazing Period | Temporal* Utilization Rate | Seasonal** Utilization Rate |
|---|---|---|
| Cont. (>21 days) | 35% | 40–45% |
| 7–10 days | 40% | 50% |
| 3–5 days | 50% | 65% |
| 1–2 days | 60% | 70+% |

*Temporal Utilization Rate is the % of forage utilized (grazed) above the 'stop grazing heights' during one grazing period.
**Seasonal Utilization Rate is the % of the total annual forage production that was harvested by the grazing animal above the stop grazing heights.

**Table F-3**. North Carolina State University Utilization Table.

| Grazing Period (Days) | Utilization Rate |
|---|---|
| Hay (for comparison) | 85% |
| 1–4 | 75% |
| 5–14 | 60% |
| 15–21 | 45% |
| Continuous (>21) | 35% |

**Figure F-36**. Forage utilization as it affects forage intake* (adapted from Hodgson 1990).




* Available forage can be far in excess of that really needed to satisfy herd appetite if stocking rate is low. Animals can readily get all they can eat, but forage is wasted.

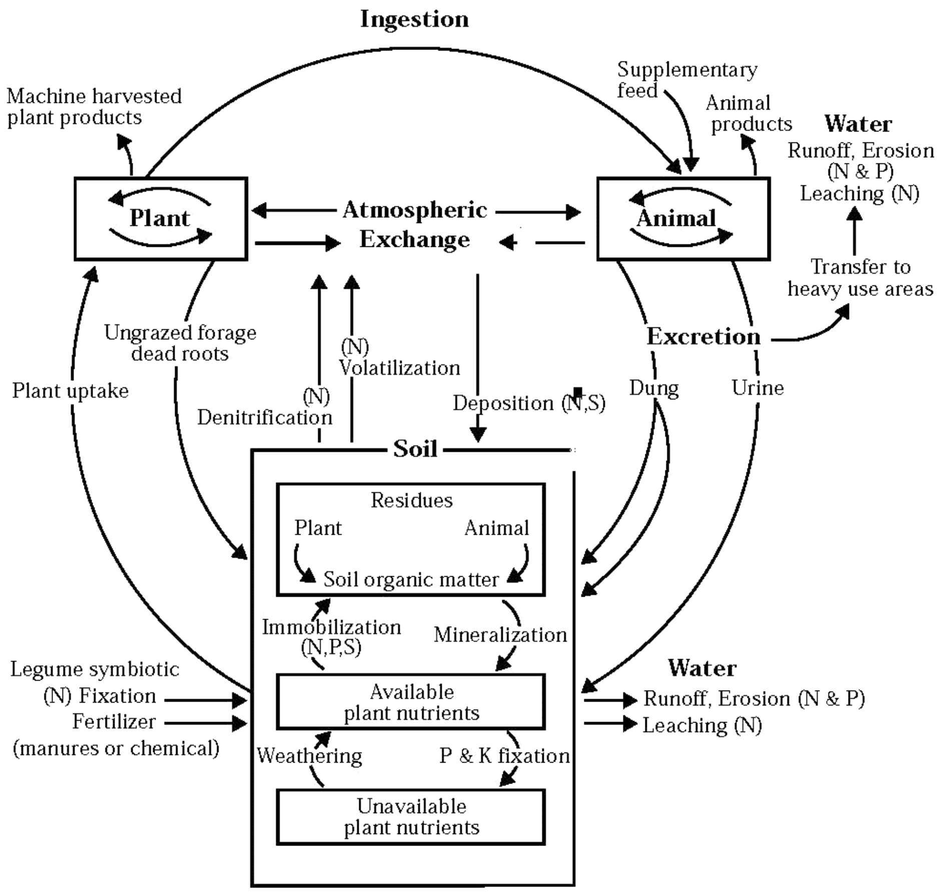
(10) Allocated forage availability must be high for high performance livestock for them to maximize intake rates that sustain high rates of gain or milk production. Intake declines as soon as dry matter per bite goes down, and the number of bites per grazing period goes up. The livestock classes shown at the upper end of the curve in Figure F-35 may need to be followed on rotational pastures with a less demanding herd of livestock. For example, the milking herd on a dairy farm can be followed by dry cows and replacement heifers. On other farms, calves, lambs, and colts may be allowed to forward creep graze ahead of their mothers. Creep grazing can be accomplished easily by allowing the young to walk under temporary fencing into the next paddock. Once past peak lactation, their mothers have a lesser intake requirement. This increases the overall utilization rate for the good of the forage stand and the efficiency of the pasture system.

(11) To summarize, livestock must be given a forage allowance (pounds of dry matter per animal unit) that covers their forage requirement.

C. Nutrient management on pastures differs from forage crop production nutrient management.

(1) Most nutrients are recycled within a pasture’s boundaries (figure F-37). Few of the nutrients brought onto the pasture as feed supplements, manures, atmospheric deposition, or commercial fertilizer leave its boundaries as animal products.

**Figure F-37.** Nutrient cycling in a pasture ecosystem (adapted from Barnes et al. 1995).




(2) Second, nutrients can be redistributed unequally on pastures by preferential animal movement. Shady areas, watering sites, laneways, salt blocks, rubbing areas, natural waterbodies, windbreaks, buildings, and sunning areas can cause a disproportionate amount of dung and urine spots to be deposited in localized areas. This redistribution of nutrients can cause plant nutrient deficiencies in some areas and excess nutrients in other areas.
(3) Because of the high application rate, loss of N at urine spots through leaching out of the root zone is possible in high rainfall areas. High losses of urea N at urine spots during dry weather also occurs.
(4) Phosphorus (P) and potassium (K) levels are rather stable in pasture soils. Pastures should be soil tested every three to five years for these two elements.
(5) Soil reaction, or pH level, should also be noted when the soil test results return. Keep the soil reaction within the range of acceptable forage production. Most legumes grow best in a slightly acid to neutral soil. Where aluminum toxicity can inhibit forage growth, maintain soil pH at 5.5 or higher. Rhizobium activity, symbionts that fix nitrogen in legume root nodules, is also reduced for most strains of Rhizobium as the pH falls below 6.0.
(6) Nitrogen (N) can leave by three pathways: volatilize, leach, or run off. The distribution of dung and urine is uneven. On an annual basis, a highly stocked pasture receives excreted N on less than 35 percent of its area. Where the stocking rate is an AU per acre, only 16 percent of the pasture surface receives any excretal N.
(7) Rotational stocked pastures tend to have a more even distribution of manure than do continuous set stocked pastures. Increasing the stock density within the rotation will likely

further improve the distribution. However, it is important that water, feeding areas, salt boxes, mineral boxes, and shade are evenly distributed on a rotational pasture. Poorly laid out paddocks and single-source water, feeding, salt, mineral, and shade areas cause livestock to camp at these sites just as they do on continuous set stocked pastures.

(8) Nitrogen can be supplied for forage growth two ways: apply a nitrogen fertilizer or add a legume component to the forage mixture growing on the pasture. When applying nitrogen fertilizers, organic or inorganic, rates of application should be low enough to prevent luxury consumption by plants and avoid leaching of nitrate through the root zone. Overfertilization of summer annual grass pastures with N can also cause nitrate and prussic acid poisoning in livestock if plant growth is stressed by frost or drought. Early spring growth applications must be avoided on all pastures where grass tetany is known to be a problem to livestock. If a legume component is desired to improve animal intake and nutrition, N fertilizer rates and timing should also avoid giving the grasses a competitive advantage over the legumes.

(9) Legumes can fix atmospheric nitrogen by acting as a host to rhizobium bacteria. See Table F-4. Note that legumes do not always grow well in all parts of the country. The values presented in this table are not absolutes, it is advised to refer to a local Land Grant University for more specific information.

**Table F-4.** Seasonal total of nitrogen fixation by forage legumes and legume-grass mixtures [1/]

| Legume or Legume grass | Total N fixation (lb/acre)[2/] |
|---|---|
| Alfalfa | 70–300 |
| Alfalfa-orchardgrass | 13–121 |
| Alfalfa-reed canarygrass | 73–226 |
| Berseem clover | 55–210 |
| Birdsfoot trefoil | 44–100 |
| Birdsfoot trefoil-reed canarygrass | 27–116 |
| Ladino clover | 100–179 |
| Red clover | 20–200 |
| Red clover- reed canarygrass | 5–136 |
| Subterranean clover | 52–163 |
| Subterranean clover-soft chess | 19–92 |
| White clover | 103–114 |

[1/] Sources: Ball et al. 1991, Barnes et al. 1995, Chessmore 1979, and Graffis et al. 1985.

[2/] Ranges given where available

(10) Nitrogen fertilizer additions, whether from fertilizers or N fixing legumes, induce long-term soil acidification in the topsoil and subsoil. As an example, when added to the soil, 100 pounds of urea, whether from urine or chemical fertilizer, requires 84 pounds of calcium carbonate (lime) to neutralize the soil. In fact, all nitrogen carriers containing either ammonia or urea acidify the soil.

(11) Use of pastures as sites for manure disposal must be done with some caution. Sheep are susceptible to copper (Cu) toxicity. Sheep should not be allowed to graze pastures with recent applications of poultry litter or swine manure. Both manures may contain high Cu concentrations. High rates of poultry litter applied to endophyte-infected tall fescue pastures can also intensify bovine fat necrosis outbreaks. Ideally, no more than four tons per acre of poultry litter should be spread on tall fescue pastures. It is also important not to overload pasture soils with P and K either. Long-term accumulations of these nutrients can induce deficiencies of other essential nutrients in plants and animals. For more information on animal husbandry, see Subpart H of this handbook.

(12) Another trace element of importance is boron (B). It improves legume growth. Boron can be added to the soil using borax or B-containing mixed fertilizer. It must be added in low amounts (0.5 to 3 pounds of B per acre) to avoid toxicity problems.

(13) Grazing management can be helpful in managing nutrients on pasture. Conscious efforts can be made to ensure the best distribution of dung and urine as possible within the setting involved.

D. Prescribed burning

Bermudagrass pastures can be burned a week or so after the last killing frost in the spring to control winter annual weeds, some leaf diseases, and insects such as spittlebugs. It also removes low quality dead grass and hastens green-up. Tall warm-season grasses – such as switchgrass, big bluestem, and Indian grass – should be burned periodically in late spring to improve forage quality and remove invading cool-season grasses. Burning should take place before any regrowth of the warm-season grasses; otherwise, stand thinning occurs.

E. Managing forage cropland

(1) Hayland and cropland produce machine-harvested forage, but sometimes can be used as sources of supplemental, emergency, and seasonal pasture for grazing, or to improve soil health.

(2) When cropland is used for grazing, it is important to continue a rotational system where possible. Increasing rotation cycles while trampling some residues onto the soil surface can reduce potential compaction issues. Remove livestock before the growing point is grazed on annual plants if regrowth is desired.

(3) When hay is mechanically harvested from perennial crop fields, ensure that the timing and methods not only allow for high quality hay, but desired forage species are maintained or enhanced. See the NRCS conservation practice Forage Harvest Management (511) for further information.

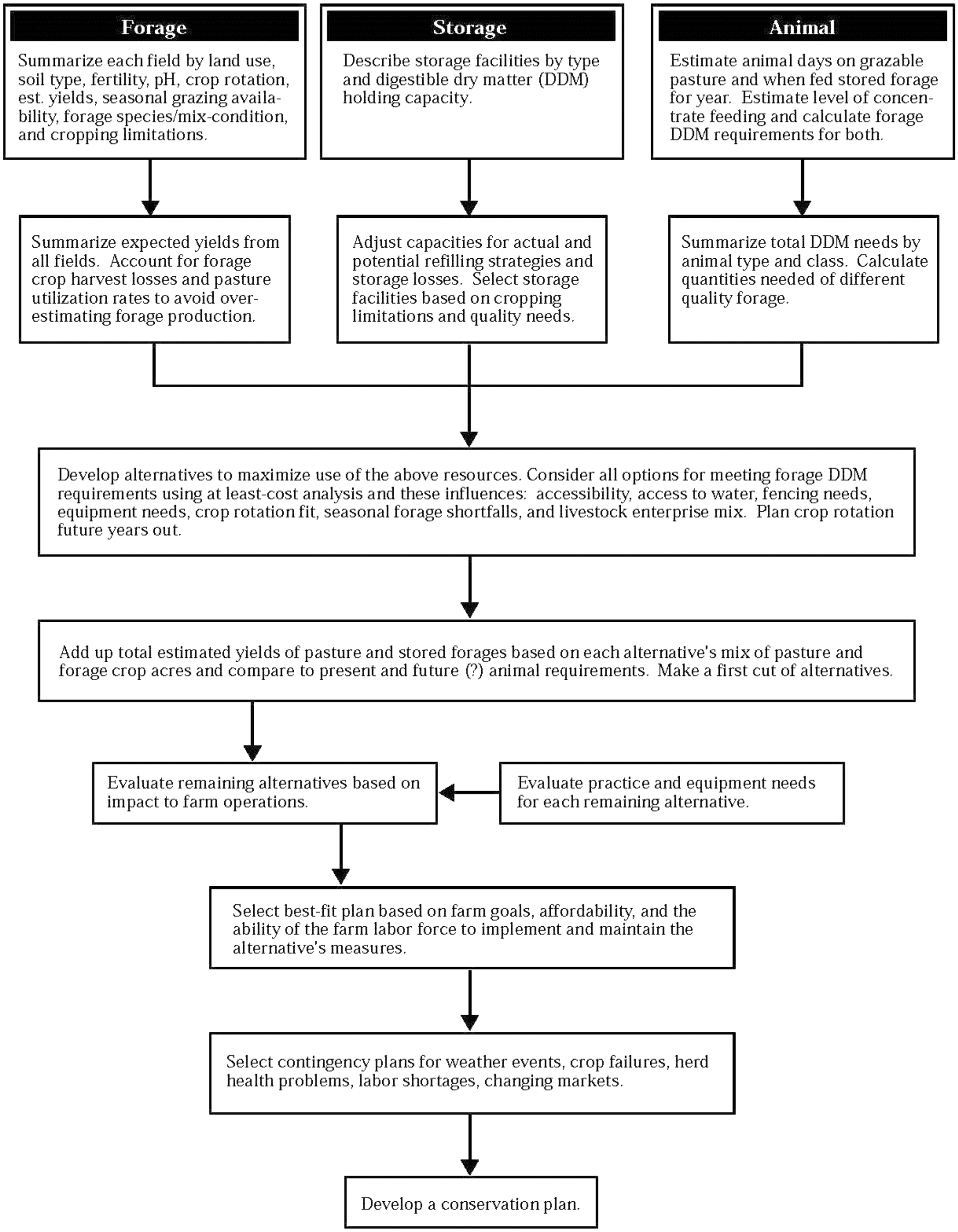
(4) Forage crop production

(i) Forage crop production is capital, labor, and machinery intensive. It requires silage storage, dry hay storage, sometimes automated feeding systems, and a full line of machinery from seedbed preparation to harvest, feeding operations, waste handling, and often livestock confinement facilities.

(ii) Forage crop production is usually done in one of two approaches.

- One approach is used to support pasture production. This grassland farming is used where mechanically harvested forage crops are only produced to carry the livestock through periods when pasture is dormant or in low supply. With this approach, the balance between pasture and forage crop production shifts from time to time, depending on pasture availability and which is most economical to produce and feed.
- The other approach does not use pasture production. This is often done to achieve economy of scale. Farms with large herds and a low land-to-livestock ratio find this most convenient. These operations may range from importing varying amounts of a portion of the feed to the point of purchasing all feed.
- Whichever approach the producer chooses, management of forage crop production remains essentially the same. The goal is to efficiently produce high quality forages to the maximum potential of the site and efficiently provide feed for the livestock.
- The first approach to forage crop production requires the highest degree of integration of all grazing land resources on the farm or ranch. To integrate well requires analyzing the farm or ranch operation available resources, the tools that are available to produce forages, and how those tools can be used to best advantage on the specific site being analyzed. This thought and decision-making process is diagrammed in figure F-38.

**Figure F-38.** Forage integration model (adapted from Barnes et al. 1995). The objective is to match the quantity and quality of forage available as pasture or stored forage with the requirements of specific livestock classes and with the available or potential grazing and storage options.



(iii) After integrating pasture and forage crop production acres into a workable plan for the farm or ranch, the forages that will meet the landowners or manager's objectives and their harvesting methods will need to be analyzed.

(iv) Pasture states of ecological sites characterize major soil limitations and give guidance on how they can be overcome. They help forage site selection by pointing out which forage species are suitable for the soils on a land unit, as well as management interpretations for the site.

F. Conclusions

(1) With this management section guidance for forage crop and pasture lands, State specialists should prepare more specific guidelines for field office personnel to use in planning and applying resource conservation practices. Several Land Grant Universities produce agronomy manuals or guides that give more specific recommendations than can be placed in a national publication. Seeding rates, seeding mixtures, stubble heights, irrigation rates and scheduling, noxious weed lists, and recommended species and cultivars are just a few of the more specific details needed to have a complete field office technical guide. As much as possible, this material should be condensed into tables or charts that are easily read and understood. Design procedures should be formalized, readily followed, and placed on job sheets.

(2) More information is provided in subpart E, which gives guidance on creating an inventory of a land unit's resources. Having a complete pasture and forage crop production inventory provides information on how to feed the livestock on the land unit in the most efficient way. Once the inventory for the land unit is done, conservation planning options are discussed and weighed with the land manager. Many of the conservation practices' information and guidance listed in this chapter will make up the final resource conservation plan. Subpart H: Livestock Nutrition, Husbandry, and Behavior of this handbook gives instruction on fulfilling the needs of the livestock raised on the land unit. Conservation planning and application on grazing lands are detailed in subpart D: Conservation Planning on Grazing lands. How each type of grazing management system works, and the advantages and disadvantages of each type, must be understood. A land manager rarely adopts any grazing management system or forage cropland system exactly as it is conceptualized in a handbook or textbook. The management that gets applied to the land is a combination of things that come closest to achieving the needs of the resources, landowner, and livestock in an efficient and economically sound manner.

## 645.0604 Procedures and Worksheets for Planning Grazing Management

A. General

(1) Calculating Stocking Rates

(i) Determining the grazing capacity of an area can be complex and confusing and is the main factor affecting the success of a managed grazing strategy. The task of determining the amount of air-dry weight of the current year's standing crop is often variable and unpredictable. Adding to the complexity are species quality, quantity, and distribution. See subpart E of this handbook for more information on inventory, assessments, and monitoring techniques on grazing lands.

(ii) Stocking rate is defined as the number of specific kinds and classes of animals grazing or utilizing a unit of land for a specific period of time. Stocking rate may be expressed as animals per acre, hectare, or section, or the reciprocal (area of land/animal). When dual use is practiced (e.g., cattle and sheep), stocking rate is often expressed as animal units per unit of land or the reciprocal.

(iii) Many methods could be used to determine the appropriate stocking rate within a grazing unit. Often the past stocking history (producer records) and the trend of the plant community are the best indicators of a proper stocking rate.

(iv) Three techniques for forage inventory and stocking rates are described in Examples D-1, D-2, and D-3 in subpart D: Conservation Planning on Grazing Lands, section 645.0406 of this handbook. Using different techniques and comparing the results will help refine the numbers used for planning.

(v) Rates of stocking vary over time, depending on season of use, climate variations, site, and previous and current management goals. A safe starting stocking rate is an estimated stocking rate that is fine-tuned by the client by adaptive management through the year and from year to year. See exhibit F-1: Estimating Initial Stocking Rates Technical Note 3 in this subpart for more information.

(2) Grazing Resource Analysis System (GRAS) is an NRCS tool that is integrated within the Conservation Desktop (CD) Planning platform. The GRAS tool enables planners to more efficiently combine field data with software capability in CD to develop forage inventories, forage partition profiles, calculate harvest roughage, develop grazing schedules, develop monitoring and contingency plans, and compute feed and forage balance sheets. The GRAS tool provides:

(i) Quick stocking rate reports
(ii) Forage inventory reports
(iii) Forage adjustment reports
(iv) Harvest roughage reports
(v) Animal demand reports by herd and animal group
(vi) Grazing schedule reports
(vii) Forage animal balance reports
(viii) Grazing schedule contingency plans
(ix) Grazing system monitoring reports
(x) Managed grazing practice designs

(3) Harvest efficiency

Harvest efficiency is the percentage of forage actually ingested by the animals from the total amount of forage produced. Harvest efficiency increases as the number of animals increases in an area, and they consume plant material before it senesces, transfers to litter, or otherwise leaves the area. Continued season-long grazing or increased stocking rates can eventually decrease forage intake and forage production per unit area. See exhibit F-2 Harvest Efficiency in Prescribed Gazing Range Technical Note in this subpart for more information.

(4) Animal preference

It is important to know what species different classes of livestock and wildlife will utilize when developing a feed and forage balance sheet and in calculating carrying capacity. An area may appear to have plenty of vegetation available, but if it is not the type of vegetation suitable to the class of livestock grazing, it should not be counted in the feed and forage balance sheet. See Table F-5 for diet preference by animal species.

**Table F-5.** Diet Preference by Animal Species

| Diet Preference Animal Species | Type of Diet | | |
|---|---|---|---|
| | Grasses | Broadleaf weeds and legumes | Browse[1/] |
| Cattle | 65–75 | 20–30 | 5–10 |
| Horses | 70-80 | 15-25 | 0–5 |
| Sheep | 45–55 | 30–40 | 10–20 |
| Goats | 20–30 | 10–30 | 40–60 |
| White-tail deer | 10–30 | 30–50 | 30–50 |
| Elk, red, and fallow deer | 30–60 | 40–50 | 10–30 |

[1/] Shrubs or Trees

Source: D. Forbes and G.W. Evers, Texas A&M Univ.; D.I. Bransby, Auburn Univ.; M.A. McCann, Virginia Tech Univ.; and W.R. Getz, Fort Valley State Univ. in Southern Forages 3rd Edit. (Ball 2002).

(5) Adjustment factors used to determine stocking rate guide

Adjustments in stocking rates should be considered for areas that are not grazed by livestock because of physical factors such as difficulty of access (slope) and distance to water. The adjustments should be made only for the area that is considered necessary for reduction of the animal numbers. For example, 40 percent of a management unit may have 30 percent slopes; therefore, the adjustment is only calculated for 40 percent of the unit. Distance to drinking water also reduces grazing capacity below levels indicated by forage production. Local guides should be developed for use in inventorying and determining safe initial stocking rates. Local guides should also contain adjustments for different kinds and classes of livestock. Table F-6 gives example adjustments for slope on rangelands, and table F-7 gives an example of adjustment for water distribution on rangelands.

**Table F-6.** Adjustments for slope on rangelands (This is a general guide. Local guidance may be more specific). Other factors will influence these values like species of grazing animal, breed, class. climate etc.

| Percent slope | Percent adjustment |
|---|---|
| 0-15 | 0 |
| 15-30 | 30 |
| 31-60 | 60 |
| > 60 | 100 |

**Table F-7.** Adjustments for water distribution on rangelands (This is a general guide. Local guidance may be more specific). Other factors will influence these values like species of grazing animal, breed, class, climate, etc.

| Distance (miles) | Percent adjustment |
|---|---|
| ½ to 1 | 0 |
| 1 to 2 | 50 |
| 2 to 3 | 75 |

B. Forage inventory

(1) Forage inventory based on trend, health, and utilization

(i) Often the best method for establishing the initial stocking rate is to assist the client in making a trend study and utilization check on the key grazing area of the management units (see figures F-40 and F-41). A recording of current stocking rate, along with an evaluation of trend or health of the plant community and percent use of the key species, can provide an insight to the correct stocking rate for the grazing period.

(ii) Consideration should be given for the past and current growing conditions. Together these evaluations can be used by the client to determine if stocking rate for the grazing unit has been too high, low, or correct for the grazing period. Following this analysis, the client can readily observe and make a decision on correct stocking rates, as well as future management needs. After the annual stocking rate is determined, projected production by the day, week, month, or season can be determined by applying growth curve factors (see figures F-42 and F-43). Production from each management unit is then totaled to determine an estimated initial stocking rate for the operating unit.

**Figure F-40.** Worksheet–Forage Inventory Based on Current Stocking Rate, Trend, Health and Utilization. This is a method for determining fixed stocking rate.

**Cooperator:_____________________________________________**

**Planner:_________________________________________ Date:____________________**

| Pasture | Acres | Current stocking rate | | | Trend | Percent use of key species | Selected stocking rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AU | Mo. | AUM | | | AU | Mo. | AUM |
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Notes:

**Instructions for Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization**

1. Cooperator's name.
2. Planner's name.
3. Date of completion of the inventory.
4. List the pastures or fields to be inventoried.
5. Enter the acres in each of the pastures or fields listed.
6. Record the animal unit equivalents normally stocked in each pasture.
7. Record the number of months the animals listed in item 6 are in each of the pastures.
8. Multiply item 6 times item 7 and record the product. This is the number of animal unit months with which the pasture has been stocked.
9. Record the apparent trend of the vegetation in the pasture.
10. Record the observed percent utilization of the key grazing species in each of the pastures.
11. After evaluating the apparent trend and the percent use of the key species with the land manager, record the animal unit equivalents the land manager thinks is needed to ensure an upward trend and proper management of the key species.
12. Record the number of months the animal will be in the pasture.
13. Multiply item 11 by item 12 and record the product. This is the animal unit months of grazing that it is estimated that the pasture will produce for the animal being evaluated.
14. Record the total acres being evaluated in all pastures.
15. Record the total animal unit months that represents the current stocking rate for all of the pastures being evaluated.
16. Record the total animal unit months that is the new recommended safe starting stocking rate for the area evaluated.
17. Record any notes of explanation needed for understanding evaluations or needed follow-up.

**Figure F-41.** Example: Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization (Method for Determining Fixed Stocking Rate)

**Cooperator:**__*(1)*__________________________________________

**Planner:**__*(2)*__________________________________ **Date:**__*(3)*________________

| Pasture | Acres | Current stocking rate | | | Trend | Percent use of key species | Selected stocking rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AU | Mo. | AUM | | | AU | Mo. | AUM |
| *(4)* 1 | *(5)* 320 | *(6)* 20 | *(7)* 12 | *(8)* 240 | *(9)* - | *(10)* 60 | *(11)* 16 | *(12)* 12 | *(13)* 192 |
| 2 | 640 | 28 | 12 | 336 | 0 | 40 | 32 | 12 | 384 |
| 3 | 320 | 40 | 6 | 240 | - | 60 | 36 | 6 | 216 |
| 4 | 320 | 40 | 6 | 240 | + | 50 | 40 | 6 | 240 |
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| Total | *(14)* 1,600 | | | *(15)* 1,056 | | | | | *(16)* 1,032 |

Notes:

(2) Forage inventory based on production data and growth curves

(i) Another method of establishing the initial stocking rate is based on production data and growth curves developed locally as a part of the field office technical guide. An estimate of forage supply can be made for each month and totaled for the annual production for each management unit. The forage supply for each separate month can be totaled to provide a monthly total production for the entire operating unit, as well as a total production for the operating unit (see figures F-42 and F-43).

(ii) Monthly and annual production can then be compared to the monthly forage needs of the animals to determine months of surplus and deficient forage supply. The spreadsheet should be designed to accommodate the necessary identification of response units occurring in the management units. Response units are distinguished from each other based on their ability to produce useable forage. Normally, consideration is given to:

- Range ecological sites
- Similarity index
- Pastureland and hayland alternative states in ecological site descriptions and fertilization rates
- Pastureland and hayland species
- Forest ecological sites
- Transect data
- Plant vigor
- Adjustment factors resulting from accessibility, such as distance to water or elevation change
- Harvest efficiencies resulting from grazing management strategy or system
- Barriers that restrict travel to parts of the management unit

(iii) Forage supply is determined for each of the grazing units (ecological site or alternative state) and totaled to determine the production for the management unit (pasture or field). It can be expressed as production per day, week, month, or season, and totaled for the year.

(iv) Production for the operating unit is then determined by totaling the production of each management unit. This is expressed as daily, weekly, monthly, annual, or seasonal totals. The forage inventory should be developed to adequately express the forage production to allow the necessary detail of planning for grazing management.

**Figure F-42.** Forage Inventory

**Cooperator:** ______________ **Technician:** ______________ **Date:** __________

| Pasture | Kind of Forage and Production Factors & HE | Acres | Pro-duc-tion AUM/AC | Stocking rate w/o adj. AUM | Trend | Adj. factor | Total AUM | (12) MONTHS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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Notes:

**Instructions for Forage Inventory**

1. Enter name of the client.
2. Enter name of the person providing assistance to client.
3. Enter date of assistance.
4. Record the name and/or number of the pasture or field.
5. Record the information needed to reflect the production level. (note: HE=harvest efficiency)
6. Record the acres in each management unit or response unit located in each management unit.
7. Record the expected animal unit months production per acre for the entire growing season.
8. Multiply item 6 times item 7 and record the product. This is the estimated AUMs of production without adjustment for trend, vigor or some unaccounted reason.
9. Record the current trend or apparent trend of the plant community.
10. Record the needed adjustment to the stocking rate in item 8 to reflect the reduced production or harvest efficiency for which you have not accounted. This should be the number that represents the percentage of total production in item 8 that will be available.
11. Multiply item 10 times item 8 and record the product. This is the AUMs estimated to be produced on the response unit or management unit.
12. Record the abbreviations for the months above the 12 columns. You may record these starting with any month to best reflect the growing and grazing seasons in your area.
13. Record the AUMs produced each month. This is calculated by multiplying the percentage produced each month times the total AUMs recorded in item 11.
14. Record the name indicating the area being inventoried.
15. Record the total acres inventoried.
16. Record the total AUMs produced on the area inventoried.
17. Record the total AUMs produced on the area inventoried by month.
18. Record information concerning purchase or harvest of hay.
19. Record information concerning the purchase or securing of protein supplement.
20. Record the AUMs of hay purchased or harvested.
21. Record AUMs of protein if applicable.
22. Record any explanation needed to understand the forage inventory.

**Figure F-43.** Example-Forage Inventory

**Cooperator:** (1) J.R. Stockton **Technician:** (2) R.C. Jones **Date:** (3) 4|9|96

| Pasture | Kind of Forage and Production Factors & HE | Acres | Pro-duc-tion AUM/AC | Stocking rate w/o adj. AUM | Trend | Adj. factor | Total AUM | (12) MONTHS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | A | M | J | J | A | S | O | N | D | J | F | M |
| (4) 1 | | (6) 50 | (7) 10 | (8) 500 | (9) + | (10) 0 | (11) 500 | (13) 0 | Hay 50 | Hay 100 | 150 | 100 | 50 | 50 | | | | | |
| 2 | Range | | | | | | | | | | | | | | | | | | |
| | LSH, SI 35 | 200 | .6 | 120 | + | 0 | 120 | 12 | 18 | 24 | 24 | 12 | 12 | 12 | 6 | | | | |
| | CB, SI 30 | 100 | 1.2 | 120 | - | 0 | 120 | 12 | 18 | 24 | 24 | 12 | 12 | 12 | 6 | | | | |
| | Steep Rocky, SI 70 | 200 | .3 | 60 | + | .9 | 54 | 6 | 8 | 11 | 11 | 5 | 5 | 5 | 3 | | | | |
| | Total for range | 500 | - | - | - | - | 294 | 30 | 44 | 59 | 59 | 29 | 29 | 29 | 15 | | | | |
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| | | | | | | | | | | | | | | | | | | | |
| Total | (14) Ranch | (15) 550 | xxxxxx | xxxxxx | xxxx | xxx | (16) 794 | (17) 30 | 94 | 159 | 209 | 129 | 79 | 79 | 15 | 0 | 0 | 0 | 0 |
| Feed | (18) Hay: Harvest hay from Field 1 May, June 83 TONS = 210 AUM * | | | | | | (20) | | | | | | | | | | | | |
| | (19) Protein: Purchase 2 lb/AU/Dec., Jan., Feb. 6 TONS | | | | | | (21) | | | | | | | | | X | X | X | |

(22) Notes: 794 AUM = 66 AU

* Hay Production Calculations for Pasture 1:
150 AU x 790.8 lb = 118,620 lb harvested by grazing
118,620 / .50 = 237,240 lb produced on pasture (.50 = 50% harvest efficiency)
237,240 x .70 = 166,068 lb harvested as hay (.70 = 70% harvest efficiency for hay)
166,068 / 2,000 = 83 tons hay
166,068 / 790.8 = 210 AUM hay

(3) Stocking rate determinations

(i) Usable production method

This method of determining stocking rates is based on measuring or estimating the total amount of forage (standing crop) per acre and converting green weight to air dry weights and into AUMs. Air dry conversion factors can be determined by using conversion tables based on forage species or similar functional groups and stage of growth (see subpart E, tables E-6 through E-10).

(ii) The only production to be considered in determining stocking rate is the current year's forage growth below 4.5 feet vertical height. Forage from plant species that are undesirable, non-consumed, or toxic to the kind and class of livestock intended to graze the area should not be counted. The air-dry weight is summarized for the entire area to be grazed after any necessary adjustments are made.

(iii) The amount of forage available for consumption is multiplied by the harvest efficiency expected for the area. This is the amount of forage allocated for the animal's consumption. This amount is then divided by the amount of forage allocated to an animal unit month (AUM). This gives the number of animal unit months the area can safely support if the estimated or expected forage production occurs.

(iv) Formula F-1 is an example of the calculation to determine the stocking rate for an area that is producing 2,000 pounds per acre of total annual forage production. To arrive at the total AUMs for that grazing unit (pasture), the AUMs per acre are multiplied by the number of acres represented by each level of production.

**Formula F-1.** Example of the calculating stocking rate

2,000 lb/ac x 0.25 (harvest efficiency) = 500 lb forage consumed

$$\frac{500\text{lb}}{790\text{ lb(forage for 1 animal unit for 1 month}} = 0.63\text{ AUMs } \div \text{ ac or } 1.58\text{ ac/AUM}$$

(4) Forage value rating method

(i) Forage value is a utilitarian classification indicating the grazing value of important plant species for specific kinds of livestock or wildlife. The classification is based on palatability or preference of the animal for a species in relation to other species, the relative length of the period that the plant is available for grazing, and normal relative abundance of the plant. The five forage value categories recognized are:

- Preferred plants
- Desirable plants
- Undesirable plants
- Non-consumed plants
- Toxic plants

(ii) Preferred plants

Preferred plants are species that are preferred by animals and are grazed first by choice. These plants are generally more sensitive to grazing misuse than other plants and decline under continued heavy grazing.

(iii) Desirable plants

Desirable plants are useful forage plants. Although not as highly preferred by grazing animals, they can provide forage. Some of these plants may increase, if the more highly preferred plants are grazed heavily.

(iv) Undesirable plants

Undesirable plants are species that are not readily eaten by animals and species that conflict with or do not contribute to the management objective. These plants are relatively unpalatable to grazing animals and may become more abundant if the preferred species are over utilized or grazed out.

(v) Non-consumed plants

Non-consumed plants are unpalatable to grazing animals, or they are unavailable for use because of structural or chemical adaptations. They may become abundant if more highly preferred species are over utilized or grazed out.

(vi) Toxic plants

Toxic plants may accumulate or produce a substance toxic to animals that cause sickness, death, or deviation from normal health (synonym = poisonous plants). They have various palatability ratings and may or may not be consumed. They may become abundant if unpalatable, and if the more highly preferred species are removed from the community.

(5) These ratings are used in the determination for understory stocking rates for grazed forest. The amount and nature of the understory vegetation in grazed forest are highly responsive to the amount and duration of shade provided by the overstory canopy. Significant changes in the kinds and abundance of the plants occur as the canopy changes, often regardless of the grazing use. Some of the changes occur slowly and gradually as a result of normal changes in tree size and spacing. Changes following intensive woodland harvest, thinning, or fire may occur dramatically and quickly. For these reasons, the forage value ratings of grazed forest are not an ecological evaluation of the understory as is used in the range similarity index rating for rangeland. This is a utilitarian rating of the existing forage value of a specific area of grazed forest. These ratings are based on the percentage, by air dry weight, of the existing understory plant community made up of preferred and desirable plant species. Four value ratings are recognized in table F-8. See section 645.0602 (B) for more on managing grazeable forests.

**Table F-8.** Forage Value Ratings

| Forage value rating | Minimum percentage |
|---|---|
| Very high | 50 preferred + desirable = 90 |
| High | 30 preferred + desirable = 60 |
| Moderate | 10 preferred + desirable = 30 |
| Low | Less than 10 preferred |

(6) To achieve a given forage value rating, first determine the percentage preferred. Add the percentage desirable. If the required total percentage of preferred and desirable are not achieved (90, 60, 30), reduce the forage value rating to the next lowest rating. A very high forage value rating for a given animal species requires that at least 90 percent of the plant composition is rated preferred and desirable, with at least 50 percent being preferred. A high forage value rating requires a total of 60 percent preferred and desirable, with at least 30 percent being preferred.

(7) The production of the understory plants can vary greatly, even within the same canopy class. Forage value rating must always consider the production of air-dry forage when determining stocking rates. Introduced perennial species are considered preferred or desirable plants if they are adapted and produce high quality forage.

(8) Figure F-44, Worksheet for Determining Forage Composition and Value Rating, and example figure F-45 is a grazeable woodland site guide that uses canopy class and forage value ratings and suggested stocking rates.

(9) Figures F-7 and F-8 in section 645.0602 of this subpart describe in detail the calculations for determining stocking rates based on preferences of forage plants by specific animal species. These calculations should be used for establishing safe starting stocking rates for each forage value rating on a given site.

**Figure F-44.** Worksheet for Determining Forage Composition and Value Rating

**Ecological Site:** ________________

**Pasture Number:** ______

**Date:** ________________

**Operator:** ________________________

**Location:** ________________________

**Conservationist:** ________________

**Canopy:** ________________________

| Plant species | Present composition | | Animal: | | | Animal: | | | Animal: | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight | % | Forage value | P | D | Forage value | P | D | Forage value | P | D |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |
| | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | |
| Forage value rating 1/ | | | | | | | | | | | |
| Planned trend 2/ | | | | | | | | | | | |

Total estimated yield in very high forage value rating for cattle: ________

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

| | |
|---|---|
| Very high | 50% P + D = 90% |
| High | 30% P + D = 60% |
| Moderate | 10% P + D = 30% |
| Low | Less than 10% P |

2/ Planned trend symbols:

| | |
|---|---|
| Improving | + |
| Non-detectable | □ |
| Moving Away | – |

* Key grazing plant

Estimated initial stocking rate: __________

Notes:

**Instructions for Worksheet for Determining Forage Composition and Value Rating**

1. Record the name of the site that you are inventorying.
2. Record the management unit number.
3. Record the date of the inventory.
4. Record the name of the client.
5. Record the field office name.
6. Record the name or initials of the person providing the technical assistance.
7. Record the canopy of the overstory of woody species.
8. Record the plant species inventoried on the site.
9. Record the weight of each species in pounds per acre.
10. Record the percentage composition for each species.
11. Record the animal for which you are computing the forage value rating.
12. For each plant species, list the forage value (preferred or desirable) for the animal of concern.
13. For the plant species rated as preferred, list the percentage composition found in the present composition. (See item 10).
14. For the plant species rated as desirable, list the percentage composition found in the present composition. (See item 10).
15. Record the total weight in pounds per acre of the plants inventoried.
16. Record 100%.
17. Record the total percentage of the preferred plants.
18. Record the total percentage of the desirable plants.
19. Record the forage value rating for each animal as calculated using the chart provided.
20. Record the direction of plant community movement in relations to the desired plant community for each of the animals of concern. Is the forage value rating improving, not detectable, or moving away from the desired plant community for the animal of concern?
21. Record the total estimated yield for a very high value rating for livestock as a point of reference. This data should be recorded in the ecological site description for rangeland or forest land.
22. Identify the key grazing plant for each animal of concern.
23. Record the estimated safe starting stocking rate for the site. This may be taken from the ecological site description or calculated based on the production of preferred and desirable species.

    Example: Cattle
    500 pounds preferred times 35% harvest efficiency=175 pounds
    200 pounds desirable times 25% harvest efficiency =50 pounds
    Total harvest =225 pounds
    9.490 (pounds in AUY) divided by 225 pounds = 42 acres required per animal unit of cattle.
24. Record notes needed to ensure understanding of inventory.

**Figure F-45.** Worksheet Example for Determining Forage Composition and Value Rating

(1) **Ecological Site:** Sandy Loam

(2) **Pasture Number:** 12

(3) **Date:** 4/10/96

(4) **Operator:** Pat Stockton

(5) **Location:** Happy Hollow

(6) **Conservationist:** RHJ

(7) **Canopy** 45%

| (8) Plant species | Present compostion (9) Weight | (10) % | Animal: (11) Cattle Forage value (12) | (13) P | (14) D | Animal: (11) Deer Forage value (12) | (13) P | (14) D | Animal: (11) Turkey Forage value (12) | (13) P | (14) D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinehill Bluestem | 500 | 50 | P * | 50 | | UD | | | P * | 50 | |
| Low Panic | 50 | 5 | D | | 5 | D | | 5 | D | | 5 |
| Sweet Gum | 100 | 10 | UD | | | D | | 10 | UD | | |
| American Beauty Berry | 100 | 10 | D | | 10 | P | 10 | | D | | 10 |
| Carpet Grass | 50 | 5 | D | | 5 | UD | | | D | | 5 |
| St. Andrews Cross | 50 | 5 | UD | | | D | | 5 | D | | 5 |
| Sassafras | 150 | 15 | UD | | | P * | 15 | | UD | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| TOTAL | (15) 1000 | (16) 100 | | (17) 50 | (18) 20 | | (17) 25 | (18) 20 | | (17) 50 | (18) 25 |
| Forage value rating 1/ | | | (19) High | | | (19) Moderate | | | (19) High | | |
| Planned trend 2/ | | | | (20) + | | | (20) + | | | (20) + | |

(21) Total estimated yield in very high forage value rating for cattle: 1404 lb/Ac

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

| | |
|---|---|
| Very high | 50% P + D = 90% |
| High | 30% P + D = 60% |
| Moderate | 10% P + D = 30% |
| Low | Less than 10% P |

2/ Planned trend symbols:

| | |
|---|---|
| Improving | + |
| Non-detectable | ☐ |
| Moving Away | – |

(22) * Key grazing plant

(23) Estimated initial stocking rate: 1 AU to 42 Ac

(24) Notes:

C. Animal inventory

(1) An inventory of the domestic animals occupying or planned to occupy the operating unit must be developed. This animal inventory should be separated into the necessary herds to allow the desired husbandry to be practiced. This is done generally by kind, breed, class, and age. If a management unit is critical to a particular herd, it should be noted. The number of livestock is shown in each management unit to be grazed by the day, week, month, or season, and a total is given so that the forage demand can be planned in relation to forage production.

(2) Herbivorous wildlife numbers should be determined by management unit and their forage requirements expressed in the same manner as the livestock. If they are migratory, such as elk, determine the time they are expected to be in the management unit. See State-specific Livestock Inventory and Forage Balance sheets as they may provide more specific information for that state and wildlife.

(3) The animal inventory is used in combination with the forage inventory to balance the forage supply with the demand. See figures F-47 and F-48 for a Worksheet for Livestock Inventory and Forage Balance form and example.

**Figure F-46.** Worksheet for Livestock Inventory and Forage Balance

**Cooperator:** ______________________________ **Date:** ____________ **Technician:** _________________

**Livestock Numbers and Forage Needs**

| | | | | Animal units of forage needed | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Livestock | Planned number | AU equiv. | Animal units | Months | | | | | | | | | | | | Total AUM's |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| **Total forage available (AUM's)** 1/ | | | | | | | | | | | | | | | | |
| Total forage needs (AUM's) | | | | | | | | | | | | | | | | |
| Difference (+) or (-) (AUM's) 2/ | | | | | | | | | | | | | | | | |

1/ Take this data from forage inventory.
2/ Subtract total forage needs from total forage available.

**NOTES:**

**Instructions for Worksheet for Livestock Inventory and Forage Balance**

1. Enter client's name.
2. Enter date of technical assistance.
3. Enter name of person providing technical assistance.
4. Record the identification of a specific herd, flock, etc. of animals being inventoried. This generally includes information such as kind, breed, class and age. Record each different group of animals. Maintain separate groups needed for desired husbandry to be practiced.
5. Record the number of animals in the group identified on the line.
6. Record the animal unit equivalents for the identified group.
7. Multiply the planned number of animals (item 5) times the AU equivalents (item 6) and record the product. This number represents the animal units of the particular number of animals recorded on this line.
8. Record the months in the same manner as you did in the forage inventory. This should start with the month that best reflects the growing and grazing season for the year. Record the animal unit equivalents in the months the animals will be on the operating unit during the year.
9. Enter the total of the animal unit months recorded for each line.
10. Continue to list the animals as in item 4 above.
11. On this line, list the AUMs in each month. This information comes from the forage inventory that has been developed for the operating unit.
12. Total the animal units column, and the AUMs for each month, and the total AUMs column, indicating the total forage needed.
13. Subtract the total forage needs line from the total forage available line and record the AUM differences, indicating whether there is a shortage (-) or excess (+) of forage available that month, and for the year.
14. Record notes needed to explain any part of the worksheet.

**Figure F-47.** Example Worksheet for Livestock Inventory and Forage Balance

## Example – Livestock Inventory and Forage Balance Worksheet

**Cooperator:** (1) Name **Date:** (2) 4/10/96 **Technician:** (3) Conservationist

### Livestock Numbers and Forage Needs

| Livestock | Planned number | AU equiv. | Animal units | Animal units of forage needed – Months: A | M | J | J | A | S | O | N | D | J | F | M | Total AUM's |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (4) Cows | (5) 60 | (6) x 1 = | (7) 60 | (8) 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | (9) 720 |
| (10) Bulls | 3 | x 1.25 = | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 48 |
| | | x = | | | | | | | | | | | | | | |
| | | x = | | | | | | | | | | | | | | |
| | | x = | | | | | | | | | | | | | | |
| (11) **Total forage available (AUM's) 1/** | | | 66 | 30 | 94 | 159 | 209 | 129 | 79 | 79 | 15 | 0 | 0 | 0 | 0 | 794 |
| (12) Total forage needs (AUM's) | | | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 768 |
| (13) Difference (+) or (-) (AUM's) 2/ | | | +2 | -34 | +30 | +95 | +165 | +65 | +15 | +15 | -49 | -64 | -64 | -64 | -64 | +26 |

1/ Take this data from forage inventory.
2/ Subtract total forage needs from total forage available.

**NOTES:** (14)

(190-vi, NRPH, September 1997)

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## 645.0606 Exhibits

### Exhibit F-1. Estimating Initial Stocking Rates Technical Note 3 USDA NRCS Boise, Idaho.

# TECHNICAL NOTE

USDA - Natural Resources Conservation Service
Boise, Idaho

TN RANGE NO. 3 JUNE 2009 updated 2021

## ESTIMATING INITIAL STOCKING RATES

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*Collecting Production Data Using 9.6 ft$^2$ Hoop, Clippers, Scale, and Cloth Bag; Photo: Brendan Brazee, NRCS, Boise, ID*

## ESTIMATING INITIAL STOCKING RATES

**Dan Ogle, Plant Materials Specialist, NRCS, Boise, ID, (retired)**
**Brendan Brazee, State Rangeland Management Specialist, NRCS, Boise, ID**

Stocking rate, defined as, the number of animals allotted to an area for a given length of time is one of the most important grazing management tools a rancher or land manager can manipulate, regardless of the grazing system, vegetation type or kind and class of livestock. Stocking rate has the largest impact on animal performance and the health of the forage resource of all of the management tools available, because it directly influences:

- Animal productivity
- Forage production
- Forage quality
- Species composition over the long term
- Plant physiology
- Profitability of the operation

Establishing a proper stocking rate is critical to maintaining animal performance and optimizing forage performance while also sustaining the health of the land resource over the long term. Factors that affect stocking rate include the animal species, class of livestock (dry cow, lactating cow, bull, steer, etc.), acres available for grazing, rainfall, topography, water distribution, forage species, forage productivity including regrowth characteristics, and facilitating practices such as grazing system, irrigation and fertility program. Effective managers will balance animal performance and forage production over the long term. With this in mind, setting the appropriate initial stocking rate consists of determining (1) how much forage is required by the type and class of animals raised (forage demand); (2) how much forage is produced during the year and how much is available for livestock consumption (available forage); and (3) how long will animals be using the area (duration of grazing).

### FORAGE DEMAND

The basis for measuring forage demand is the *animal unit* (AU), which is defined as the amount of forage required to maintain a 1000-pound cow with calf. Studies have established that an AU requires on average 3.0 percent of the body weight in air dry forage daily (30 pounds per day for a 1000-pound cow). An *animal unit month* (AUM) is the average amount of dry weight forage required by a lactating 1000-pound cow and her calf for one month (30.4 days), or 912.5 pounds.

Not all kinds of livestock or wildlife have the same forage demand as a 1000-pound lactating cow. In addition, forage demand varies within a species depending on its class, i.e., its growth rate (e.g. heifers and steers vs. mature cow), lactation and maintenance (e.g., dry cow vs. cow with calf). For this reason, *animal unit equivalents* (AUE) have been developed to assist with the approximate determination of forage demand based on the kind, class and size of animal (see Table 1).

**TABLE 1**
**Animal Unit Equivalents (AUEs)**

| Domestic Animal Kind-Class | AUE | Wildlife Animal Kind-Class | AUE |
|---|---|---|---|
| Cow – dry | 1.00 | Antelope | 0.10 |
| Cow with calf | 1.00 | Bison | 1.00 |
| Bull – mature | 1.25 | Deer – whitetail | 0.13 |
| Calf – weaned | 0.60 | Deer – mule | 0.17 |
| Steer/Heifer - 2 Years | 0.80 | Elk | 0.48 |
| Sheep – mature ewe or ram | 0.20 | Goat – mountain | 0.14 |
| Sheep – yearling | 0.15 | Moose | 0.83 |
| Goat | 0.17 | Sheep – bighorn (ewe) | 0.14 |
| Horse – mature | 1.25- 2.00 | Sheep – bighorn (ram) | 0.18 |

For cow herds with animals having a different average weight than the 1000 pound average used above, AUE can be adjusted (i.e., every 100 pounds of animal weight equates to about 0.10 Animals Units thus a 1200-pound cow with a calf would be 1.2 AUE or a 1600 pound bull would be 1.6 AUE).

Example: A land manager needs to determine how much pasture he will need to acquire prior to implementing a brush management project which will require him to defer grazing from June 1st through October 30th this year. The herd consists of 300 pair of 1100 lbs Angus cross cattle with 15 Angus bulls during July and August.

*Calculation*: *#Head x AUE x Time in months = AUM's*
300 Cow/calf pairs x 1.1 AUE x 5 months = 1650 AUM's
15 Bulls x 1.25 AUE x 2 months = 38 AUM's

The manager will need to find a forage supply that will provide approximately 1700 AUM's for the deferment period.

## FORAGE PRODUCTION

The next step in estimating initial stocking rate is to determine the amount of forage being produced. The local climate (temperature and precipitation), soil (texture – depth – fertility) and current vegetation management largely affect total forage production for an area. Total production of forage can be estimated by using simple clipping procedures and converting the green weight estimates to present reconstructed weights. You will need a frame of a known area (Table 2), clippers, paper bags and a scale that measures in grams. Additional information will be needed for reconstruction including degree of use, knowledge of growth curves, and familiarity with typical or "normal" growing season climate variables.

Detailed information on how to collect plant production data can be found in the National Range and Pasture Handbook, Subpart E (https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/?cid=stelprdb1043084 )and the Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Volume II Chapter 9 (https://jornada.nmsu.edu/files/Volume_II.pdf)

**TABLE 2**
**Range Hoop and Square Subplot**
**Dimensions and Conversion Factors**

**9.60 $ft^2$**
Radius = 1.75 feet
Hoop Circumference = 10.996 feet
Square Plot Dimensions = 3.098 X 3.098 ft
Conversion Factor = Grams X 10 = lbs/ac
= Grams X 11.21 = kg/ha

**4.80 $ft^2$**
Radius = 1.24 feet
Hoop Circumference = 7.77 feet
Square Plot Dimensions = 2.19 X 2.19 ft
Conversion Factor = Grams X 20 = lbs/ac
= Grams X 22.42 = kg/ha

**2.40 $ft^2$**
Radius = 0.87 feet
Hoop Circumference = 5.498 feet
Square Plot Dimensions = 1.55 X 1.55 ft
Conversion Factor = Grams X 40 = lbs/ac
= Grams X 44.85 = kg/ha

**1.0 $m^2$**
Radius = 0.564 meter
Hoop Circumference = 3.545 meters
Square Plot Dimensions = 1.0 X 1.0 meter
Conversion Factor = Grams X 10 = kg/ha
= Grams X 8.93 = lbs/ac

**0.50 $m^2$**
Radius = 0.399 meter
Hoop Circumference = 2.51 meters
Square Plot Dimensions = 0.5 X 1.0 meter
Conversion Factor = Grams X 20 = kg/ha
= Grams X 17.86 = lbs/ac

**0.25 $m^2$**
Radius = 0.282 meter
Hoop Circumference = 1.77 meters
Square Plot Dimensions = 0.5 X 0.5 meter
Conversion Factor = Grams X 40 = kg/ha
= Grams X 35.71 = lbs/ac

The size of subplot to use depends on the nature of the area being sampled. Forage production varies between and within pastures and rangeland areas, so efforts to estimate total production should attempt to represent this variation as much as possible. Sites such as pastures that are uniformly vegetated with few species and consistent cover can be adequately sampled with smaller subplots (e.g., 2.4- 4.8 $ft^2$). Rangeland ecological sites that have many species and/or are sparsely vegetated require larger subplots (example 9.6 $ft^2$) to capture and reflect variation in site. It is recommended to sample at least 10 subplots. Collecting data for additional subplots can also increase the accuracy of the estimates.

***Collecting Yield Data at Coffee Point Test Site – North of Aberdeen, Idaho;***

***Photo: Loren St. John, NRCS, Aberdeen, ID***

## DATA COLLECTION FOR ESTIMATING FORAGE PRODUCTION

**Step 1: Determine Sample Area**
The area to be sampled should be representative of the grazing unit. The subplots should be located with in the same Ecological Site on rangeland or in areas of similar growth and production potential within pasture systems.

**Step 2: Determine Correction Factor for Clipped/Estimated green weights**
Select at least two of the ten subplots to collect clipped data. These subplots should contain a majority of the species found in the sampling area. The clipped weight for each species is then divided by the estimated weight for the clipped subplots. The resulting factor is used to adjust green weight estimates based upon actual weights.

For example, the data collector clipped Idaho fescue in subplots 3 and 7 estimating 15 grams green weight. The clipped weight for the two plots was 17 grams. The correction factor can be multiplied by the average green weight of the ten subplots to determine the corrected green weight. 17gram/13 grams = 1.13, 1.13 x 124 lbs/ac = 140.5 lbs/ac corrected green weight.
See ID-CPA-006 in Appendix **C.**

**Step 3: Determine Percent Dry Weight**
The corrected green weight can be converted to dry weights using estimated dry matter ranges from *Table 3 Green Weight to Dry Weight Conversion.* Appendix A - *Dry Weight Percent of Selected Grasses, Grasslikes, Forbs, Shrubs, and Trees for Idaho* provides a more accurate conversion for most common range species.

**TABLE 3**
**Green Weight to Dry Weight Conversions**
**Native Range (Green Wt x Percent = Air Dry Weight)**

| Grasses | % Dry Matter | Forbs | % Dry Matter | Deciduous Shrubs | % Dry Matter |
|---|---|---|---|---|---|
| Pre-Boot | 25-35% | Pre-Bloom | 15-25% | New Foliage | 25-40% |
| Full-Bloom | 35-45% | Full-Bloom | 25-35% | Mature Foliage | 40-55% |
| Soft-Dough | 45-55% | Soft-Dough | 35-45% | **Evergreen Shrubs** | **% Dry Matter** |
| Hard-Dough | 55-60% | Hard-Dough | 45-55% | New Foliage | 35-55% |
| Seed-Ripe | 60-70% | Seed-Ripe | 55-65% | Mature Foliage | 55-70% |
| Drying | 70-95% | Drying | 65-95% | | |

**Seeded Pasture (Green Wt x Percent = Air Dry Weight)**

| Grasses | % Dry Matter | Forbs/Legumes | % Dry Matter |
|---|---|---|---|
| Pre-Boot | 20-35% | Pre-Bloom | 15-25% |
| Full-Bloom | 35-45% | Full-Bloom | 25-35% |
| Soft-Dough | 45-55% | Soft-Dough | 35-45% |
| Hard-Dough | 55-60% | Hard-Dough | 45-55% |
| Seed Ripe | 60-70% | Seed Ripe | 55-65% |
| Drying | 70-95% | Drying | 65-95% |

**Step 4: Determine Percent Growth Ungrazed**
This is the average percent ungrazed by species for the sample area. For example if a species averages 40% utilization then record 60% for percent growth ungrazed.

**Step 5: Determine Percent Growth Curve Complete**
This is the cumulative proportion of growth completed for the current year. The growth adjustment corrects for how much the plant has grown for the year compared against the potential for the year or 100%. Climatic variations are not considered in this step.

**Step 6: Determine Percent Normal Production**
This is the effect of growing conditions on individual species. Precipitation timing and amount, temperature, and their relations may have an impact on species production. A value of 100% would be considered normal production.

**Step 7: Determine Reconstruction Factor**
The reconstruction factor coverts the corrected green weight of sampled vegetation into reconstructed present weight based upon steps 3- 6. This number represents the total expected production for the sample area at the end of the current growing season. The following formula is used, for further example see ID-CPA-006 in Appendix **C.**

$$\frac{\text{\% Dry weight}}{\text{(\% Current Growth Ungrazed)(\% Growth Curve Complete)(\% Normal Production)}}$$

= Reconstruction Factor x Corrected Green Weight = Reconstructed Present Weight

## ADJUSTMENTS TO FORAGE PRODUCTION FOR ESTIMATING STOCKING RATE

When estimating stocking rates it is a good idea to evaluate availability of forage for livestock based upon topography, distance to water, and type or class of livestock in the operation. Adjustment to the total production for these variables can have a significant effect on stocking rate and can identify opportunities for installation of facilitating practices such as stockwater pipelines and troughs. The total production of a grazing unit can be adjusted based on distance from water and percent slope. Table 4 shows the general guidelines for determining the amount of adjustment. Local knowledge should be used when available to assess if adjustments are reasonable. An example of how percent slope and distance to water can effect estimated stocking rate see ID-CPA-008 in Appendix C.

**Table 4**
**Distance to Water and Percent Slope Adjustment Factors for Rangeland.**
**For further guidance see Subpart F NRPH**

| Distance to Water in feet | Percent Adjustment |
|---|---|
| 2640 | 100% |
| 5280 | 90% |
| 7920 | 70% |
| 10560 | 50% |

| Percent Slope | Percent Adjustment |
|---|---|
| 0-15 | 100% |
| 15-30 | 70% |
| 31-60 | 40% |
| >60 | 0% |

**Utilization and Harvest Efficiency**

Plants have a tolerance to grazing, but if herbage removal exceeds a critical point, most plants will lose vigor, produce less and if excessive removal continues, the plants will eventually die. Proper utilization is the approximate point of forage harvest that will not lead to range or pasture deterioration or decreased animal performance. The key to proper utilization is to leave sufficient leaf area to allow the plant to restore depleted energy reserves in response to grazing and thus maintain desirable productivity and composition.

A common starting point or rule for planning an appropriate level of utilization is "take half and leave half" or 50 percent utilization of annual forage production. This utilization includes forage actually consumed by the animal, but also damage to plants caused by trampling, loafing and other non-livestock factors such as loss to insects or utilization by wildlife. Some estimate as much as 25% of total annual production is lost to livestock damage and other competitive uses under low stocking density continuous grazing program. This can be referred to as harvest efficiency which is defined as the percentage of total *annual* standing forage that is consumed by the grazing animal. Harvest efficiency should not be confused with grazing efficiency which refers to the percentage of *allowable* standing forage consumed and results in higher percentages. Harvest efficiencies above 35% have a negative impact on animal performance. Table 5 provides guidance on determining harvest efficiency based upon type of grazing system and management level used for the operation.

An example of how Harvest Efficiency and the rule of thumb "Take Half, Leave Half " are related.

(1000 lbs/ac x 50% Use) – (1000 lbs/ac x 25% loss due to trampling, fouling, insects, etc.)
= 500 lbs/ac – 250lbs/ac = 250 lbs/ac of available forage.

To simplify the equation use 1000 lbs/ac x 25% Harvest Efficiency = 250 lbs/ac available forage.

**Table 5 – Harvest Efficiency**

| Grazing Management Level | Harvest Efficiency |
|---|---|
| Continuous, Season Long | 25% |
| Deferred Rotation, 2+ Pastures | 25-30% |
| Rest Rotation, Multiple Pastures | 25-30% |
| Short Duration , High Intensity | 30-35% |

**Animal Performance Considerations**

At low stocking rates, individual animal performance is maximized because animals are free to select high quality forage. Consequently, with low grazing pressure, palatable plant species in under-stocked pastures are at risk of over-utilization, because animals have unrestricted choice and will repeatedly consume the preferred species first (thus the same preferred plants will be grazed over and over again). Furthermore, total animal production per unit area will be low because of fewer animals in the pasture.

As stocking rate increases to a moderate level, individual performance declines. This is because the average forage quality consumed per animal is reduced as a direct result of the increase in animals per unit area. However, total animal production per unit area increases as more animals are carried per acre. Under normal conditions, a moderate stocking rate will not adversely impact the forage resource.

At high stocking rates, total animal production per area declines as a result of poor individual animal performance. Individual animal performance is poor because each animal in the herd must compete for limited and rapidly diminishing supply of quality forage. As the forage resources diminish, the available nutrients for each animal declines and animals nutrient demand may not be met. Without consideration of other management options such as rapid rotation into ungrazed fields or pastures that have been grazed and have regrown, a reduction in the most palatable species will occur, weedy or undesirable species will increase and a decline in carrying capacity will eventually occur.

## ADJUSTMENTS WITH MANAGEMENT

It is the three components of stocking rate – animal numbers, grazing area and grazing period, that managers have the most influence over when making grazing management decisions. A manager can adjust the number of animals, alter pasture size or manipulate the amount of time an area is grazed or the amount of time an area is rested.

The decision to manipulate one or more of the components should be guided by animal and pasture management objectives and economic considerations. Decisions to change animal numbers are most feasible when the area is either under-stocked or over-stocked (i.e., drought could require or necessitate a temporary reduction in herd size to minimize the impact on the reduced forage base). As herd size is changed, the grazing period must be adjusted accordingly to maintain the desired stocking rate.

Adjusting pasture size is not always economically feasible. However, there may be situations when altering pasture configuration or subdividing a single large pasture into smaller units, will improve grazing distribution and animal performance. Several factors should be considered when adjusting pasture size. Decreasing pasture size will require smaller herd numbers or a shorter grazing period. Shorter grazing periods require more intensive management because the margin for error on the time animals are in pasture is increased. Second, increasing pasture size without increasing animal numbers will result in reduced grazing distribution even if the grazing period is increased. Uneven grazing distribution in large pastures leads to patchy grazing with a mixture of under- and over-utilized areas. Eventually over-utilized areas lose desirable plants, productivity and support fewer animals.

The easiest, most flexible and economically feasible component of stocking rate to manipulate is the grazing period. By managing the amount of time a pasture is grazed, a manager can easily and quickly compensate for situations of over-stocking that arise from time to time. For example, short term drought will cause pasture production to be reduced. Decreasing the grazing period for each grazing unit can temporarily prevent over-grazing without reducing animal numbers.

## PLANNING GRAZING PERIOD

Once the estimated carrying capacity has been determined for the ranch, the amount of time a group of animals spends in each pasture should be determined to complete the process of setting the initial stocking rate. The amount of time spent by livestock in each pasture depends largely on the grazing area itself, the type of operation and the management goals of the operation.

Stocking rates are commonly expressed as the number of animal units (AU) per unit time per unit area (usually an acre). Operations that use large pastures or grazing units typically base stocking rates on months to be most useful. For example each pasture's stocking rate may be expressed as animal unit months per acre (AUMs/Acre) or acres per animal unit month (Acres/AUM). Whereas, operations that use smaller pastures may find the numbers of days (D) a pasture can support a particular number of animals (AUDs/Acre) to be more useful.

The carrying capacity of a unit of land is commonly expressed in animal unit months (AUMs). An AUM is the measure of the forage supply within the management unit, based on the amount required to support an animal unit (AU) for one month. The value of determining the carrying capacity for the ranch, pasture or management unit is that it connects forage supply with forage consumption and is thus the absolute foundation to proper grazing management.

# Appendix A

**Dry Weight Percent of Selected Grasses, Grasslikes, Forbs, Shrubs, and Trees for Idaho**
**(please see state specific guidance for your area)**

# DRY WEIGHT PERCENT OF SELECTED GRASSES, GRASSLIKES, FORBS, SHRUBS, AND TREES FOR IDAHO

Modified : Dan Ogle, Plant Materials Specialist & Brendan Brazee, Rangeland Management Specialist Idaho NRCS

Version : Feb-2009

## GRASS AND GRASSLIKES

**GRASS PHENOLOGICAL STAGE CLASSIFICATION:**

1 -GREEN LEAVES BEFORE BOOT
2- BOOT STAGE
3- SEED SOFT DOUGH TO RIPE
4- SEED DESIMINATION
5- WINTER DORMANCY CURED

### INTRODUCED COOL-SEASON PERENNIAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| AGCR | 25-30 | 40-45 | 50-55 | 60-65 | 85-90 | Agropyron cristatum | Agropyron cristatum | Fairway crested wheatgrass |
| AGDE2 | 25-30 | 40-45 | 50-55 | 60-65 | 85-90 | Agropyron desertorum | Agropyron desertorum | Standard crested wheatgrass |
| AGCRxAGDE2 | 25-30 | 40-45 | 50-55 | 60-65 | 85-90 | A. cristatum x A. desertorum | | Hycrest crested wheatgrass |
| AGFR | 25-30 | 40-45 | 50-55 | 60-65 | 85-90 | Agropyron fragile | Agropyron sibiricum | Siberian wheatgrass |
| ALAR | 20-25 | 35-40 | 45-50 | 55-60 | 80-90 | Alopecurus arundinaceus | Alopecurus arundinaceus | Creeping foxtail |
| ARELE | 20-25 | 35-40 | 40-45 | 50-55 | 75-85 | Arrhenatherum elatius var. elatius | Arrhenatherum elatius | Tall oatgrass |
| BRER3 | 20-25 | 35-40 | 40-45 | 50-55 | 75-85 | Bromus erectus | Bromus riparius | Meadow brome |
| BRIN2 | 20-25 | 35-40 | 40-45 | 50-55 | 75-85 | Bromus inermis | Bromus inermis | Smooth brome |
| DAGL | 20-25 | 30-35 | 40-45 | 50-55 | 75-85 | Dactylis glomerata | Dactylus glomerata | Orchardgrass |
| FETR3 | 25-35 | 40-45 | 45-50 | 55-60 | 75-85 | Festuca trachyphylla | Festuca ovina duriuscula | Hard fescue |
| FEOV | 25-35 | 40-45 | 45-50 | 55-60 | 75-85 | Festuca ovina | Festuca ovina | Sheep fescue |
| LOPE | 25-30 | 40-45 | 45-55 | 55-60 | 75-85 | Lolium perenne | Lolium perenne | Perennial ryegrass |
| PHAR3 | 20-25 | 40-45 | 50-55 | 55-60 | 75-85 | Phalaris arundinacea | Phalaris arundinacea | Reed canarygrass |
| PHPR3 | 20-25 | 35-40 | 45-55 | 55-65 | 80-90 | Phleum pratensis | Phleum pratensis | Timothy |
| POPR | 20-25 | 35-40 | 45-50 | 55-60 | 75-85 | Poa pratensis | Poa pratensis | Kentucky bluegrass |
| SCPH | 20-25 | 35-40 | 45-50 | 55-60 | 75-85 | Schedonorus phoenix | Festuca arundinacea | Tall fescue |
| THIN6 | 25-30 | 40-45 | 50-55 | 55-60 | 75-85 | Thinopyrum intermedium | Agropyron intermedium | Intermediate wheatgrass |
| THIN6 | 25-30 | 40-45 | 50-55 | 55-60 | 75-85 | Thinopyrum intermedium | Agropyron trichophorum | Pubescent wheatgrass |
| THPO7 | 25-30 | 40-45 | 50-55 | 60-65 | 85-90 | Thinopyrum ponticum | Agropyron elongatum | Tall wheatgrass |
| PSJU3 | 20-25 | 35-40 | 45-50 | 55-65 | 70-85 | Psathyrostachys juncea | Elymus junceus | Russian wildrye |

### NATIVE COOL-SEASON PERENNIAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| ACHY | 30-35 | 45-50 | 50-55 | 60-75 | 80 | Achnatherum hymenoides | Oryzopsis hymenoides | Indian ricegrass |
| ACLE9 | 25-30 | 40-45 | 50-55 | 60-65 | 70+ | Achnatherum lettermanii | Stipa lettermani | Letterman needlegrass |
| ACNEN2 | 25-30 | 40-45 | 50 | 55-60 | 75+ | Achnatherum nelsonii ssp. nelsonii | Stipa columbiana | Columbia needlegrass |
| ACTH7 | 25-30 | 40-45 | 50-55 | 60-65 | 80+ | Achnatherum thurberianum | Stipa thurberiana | Thurber needlegrass |
| BRMA4 | 20-25 | 35-40 | 40-45 | 50-75 | 65-85 | Bromus marginatus | Bromus marginatus | Mountain brome |
| CARU | 25-30 | 35-40 | 40-45 | 45-50 | | Calamagrostis rubescens | Calamagrostis rubescens | Pinegrass |
| DECA18 | | | | | | Deschampsia cespitosa | Deschampsia cespitosa | Tufted hairgrass |
| ELEL5 | 25-35 | 45-50 | 55-60 | 65-70 | 85-90 | Elymus elymoides | Sitanion hystrix | Bottlebrush squirreltail |
| ELGL | 25 | 35 | 40 | 75 | 75-85 | Elymus glaucus | Elymus glaucus | Blue wildrye |
| ELLA3 | 25-30 | 45-50 | 53-56 | 60-65 | 80-90 | Elymus lanceolatus ssp. lanceolatus | Agropyron riparium | Streambank wheatgrass |
| ELLAL | 25 | 45-50 | 55-60 | 60-65 | 85-90 | Elymus lanceolatus ssp. lanceolatus | Agropyron dasystachyum | Thickspike wheatgrass |
| ELTRT | 25-30 | 40-45 | 50-55 | 60-65 | 75-90 | Elymus trachycaulus ssp. trachycaulus | Agropyron trachycaulum | Slender wheatgrass |
| ELWA2 | 25-30 | 40-50 | 50-55 | 55-65 | 80-90 | Elymus wawawaiensis | Agropyron spicatum | Snake River wheatgrass |
| FEID | 25-35 | 40 | 45-50 | 50-60 | 75-85 | Festuca idahoensis | Festuca idahoensis | Idaho fescue |
| HECO26 | 25-35 | 40-50 | 50-55 | 60-65 | 70+ | Hesperostipa comata | Stipa comata | Needle & Thread |
| KOMA | 20-35 | 38-50 | 50-55 | 60-65 | 75-85 | Koeleria macrantha | Koeleria cristata | Prairie junegrass |
| LECI4 | 25-30 | 45-50 | 50-55 | 60-65 | 65-80 | Leymus cinereus | Elymus cinereus | Basin wildrye |
| LESAS | | | | 70 | 90 | Leymus salinus ssp. salmonis | Elymus salina | Salmon wildrye |
| MEBU | 20-30 | 40-45 | 45-50 | 50-55 | 80-85 | Melica bulbosa | Melica bulbosa | Oniongrass |
| PASM | 25-35 | 45-55 | 53-58 | 60-65 | 70-90 | Pascopyrum smithii | Agropyron smithii | Western wheatgrass |
| POFE | 25-35 | 45 | | 50-60 | 90-95 | Poa fendleriana | Poa fendleriana | Muttongrass |
| POSE | 25-30 | 38-45 | 50-55 | 60-65 | 70+ | Poa secunda | Poa ampla | Big bluegrass |
| POSE | 20-30 | 38-50 | 50-55 | 60-65 | 70+ | Poa secunda | Poa nevadensis | Nevada bluegrass |
| POSE | 25-30 | 40-45 | 50-55 | 55-60 | 65-90 | Poa secunda | Poa secunda | Sandberg bluegrass |
| PSSPI | 25-30 | 35-40 | 45 | 50-60 | 80-90 | Pseudoroegneria spicata spp.inermis | Agropyron inerme | Beardless wheatgrass |
| PSSPS | 25-30 | 40-50 | 50-55 | 55-65 | 80-90 | Pseudoroegneria spicata ssp. spicata | Agropyron spicatum | Bluebunch wheatgrass |

### NATIVE WARM-SEASON PERENNIAL GRASS

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| ARPUL | 28-35 | 40-45 | 50-55 | 60-65 | 85-90 | Aristida purpurea var. longiseta | Aristida longiseta | Red threeawn |
| SPCR | 30-45 | 40-50 | 50 | 60-70 | 90 | Sporobolus cryptandrus | Sporobolus cryptandrus | Sand dropseed |

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| INTRODUCED COOL-SEASON ANNUAL GRASS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
| BRAR5 | | | | 56 | | Bromus arvensis | Bromus japonicus | Japanese brome |
| BRRU2 | | | | 70 | | Bromus rubens | Bromus rubrum | Red brome |
| BRTE | 20-30 | 35-50 | 50-55 | 60-65 | 85-90 | Bromus tectorum | Bromus tectorum | Cheatgrass |

| NATIVE COOL-SEASON ANNUAL GRASS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
| VUOCG | | | | 80 | | Vulpia octoflora | Festuca octoflora | Sixweeks fescue |

| GRASSLIKE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
| CAFI | 30 | 49 | 55 | 60-67 | 80 | Carex filifolia | Carex filifolia | Threadleaf sedge |
| CAGE2 | 40 | 50 | 55 | 60 | 75 | Carex geyeri | Carex geyeri | Elk sedge |
| ELEOC | | | | 38 | | Eleocharis sp. | Eleocharis sp. | Spikerush |
| JUNCO | 20 | 40-45 | 55-60 | | | Juncus balticus | Juncus spp | Wiregrass, Baltic rush |

**FORBS**

**FORB PHENOLOGICAL STAGE CLASSIFICATION:**

1- GREEN BEFORE FLOWERING
2 - FULL BLOOM PETALS FALLING
3 - FRUIT RIPENING
4 - FRUIT RIPE OR FALL DORMANCY
5 - SEED DESIMINATION OR WINTER DORMANCY

| INTRODUCED FORBS/LEGUMES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
| COAR4 | | 35 | | | | Convolvulus arvensis | Convolvulus spp | Field bindweed |
| CYOF | 20 | 35 | | 90 | | Cynoglossum officinale | Cynoglossum officinale | Houndstonque |
| SAKA | 30 | 50 | | 100 | | Salsola kali | Salsola kali | Russian thistle |
| SATR12 | 25 | 30 | 45 | 50 | 65 | Salsola tragus | Salsola tenuifolia | Prickly Russian thistle |
| TRDU | 33 | | | | | Tragopogon dubius | Tragopogon dubius | Salsify |
| TRLA30 | 30 | 50 | | 75 | | Tragopogon lamottei | Tragopogon pratensis | Goatsbeard |
| ASCI4 | 20 | 30 | | | | Astragalus cicer | Astragalus cicer | Cicer milkvetch |
| ERCI6 | | 40 | | 60 | | Erodium cicutarium | Erodium spp | Alfilaria |
| MESA | 20 | 30 | | 39-42 | | Medicago sativa | Medicago sativa | Alfalfa |
| MELIL | 20 | 30 | | | | Melilotus | Melilotus spp. | Sweetclover |
| ONVI | 20 | 30 | | | | Onobrychis sativa | Onobrychis sativa | Sainfoin |

| NATIVE PERENNIAL FORBS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
| ACMI2 | | 31-49 | | | | Achillea millefolium | Achillea millefolium | Western yarrow |
| AGUR | 25 | 30-40 | 45 | | | Agastache urticifolia | Agastache urticifolia | Horsemint/hyssop |
| AGGL | 17-20 | 45 | | | | Agoseris glauca | Agoseris pumila | Mountain dandelion |
| ALAC4 | 15 | 20-40 | | 70 | 70-90 | Allium acuminatum | Allium acuminatum | Onion |
| ANRO2 | 35 | 55 | | 85 | | Antennaria rosea | Antennaria rosea | Pussytoes |
| ARLU | 18 | | | 43-45 | 65+ | Artemisia ludoviciana | Artemisia ludoviciana | Louisiana sagewort |
| ASCO9 | | | 47 | | | Astragalus columbianus | Astragalus columbia | Columbia vetch |
| ASSP4 | 31 | | | | | Astragalus spaldingii | Astrogalus spaldingii | Milkvetch, spalding's |
| BASA3 | 17-32 | 27-36 | 35-45 | 45-50 | 65+ | Balsamorhiza sagittata | Balsamorhiza sagittata | Arrowleaf balsamroot |
| CAAN7 | | 27 | 30 | 35 | 50+ | Castilleja angustifolia | Castilleja spp. | Indian paintbrush |
| COUMP | 20 | 50 | | | | Comandra umbellata ssp. pallida | Comandra palida | Bastard toadflax |
| CRCA2 | 20-25 | 30-40 | 35 | 40 | 50 | Crepis acuminata | Crepis acuminata | Tapertip hawksbeard |
| CRFL5 | | | | 58 | | Cryptantha flava | Cryptantha flava | Yellow cryptantha |
| DEOC | 22 | 28 | 30 | 35 | 50 | Delphinium ×occidentale | Delphinium spp. | Tall larkspur |
| DENU2 | 25 | 30 | 35 | 40 | 50 | Delphinium nuttallianum | Delphinium spp. | Low larkspur |
| DICA14 | | | | 70 | | Dichelostemma capitatum | Dicheloatemma spp | Bluedicks |
| ERCH4 | | | | | 60-100 | Erigeron chrysopsidis | Erigeron chrysopsidis | Dwarf yellow fleabane |
| ERCO7 | | 50 | | | | Erigeron concinnus | Erigeron pumulus | Low Fleabane |
| ERSP4 | 22 | 25 | 33 | 35 | 55 | Erigeron speciosus | Erigeron speciosus | Daisies |
| ERHE2 | 45-50 | | 67-70 | 90 | | Eriogonum heracleoides | Erigonum heraculoides | Wyeth buckwheat |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ERUM | 20-25 | 30-40 | 46 | 50-55 | 65+ | Eriogonum umbellatum | Eriogonum umbellatum | Sulphur-flower buckwheat |
| FRSP | | 20 | 20 | | | Frasera speciosa | Fraseria speciosa | Elkweed |
| GABO2 | 17-20 | | | 45-50 | 85 | Galium boreale | Galium boreale | Bedstraw |
| GEMA4 | 20 | | | | | Geum macrophyllum | Geum macrophyllum | Largeleaf avens |
| GETR | | 39 | | | | Geum triflorum | Geum triflorum | Old Man's Whiskers |
| HEUN | 20 | 30-35 | 38-45 | 50-55 | 65+ | Helianthella uniflora | Helianthella uniflora | Oneflower sunflower |
| HEMA80 | 20 | 20 | 20 | 22 | 30 | Heracleum maximum | Heracleum lanatum | Cow parsnip |
| HECH | 40 | | | | | Heuchera chlorantha | Heuchera spp. | Alumroot |
| HICY | 20 | | | | | Hieracium cynoglossoides | Hieracium cynoglossoides | Houndstongue hawkweed |
| HISCA | 15-20 | 25-30 | | 35-40 | 65+ | Hieracium scouleri var. albertinum | Hieracium albertinum | Hawkweed |
| LIPU11 | | | | 60 | | Leptodactylon pungens | Leptodactylon pungens | Granite gilia |
| LOMA3 | 15-20 | 20-25 | 26-30 | 37 | 50 | Lomatium macrocarpum | Lomatium spp. | Biscuitroot |
| LUARM4 | | | | | 57 | Lupinus arbustus | Lupinus laxiflorus | Spur Lupine |
| LESU4 | | | 32 | | 39 | Lupinus sericeus | Lupinus sericeus | Silky Lupine |
| LUPIN | 18-25 | 25-30 | 30-35 | 40-45 | 50-90 | Lupinus | Lupinus spp. | Lupine |
| MEAR6 | 15-18 | 20-25 | 22 | 30 | 50-75 | Mertensia arizonica | Mertensia leonardi | Bluebells |
| OSOC | 15-18 | 21 | 25 | 30 | 50-70 | Osmorhiza occidentalis | Osmorhiza occidentalis | Sweet anise |
| PELO | | 60 | | | | Pectis longipes | Pectis longpipes | Longstalk cinchweed |
| PEBA2 | 13-20 | 25 | 30-35 | 35-40 | 50-75 | Penstemon barbatus | Penstemon barbatus | Beardlip penstemon |
| PELI2 | | 50 | | | | Penstemon linarioides | Penstemon linarioides | Toadflax penstemon |
| ACNA2 | | | | 64 | | Acourtia nana | Perezia nana | Dwarf desertpeony |
| PHHO | 35 | 50 | | 75 | | Phlox hoodii | Phlox hoodii | Hoods phlox |
| PHLO2 | 20-25 | 35-40 | 50 | | 70-80 | Phlox longifolia | Phlox longifolia | Longleaf phlox |
| POFO | 15 | 20-30 | 30 | 35-50 | 60+ | Polemonium foliosissimum | Polemonium foliosissimum | Jacobs ladder |
| POAR7 | 50 | | | | | Potentilla arguta | Potentilla arguta | Galley cinquefoil |
| POGR9 | 44 | 50 | | | | Potentilla gracilis | Potentilla gracilis | Northwest cinquefoil |
| POTEN | 15-20 | 25 | 30-35 | 38-45 | 55+ | Potentilla | Potentilla spp. | Cinquefoil |
| RUOC2 | 20 | 25-35 | | 30-40 | 55-70 | Rudbeckia occidentalis | Rudbeckia occidentalis | Coneflower |
| PACA15 | | 24 | | | | Packera cana | Senecio canus | Wooly groundsel |
| SESE2 | 15-20 | 25-30 | 35 | 40 | 55+ | Senecio serra | Senecio serra | Butterweed |
| SOMI2 | 30 | | | | | Solidago Missouriensis | Solidago Missouriensis | Missouri goldenrod |
| PSJA2 | 23 | 25 | 30 | 31 | 90 | Pseudostellaria jamesiana | Stellaria jamesiana | Starwort |
| TAOF | 20 | 25 | | | | Taraxacum officinale | Taraxacum officinale | Dandelion |
| THFE | 23 | 30 | 36 | 40 | 70 | Thalictrum fendleri | Thalictrum fendleri | Meadow rue |
| TRRA5 | 30 | | | | | Tragia ramosa | Tragia spp | Noseburn |
| VAOC2 | | 20 | | 25 | | Valeriana occidentalis | Valeriana occidentalis | Valerian |
| HEMUM | 30 | 55 | | 90 | | Heliomeris multiflora var. multiflora | Viguiera multiflora | Showy goldeneye |
| VIOLA | 15-20 | 20-25 | 30 | 38 | | Viola | Viola spp. | Violet |
| WYAM | 20-25 | 25-30 | 35 | 40 | 55+ | Wyethia amplexicaulis | Wyethia amplexicaulis | Mulesear |

**NATIVE BIENNIAL/ANNUAL FORB**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| ARCA12 | 30-35 | 65 | | 80-85 | | Artemisia campestris ssp. borealis | Artemisia spp | Sageworts |
| CHAL7 | 29 | | | | | Chenopodium album | Chenopodium spp | Lambsquarters |
| CRSE11 | 50 | | | | | Croton setigerus | Croton spp | Dove seed |
| ERFL | 30 | | | | | Erigeron flagellaris | Erigeron flagellaris | Trailing daisy |
| GEVI2 | 20 | 38 | 30-35 | 40-45 | 55-70 | Geranium viscosissimum | Geranium viscosissimum | Sticky geranium |
| HEAN3 | 25 | 50 | | 95 | | Helianthus annuus | Helianthus annuus | Annual sunflower |
| LALOCO | 25 | 45 | | 95 | | Lappula occidentalis var. occidentalis | Lappula redowskii | Stickseed |
| ORLU2 | 15 | 20 | 25 | 35 | 45+ | Orthocarpus luteus | Orthocarpus spp. | Owl-clover |
| PODO4 | 25 | 40 | | 85 | | Polygonum douglasi | Polygonum douglasi | Knotweed |
| SEIN2 | 15-20 | 23-30 | 30-40 | 40-45 | 55+ | Senecio integerrimus | Senecio integerrimus | Lambstongue |
| SOAM | 20 | | | | | Solanum americanum | Solanum nigrum | Black nightshade |
| SPCO | 40-45 | 55 | | 80-90 | | Sphaeralcea coccinea | Sphaeralcea coccinea | Scarlet globemallow |
| THIN | | | 50 | | | Thelypodium integrifolium | thelypodium integrifolium | Entire leaved thelypod |
| AMRE | | 20 | | | | Amaranthus retroflexus | Amaranthus spp | Red root |
| AMTE3 | | | | 80 | | Amsinckia tessellata | Amsinckia spp | Fiddle neck |
| ERIN4 | | | | 70 | | Eriogonum inflatum | Eriogonum inflatum | Indian pipe weed |
| LAPPU | | | | 85 | | Lappula | Lappula spp | Stick seed |
| PLOV | | | | 75 | | Plantago ovata | Plantago spp | Indian wheat |
| POHA5 | | 10 | | 50 | | Portulaca halimoides | Portulaca spp | Purslane |

**NATIVE VINE**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| LABR | 15-20 | | 25-40 | | 50-80 | Lathyrus brachycalyx | Lathyrus spp. | Peavine, Bonneville pea |
| VIAM | 20 | 25-30 | | 75 | | Vicia americana | Vicia americana | American vetch |
| HULU | 30 | | | 80 | | Humulus lupulus | Humulus spp | Hop |

**TREE/SHRUB/SUBSHRUB**

**SHRUB PHENOLOGICAL STAGE CLASSIFICATION:**
1 - GREEN LEAVES ONLY OR FULL LEAF STAGE
2 - FLOWERS IN BUD, GREEN FLOWERING STAGE
3 - FLOWERS OPEN OR FRUIT DROP
4 - SEED MATURITY OR FALL DORMANCY * = GREEN FRUIT WT
5 - WINTER DORMANCY OR CURED LEAVES ** = DRY FRUIT WEIGHT

**NATIVE SHRUB**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| ARAR8 | 45 | 60 | 54-70 | 60-75 | | Artemisia arbuscula | Artemisia arbuscula | Low sagebrush |
| ARNO4 | 40 | 55 | 50-75 | 60-75 | | Artemisia nova | Artemisia nova | Black sagebrush |
| ARTR2 | 35-55 | 40-65 | 50 | 55-75 | 60-90 | Artemisia tridentata | Artemisia tridentata | Big sagebrush |
| ARTRW8 | 75 | 61 | | | | Artemisia tridentata ssp. wyomingensis | Artemisia tridemtata wyomingen | Wyoming big sagebrush |
| ARTR4 | 40 | | 38-50 | | | Artemisia tripartita | Artemisia tripartita | Threetip sagebrush |
| ARCA13 | 35 | 50 | 70 | | | Artemisia cana | Artemisia cana | Silver sagebrush |
| ARFI2 | 40 | 55 | 75 | | | Artemisia filifolia | Artemisia filifolia | Sand sagebrush |
| ATCA2 | 58 | | | 60 | | Atriplex canescens | Atriplex canescens | Fourwing saltbush |
| ATCO | 40 | 60 | 75 | | | Atriplex confertifolia | Atriplex confertifolia | Shadscale |
| Cespp | | | | 70 | | Ceanothus species | Ceanothus species | Snowbrush |
| ERNAO | 30-40 | 45-50 | 55-60 | 65 | 70+ | Ericameria nauseosa ssp. consimilis | Chrysothamnus nauseosus | Rubber rabbitbrush |
| CHVI8 | 30 | 37-45 | 50-60 | 65 | 70+ | Chrysothamnus viscidiflorus | Chrysothamnus viscidiflorus | Green rabbitbrush |
| EPVI | 10 | | | 55 | | Ephedra viridis | Ephedra spp | Mormon-tea |
| KRLA2 | 20-25 | 60-67 | 65 | | | Krascheninnikovia lanata | Eurotia lanata | Winterfat |
| FLCE | | | | | 63 | Flourensia cernua | Flourensia cernua | Tar bush |
| HODI | 50 | | | | | Holodiscus discolor | Holodiscus discolor | Oceanspray |
| MENOD | | 40 | | 50 | | Menodora | Menodora spp | Twinberry |
| NOLIN | | | | 60 | | Nolina | Nolina spp | Beargrass (leaves only) |
| OPUNT | | | | 30 | | Opuntia | Opuntia spp | Pricklypear (fruit only) |
| OPUNT | 10 | 15 | 13-20 | 10* | 70** | Opuntia | Opuntia spp. | Pricklypear |
| PHLE4 | 33 | | | | | Philadelphus lewisii | Philadelphus lewisii | Mockorange |
| PHMA5 | | | | 74 | | Physocarpus malvaceus | Physocarpus malvaceus | Ninebark |
| PUTR2 | 30-35 | 40-45 | 55-65 | 65 | | Purshia tridentata | Purshia tridentata | Bitterbrush |
| RHTR | | | | 50 | | Rhus trilobata | Rhus trilobata | Skunkbush sumac |
| RIBES | | | 45 | | | Ribes | Ribes | Currant |
| ROWO | 20-25 | 35 | 35-50 | 50* | 85** | Rosa woodsii | Rosa spp. | Rose |
| SAVE4 | 35 | 38-45 | 60 | | | Sarcobatus vermiculatus | Sarcobatus vermiculatus | Greasewood |
| SEFLF | | | | 20* | | Senecio flaccidus | Senecio longilobus | Woolly groundsel |
| SYAL | 25-30 | 35-40 | 65 | 30-40* | 85** | Symphoricarpos albus | Symphoricarpos spp | Snowberry |
| TECA2 | | | 55 | 70 | | Tetradymia canescens | Tetradymia canescens | Horsebrush |

**NATIVE TREE/SHRUB**

| PLANT CODE | 1 | 2 | 3 | 4 | 5 | PRESENT SCIENTIFIC NAME | HISTORIC SCIENTIFIC NAME | COMMON NAME |
|---|---|---|---|---|---|---|---|---|
| ACGL | 30 | | | | | Acer glabrum | Acer glabrum | Rocky Mtn. maple |
| AMAL2 | 35 | 45 | 85 | 30* | 85** | Amelanchier alnifolia | Amelanchier alnifolia | Serviceberry |
| CEVE | 35 | 45 | 50 | 65 | | Ceanothus velutinus | Ceanothus velutinus | Snowbrush |
| JUOS | | | 58 | | | Juniperus osteosperma | Juniperus osteosperma | Utah Juniper |
| JUSC2 | 45 | 55 | 60 | 35* | 85** | Juniperus scopulorum | Juniperus scopulorum | Rocky MountainJuniper |
| POTR5 | 20 | 20 | 37-50 | 52-56 | | Populus tremuloides | Populus tremuloides | Quaking aspen |
| PREM | | | 43 | 69 | | Prunus emarginata | Prunus emarginata | Bitter-cherry |
| PRVI | 30 | 40-46 | 65 | 40* | 90** | Prunus virginiana | Prunus virginiana | Chokecherry |
| SALIX | | 30 | | | | Salix | Salix spp. | Willow |
| SANIC6 | 15 | 45 | 60 | 30* | 80** | Sambucus cerulea | Sambucus cerulea | Elderberry |

4 of 4

# Appendix B

## Relative Forage Preference of Plants for Grazing Use by Season in Idaho

## Relative Forage Preference Of Plants For Grazing Use by Season

Idaho NRCS 2-2009

1= Preferred 2= Desirable * = May be Poisonous or Otherwise Injurious 2*= Desirable but possibly injurious

| COMMON PLANT NAME | Pl. Sym | Pl. Chr | CATTLE | | | | SHEEP | | | | HORSES | | | | ELK | | | | DEER | | | | ANTELOPE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W | SP | SU | F | W | SP | SU | F | W | SP | SU | F | W | SP | SU | F | W | SP | SU | F | W | SP | SU | F |
| Rockymountain Maple | ACGL | NT | | | | | | | | | | | | | | | | | 1 | | 2 | | | | | |
| Needlegrass | ACHNA | PNG | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Indian Ricegrass | ACHY | PNG | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Letterman Needlegrass | ACLE9 | PNG | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Common Yarrow | ACMI2 | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Western Yarrow | ACMIL | PNF | | 2 | | 2 | | 2 | | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | | | |
| Columbia Needlegrass | ACNE9 | PNG | 2 | 1 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Western Needlegrass | ACOC3 | PNG | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Swallen Ricegrass | ACSW3 | PNG | 2 | 1 | 1 | 2 | | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 1 | | 2 | | 1 | 2 | 2 |
| Thurber Needlegrass | ACTH7 | PNG | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Cusick Gianthyssop | AGCU | PNF | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Redtop Bentgrass | AGGI2 | PIG | 2 | 1 | 1 | 2 | | 1 | 2 | | 2 | 1 | 1 | 2 | | 1 | 2 | | | 2 | | | | | | |
| Mountain Agoseris | AGGL | PNF | | 2 | | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Bentgrass | AGROS2 | PNF | 2 | 1 | 1 | 2 | | 1 | 2 | | 2 | 1 | 1 | 2 | | 1 | 2 | | | 2 | | | | 2 | | |
| Nettleleaf Gianthyssop | AGUR | PNF | | 2 | 2 | 2 | | 1 | 1 | 2 | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Onion | ALLIU | PNF | | 1 | | | | 1 | 2 | | | | | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Serviceberry | AMELA | NS | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Fiddleneck | AMSIN | ANF | | | | | | | | | | | | | | | | | | | | | | | | |
| Pussytoes | ANTEN | PNF | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Pussytoes | ANTEN | PNF | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Dogbane | APOCY | PNF | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | 2 | | | | | |
| Rockcress | ARABI2 | PNF | | | | | | | | | | | | | | | | | 2 | 2 | | 2 | 2 | 2 | | 2 |
| Low Sagebrush | ARAR8 | NS | | | | | | | 2 | 2 | | | | | | | | | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| Alkali Sagebrush | ARARL | NS | | | | | 2 | | | 2 | | | | | | | | | 2 | 2 | 2 | 2 | | 1 | 1 | 1 |
| Silver Sagebrush | ARCA13 | NS | 2 | | | 2 | | | 2 | 2 | 2 | | | 2 | 2 | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Heartleaf Arnica | ARCO9 | PNF | | 2 | | | | 2 | 2 | | | 2 | 2 | | | 1 | 1 | | | 2 | 2 | | | | | |
| Herbaceous Sagewort | ARDR4 | PNF | | | | | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 |
| Sandwort | ARENA | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Fringed Sagebrush | ARFR4 | NHS | | | | | 2 | | | 2 | | | | | 2 | | | | 2 | | | | 2 | 2 | 2 | 2 |
| Louisiana Sagewort | ARLU | PNF | | | | | | | | 2 | | | | | | | | | 2 | 2 | 2 | 2 | | 1 | 1 | 1 |
| Black Sagebrush | ARNO4 | NS | | | | | 1 | 2 | 2 | 1 | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Red Threeawn | ARPUL | PNG | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Stiff Sagebrush | ARRI2 | NS | | | | | | | | | | | | | | | | | | | | | | | | |
| Threetip Sagebrush | ARTR4 | NS | | | | | | | | | | | | | | | | | 2 | 2 | | | | | | |
| Subalpine Big Sagebrush | ARTRS2 | NS | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Basin Big Sagebrush | ARTRT | NS | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Mountain Big Sagebrush | ARTRV | NS | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | | | | | 2 | | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Wyoming Big Sagebrush | ARTRW8 | PNS | 2 | | | | 2 | | | | | | | | 2 | | | | 2 | 2 | 2 | 2 | | 1 | 1 | 1 |
| Foothills Big Sagebrush | ARTRX | NS | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Bearberry | ARUV | NS | | | | | | | | | | | | | | | | | 2 | 2 | | 2 | | | | |
| Aster * | ASTER | PNF | | | | | | 2 | 2 | | | | | | | | | | 2 | | 2 | 2 | | 2 | 2 | |
| Milkvetch | ASTRA | PNF | | * | * | | | * | * | | | * | * | | | | | | | | 2 | | | 2 | 2 | |
| Fourwing Saltbush | ATCA2 | NS | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | | | | | | | | | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Shadscale Saltbush | ATCO | NS | 2 | 1 | | 2 | 2 | 1 | | 2 | | | | | 2 | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Nuttall Saltbush | ATNU2 | NHS | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Hooker's Balsamroot | BAHO | PNF | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | 2 | | | 2 | 2 | |
| Cutleaf Balsamroot | BAMA4 | PNF | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | 2 | | | 2 | 2 | |
| Arrowleaf Balsamroot | BASA3 | PNF | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | | 2 | 1 | 1 | 2 | | 1 | 1 | |
| Nodding Brome | BRAN | PNG | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Rattlesnake Brome | BRBR5 | AIG | | 1 | 2 | 2 | | 1 | | 2 | | 1 | 2 | 2 | | 1 | | 2 | | 1 | | 1 | | 1 | | 1 |
| California brome | BRCA5 | PNG | | 1 | 2 | 2 | | 1 | | 2 | 1 | 2 | 2 | | | 1 | | 2 | | 1 | | 1 | | 1 | | 1 |
| Mountain Brome | BRCA5 | PNG | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 2 | | | | 2 | | |
| Japanese Brome | BRJA | AIG | | 1 | 2 | 2 | | 1 | | 2 | | 1 | 2 | 2 | | 1 | 2 | | | 2 | | | | 2 | | |
| Cheatgrass Brome | BRTE | AIG | | 1 | 2* | 2* | | 1 | * | 2* | | 1 | 2* | 2* | | 1 | * | 2* | | 1 | * | 1* | | 1 | * | 1 |
| Columbia Brome | BRVU | PNG | 2 | 2 | 2 | 2 | | 2 | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Douglas Sedge | CADO2 | PNGL | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Mariposa Lily | CAEU | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Threadleaf Sedge | CAFI | PNGL | 2 | 1 | 2 | 2 | | 2 | | | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Elk Sedge | CAGE2 | PNGL | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | | 2 | | | | 2 | |
| Camas | CAMAS | PNF | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | 2 | | | 2 | 2 | |
| Nebraska Sedge | CANE2 | PNGL | 2 | 1 | 1 | 2 | | 2 | | | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Liddon's Sedge | CAPE7 | PNGL | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Sedge | CAREX | PNGL | 2 | 2 | 2 | 2 | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Pine Reedgrass | CARU | PNG | | 2 | 2 | 2 | | | | | | | | | | 2 | 2 | 2 | | 2 | | | | 2 | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indian Paintbrush | CASTI2 | PNF | | 2 | | | | 2 | 2 | | | | | | | 2 | | | | 2 | 2 | | | 2 | 2 | |
| Curleaf Mountain Mahog. | CELE3 | NS | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | | | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| Redstem Ceanothus | CESA | PNS | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | | |
| Snowbrush Ceanothus | CEVE | NS | | | | | | | | | | | | | 2 | 2 | 2 | 2 | | 1 | 1 | | | | | |
| Salmonriver Rabbitbrush | CHPAI3 | NS | | | | | | | | | | | | | | | | | | | | | | | | |
| Tallgreen Rabbitbrush | CHVI8 | NS | | | | 2 | | | | 2 | | | | | | | | | 2 | | | | | | | 2 |
| Twistedleaf Rabbitbrush | CHVIP4 | NS | | | | | | | | | | | | | | | | | 2 | | | | 2 | | | |
| Varied Green Rabbitbrush | CHVIV | NS | | | | 2 | | | | 2 | | | | | | | | | 2 | | | | | | | 2 |
| Dwarfgreen Rabbitbrush | CHVIV4 | NS | | | | 2 | | | | 2 | | | | | | | | | 2 | | | | | | | 2 |
| Thistle | CIRSI | BNF | | | | | | | | | | 2 | 2 | | | 2 | 2 | | | | | | | | | |
| False Toadflax | COMAN | PIF | | | | | | | | | | | | | | | | | | | | | | | | |
| Tapertip Hawksbeard | CRAC2 | PNF | | 2 | 2 | | | 1 | 1 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Cryptantha | CRYPT | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| California Danthonia | DACA3 | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | | | 2 | | | | 2 | | |
| Shrubby Cinquefoil | DAFL3 | NS | | | | | | | | | | | | | 2 | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Timber Danthonia | DAIN | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Onespike Danthonia | DAUN | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Low Larkspur | DEBI | PNF | 2 | * | * | | | 2 | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Tufted Hairgrass | DECA18 | PNG | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 2 | | | | 2 | | |
| Tansy Mustard | DESCU | BNF | | 2* | * | | | 2 | 2 | | | 2 | | | | 2 | | | | 2 | | | | 2 | | |
| Inland Saltgrass | DISP | PNG | 2 | 2 | 2 | | | 2 | | | 2 | 2 | 2 | | 2 | 2 | 2 | | | 2 | | | | 2 | | |
| Bottlebrush Squirreltail | ELELE | PNG | | 2 | 2 | | | 2 | | | | 2 | | 2 | | 2 | | 2 | | 2 | | | | 2 | | |
| Blue Wildrye | ELGL | PNG | | 2 | 2 | | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | | |
| Streambank Wheatgrass | ELLA3 | PNG | 2 | 1 | 2 | 2 | | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Thickspike Wheatgrass | ELMA7 | PNG | 2 | 1 | 2 | 2 | | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Quackgrass Wheatgrass | ELRE4 | PIG | | 2 | | | | | | | | 2 | | | | 2 | | | | 1 | 2 | | | 2 | 2 | |
| Slender Wheatgrass | ELTR7 | PNG | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Willowweed | EPILO | PNF | | 2 | | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | 2 | | | 2 | 2 | |
| Cutleaf Filaree | ERCI6 | AIF | | 1 | 1 | 2 | | 1 | 1 | 2 | | 1 | 1 | 2 | | 1 | 1 | 2 | | 1 | 1 | 2 | | 1 | 1 | 2 |
| Wyeth Eriogonum | ERHE2 | NHS | | | 2 | | | 2 | 2 | | | | | | | | | | | | | | | | | |
| Fleabane | ERIGE2 | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Eriogonum | ERIOG | NHS | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Tallgrey Rabbitbrush | ERNA10 | NS | | | | 2 | | | | 2 | | | | 2 | | | | | 2 | | | | 2 | | | |
| Dwarfgray Rabbitbrush | ERNAN4 | NS | | | | 2 | | | | 2 | | | | | | | | | 2 | | | | | | | 2 |
| Broadleaf Eriogonum | ERNEH | NHS | | | 2 | | | 2 | 2 | | | | | | | | | | | | | | | | | |
| Wallflower | ERYSI | PNF | | | | | | 2 | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Rough Fescue | FECA4 | PNG | | | | | | | | | | | | | | | | | | | | | | | | |
| Idaho Fescue | FEID | PNG | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Western Fescue | FEOC | PNG | 2 | 2 | 2 | 2 | | 2 | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Green Fescue | FEVI | PNG | | | 2 | 2 | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | 2 | | | 2 | | | | | |
| Strawberry | FRAGA | PNF | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Whitestemmed Elkweed | FRAL2 | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Northern Bedstraw | GABO2 | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Richardson Geranium | GERI | PNF | | 2 | 2 | | | 1 | 1 | | | 2 | 2 | | | 2 | 2 | | | 1 | 1 | | | 2 | 2 | |
| Sticky Geranium | GEVI2 | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Spiny Hopsage | GRSP | NS | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Curlycup Gumweed | GRSQ | BNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Broom Snakeweed | GUSA2 | NHS | | | | | 2 | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | 2 | 2 |
| Stickseed | HACKE | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Halogeton | HAGL | AIF | * | * | * | * | * | * | * | * | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Goldenweed | HAPLO2 | PNF | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Common Sunflower | HEAN3 | ANF | | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | |
| Needle and thread Grass | HECO26 | PNG | 2 | 1 | 2 | 2 | 2* | 1 | 2 | 2** | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | * | 2* | | 2 | * | 2* |
| Helianthella | HELIA | PNF | | 2 | 1 | | | 1 | 1 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Common Cowparsnip | HEMA80 | PNF | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Alumroot | HEUCH | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| White Hawkweed | HIAL2 | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Albert Hawkweed | HICY | PNF | | 2 | 2 | | | 1 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Woolyhawkweed | HISC2 | PNF | | 2 | | | | 1 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Creambush Oceanspray | HODI | NS | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Foxtail Barley | HOJU | PNG | * | 2 | 2 | * | * | 2 | * | * | * | 2 | 2* | * | * | 2 | * | * | * | 2 | * | * | * | 2 | * | * |
| Rockymountain Iris | IRMI | PNF | | | | | | | | | | | | | | | | | | 2 | 2 | | | | | |
| Rush | JUNCU | PNGL | | | | | | | | | | | | | | | | | | | | | | | | |
| Juniper | JUNIP | NT | | | | | | | | | | | | | | | | | 1 | 2 | | 2 | 1 | | | |
| Prairie Junegrass | KOMA | PNG | 2 | 2 | 2 | 2 | | 2 | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Belvedere Summercypress | KOSC | AIF | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Common Winterfat | KRLA2 | NS | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | | 2 | 2 | | 2 | 2 | 2 | 2 |
| Lettuce | LACTU | AIF | | 2 | | | | 1 | 2 | | | 2 | 2 | | | 2 | 2 | | | 1 | 1 | | | 1 | 1 | |
| Peavine | LATHY | PNF | | 2 | 2 | | | 2 | 1 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Colorado wildrye | LEAM | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | | | 2 | | | | 2 | | |
| Basin Wildrye | LEC14 | PNG | 2 | 2 | 2 | | | 2 | | | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | | | 2 | | |

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| Yellow Wildrye | LEFL4 | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Spike Fescue | LEKI2 | PNG | | 2 | 2 | | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | | | 2 | | | | 2 | | |
| Pepperweed | LEPID | ANF | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | |
| Bitterroot Lewisia | LERE7 | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Salmon Wildrye | LESA2 | PNG | 2 | 1 | 1 | 2 | | 1 | 2 | | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 2 | | | | 2 | | |
| Bladderpod | LESQU | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Creeping Wildrye | LETR5 | PNG | 2 | 1 | 2 | 2 | | 2 | | | 2 | 1 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Lewisia | LEWIS | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Licoriceroot | LIGUS | PNF | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Twinflower | LINNA | PNG | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | | | | | |
| Lewis Flax | LIPE2 | PIS | | | | | | | | | | | | | | | | | | | | | | | | |
| White Stoneseed | LIRU4 | PNF | | | 2 | 2 | | 2 | 2 | 2 | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Butterand eggs Toadflax | LIVU2 | PIF | | | | | | | | | | | | | | | | | | | | | | | | |
| Biscuitroot | LOMAT | PNF | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | | | 2 | 2 | |
| Honeysuckle | LONIC | PNS | | | | | | | | | | | | | 2 | | | | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Lupine | LUPIN | PNF | | * | | | | 2* | 2 | | | * | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Rush Skeletonplant | LYJU | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Fat Falsesolomonseal | MARAR | PNF | | 2 | 2 | | | 1 | 1 | 2 | | 2 | 2 | | | 2 | 2 | | | 1 | 1 | 2 | | 2 | 2 | |
| Low Oregon Grape | MARE11 | PNS | | | | | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 |
| Starry Falsesolomonseal | MAST4 | PNF | | 2 | 2 | | | 1 | 1 | 2 | | 2 | 2 | | | 2 | 2 | | | 1 | 1 | 2 | | 2 | 2 | |
| Bulbous Oniongrass | MEBU | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Bluebell | MERTE | PNF | | 2 | 2 | | | 1 | 1 | | | 2 | | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Purple Oniongrass | MESP | PNG | 2 | 1 | 1 | 2 | | 1 | 2 | | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 1 | | | | 1 | | |
| Alkali Muhly | MUAS | PNG | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| Mat Muhly | MURI | PNG | | 2 | 2 | | | 2 | | | | 2 | 2 | | | 2 | 2 | | | 2 | | | | 2 | | |
| Plains Pricklypear | OPPO | NS4S | | * | * | | | * | * | | | | | | | | | | | | | | 2 | 2 | 2 | 2 |
| Little Ricegrass | OREX | PNG | | 2 | 2 | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Owlclover | ORTHO | ANF | | | | | | | | | | | | | | | | | | | | | | | | |
| Sweetroot | OSMOR | PNF | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | 2 | | | 2 | 2 | |
| Western Wheatgrass | PASM | PNG | 2 | 1 | 2 | 2 | | 2 | | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 1 | | | | 2 | | |
| Lousewart | PEDIC | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Penstemon | PENST | PNF | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Phacelia | PHACE | ANF | | | | | | | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Alpine Timothy | PHAL2 | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 2 | | | 1 | 2 | | |
| Hoods Phlox | PHHO | PNF | | | | | | 2 | | | | | | | | | | | | | | | | 2 | | |
| Longleaf Phlox | PHLO2 | PNF | | | | | | 2 | | | | 2 | 2 | 2 | | | | | | | | | | 2 | | |
| Phlox | PHLOX | PNF | 2 | 2 | | | 2 | 2 | 2 | | 2 | 2 | | | 2 | 2 | | | | 2 | | | | 2 | | |
| Mallow Ninebark | PHMA5 | NS | | | | | | | | | | | | | 2 | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Bud Sagebrush | PIDE4 | NS | | 2* | | | 2* | 1* | 2* | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Big Bluegrass | POAM | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | | 1 | | | | 1 | | |
| Bluegrass | POAM | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | | 1 | | 2 | | 1 | | 2 |
| Bulbous Bluegrass | POBU | PIG | | 2 | | 2 | | 2 | | | | 2 | 2 | 2 | | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Cusick Bluegrass | POCU3 | PNG | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Alkali Bluegrass | POJU | PNG | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Nerved Bluegrass | PONE2 | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Kentucky Bluegrass | POPR | PIG | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Cottonwood | POPUL | NT | | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Pine Bluegrass | POSC | PNG | 2 | 1 | 2 | 1 | | 1 | | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | | 2 | | | | 2 | | |
| Nevada Bluegrass | POSE | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 2 | | 1 | | 2 |
| Sandberg Bluegrass | POSE | PNG | 2 | 2 | 2 | 2 | | 1 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 1 | | 2 | | 1 | | 2 |
| Cinquefoil | POTEN | PNF | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Quaking Aspen | POTR5 | PNT | | 2 | | | | | 1 | 2 | | | | | | 2 | | | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Bittercherry | PREM | NT | | | 2 | | | | 2 | | | | | | | | 2 | | 2 | 2 | 2 | 2 | | 2 | 2 | 2 |
| Black Chokecherry | PRVI | NT | | * | * | 2 | | * | * | 2 | | | | | | | | | 2 | 1 | 1 | | | 2 | | |
| Common Chokecherry | PRVI | NT | | * | * | 2 | | * | * | 2 | | | | | | | | | 2 | 1 | 1 | 2 | | 2 | | |
| Scurfpea | PSORA | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Foxtail Wheatgrass | PSSA2 | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | | 1 | | 2 | | 1 | | 2 |
| Beardless Wheatgrass | PSSPI | PNG | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | | 1 | | | | 1 | | |
| Bluebunch Wheatgrass | PSSPS | PNG | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | | 2 | | 1 | | 2 |
| Brackenfern | PTAQ | PNF | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | | | | | | |
| Antelope Bitterbrush | PUTR4 | NS | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| Buttercup | RANUN | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Currant | RIBES | NS | | | | 2 | | | | 2 | | | | | | | | 2 | | 2 | 2 | | | 2 | 2 | |
| Baldhip Rose | ROGY | NS | | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Rose | ROSA | PNS | | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Woods Rose | ROWO | NS | | | 2 | 2 | | | 2 | 2 | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Blackberry | RUBUS | NS | | | | | | | | | | | | | | | | | | | 2 | | | | | |
| Western Coneflower | RUOC2 | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Western Thimbleberry | RUPA | PNS | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | | | | |
| Willow | SALIX | NT | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Elderberry | SAMBU | NS | 2 | | 1 | 2 | 2 | | 1 | 1 | | | | | 2 | | 2 | 2 | | 1 | 1 | | | 1 | 1 | |

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| Scoular Willow | SASC | NT | | | 2 | | | | 2 | 2 | | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Black Greasewood | SAVE4 | NS | 2 | 2* | | | 2 | 2* | | | 2 | 2 | | | | | | | 2 | | | | 2 | | | |
| Bulrush | SCIRP | | | | | | | | | | | | | | | | | | | | | | | | | |
| Stonecrop | SEDUM | PNS4F | | | | | | | | | | | | | | | | | | 2 | | | | 2 | | |
| Butterweed Groundsel | SESE2 | PNF | | 2 | 2 | | | 2 | 1 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Goldenrod | SOLID | PNF | | | | | | 2 | 2 | | | | 2 | 2 | | | | | | 2 | 2 | | | 2 | 2 | |
| Mountain Ash | SORBU | NS | | | | | | | | | | | | | 2 | | 2 | 2 | | | | | | | | |
| Alkali Sacaton Dropseed | SPAI | PNG | 2 | 2 | 1 | | | | 2 | | 2 | 2 | 1 | | | 2 | | | | | | | | | | |
| Nuttal Tansy | SPAR2 | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Globemallow, Scarlet | SPCO | PNF | | | | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Scarlet Globemallow | SPCO | PNF | | 2 | 2 | | | 1 | 2 | 2 | | 2 | 2 | | | 2 | 2 | | | 1 | 2 | 2 | | 1 | 2 | 2 |
| Sand Dropseed | SPCR | PNG | 2 | 2 | 2 | 2 | | 2 | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Alkali Cordgrass | SPGR | PNG | 2 | 2 | 2 | 2 | | 2 | | | 2 | 2 | 2 | 2 | | 2 | | | | | | | | | | |
| Spirea | SPIRA | NS | | | | 2 | | | | | | | | | | | | 2 | 2 | | 2 | 2 | 2 | | | 2 |
| Prairie Cordgrass | SPPE | PNG | | 2 | 2 | | | 2 | | | | 2 | 2 | | | 2 | 2 | | | 2 | | | | 2 | | |
| Common Snowberry | STAL | NS | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Lemmon Needlegrass | STLE2 | PNG | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | | | | 2 | | |
| Thorn Skeletonweed | STSP6 | PNF | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | | | | | | |
| Western Snowberry | SYOC | NS | | | | | | | 2 | 2 | | | | | | | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| Mountain Snowberry | SYOR2 | NS | | | 2 | 2 | | | 1 | 1 | | | 2 | 2 | | | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Utah Snowberry | SYORU | NS | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Medusahead Wildrye | TACA8 | AIG | | 2 | 2 | | | | | | | 2 | 2 | | | 2 | | | | 2 | | | | 2 | | |
| Dandelion | TAOF | PIF | | 1 | 2 | 2 | | 1 | 1 | 2 | | 1 | 2 | 2 | | 1 | 2 | 2 | | 1 | 2 | 2 | | 1 | 2 | 2 |
| Gray Horsebrush | TECA2 | NS | | | | | * | * | * | * | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Littleleaf Horsebrush | TEGL | NS | | | | | * | * | * | * | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Nuttall Horsebrush | TENU2 | NS | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Spiny Horsebrush | TESP2 | NS | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | | | | | | |
| Meadowrue | THALI2 | PNF | | | | | | 2 | 1 | 2 | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Thermopsis | THERM | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Townsendia | TOWNS | BNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Arrowgrass | TRCO4 | PNF | * | * | * | * | * | * | * | * | | * | * | * | | | | | | | | | | | | |
| Salsify | TRDU | AIF | | 1 | 2 | | | 1 | 1 | 2 | | 1 | 2 | | | | | | | | | | | | | |
| Douglas Broadiaea | TRGRG2 | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Clover | TRIFO | PNF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 2 | 2 | | | 2 | 2 | |
| Trisetum | TRISE | | 2 | 1 | 2 | 2 | | 2 | | | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Spike Trisetum | TRSP2 | PNG | 2 | 1 | 2 | 2 | | 2 | | | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | | 2 | | | | 2 | | |
| Blueberry | VACCI | NS | | | | | | | | | | | | | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Valerian | VALER | PNF | | | 2 | | | 2 | | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Falsehellebore | VECA2 | PNF | | * | * | * | | * | * | * | | | | | | | | | | 2 | 2 | | | | | |
| American Vetch | VIAM | PNF | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 2 | 2 | | | 2 | 2 | |
| Vetch | VICIA | PNF | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | | 2 | 2 | | | 2 | 2 | |
| Violet | VIOLA | PNF | | | 2 | | | 2 | 2 | | | | | | | | | | | 2 | 2 | | | 2 | 2 | |
| Hairy Winter Vetch | VIVI | PIF | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | | | 2 | 2 | |
| Sixweeks Fescue | VUOC | ANG | | | | | | | | | | | | | | | | | | | | | | | | |
| Mulesear Wyethia | WYAM | PNF | | | | | | | | | | | | | | 2 | | | | 2 | 2 | | | 2 | | |
| Whitehead Wyethia | WYHE2 | PNF | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | 2 | | | | | |
| Wooly Wyethia | WYMO | PNF | | 2 | | | | 2 | | | | 2 | | | | 2 | | | | 2 | 2 | | | | | |
| Common Beargrass | XETE | PNF | | | | | | | | | | | | | | | | | | | | | | | | |
| Deathcamas | ZIGAD | PNF | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | | | | | | |

# Appendix C

## Example Calculations and Related Documents

The following is an example of how to calculate estimated stocking rates from data collected during the inventory process. Maps are included for reference.

- **ID-CPA-006 Similarity Index Worksheet** – This form estimates total annual production for the Loamy 16+ ecological site found on the Summer Place grazing unit.

To calculate AUM's/acre based upon total production use this formula:

AUM's/ac = Total Production (lbs per acre) / 912.5 lbs per AUM x % Harvest Efficiency (HE) x Acres

AUM's/ac = 1157 lbs per acre / 912.5 lbs per AUM x 25% HE

= 0.32 AUM's/ac

- **ID-CPA-013 Stocking Rate and Forage Value Rating** – This form estimates stocking rate by plant preference ratings. Harvest efficiencies are applied to total production by species based upon animal preference values by season. Harvest efficiency (HE) for preferred is 35%, desirable is 25%, and undesirable 15%.

To calculate use total production values from ID-CPA-006 and separate by Plant preference as shown on the ID-CPA-013.

For Cattle we would use 1157 lbs/ac for the Loamy 16+ ecological site divided into the three categories:

$$\text{AUM's/ac} = \frac{(\text{preferred production x 35\% HE}) + (\text{desirable production x 25\% HE}) + (\text{undesirable production x 15\% HE})}{\text{912.5 lbs per AUM}}$$

$$\text{AUM's/ac} = \frac{(\text{334 lbs per acre x 35\% HE}) + (\text{631 lbs per acre x 25\% HE}) + (\text{175 lbs per acre x 15\% HE})}{\text{912.5 lbs per AUM}}$$

AUM's/ac = 300.9 / 912.5

= 0.33 AUM's/ac

- **ID-CPA-008 Range & Pasture Computation Worksheet** – This form allows you to summarize data collected and provide for additional adjustment to estimated stocking rates due to slope percent and distance to water. By using response units a manger or conservation planner may be able to identify opportunities to improve access to available resources. For this example the response units are composed of Ecological Site, Distance to Water, and % Slope.

For the Summer Place grazing unit we can estimate that there are 548 total AUM's available.

Now that we have calculated an estimated amount for total AUM's at the summer place we can determine the time and numbers of livestock that the grazing unit can support. Remember that these are only initial estimates with actual stocking rates adjusted according to monitoring data in conjunction with actual use, climate, and other pertinent data.

**Example 1 – How Many?**

The owner of the Summer Place grazing unit would like to know how many head he can graze from July 1st to August 30th in this pasture. The base herd of the ranch consists of Angus cross cattle averaging about 1200 lbs.

*AUM = # Head x AUE x Time (months)*

548 AUM's = # Head x 1.2 AU x 2 Months

548 AUM's = # Head x 2.4 AUM

548 AUM's / 2.4 AUM's = 228.33 or 229 Head from July 1st to August 30th

**Example 2 – How long?**

The owner of the Summer Place would like to know how long he can put 300 Angus cross cows and 12 Bulls in this unit. The AUE for the cows will remain at 1.2 and the Bulls should be 1.25 AU.

*AUM = # Head x AUE x Time (months)*

548 AUM's = (300 Head x 1.2 AU) + (12 Head x 1.25 AU) x Time

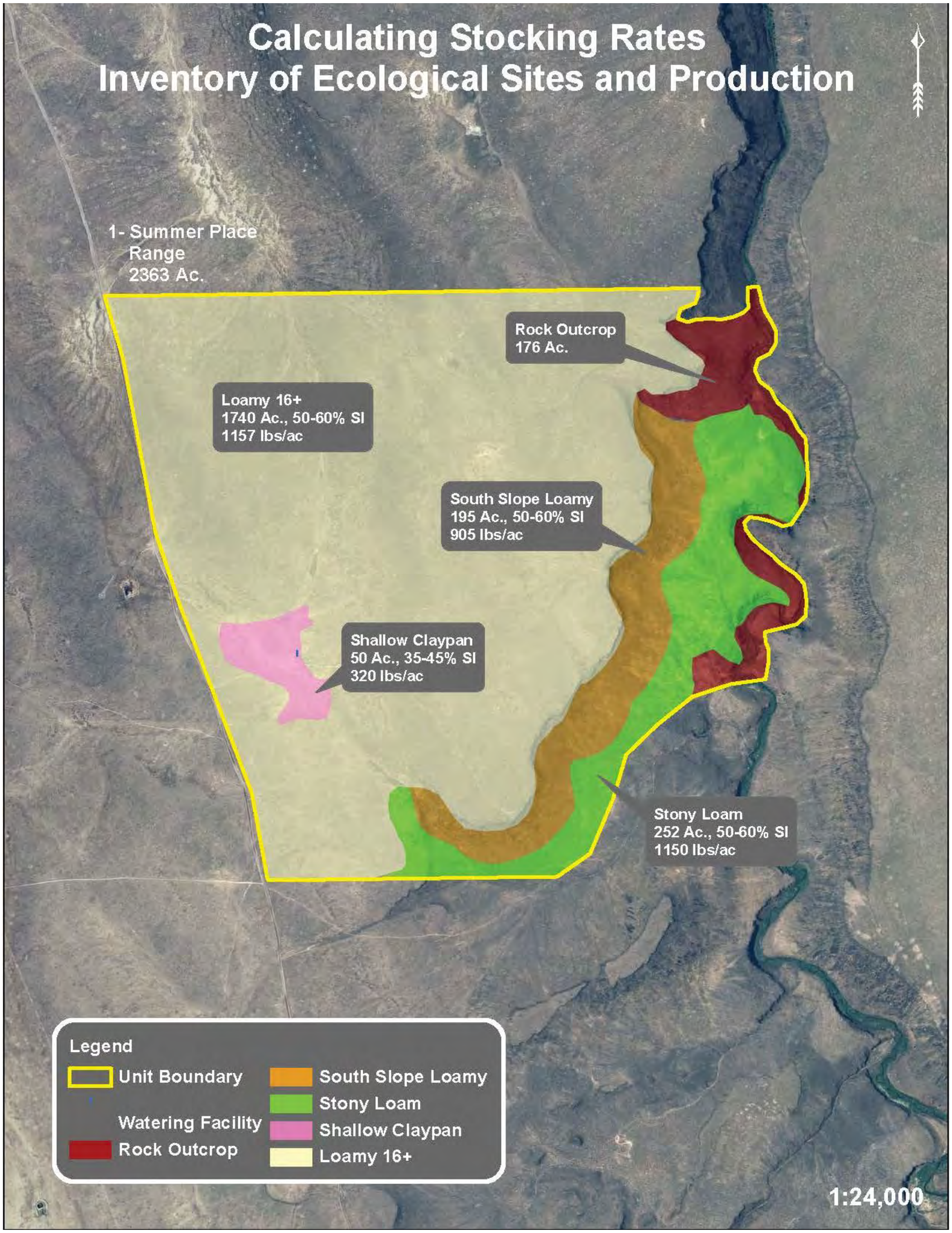
548 AUM's = (360 AU + 15 AU) x Time

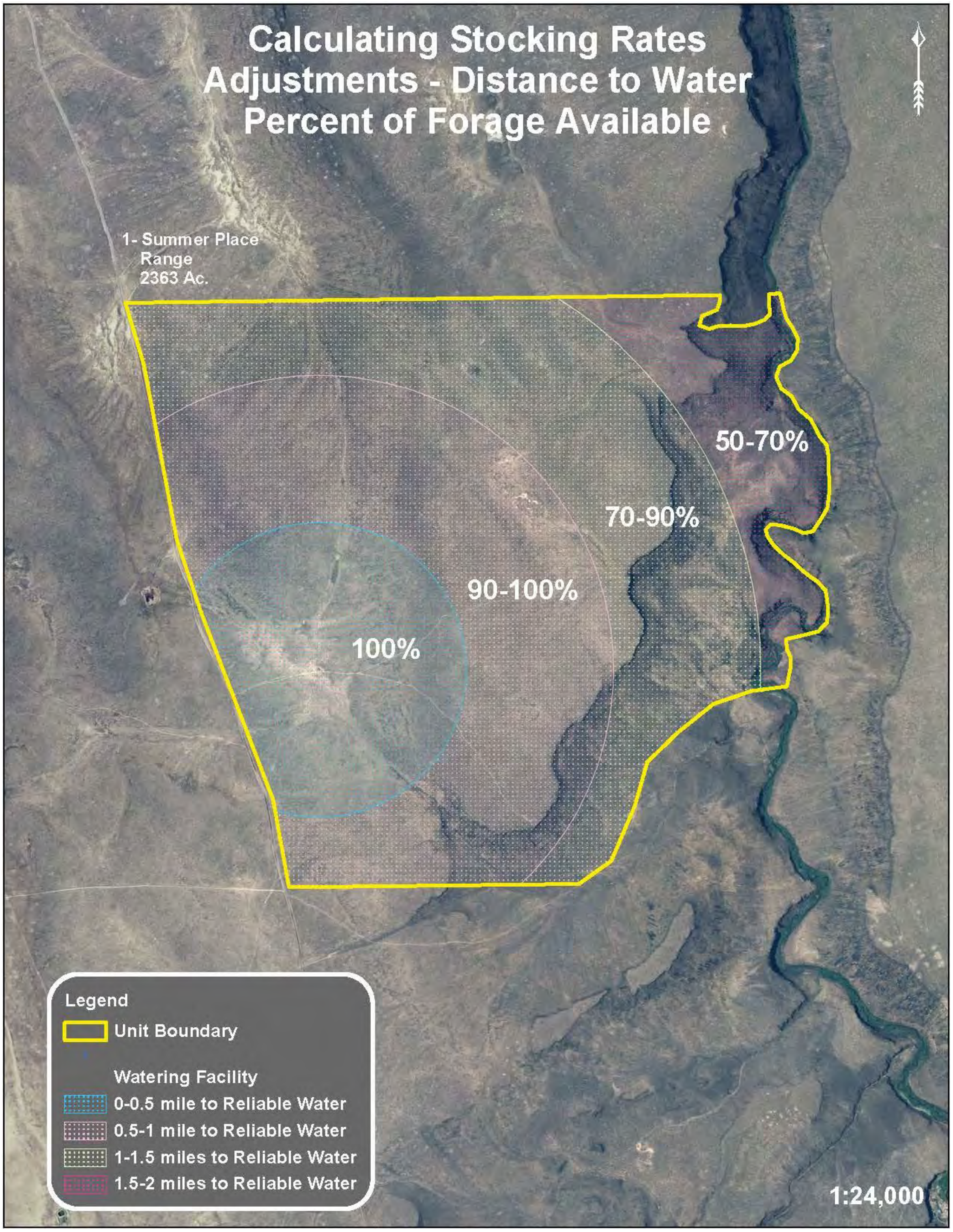
548 AUM's = 375 AU x Time

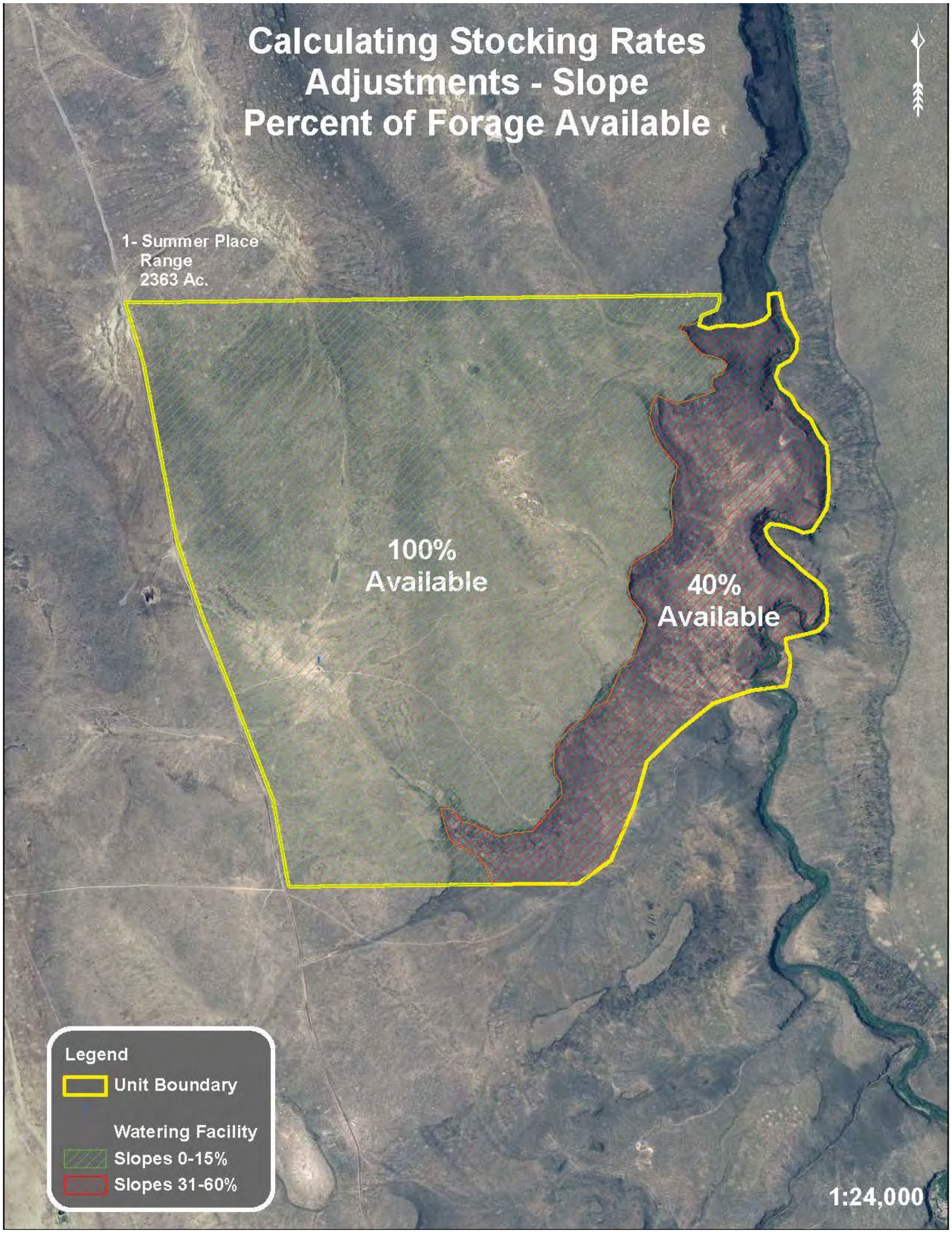
548 AUM's / 375 AU = 1.46 Months

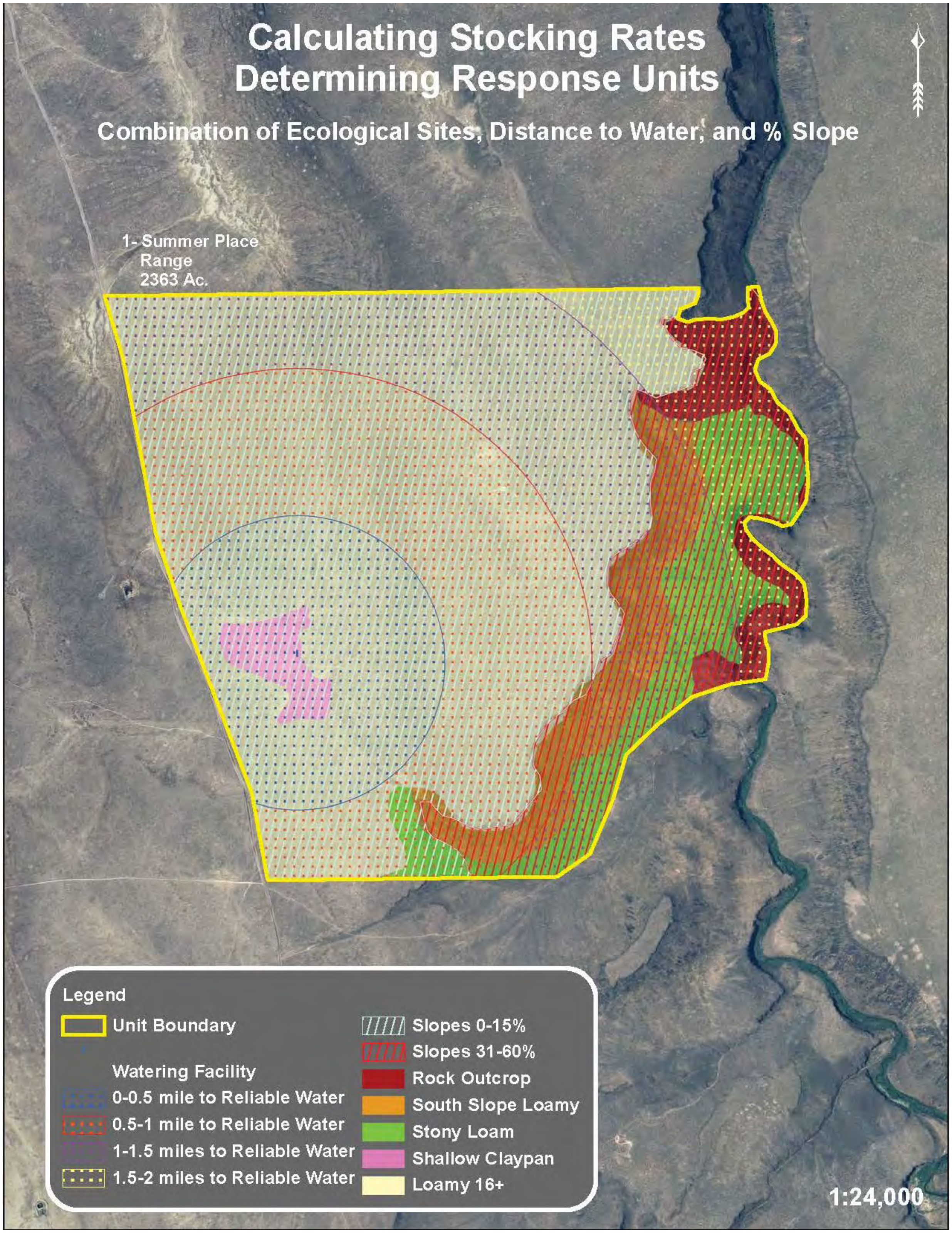
1.46 Months x 30.4 Days per Month *(365 day per year / 12 months)*

44.38 Or 44 Days which would be from July 1st through August 13th


Calculating Stocking Rates
Inventory of Ecological Sites and Production
1- Summer Place
Range
2363 Ac.
Rock Outcrop
176 Ac.
Loamy 16+
1740 Ac., 50-60% SI
1157 lbs/ac
South Slope Loamy
195 Ac., 50-60% SI
905 lbs/ac
Shallow Claypan
50 Ac., 35-45% SI
320 lbs/ac
Stony Loam
252 Ac., 50-60% SI
1150 lbs/ac
Legend
Unit Boundary
Watering Facility
Rock Outcrop
South Slope Loamy
Stony Loam
Shallow Claypan
Loamy 16+
1:24,000


Calculating Stocking Rates
Adjustments - Distance to Water
Percent of Forage Available
1- Summer Place
Range
2363 Ac.
50-70%
70-90%
90-100%
100%
Legend
Unit Boundary
Watering Facility
0-0.5 mile to Reliable Water
0.5-1 mile to Reliable Water
1-1.5 miles to Reliable Water
1.5-2 miles to Reliable Water
1:24,000


Calculating Stocking Rates
Adjustments - Slope
Percent of Forage Available
1- Summer Place
Range
2363 Ac.
100%
Available
40%
Available
Legend
Unit Boundary
Watering Facility
Slopes 0-15%
Slopes 31-60%
1:24,000


Calculating Stocking Rates
Determining Response Units
Combination of Ecological Sites, Distance to Water, and % Slope
1- Summer Place
Range
2363 Ac.
Legend
Unit Boundary
Watering Facility
0-0.5 mile to Reliable Water
0.5-1 mile to Reliable Water
1-1.5 miles to Reliable Water
1.5-2 miles to Reliable Water
Slopes 0-15%
Slopes 31-60%
Rock Outcrop
South Slope Loamy
Stony Loam
Shallow Claypan
Loamy 16+
1:24,000

NRCS
Natural Resources Conservation Service

**Prescribed Grazing - 528**
**Similarity Index Worksheet**

**ID-CPA-006**
**Idaho**
**February 2008**

**Client:** Example Production **Date:** 9/1/2008 **Transect No.:** ______ **Section:** ______

**Conservationist:** Range Guy **County:** South **GPS:** ______ **Township:** ______

**Ecological Site:** Loamy 16+ Artrv/Feid **MLRA:** 25 **Reference Vegetation State:** ______ **Range:** ______

Plant Information — Number of Plots in Transect: 10 — Estimated or Clipped Weight Per Species

Plot Size: 9.6

| A: Plant Name | P-1 | P-2 | P-3 | P-4 | P-5 | P-6 | P-7 | P-8 | P-9 | P-10 | A1: Average Plot/ Estimated Green Wt. (lbs/ac) | A2: Conversion Factor Used | A3: Estimated Weight (Weight Clipped Plots) | A4: Clipped Weight (Weight Clipped Plots) | A5: Clipped / Estimated plot conversion factor | B: Clip / Estimated corrected green weight (lbs/ac) | C*: % dry weight | D*: % current growth ungrazed | E*: % growth curve completed | F*: % of normal production | G: Reconstruction factor (d)(e)(f) | H: Reconstructed present weight (lbs/ac) | I: Weight in reference state (lbs/ac) | J: Weight allowable (lbs/ac) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FEID | 17 | 15 | 5 | 10 | 10 | 0 | 10 | 28 | 17 | 12 | 124.0 | 10.00 | 15 | 17 | 1.13 | 140.5 | 90% | 80% | 95% | 100% | 1.18 | 166.4 | 570 | 166.4 |
| PSSP6 | 0 | 0 | 20 | 25 | 5 | 35 | 10 | 0 | 0 | 16 | 111.0 | 10.00 | 41 | 44 | 1.07 | 119.1 | 90% | 80% | 95% | 100% | 1.18 | 141.1 | 110 | 110.0 |
| ACNE9 | 0 | 0 | 0 | 0 | 9 | 0 | 1 | 2 | 0 | 0 | 12.0 | 10.00 | 9 | 9 | 1.00 | 12.0 | 85% | 80% | 95% | 100% | 1.12 | 13.4 | 90 | 13.4 |
| ACOC3 | 8 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18.0 | 10.00 | 8 | 9 | 1.13 | 20.3 | 85% | 80% | 95% | 100% | 1.12 | 22.6 | 90 | 22.6 |
| PONE3 | 6 | 2 | 0 | 3 | 2 | 1 | 1 | 1 | 5 | 2 | 23.0 | 10.00 | 6 | 6 | 1.00 | 23.0 | 90% | 80% | 95% | 100% | 1.18 | 27.2 | 18 | 18.0 |
| BRJA | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 3 | 11.0 | 10.00 | 2 | 2 | 1.00 | 11.0 | 90% | 90% | 100% | 100% | 1.00 | 11.0 | 0 | 0.0 |
| POBU | 4 | 3 | 1 | 4 | 4 | T | 2 | 2 | 1 | 1 | 22.0 | 10.00 | 4 | 5 | 1.25 | 27.5 | 90% | 90% | 100% | 100% | 1.00 | 27.5 | 0 | 0.0 |
| ELEL5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 2 | 7.0 | 10.00 | 5 | 6 | 1.20 | 8.4 | 85% | 80% | 90% | 100% | 1.18 | 9.9 | 45 | 9.9 |
| BASA3 | 10 | 15 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 40.0 | 10.00 | 25 | 28 | 1.12 | 44.8 | 90% | 70% | 100% | 100% | 1.29 | 57.6 | 110 | 57.6 |
| CRAC2 | 1 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 6.0 | 10.00 | 3 | 3 | 1.00 | 6.0 | 85% | 85% | 95% | 100% | 1.05 | 6.3 | 110 | 6.3 |
| LUPINE | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 5 | 8 | 21.0 | 10.00 | 8 | 7 | 0.88 | 18.4 | 80% | 95% | 90% | 100% | 0.94 | 17.2 | 30 | 17.2 |
| PHLO | 0 | 2 | 0 | 0 | T | T | 2 | 0 | 0 | 1 | 5.0 | 10.0 | 2 | 2 | 1.00 | 5.0 | 90% | 95% | 100% | 100% | 0.95 | 4.7 | 22 | 4.7 |
| ERPU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2.0 | 10.0 | 2 | 2 | 1.00 | 2.0 | 90% | 95% | 100% | 100% | 0.95 | 1.9 | 22 | 1.9 |
| ZYVE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3.0 | 10.0 | 3 | 3 | 1.00 | 3.0 | 90% | 90% | 100% | 100% | 1.00 | 3.0 | 53 | 3.0 |
| ASTRAGALUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2.0 | 10.0 | 2 | 2 | 1.00 | 2.0 | 80% | 95% | 90% | 100% | 0.94 | 1.9 | 18 | 1.9 |
| ACMI | T | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2.0 | 10.0 | 1 | 1 | 1.00 | 2.0 | 80% | 95% | 90% | 100% | 0.94 | 1.9 | 31 | 1.9 |

% Litter
% Cover
% Bareground (%)
% Rock cover (%)
**Remarks:** **Total Cover:**

**Boxes with red indicate estimated weights for clipped plots. Total clipped weight for plots have been transferred from field sheet into column A4. Total reconstructed weight for site is 1157 lbs/ac**

| | H | I | J |
|---|---|---|---|
| **From Large Plot Extension Sheet** | 643.2 | 419.0 | 320.1 |

| | |
|---|---|
| **K. Total normal production for Ecological Site:** | 1200 |
| **Reconstructed Present Total Weight lbs/ac.** | 1156.9 |
| **Weight in Reference state (total of weight in column I):** | 1738.0 |
| **L. Total weight of allowable present (total of weight in column J):** | 755.0 |
| **M. Similarity index (L divided by K x 100 = M):** | 62.9 |

NRCS
Natural Resources Conservation Service

**Prescribed Grazing - 528**
Similarity Index Worksheet

**ID-CPA-006**
Idaho
February 2008

## Large Plot Extension Sheet

Number of Plots in Transect: 2

Plot Size: 436

| A Plant Information: Plant Name | Estimated or Clipped Weight Per Species: P-1 | P-2 | P-3 | P-4 | P-5 | P-6 | P-7 | P-8 | P-9 | P-10 | A1 Average Plot/ Estimated Green Wt. (lbs/ac) | A2 Conversion Factor Used | A3 Weight Clipped Plots: Estimated Weight | A4 Clipped Weight | A5 Clipped/ Estimated plot conversion factor | B Clip / Estimated corrected green weight (lbs/ac) | C* % dry weight | D* % current growth ungrazed | E* %growth curve completed | F* %of normal production | G Reconstruction factor (d)(e)(f) | H Reconstructed present weight (lbs/ac) | I Weight in reference state (lbs/ac) | J Weight allowable (lbs/ac) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ATTRV | 1800 | 2200 | | | | | | | | | 440.0 | 0.22 | 1 | 1 | 1.00 | 440.0 | 65% | 90% | 80% | 100% | 0.9 | 397.2 | 220 | 220.0 |
| CHVI8 | 600 | 400 | | | | | | | | | 110.0 | 0.22 | 1 | 1 | 1.00 | 110.0 | 65% | 90% | 80% | 100% | 0.9 | 99.3 | 22 | 22.0 |
| SYAL | 550 | 500 | | | | | | | | | 115.5 | 0.22 | 1 | 1 | 1.00 | 115.5 | 60% | 90% | 85% | 100% | 0.8 | 90.6 | 22 | 22.0 |
| PUTR | 350 | 250 | | | | | | | | | 66.0 | 0.22 | 1 | 1 | 1.00 | 66.0 | 65% | 85% | 90% | 100% | 0.8 | 56.1 | 155 | 56.1 |

Remarks:

| | |
|---|---|
| Reconstructed Present Total Weight lbs/ac. | 643.2 |
| Weight in Reference state (total of weight in column I): | 419.0 |
| Total weight of allowable present (total of weight in column J): | 320.1 |

| | Prescribed Grazing - 528<br>Stocking Rate and Forage Value Rating | | | | | | | | | | ID-CPA-013<br>Idaho |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Resources Conservation Service | | | | | | | | | | | February 2008 |
| Client: | Example Production | | | Location: Field 1 | | | | | Date: | 9/1/2008 | |
| Conservationist: | Range Guy | | | Plant Community: | LY 16+ ARTRV/FEID | | | | | | |
| Plant Species | Present Composition | | Animal: Cattle | | | Animal: Sheep | | | Animal: | | |
| | Lbs/AC | % | P | D | U | P | D | U | P | D | U |
| Idaho Fescue | 166.0 | 14% | 166.0 | | | 166.0 | | | | | |
| Bluebunch Wheatgrass | 141.0 | 12% | 141.0 | | | | 141.0 | | | | |
| Columbia Needlegrass | 13.0 | 1% | | 13.0 | | | | 13.0 | | | |
| Monkshood **** | 23.0 | 2% | | | 23 | | | 23.0 | | | |
| Nevada Bluegrass | 27.0 | 2% | 27.0 | | | | 27.0 | | | | |
| Japanese Brome | 11.0 | 1% | | | 11.0 | | | 11.0 | | | |
| Bulbous Bluegrass | 28.0 | 2% | | | 11.0 | | | 11.0 | | | |
| Bottlebrush Squirreltail | 10.0 | 1% | | 10.0 | | | | 10.0 | | | |
| Arrowleaf Balsamroot | 58.0 | 5% | | 58.0 | | | 58.0 | | | | |
| Tapertip Hawksbeard | 6.0 | 1% | | 6.0 | | 6.0 | | | | | |
| Lupine **** | 17.0 | 1% | | | 17.0 | | 17.0 | | | | |
| Longleaf Phlox | 5.0 | 0% | | | 5.0 | | | 5.0 | | | |
| Shaggy Fleabane | 2.0 | 0% | | | 2.0 | | 2.0 | | | | |
| Death Camas **** | 3.0 | 0% | | | 3.0 | | | 3.0 | | | |
| Locoweed **** | 2.0 | 0% | | | 2.0 | | | 2.0 | | | |
| Yarrow | 2.0 | 0% | | | 2.0 | | 2.0 | | | | |
| Mountain Big Sagebrush | 397.0 | 34% | | 397.0 | | | 397.0 | | | | |
| Green Rabbitbrush | 99.0 | 9% | | | 99.0 | | | 99.0 | | | |
| Snowberry | 91.0 | 8% | | 91.0 | | 91.0 | | | | | |
| Antelope Bitterbrush | 56.0 | 5% | | 56.0 | | | 56.0 | | | | |
| **Total** | **1157.0** | | **334.0** | **631.0** | **175.0** | **263.0** | **700.0** | **177.0** | | | |
| **Percent by Preference** | | | **29%** | **55%** | **15%** | **23%** | **61%** | **15%** | | | |
| **Forage Value Rating** | | | | **Moderate** | | | **Moderate** | | | | |
| **Estimated Stocking Rate AUM/AC** | | | | **0.33** | | | **0.32** | | | | |

**Comments:** Pounds per acre for individual species from reconstructed weights on ID-CPA-006

**NRCS** | **Prescribed Grazing - 528** | **ID-CPA-008**

**Range & Pasture Computation Worksheet** | **Idaho**

**Natural Resources Conservation Service** | **February 2008**

Ranch : **Example - Adjustment Calculations as Response Units** Location : **Summer Place**

Technician's Name : **Range Guy** Date : **9/1/2008**

| | Mangement Unit Name | Total Acres | Response Unit | Acres | Similarity Index | Forage Value | Total Lbs/ Ac | Harvest Efficiency | Adjustment Factors | AUM's/AC | AUM's |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ecological Site / Forage Type | | | | | | | | |
| 1 | Summer Place | 1740 | Ly 16+ 100/100 | 385 | 50% | | 1157 | 25% | 100% | 0.32 | 122 |
| | Loamy 16+ | | Ly 16+ 95/100 | 775 | 53% | | 1157 | 25% | 95% | 0.30 | 233 |
| | | | Ly 16+ 80/100 | 510 | 55% | | 1157 | 25% | 80% | 0.25 | 129 |
| | | | Ly 16+ 60/100 | 70 | 60% | | 1157 | 25% | 60% | 0.19 | 13 |
| | | | | | | | | | MU Total | | 498 |
| 2 | Summer Place | 50 | Shallow Claypan 100/100 | 50 | 40% | | 320 | 25% | 100% | 0.09 | 4 |
| | Shallow Claypan | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | MU Total | | 4 |
| 3 | Summer Place | 195 | South Slope Ly 95/100 | 6 | 50% | | 905 | 25% | 95% | 0.24 | 1 |
| | South Slope Loamy | | South Slope Ly 95/40 | 54 | 58% | | 905 | 25% | 38% | 0.09 | 5 |
| | | | South Slope Ly 80/40 | 129 | 53% | | 905 | 25% | 32% | 0.08 | 10 |
| | | | South Slope Ly 60/40 | 6 | 60% | | 905 | 25% | 24% | 0.06 | 0 |
| | | | | | | | | | MU Total | | 17 |
| 4 | Summer Place | 252 | Stony Loam 95/100 | 27 | 50% | | 1150 | 25% | 95% | 0.30 | 8 |
| | Stony Loam | | Stony Loam 95/40 | 5 | 54% | | 1150 | 25% | 38% | 0.12 | 1 |
| | | | Stony Loam 80/40 | 130 | 58% | | 1150 | 25% | 32% | 0.10 | 13 |
| | | | Stony oam 60/40 | 90 | 60% | | 1150 | 25% | 24% | 0.08 | 7 |
| | | | | | | | | | MU Total | | 29 |
| 5 | Summer Place | 126 | Rock Outcrop | 176 | N/A | | 400 | 1% | 1% | 0.00 | 0 |
| | Rock Out crop | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | MU Total | | 0 |
| | Total Acres | 2363 | Total AUM's For Operation | | | | | | | | 548 |

This a summary of response units broken down by ecological site, distance to water, and percent slope. The values used for total lbs/acre should be calculated based upon data collection ( See example ID-CPA-006). The values for adjustment factors are guidelines and should be adjusted based upon historic use patterns and livestock distribution, type and class of livestock, livestock behavior, climate, type of grazing system used, and several other variables depending on site. Notice how the cumulative effects of distance to water and percent slope can greatly reduce total AUM's. For example the Stony Loam 95/100 response unit has only a slight adjustment for water and a suggested initial stocking rate of 0.3 AUM's/ac. When compared to the Stony Loam 60/40 response unit which has adjustments for water (60%) and slope (40%) the recommended stocking rate is reduced to 0.08 AUM's/ac. This is a difference of approximately 9 Acres/AUM.

**Exhibit F-2. Harvest Efficiency in Prescribed Gazing Range Technical Note USDA NRCS Idaho-Utah.**

# TECHNICAL NOTE

USDA - Natural Resources Conservation Service
Boise, Idaho – Salt Lake City, Utah

**TN RANGE NO. 73** **July 2012 (updated 2021)**

## Harvest Efficiency in Prescribed Grazing

**Shane Green, State Range Conservationist, NRCS National Grazingland Team**
**Brendan Brazee, State Range Conservationist, NRCS, Boise, Idaho**

**This technical note transmits information on the concepts and terminology surrounding harvest efficiency, and how they can be applied in conservation planning.**

Background

Most range conservationists learned the concept of utilization during their education in range management. The old "take half, leave half" rule of thumb (figure 1) still applies with the new concept of harvest efficiency. The term 'harvest efficiency' is relatively new in range management. This term first appeared in the Journal of Range Management in 1980 (Beaty and Engel, 1980), and was first introduced in NRCS through the 1997 edition of the National Range and Pasture Handbook (NRPH). The Society for Range Management Glossary of Terms Used in Range Management (1989 edition) did not contain the term "harvest efficiency", but the concept could be found in the definition of Utilization (Use): *The proportion of current year's forage production that is consumed or destroyed by grazing animals.* Recognizing that some forage is consumed and some is destroyed is a key concept to understanding harvest efficiency.

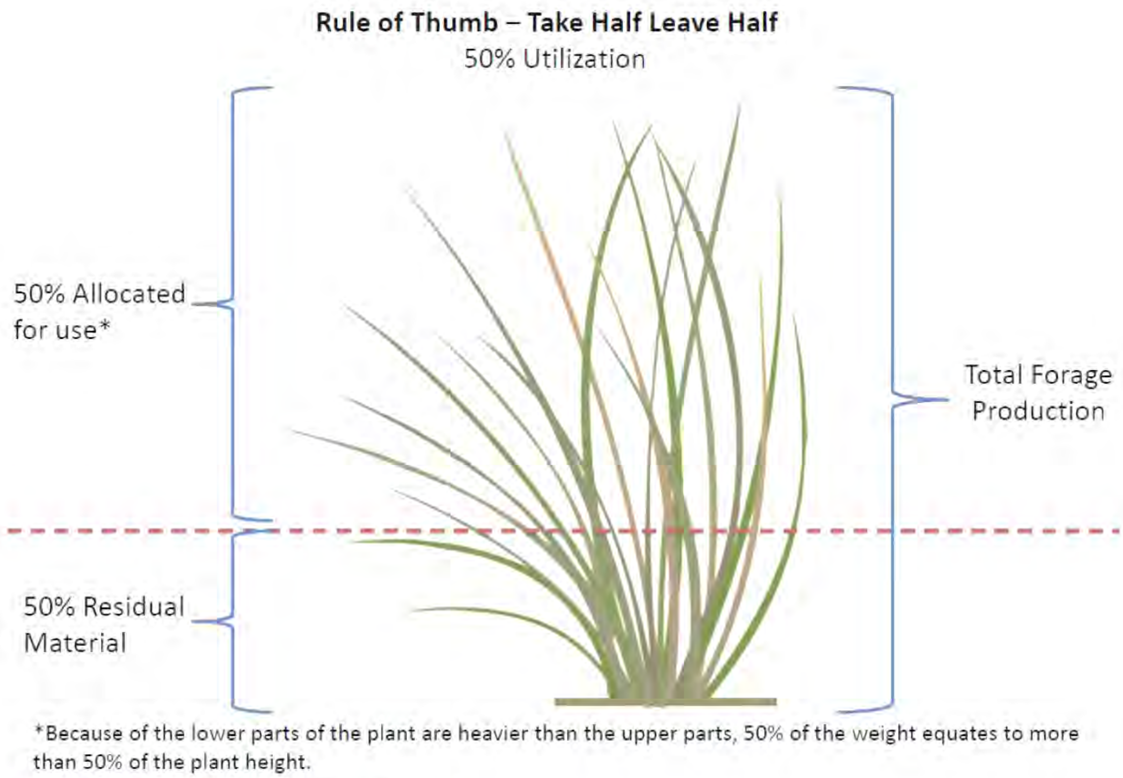



Figure 1 – Illustration of the utilization concept

Definition

The NRPH defines harvest efficiency as "*The total percent of vegetation harvested by a machine or ingested by a grazing animal compared to the total amount of vegetation grown in the area in a given year.... Harvest efficiency is the percentage of forage actually ingested by the animals from the total amount of forage produced.*" Figure 2 illustrates this concept.

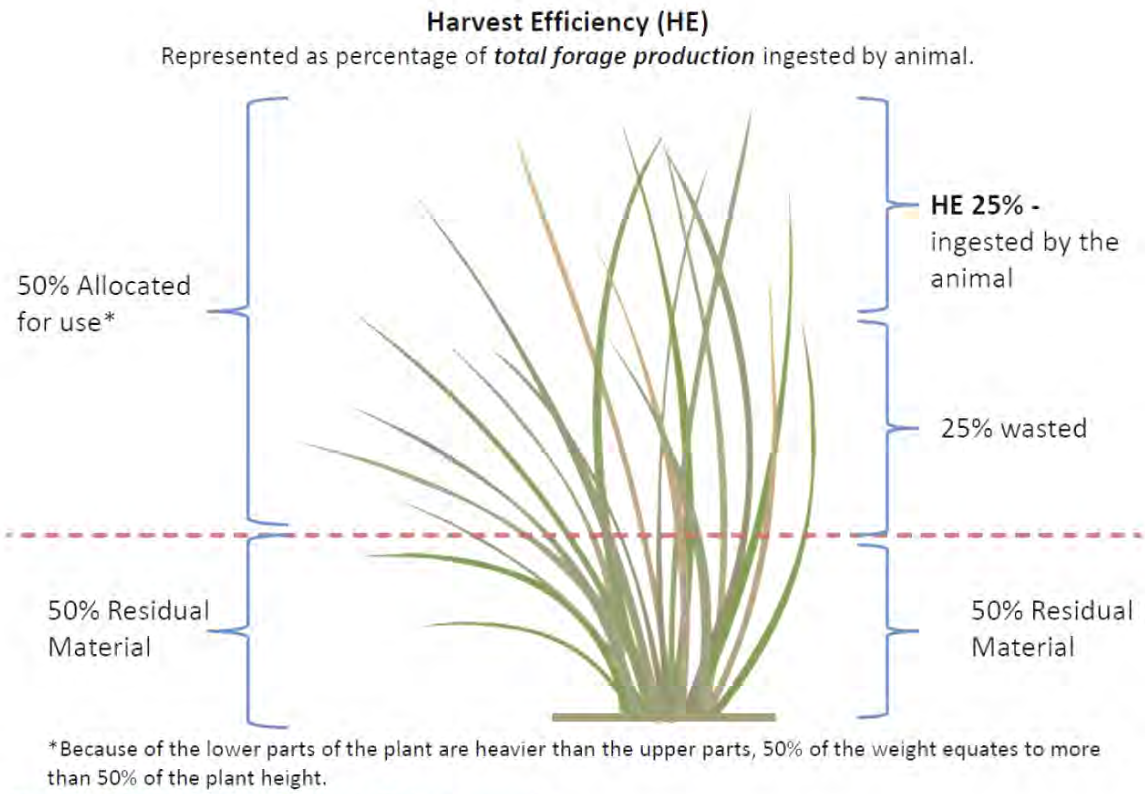



**Figure 2 – Illustration of the harvest efficiency concept**

Total forage production (TFP) includes only the forage species in the plant community, and represents <u>all</u> of their above ground annual production, not just that portion above a stubble height. The 'Leave Half' portion (50%) represents post-grazing residual forage (R). This is the most important part of the old take half, leave half rule of thumb for grazing. The 'Take Half' portion (50%) allocated for use represents utilization (U), and includes both consumed and destroyed portions. The 'ingested' portion (25%) represents harvest efficiency (HE), or that portion that actually ingested by the grazing animal. The 'wasted' portion (25%) represents forage that was utilized but went to waste through trampling, desiccation, manure and urine, bedding, etc.

***<u>Units and Equations</u>***

*Animal Unit Day (AUD)*

*Daily Herbage Intake (DHI) = lbs/AUD*

*Stocking Rate (SR) = AUD/area*

*Intake (I) = DHI * SR*

*Total Forage Production (TFP) = lbs/area*

*Harvest Efficiency (HE) = I/TFP*100*

*Residual (R) = lbs/area*

*Utilization (U) = 1-(R/TFP)*100*

*Grazing Efficiency (GE) = I/(TFP-R)*100*

<u>Finding the Correct Value</u>

The NRPH recommends the following: "*For continuous grazing, harvest efficiency usually averages:*
*Rangeland 25 percent*
*Pastureland 30 percent*
*Grazed cropland 35 percent*"

These values can fluctuate depending on the stocking density. As further explanation, the NRPH says "*Harvest efficiency increases as the number of* *animals increases in an area and they consume plant material before it senesces, transfers to litter, or otherwise leaves the area.*" Recent research has verified these values to be correct. If total forage production (TFP) is estimated and animal intake (I) is assumed to be a generally accepted value, the actual harvest efficiency can be calculated. The equation is:

$$I/TFP*100 = HE$$

For example:

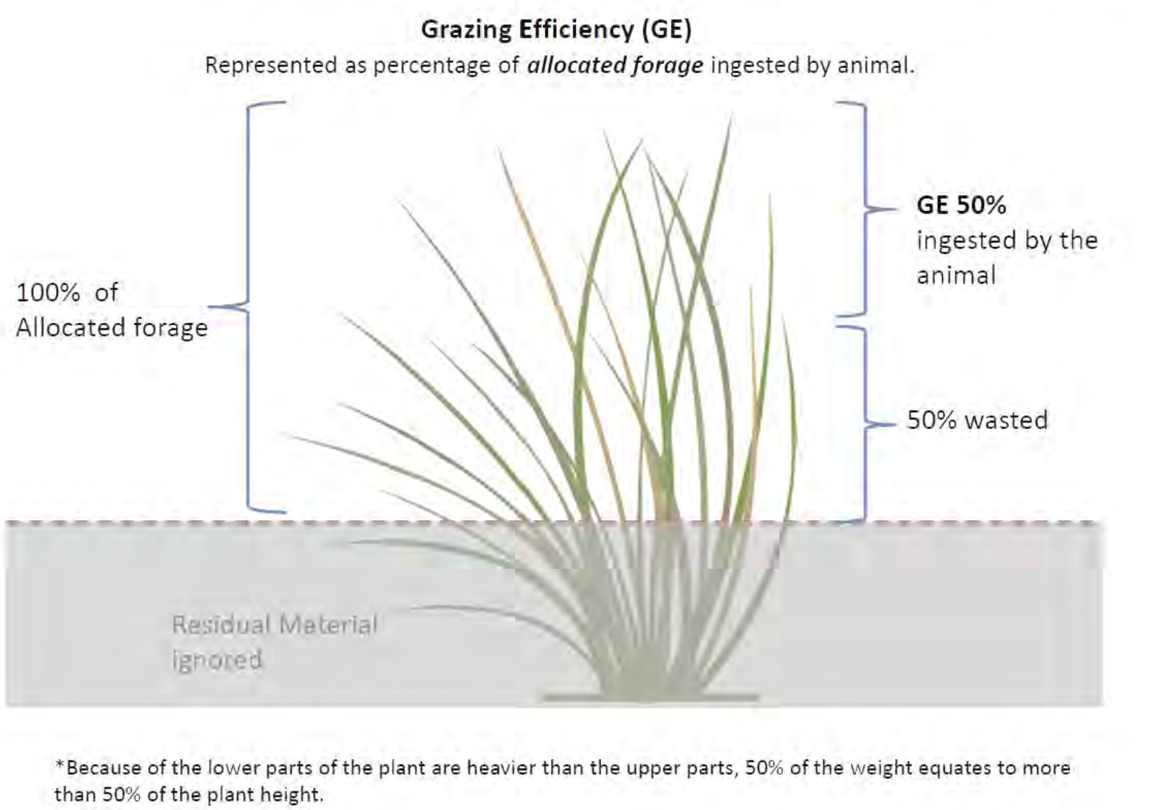
$$\frac{30\text{ lbs forage/day}^{1} * 50\text{ mother cows (1000 lbs each)} * 90\text{ days in the pasture}}{1500\text{ acre pasture} * 375\text{ lbs/ac total forage production}} * 100 = 24\%\text{ Harvest Efficiency}$$

If the residual (R) left over following grazing is estimated, utilization (U) can be calculated as well. The equation is:

$$1\text{-}(R/TFP)*100 = U$$

For example:

$$1 - \frac{1500\text{ acre pasture} * (188\text{ lbs})/\text{ac residual forage following grazing}}{1500\text{ acre pasture} * 375\text{ lbs/ac total forage production}} * 100 = 50\%\text{ Utilization}$$




[1] Daily intake rate for an animal unit NRCS uses, National Range and Pasture Handbook 600.0603(a)

Figure 3 – Illustration of the grazing efficiency concept.

Figure 3 – Illustration of the grazing efficiency concept

The relationship between utilization and harvest efficiency has been documented. Grazing studies on rangelands in Wyoming, South Dakota, Kansas, Colorado, North Dakota, and Oklahoma have shown that at 50% utilization rates, harvest efficiency is 25%. If utilization is increased to 65%, harvest efficiency increases to about 37%. If utilization is decreased to 40%, harvest efficiency decreases to about 15% (Smart et al, 2010). However, utilization rates should not be increased for the sole purpose of improving harvest efficiency.

Another related expression of efficiency is grazing efficiency (GE) (figure 3). Of all forage utilized (this includes what is wasted), that portion actually ingested by the animal is grazing efficiency. The equation for grazing efficiency is:

$$I/(TFP-R)*100 = GE$$

For example:

$$\frac{\text{30 lbs forage/day}[2] * \text{50 mother cows (1000 lbs each)} * \text{90 days in the pasture}}{\text{1500 ac} * \text{375lbs/ac total forage production} - \text{1500 ac} * \text{(188 lbs)/ac residual}} = \text{48\% Grazing Efficiency}$$

Stock density (# of head/area) can be used as a tool to improve both harvest efficiency and grazing efficiency (Briske, 2011 and Gerrish, 2004). As stock density increases, grazing distribution improves, selectivity decreases, and the proportion of utilized forage that is actually ingested (grazing efficiency) increases. So, increased harvest efficiency and grazing efficiency can happen by increasing stock density while utilization remains at targeted levels.

[2] Daily intake rate for an animal unit NRCS uses, National Range and Pasture Handbook 600.0603(a)

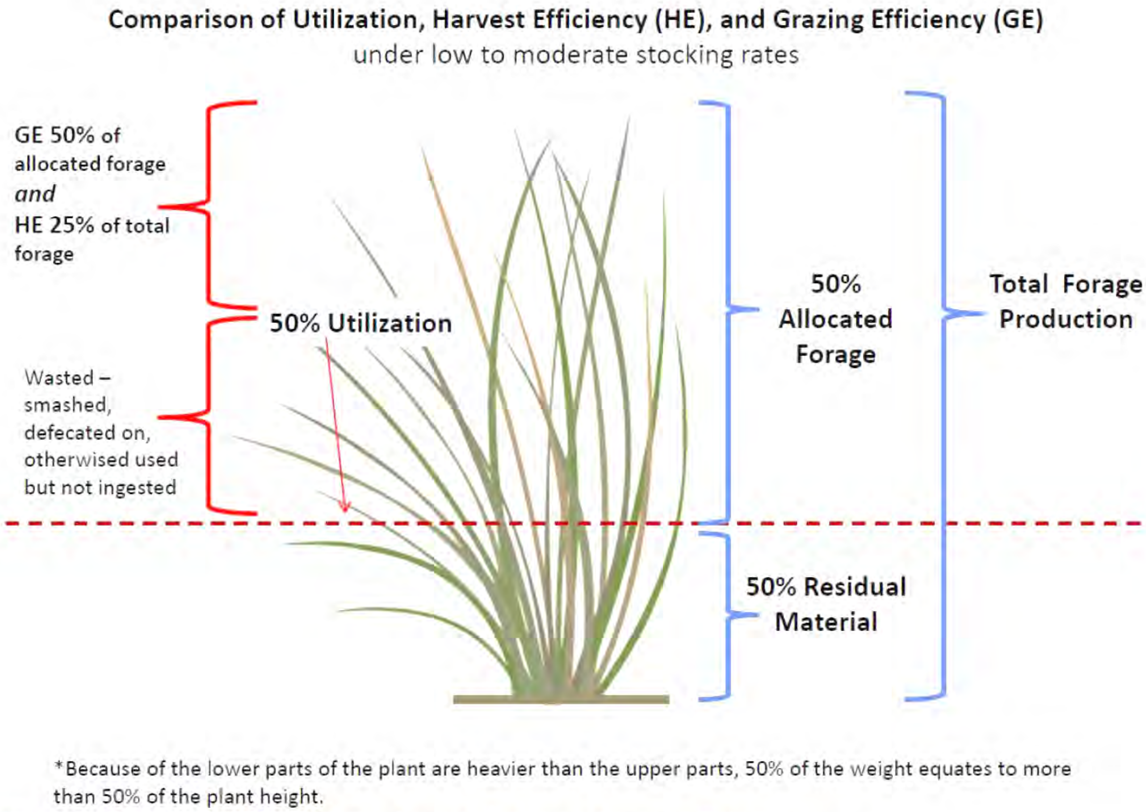



Figure 4 – Comparison of the utilization, harvest efficiency and grazing efficiency concepts

Table 1 and figure 4 contrasts the concepts of utilization, harvest efficiency, and grazing efficiency. Under a basic grazing scenario, typical values for rangeland are portrayed. Under the high stock density scenario, utilization remains at 50% but harvest efficiency improves. Understanding these concepts and relationships is key to providing sound technical advice to cooperators using the prescribed grazing practice during the conservation planning process.

| **Table 1** | | |
|---|---|---|
| **Utilization** | **Harvest Efficiency** | **Grazing Efficiency** |
| Proportion of annual forage production that is removed or destroyed | Proportion of total forage production ingested by the grazing animal | Proportion of utilization that is ingested by the grazing animal |
| **basic grazing scenario** | | |
| 50% | 25% | 50% |

| high stock density scenario | | |
|---|---|---|
| 50% | 35% | 70% |

**References for Technical Note 3.**

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# Part 645 – National Range and Pasture Handbook

## Subpart G – Rangeland Ecohydrology

### 645.0701 Introduction

A. Rangeland hydrology is founded on basic biological and physical principles and is a specialized branch of science, which studies land use effects on infiltration, runoff, and sedimentation (hydrologic assessments) in natural and reconstructed rangeland ecosystems. Water is the main driving and limiting factor on rangelands. Hydrology is an important element of consideration and discussion with rangeland producers and landowners during planning and implementation of rangeland management practices. The term "Ecohydrology" is a relatively new term, which integrates ecology with hydrology and focuses on the water cycle as influenced by biotic and other environmental factors (Hannah et al. 2004). Ecohydrology considers the complex interactions between climate, soils, vegetation, disturbance, and management.

B. About 35 percent of the land area in the world is grasslands and woodlands, 21 percent sparse and barren lands, 28 percent forest and woodlands, and 12 percent cultivated, and the remainder settlement and infrastructure and inland water (Part 645, Subpart A). Estimates of rangeland throughout the world vary. Heitschmidt and Stuth (1991) estimated that rangelands occupy 47 percent of the world's land area; Mannetje (2003) estimated 50 percent. About 26 percent of the global land surface is grazed and is the most prevalent land use throughout the world (FAO 2012). Managed grazing systems have increased more than 600 percent during the last three centuries, amounting to about 1.5 billion animal units (AU) in 1990 (Asner et al. 2004). In the United States, rangeland comprises about 50 percent of the land area (770 million acres (FAO 2011)). Privately owned rangeland comprises over half of the rangeland in the United States (~406–409 million acres) and pastureland (~119–121 million acres). These lands are over 27 percent (528 million acres) of the total combined acreage of the contiguous 48 states.

C. Rangeland comprises over two-thirds of the Nation's watershed area (FAO 1989) and provides a significant part of its water. The increasing importance of water has added a new dimension in range management strategies. In the southwestern and western United States, rangeland watersheds are the source of most surface water flow and aquifer recharge. Management on these lands can have a positive or negative effect on plant cover and compositional change, which ultimately influences water quality and quantity. Since the need for clean water is critical, and rangelands comprise a vast watershed area in the United States, policies and activities must be formulated and implemented to arrest resource degradation.

D. Watershed management on rangeland not only focuses on the protection and conservation of water resources, but also considers that vegetation resources are managed for many other goods and services [food and fiber production, wildlife habitat, mining, petroleum products, and recreation (Brooks et al. 1991)]. The most significant factor facing resource managers and conservation planners is that no uniform set of management guidelines fits all rangeland community types, pastures, or other units of grazing land. Plant communities and associated environmental factors are multivariate in nature, and interactions between plants, soils, environment, and management are complex and unique among rangeland community types (Gifford 1985). Resource managers are challenged with synthesizing an overwhelming amount of scientific information relative to ecology, soils, hydrology, plant science, and grazing management. ecological site descriptions (ESD) can provide a conceptual view of the rangeland landscape. Carefully crafted narratives, examples, and descriptions of hydrologic function and erosion dynamics are important aspects of managing lands (example in appendix G-A).

E. Conservation strategies on rangeland can be classified as preventive or restorative. Scientifically based strategies and sound management plans can prevent rangeland degradation and are more economically viable than restorative actions. Depending on the severity of resource and watershed degradation (which includes water, soil, plant, animal, air, and human resources), restoration to some desired ecological state may not be feasible from an ecological and/or economic perspective. The results of rangeland degradation can be serious and irreversible at the site and watershed scale. The principles and tools of assessing rangeland hydrology related to conservation planning and management on rangelands are articulated in this chapter. By developing a basic understanding of how hydrologic processes are affected by vegetation, soil properties, climatic events, management practices, and disturbances such as grazing and fire, one can integrate biophysical processes in discussions on rangeland conservation issues with land users and address key environmental and management questions. For example:

(1) How can a rangeland producer maximize available water for plant growth (i.e., increase the effectiveness of precipitation, reduce runoff, and limit evaporative soil surface moisture)?
(2) In discussions on grazing systems (e.g., continuous, rotational, mob) what are the effects of grazing intensity and timing of grazing on site hydrologic processes and erosion?
(3) What are the effects of plant compositional change on hydrology and erosion?
(4) How do invasive shrubs and trees such as mesquite and juniper affect hydrology and erosion?
(5) Fire is an integral and natural disturbance factor in many rangeland plant communities. What are the risks and vulnerabilities from burning, due to generation of excessive runoff and accelerated erosion?
(6) What tools are available to access hydrology and erosion on rangeland?
(7) What role can the Rangeland Hydrology and Erosion Model (RHEM) have in conservation planning and assessment?

F. Common problems and issues regarding rangeland watersheds can be categorized as ecological, management oriented, water quality and quantity, erosion, and economic. Table G-1 summarizes the most common problems and issues on rangeland and pastureland watersheds.

**Table G-1.** Common related problems and issues regarding hydrology on rangeland watersheds (Spaeth 2020).

| Category | Situation |
|---|---|
| Ecological | Understanding interrelationships: plant/soil complexes, ecology, environmental, and hydrology |
| | Climatic shifts, vegetation response, and the hydrologic cycle |
| Management oriented | Trampling impacts and effect of grazing treatments on watersheds |
| | Range improvement practices and their effect on hydrology |
| | Riparian management and hydrologic implications |
| Water quantity, quality, and erosion | Enhancement of surface water, ground water, and aquifer recharge in response to vegetation manipulation |
| | Deficient and unpredictable availability of water supplies |
| | Flooding |
| | Polluted surface water and reduced aquatic, fish, and wildlife habitat |
| | Erosion and sedimentation |
| | Sludge and animal waste applications |
| Economic | Economics of watershed restoration |

## 645.0702 Hydrologic Definitions

A. Hydrology

(1) Hydrology is the science dealing with the occurrence of water on the earth and its physical and chemical properties, transformation, combinations, and movements, especially with the course of water movement from the time of precipitation on land and movement to the sea or atmosphere.
(2) Ecohydrology is "the study of the functional interrelationships between hydrology and biota at the catchment scale, is a new approach to achieving sustainable management of water." (Zalewski 2000).
(3) Ecohydrology is the sub-discipline shared by ecological and hydrological sciences that is concerned with the effects of hydrological processes on the distribution, structure, and function of ecosystems, and on the effects of biotic processes on elements of the water cycle (Nuttle 2002).

B. Rangeland Hydrology

Rangeland hydrology is founded on basic biological and physical principles and is a specialized branch of science, which studies land use effects on infiltration, runoff, sedimentation, and nutrient cycling (hydrologic assessments) in natural and reconstructed ecosystems.

C. Watershed Management

Watershed management is the management of land for optimum production of high-quality water, regulation of water yields, and for maximum soil stability, along with other goods and services from the land.

## 645.0703 Hydrologic Cycle

A. The hydrologic cycle is a continuous process by which water is transported from the oceans to the atmosphere, to the land, through the environment, and back to the sea (figure G-1). Many sub-cycles exist such as the evaporation of inland water, evaporation of water from the soil, sublimation of snow from plants or soil, transpiration of water from plants, and the eventual return of this water to the atmosphere. The sun provides the energy required for evaporation, which drives the global water transport system.

B. Hydrologic Budget

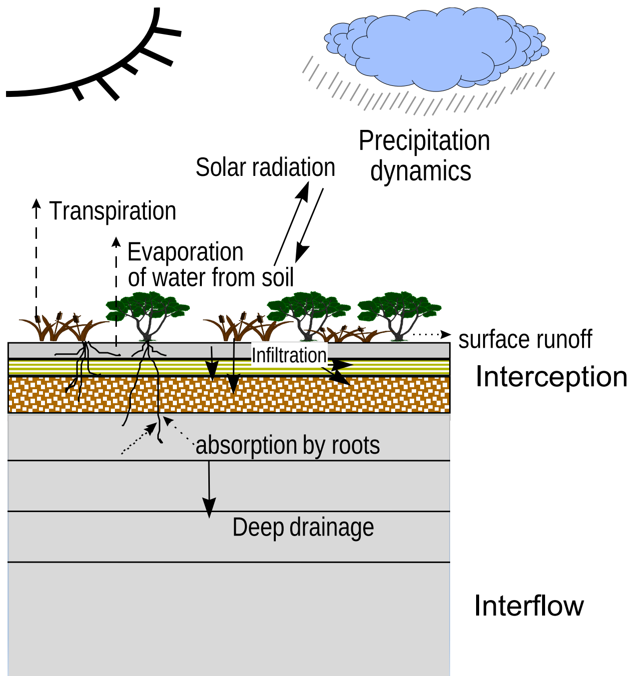
(1) The hydrologic budget can be expressed as:

$$P - R + Rg - G - E - T - I = S$$

where:

P = total precipitation
R = surface runoff
Rg = ground water flow that is effluent to a surface stream
G = ground water flow
E = evaporation
T = transpiration
I = interception
S = storage

**Figure G-1.** The hydrologic cycle with factors that affect hydrologic processes.




Factors Affecting Hydrologic Cycle

- Interception
- Kinds and amounts of vegetation
- Wildlife, livestock, and other flora and fauna
- Management effects (grazing, brush mgt)
- Fire (prescribed and wildfire)
- Runoff, soil detachment, sedimentation, nutrients
- Soil physical properties
- Soil surface characteristics (physical and biotic crusts)
- Soil chemistry
- Soil morphology
- Soil health (organic matter, litter turnover)

(2) There are many interacting factors related to soils, plants, environmental conditions, and management that affect the hydrologic cycle in rangeland watersheds. A comprehensive list appears in Table G-2.

## 645.0704 Hydrologic Cycle Components

A. Precipitation

(1) Precipitation is the primary input of the hydrologic cycle. The three major categories of precipitation are convective, orographic, and cyclonic:

(i) Convective precipitation occurs in the form of light showers and heavy cloudbursts or thunderstorms of extremely high intensity. Often, precipitation intensity varies throughout the storm. Most convective storms are random and last less than one hour and usually contribute little to overall moisture storage in the soil.

(ii) Orographic precipitation results when moist air is lifted over mountains or other natural barriers. Important factors in the orographic process include elevation, slope, aspect or orientation of slope, and distance from the moisture source.

(iii) Cyclonic precipitation may be classified as frontal and non-frontal and is related to the movement of air masses from high pressure to low pressure regions.

(2) Water originating from other sources may have an effect on a site. Shallow ground water or baseflow reserves may be utilized by deep-rooted shrubs and trees on the uplands and phreatophytes (riparian vegetation) along rivers and lakes.

**Table G-2.** Interacting factors that affect the hydrologic cycle in rangeland watersheds (Spaeth 2020).

| Soils | Plants | Environmental | Management |
|---|---|---|---|
| Soil morphology<br>Soil texture (particle size)<br>Bulk density<br>Compaction<br>Organic matter<br>Aggregate stability<br>Nutrient levels<br>Soil structure<br>Infiltration rates<br>Percolation rates<br>Saturated hydraulic conductivity<br>Runoff characteristics<br>Rills and gullies<br>Porosity<br>Erosion dynamics<br>Salinity<br>Alkalinity<br>Biotic components<br>Parent material<br>Pedogenic processes<br>Soil chemistry<br>Soil health attributes | Types of plants<br>Rooting morphology<br>Plant growth form bunch, sod)<br>Plant life form (grass, shrub, forb, tree)<br>Plant biomass, cover, density<br>Biological soil crust (mosses, lichens, algae)<br>Plant canopy layers<br>Plant architecture<br>Successional dynamics (State-and-transition model dynamics)<br>Native vs. introduced plants<br>Plant competition<br>Physiological characteristics of plant species<br>Physiological response to grazing<br>Biodiversity<br>Phenological stages | Climate<br>Types of storms<br>Precipitation type<br>Duration of storm<br>Intensity of storm<br>Topography<br>Geology<br>Aspect<br>Slope<br>Microtopography (soil roughness) | Grazing intensity<br>Timing of grazing<br>Continuous vs. rotational systems<br>Pitting<br>Chiseling<br>Herbicides<br>Seeding<br>Brush management<br>Wildfire<br>Prescribed burning<br>Past management history<br>Fencing<br>Hoof impact<br>Class of livestock<br>Disturbance<br>Stockwater location<br>Water Harvesting<br>Past disturbance from farm implements<br>Recreation<br>Kinds and types of wildlife |

B. Raindrop Dynamics

(1) Raindrop sizes vary with storm intensity, which affects soil surface stability and infiltrability. Average drop sizes for various storm intensities range from 1.25 mm in diameter at 1.27 mm $hr^{-1}$ (0.05 in $hr^{-1}$), 1.80 mm diameter at 12.7 mm $hr^{-1}$ (0.5 in $hr^{-1}$), and 2.80 mm diameter at 101.6 mm $hr^{-1}$ (4.0 in $hr^{-1}$).

(2) Falling raindrops at terminal velocity are hemispheric or oblate in shape. Raindrop velocity (2.5 mm diameter) is about 2 m $sec^{-1}$, but terminal velocities can vary with storm intensity and raindrop size (table G-3).
Recent studies indicate that raindrops can reach speeds faster than terminal velocity (Montero-Martinez et al. 2009, Thurai et al. 2013, Larsen et al. 2014). Hypotheses related to "super terminal drops" moving 30 percent faster than normal drop velocity suggest that larger faster moving raindrops break up and generate fragments from "parent raindrops" (Spaeth 2020). Kinetic energy associated with large rainstorms can splash more than 220 tons of soil per acre into the air, and bare and loose soil particles can be splashed more than 1.64 ft. in height and 4.9 ft. horizontally (Ffolliott et al. 2013).

**Table G-3.** Raindrop size and terminal velocity (Gunn and Kinzer 1949, Byers 1959, Rogers 1979, and Pruppacher 1981, Spaeth 2020).

| Storm Type | | Raindrop size (mm) | Raindrop Terminal Velocity (m sec$^{-1}$) | Raindrop Terminal Velocity (ft sec$^{-1}$) |
|---|---|---|---|---|
| Light Storm Intensity | Small droplets | 0.5 | 2.1 | 6.9 |
| | Large droplets | 2.5 | 6.5 | 21.3 |
| Moderate Storm Intensity | Small droplets | 1.0 | 4.0 | 13.1 |
| | Large droplets | 2.6 | 7.6 | 24.9 |
| Heavy Storm Intensity | Small droplets | 1.2 | 4.6 | 15.1 |
| | Large droplets | 4.0 | 8.8 | 28.9 |
| | Maximum droplet | 5.0 | 9.1 | 29.9 |
| | Hailstone | 10.0 | 10.0 | 32.8 |

C. Design Storm Frequencies

(1) Hydrologists and climatologists categorize storm events as “design storm events” to estimate risks of failure when addressing infrastructure (physical structures) and above-average soil erosion. The design storm event is used for estimating runoff volumes and durations and range from recurrence intervals of 2, 5, 10, 25, 50, 75, to 100 years. A 10-year design storm event is the storm intensity and amount that would occur at least once in 10 years or 10 times in a hundred years. Several storms of equal intensity may occur during the 10-year period or during a single year.

(2) The National Oceanic and Atmospheric Administration (NOAA) publishes precipitation and storm frequency data (NOAA Atlas 14 Point Precipitation Frequency Estimates). NOAA data tables show average recurrence of storm (1 to 1,000 years) and storm duration (5 minutes to 60-day intervals). Using Oklahoma City, Oklahoma as an example, a 5-year design storm could generate 2.13 inches in 60 minutes and 4.59 inches in 24 hours (table G-4).

(3) As the design storm increases, so does precipitation and runoff. A 50-year storm can be expected to yield 7.89 inches in 24 hours, 1.7 times the precipitation from a 5-year storm. Design storm information is useful in evaluating runoff and erosion risks on rangeland. The Rangeland Hydrology and Erosion Model (RHEM) (Nearing et al. 2011 and Hernandez et al. 2017) uses the Climate Generator (CLIGEN) (Nicks et al. 1995) stochastic weather generator to estimate precipitation intensity, duration, and frequency. The user locates the nearest weather station location, and the CLIGEN model provides 300 years of daily stochastically derived precipitation records that represent historical records. CLIGEN is used by RHEM to estimate average runoff and annual soil loss during a 300-year time span. The RHEM model also estimates 2, 5, 10, 50, and 100-year return runoff events to provide an assessment of heavy storm event impacts on a site. The impacts of design storms (2, 5, 10, 25, 50, 75, and 100 years) on rangeland are more critical for evaluating site vulnerability from raindrop splash and sheet flow soil-erosion processes than long-term.

D. Interception

(1) Vegetation intercepts raindrops, dissipating their kinetic energy. Interception is variable and is affected by plant height, leaf area, plant canopy cover, plant architecture, rainfall frequency, rainfall duration, amount of precipitation, type of precipitation, and time of precipitation (figure G-2).

(2) During small storms, water intercepted and evaporated without reaching the soil surface may be substantial, especially in shrub, tall grass, mixed grass, and bunchgrass communities. Rainfall interception loss during heavy storms is often a small proportion of the storm’s total volume (<10 percent) (Corbett and Crouse 1968).

**Table G-4.** National Oceanic and Atmospheric Administration Atlas 14 precipitation frequency estimates for Oklahoma City, Oklahoma. Average recurrence interval (years).

**NOAA Atlas 14 Point Precipitation Frequency Estimates Location Information:**
**Name:** Oklahoma City, OK, US, **Latitude:** 35.4909°, **Longitude:** -97.5101°, **Elevation:** 1209 ft.
**PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)**[1]

| | Average Recurrence Interval (years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Duration** | **1** | **2** | **5** | **10** | **25** | **50** | **100** | **200** | **500** | **1000** |
| **5-min** | **0.422** (0.331–0.544) | **0.493** (0.386–0.635) | **0.612** (0.478–0.791) | **0.714** (0.554–0.926) | **0.860** (0.647–1.15) | **0.977** (0.717–1.32) | **1.10** (0.778–1.51) | **1.22** (0.831–1.72) | **1.40** (0.912–2.00) | **1.53** (0.972–2.22) |
| **10-min** | **0.618** (0.485–0.797) | **0.722** (0.565–0.930) | **0.896** (0.699–1.16) | **1.05** (0.812–1.36) | **1.26** (0.947–1.68) | **1.43** (1.05–1.93) | **1.61** (1.14–2.21) | **1.79** (1.22–2.51) | **2.05** (1.34–2.93) | **2.24** (1.42–3.25) |
| **15-min** | **0.754** (0.591–0.972) | **0.880** (0.689–1.14) | **1.09** (0.853–1.41) | **1.28** (0.990–1.65) | **1.54** (1.16–2.05) | **1.75** (1.28–2.35) | **1.96** (1.39–2.69) | **2.19** (1.48–3.07) | **2.49** (1.63–3.57) | **2.74** (1.74–3.96) |
| **30-min** | **1.10** (0.863–1.42) | **1.29** (1.01–1.66) | **1.61** (1.25–2.08) | **1.88** (1.46–2.44) | **2.27** (1.71–3.03) | **2.58** (1.89–3.48) | **2.90** (2.06–3.99) | **3.24** (2.20–4.54) | **3.70** (2.41–5.30) | **4.06** (2.58–5.87) |
| **60-min** | **1.45** (1.14–1.87) | **1.70** (1.33–2.19) | **2.13** (1.66–2.76) | **2.51** (1.95–3.25) | **3.06** (2.30–4.10) | **3.50** (2.57–4.73) | **3.97** (2.81–5.46) | **4.46** (3.03–6.27) | **5.14** (3.36–7.38) | **5.68** (3.60–8.22) |
| **2-hr** | **1.80** (1.42–2.29) | **2.11** (1.67–2.69) | **2.66** (2.10–3.40) | **3.14** (2.46–4.03) | **3.85** (2.93–5.11) | **4.42** (3.29–5.93) | **5.03** (3.61–6.88) | **5.68** (3.90–7.93) | **6.58** (4.35–9.39) | **7.30** (4.68–10.5) |
| **3-hr** | **2.01** (1.60–2.55) | **2.36** (1.88–2.99) | **2.97** (2.36–3.77) | **3.52** (2.78–4.49) | **4.34** (3.34–5.75) | **5.02** (3.76–6.71) | **5.75** (4.15–7.83) | **6.52** (4.51–9.08) | **7.62** (5.06–10.8) | **8.49** (5.48–12.2) |
| **6-hr** | **2.40** (1.93–3.00) | **2.79** (2.25–3.50) | **3.50** (2.81–4.40) | **4.16** (3.32–5.25) | **5.16** (4.02–6.80) | **6.01** (4.56–7.98) | **6.93** (5.07–9.39) | **7.93** (5.55–11.0) | **9.36** (6.29–13.2) | **10.5** (6.85–15.0) |
| **12-hr** | **2.82** (2.30–3.49) | **3.24** (2.64–4.02) | **4.03** (3.27–5.00) | **4.77** (3.85–5.95) | **5.93** (4.69–7.77) | **6.93** (5.32–9.14) | **8.03** (5.94–10.8) | **9.23** (6.54–12.7) | **11.0** (7.46–15.4) | **12.4** (8.16–17.5) |
| **24-hr** | **3.24** (2.67–3.97) | **3.71** (3.05–4.55) | **4.59** (3.77–5.64) | **5.43** (4.43–6.70) | **6.75** (5.39–8.75) | **7.89** (6.13–10.3) | **9.15** (6.84–12.2) | **10.5** (7.55–14.4) | **12.5** (8.62–17.5) | **14.2** (9.44–19.9) |
| **2-day** | **3.68** (3.07–4.45) | **4.23** (3.52–5.12) | **5.24** (4.34–6.36) | **6.19** (5.11–7.55) | **7.68** (6.20–9.84) | **8.96** (7.02–11.6) | **10.4** (7.82–13.7) | **11.9** (8.60–16.1) | **14.1** (9.79–19.5) | **15.9** (10.7–22.2) |
| **3-day** | **4.00** (3.36–4.81) | **4.59** (3.84–5.52) | **5.67** (4.73–6.83) | **6.68** (5.54–8.09) | **8.24** (6.68–10.5) | **9.57** (7.55–12.3) | **11.0** (8.38–14.5) | **12.6** (9.18–17.0) | **14.9** (10.4–20.5) | **16.8** (11.3–23.2) |
| **4-day** | **4.27** (3.60–5.11) | **4.90** (4.12–5.86) | **6.03** (5.06–7.24) | **7.08** (5.90–8.53) | **8.69** (7.07–11.0) | **10.0** (7.95–12.8) | **11.5** (8.80–15.0) | **13.1** (9.60–17.6) | **15.4** (10.8–21.2) | **17.3** (11.8–23.9) |
| **7-day** | **4.96** (4.22–5.88) | **5.69** (4.83–6.75) | **6.97** (5.90–8.28) | **8.11** (6.82–9.68) | **9.81** (8.02–12.2) | **11.2** (8.93–14.1) | **12.7** (9.76–16.4) | **14.3** (10.5–18.9) | **16.5** (11.7–22.5) | **18.3** (12.6–25.2) |
| **10-day** | **5.57** (4.77–6.56) | **6.37** (5.44–7.51) | **7.74** (6.59–9.15) | **8.94** (7.57–10.6) | **10.7** (8.77–13.2) | **12.1** (9.68–15.1) | **13.6** (10.5–17.4) | **15.1** (11.2–19.9) | **17.3** (12.3–23.4) | **19.0** (13.1–26.1) |
| **20-day** | **7.31** (6.32–8.50) | **8.23** (7.12–9.59) | **9.78** (8.42–11.4) | **11.1** (9.49–13.0) | **12.9** (10.7–15.7) | **14.4** (11.6–17.7) | **15.8** (12.3–20.0) | **17.4** (12.9–22.5) | **19.4** (13.9–26.0) | **21.0** (14.6–28.5) |
| **30-day** | **8.70** (7.58–10.1) | **9.76** (8.49–11.3) | **11.5** (9.96–13.3) | **12.9** (11.1–15.0) | **14.9** (12.4–17.9) | **16.4** (13.3–20.0) | **18.0** (14.1–22.5) | **19.5** (14.6–25.2) | **21.6** (15.5–28.7) | **23.1** (16.2–31.3) |
| **45-day** | **10.4** (9.14–11.9) | **11.7** (10.2–13.4) | **13.7** (12.0–15.8) | **15.4** (13.4–17.8) | **17.7** (14.8–21.0) | **19.4** (15.8–23.5) | **21.1** (16.6–26.2) | **22.8** (17.2–29.2) | **24.9** (18.1–33.0) | **26.6** (18.7–35.8) |
| **60-day** | **11.8** (10.4–13.5) | **13.3** (11.7–15.2) | **15.7** (13.8–18.0) | **17.7** (15.4–20.3) | **20.2** (17.0–24.0) | **22.2** (18.2–26.7) | **24.1** (19.0–29.8) | **25.9** (19.6–33.0) | **28.3** (20.5–37.2) | **30.0** (21.3–40.3) |

(3) The form of precipitation (rain versus snow) has a significant influence on interception, with snow having higher rates of interception. As precipitation falls, it may be intercepted by vegetation (trees, shrubs, forbs and/or grasses) and stored in the canopy until it evaporates. It may slowly drip off vegetation as droplets, intercepted by secondary branches and leaves, and later falling from the canopy of shrubs and trees can form an erosive drip line under the plant. It may land directly on bare soil as splash erosion, or it may collect in the plant canopy and may run down plant stems. This water is redistributed in a concentrated way and can either infiltrate depending on the volume of water and soil surface conditions, or it can run off. It may also be intercepted by soil surface mulch or litter. In a watershed, interception must be considered as a factor in the total water balance and budget (loss of water). Interception of precipitation by vegetation and surface plant litter also plays an important role in protecting mineral soil from sheet and splash erosion. Table G-5 shows canopy interception, interill erosion, surface runoff, and infiltration for four vegetative conditions. Table G-6 shows average annual interception rates for forest, woodland, and grassland vegetation types.

**Figure G-2.** Interception rates for various rangeland species and plant growth forms. POPR–*Poa pratensis*–Kentucky bluegrass; PSSP6–*Pseudoroegneria spicata*–bluebunch wheatgrass; KOCR–*Koeleria cristata*–prairie junegrass; ARTR–*Artemisia tridentata*–big sagebrush, QUVI–*Quercus virginiana*–live oak (Spaeth 2020).

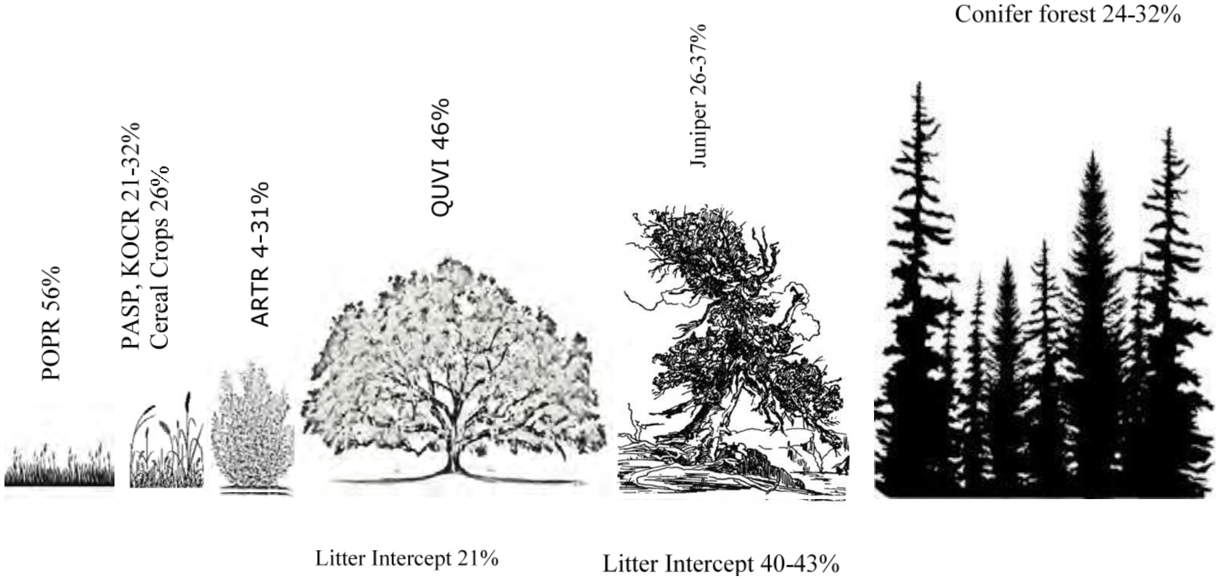



**Table G-5.** Canopy interception, interill erosion, surface runoff, and infiltration from oak mottes, bunchgrass, sodgrass, and bare ground-dominated areas. From rainfall simulation based on 10 cm rainfall rate over 30 minutes rainfall event (Blackburn et al. 1986).

| Hydrologic Component | Oak Motte | Bunchgrass | Sodgrass | Bare Ground |
|---|---|---|---|---|
| Canopy Interception (%) | 7.0 | - | - | - |
| Grass and Litter Interception (%) | - | 0.5 | 0.4 | 0.0 |
| Litter Interception (%) | 12.0 | - | - | - |
| Interill Erosion (kg/ha) | 0.0 | 200.0 | 1,400.0 | 6,000.0 |
| Surface Runoff (%) | 0.0 | 24.0 | 45.0 | 75.0 |
| Infiltration (%) | 81.0 | 75.5 | 54.6 | 25.0 |

(4) On an annual basis, tree interception is greater than grass interception. However, at maximum growth, some grasses have as much leaf area per unit area of ground as some trees (Dunne and Leopold 1978). Alfalfa can intercept as much rainfall during the growing season as a forest (Dunne and Leopold 1978). Water storage of grasses is proportional to the product of average height and ground cover (Crouse et al. 1966).

(5) Canopy interception can substantially decrease the amount of water reaching the ground in forest and prairie ecosystems (Clark 1940, Parker 1983, Gilliam et al. 1987), which ultimately evaporates and reduces available water. Studies of interception rates between trees, shrubs, and grasses on Texas rangeland show that live oak (*Quercus belangeri*), ashe juniper (*Juniperus ashei*), and honey mesquite (*Prosopis glandulosa*) canopies intercepted about 2.4 and 1.4 times more rainfall than curly mesquite (*Hilaria belangeri*), a shortgrass species, and sideoats grama (*Bouteloua curtipendula*), a midgrass species, respectively (Blackburn et al. 1986, Thurow et al. 1987). Shifts in the kind and amount of vegetation on the Edwards Plateau in Texas have the potential for greatly influencing the hydrologic water balance, and to a large extent, determining the amount of rainfall retained, lost, or yielded from a watershed (Blackburn et al. 1986).

E. Surface Detention/Storage

Excess surface water tends to accumulate in depressions, forming puddles. See figure G-3. The total volume per unit area is the surface storage capacity. Surface water storage or detention is a function of soil surface microtopography, slope, and soil physical properties such as texture, bulk density, porosity, and soil structure. Soil surface microtopography is affected by vegetation structure and life-form characteristics, and surface litter. As slope increases, initial runoff usually occurs sooner and at an increased rate because of a decrease in the size of detention storage sites. Water ponded on the soil surface is lost through evaporation or infiltrates into the soil.

**Table G-6.** Average annual rainfall interception rates for forest, woodland, and grassland vegetation types.

| Vegetation | interception (%) | Interception by litter layer after passing through canopy (%) |
|---|---|---|
| Alfalfa field (Clark 1940) | 7–36 | |
| Ashe Juniper (Thurow and Hester 1997) | 36.7 | 43 |
| Aspen forest (Dunford and Niederhof 1944) | 16 | |
| Big sagebrush (Hull and Klomp 1974, West and Gifford 1976) | 4–31 | |
| Bluestem prairie (Clark 1940) | 57–84 | |
| Brazilian tropical rain forest (Lloyd et al. 1988, Dykes 1997) | 8.9–18 | |
| Buffalo grass (Clark 1940) | 17–74 | |
| California annual grassland (Kittredge 1948, Tate 1995) | 26 | |
| Chaparral (Rowe and Colman 1951, Tate 1995) | 8–11 | |
| Conifer forest (Tate 1995) | 30 | |
| Conifer litter (Tate 1995) | 5 | |
| Curly mesquite (sod–type shortgrass) (Thurow et al. 1987) | 10.8 | |
| Hardwood forest (Beall 1934) | 21 | |
| Kentucky bluegrass (Haynes 1940) | 56 | |
| Live oak (Texas) (Thurow et al. 1987) | 46.1 | 20.7 |
| Lodgepole pine (Miner and Trappe 1957) | 24 | |
| Mixed prairie (Couturier and Ripley 1973) | 14–24 | |
| Pinyon–Juniper (Eddleman and Miller 1991, Niemeyer et al. 2016, Stringham et al. 2018) | 44–79 | |
| Ponderosa pine (Connoughton 1936) | 32 | |
| Redberry Juniper (Thurow and Hester 1997) | 25.9 | 40.1 |
| Shadscale saltbush (West and Gifford 1976) | 4 | |
| Sideoats grama (bunch–type midgrass) (Thurow et al. 1987) | 18.1 | |
| Utah Juniper (Skau 1964) | 17 | |
| Western Juniper (Young et al. 1984) | 2–27 | |
| Wheat field (Leuning et al. 1994) | 33 | |
| Wheatgrass and Junegrass prairie (Couturier and Ripley 1973) | 21–32 | |

F. Infiltration

Infiltration (figure G-4) is the process by which water enters the soil surface and is affected by the combined forces of capillarity and gravity (Hillel 1982, Brooks et al. 1991). Soil physical and chemical properties, vegetation characteristics, and soil fauna and flora interact and affect the process of infiltration. Under dry soil conditions, a higher initial infiltration rate is caused by the physical attraction of soil particles to water, which is called the matric potential gradient or matric suction gradient. Infiltration of water into the soil starts to decrease over time until a relatively constant rate is achieved (a curvilinear relationship). The cause of decreased infiltration over time is caused by one or more of the following factors: gradual decreases in the matric suction gradient; deterioration of soil structure, the breakdown of soil aggregate stability, and consequential partial sealing of the profile by detachment and migration of pore-blocking particles; and the presence of a restricting layer in the soil profile. As a precipitation event progresses and the soil surface becomes saturated, infiltration rate stabilizes according to a combination of soil and vegetation characteristics.

**Figure G-3.** Small detention ponds on the soil surface as a result of livestock hoof action near Price, Utah on a silty soil.

(i) Infiltration Dynamics

Main broad factors include soil surface conditions, subsurface conditions, flow influences, physical and biological factors, and hydrophobicity (adapted from Elliot and Ward 1995).

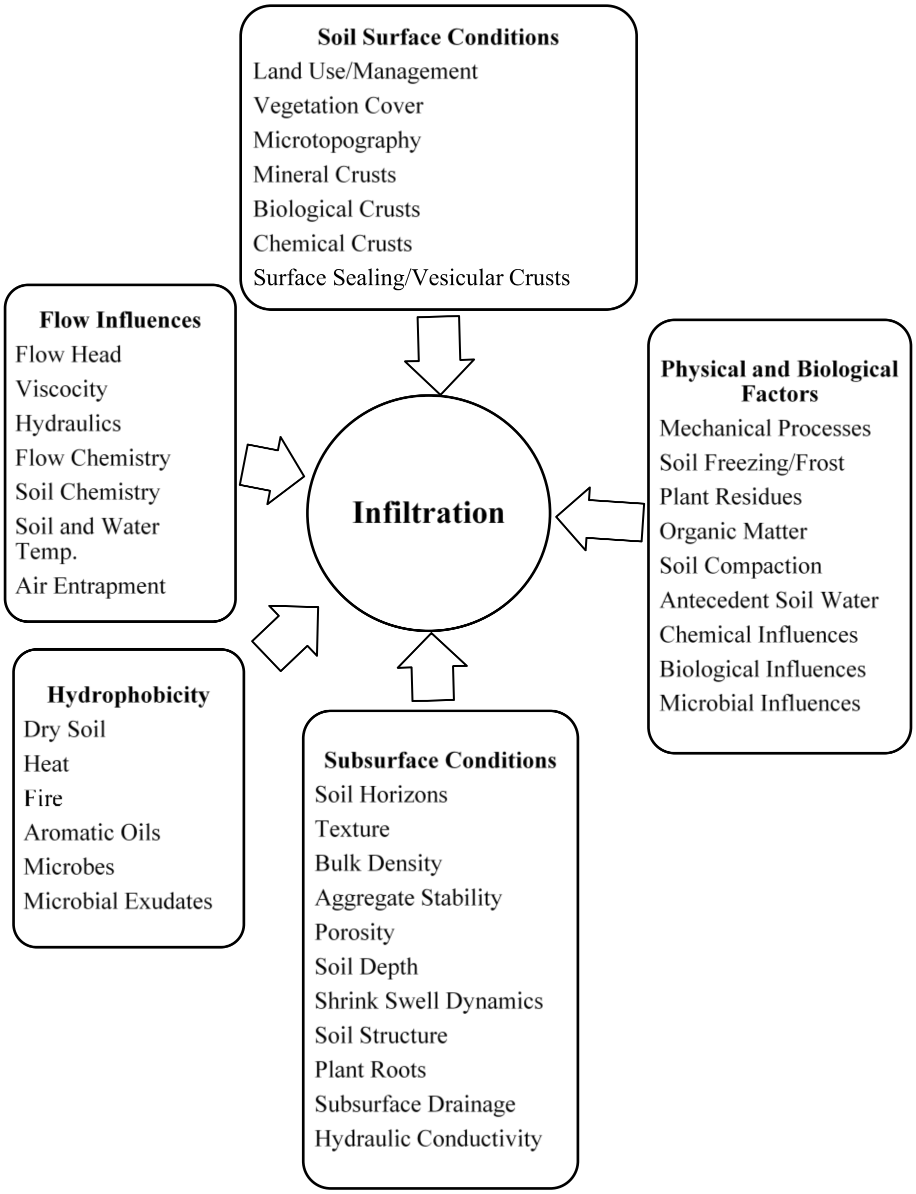
(ii) Infiltration Capacity

When rainfall rates during a storm exceed infiltration paucity of the soil, surface runoff or ponding on the soil surface occurs. Infiltration capacity of the soil is dependent on soil texture, porosity of the soil, soil structure, soil surface conditions, the physical nature of soil colloids, organic matter content, soil depth or the presence of impervious layers, macropores and biopores, antecedent soil water content, and temperature of the soil (at or near frozen conditions).

(iii) Infiltration Rate

Infiltration rate is related to the volume of water moving into the soil profile per unit area of surface area.

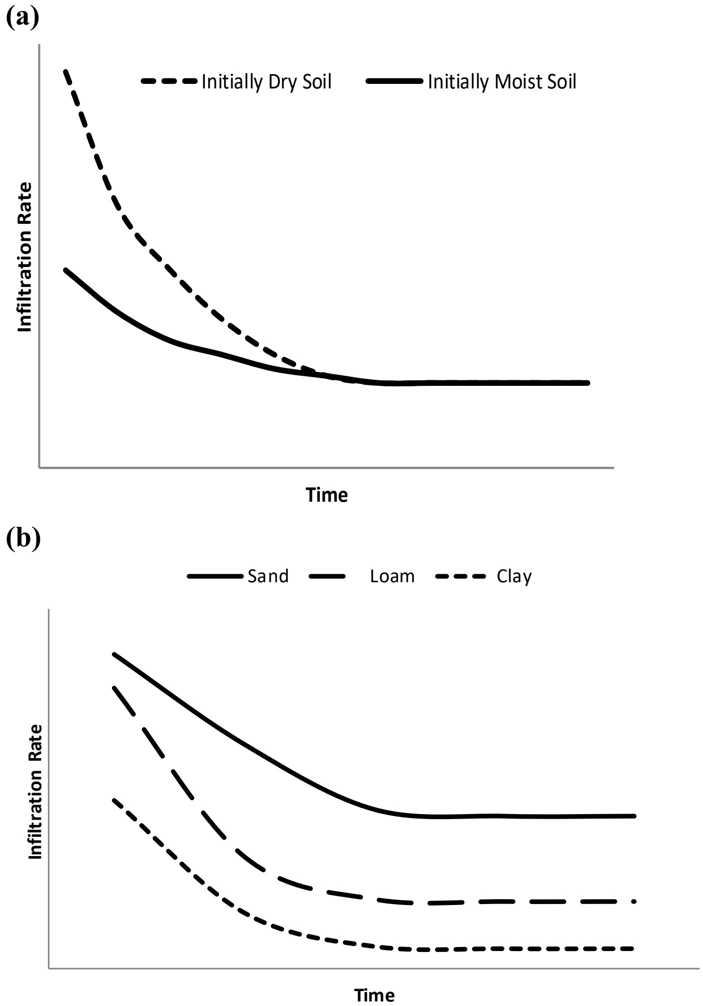
**Figure G-4.** Interrelated factors associated with infiltration.




(iv) Infiltration Curve

Infiltration curves are diagrammatic representations of infiltration over time. Figure G-5 shows infiltration over time for dry and wet soils. Soils that are initially dry infiltrate water more readily than moist or wet soil. In wet or moist soils, suction gradients are small at the onset of a rainfall event and become negligible as time progresses. Figure G-5 shows infiltration curves for sand, loam, and clay.

**Figure G-5.** Infiltration as a function of time for an initially dry **(a)** and wet soil **(b)**. Respective infiltration curves for sand, loam, and clay (Spaeth 2020).




(v) Infiltrability

Infiltrability denotes the infiltration flux resulting when water, at atmospheric pressure, is freely available at the soil surface (Hillel 1982) and depends upon initial wetness, suction, texture, structure, soil layering and its uniformity, aggregate stability, and bulk density. In soils with high clay content, infiltrability may initially be high due to macropores and cracks in the soil surface. However, as these cracks swell, infiltrability decreases. As clay particles expand, air pockets become entrapped, and the bulk compression of soil air is prevented from escaping as it is displaced by water.

G. Hydraulic Conductivity

Hydraulic conductivity is the ratio of the volume of water passing through a cross-sectional unit area per unit time (flux) to the hydraulic gradient (the driving force acting on the liquid) (Spaeth 2020). Hydraulic saturated conductivity is often symbolized as Ks and differs between unsaturated and saturated soil conditions. See figure G-6 and table G-7. In a saturated soil, there is a positive pressure potential. However, in unsaturated soil, there is subatmospheric pressure, or suction, which is analogous to a negative pressure potential (Spaeth 2020). The higher the saturated hydraulic conductivity of the soil, the higher its infiltrability.

**Figure G-6.** Comparison rates for saturated hydraulic conductivity (Ks) for various soil textural classes (data from Rawls et al. 1998).

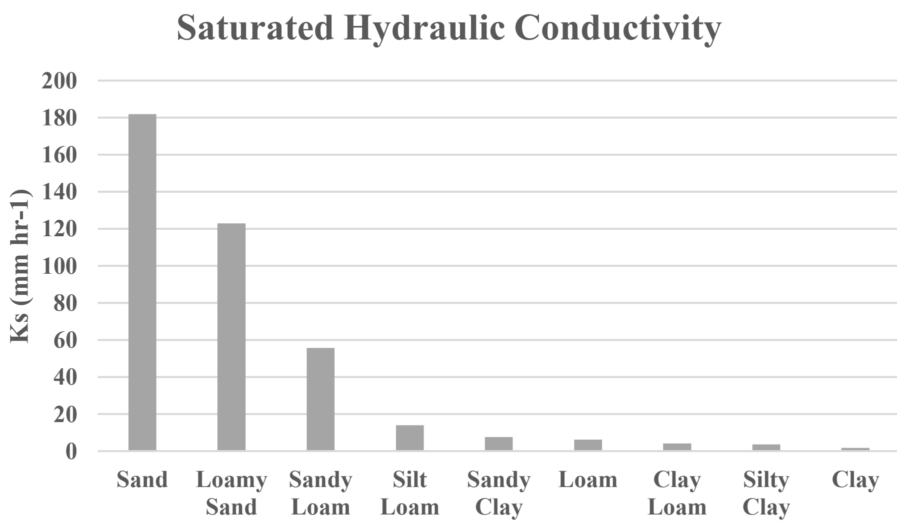



**Table G-7.** Approximate relationships between soil texture, water storage, and water intake rates under irrigation conditions (Spaeth 2020).

| Texture | Water mm @ 0.3 m (in ft. of soil) | Max. rate of water intake in $hr^{-1}$ (mm $hr^{-1}$) (bare soil conditions) |
|---|---|---|
| Sand | 12.7–17.8 (0.5–0.7) | 0.75 (19) |
| Fine sand | 17.8–22.9 (0.7–0.9) | 0.60 (15.2) |
| Loamy sand | 17.8–27.9 (0.7–1.1) | 0.50 (12.7) |
| Loamy fine sand | 20.3–30.5 (0.8–1.2) | 0.45 (11.4) |
| Sandy loam | 20.3–35.6 (0.8–1.4) | 0.40 (10.2) |
| Loam | 25.4–45.7 (1.0–1.8) | 0.35 (8.9) |
| Silt loam | 30.5–45.7 (1.2–1.8) | 0.30 (7.6) |
| Clay loam | 33.0–53.3 (1.3–2.1) | 0.25 (6.4) |
| Silty clay | 35.6–63.5 (1.4–2.5) | 0.20 (5.1) |
| Clay | 35.6–63.5 (1.4–2.5) | 0.15 (3.8) |

H. Percolation

Percolation is the downward movement of water through the soil profile. Deep drainage is the downward movement of soil water past plant roots. The amount of water lost to deep drainage depends upon soil infiltrability, evapotranspirational demands, substrate and geological conditions, and rooting dynamics of plants (Spaeth 2020).

I. Soil Water Characteristics

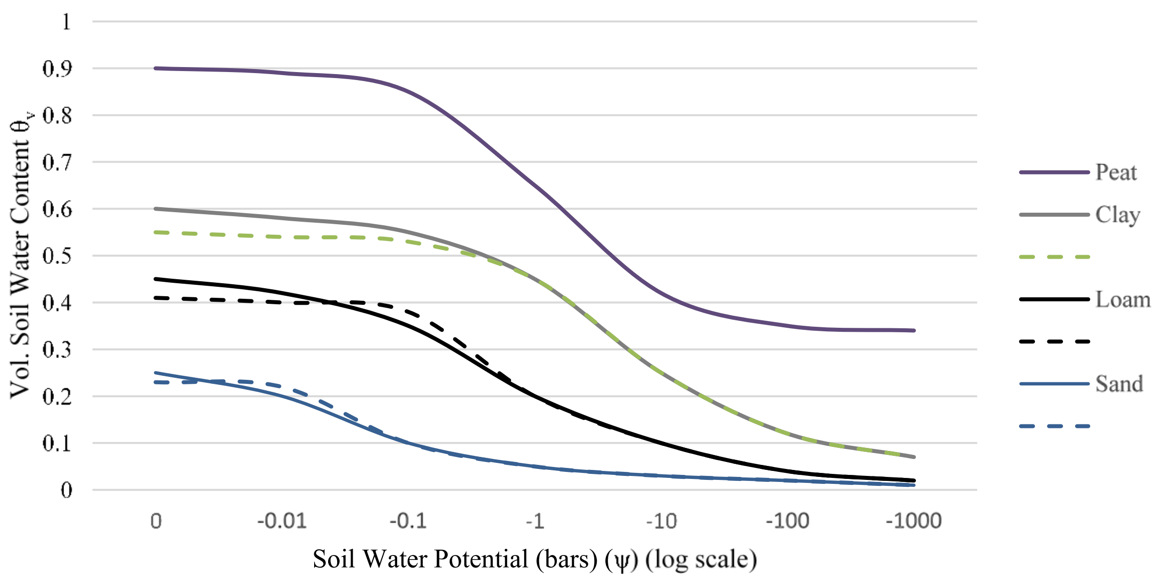
(1) Water loss in soils occurs by surface runoff, evaporation, transpiration, leaching, ratios of air and water in soil pores, and soil temperature dynamics. Soil water dynamics affect soil physical and chemical characteristics, soil biotic components, and plant growth, which are related to overall rangeland ad pastureland health. Total soil water potential ($\Psi_t$) is affected by various forces: gravitational ($\Psi_g$), matric ($\Psi_m$), hydrostatic ($\Psi_h$), and osmotic ($\Psi_o$)—all having singular potentials.

$$\Psi_t = \Psi_g + \Psi_m + \Psi_h + \Psi_o + \ldots \text{ (other possible potentials)}$$

(2) The physics of soil water potentials and dynamics are quite complex and are ultimately related to how water moves in the soil, between wet and dry soils. Regardless of the complexity of soil water dynamics, there is one important point to remember about the behavior of water in soils: water moves from areas with high water potential to areas with lower water potential. In farming and ranching enterprises, soil water content and storage capacity are of primary importance to growing a crop or forage plants. There is a curvilinear relationship between soil water potential ($\Psi_t$) and moisture content in the soil ($\theta$) (figure G-7). Several soil physical properties influence soil water content: soil texture, soil structure, soil aggregate stability, and bulk density. The latter two may change as a function of compaction from tillage implements or grazing animals.

(3) Soil water potential curves represent saturated soil condition and progressive drying. Dashed lines are effects of soil compaction or poor soil aggregate stability for soil textures, respectively. Units for volume soil water content = $m^3$ $H_2O/m^3$ soil (data from Rawls et al. 1982, 2004; Schwarzel et al. 2002; Weil and Brady 2017). The volume of soil water content is affected by pore sizes and decreases with soil water potential. Clays sustain more water at given potentials than loam and sand. Clay content in the soil determines the amount of soil micropores. As soil water potential increases, water is held more tightly in the micropores.

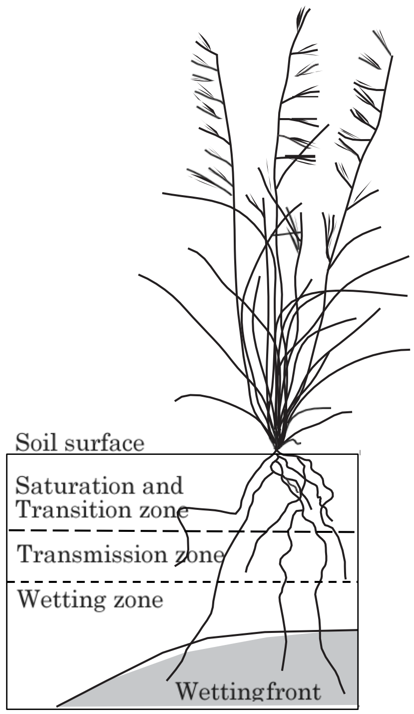
**Figure G-7.** Soil water potential curves for peat and three mineral soil textures.




J. Soil Moisture

Figure G-8 shows a moisture profile with the saturation and transition zone, transmission zone, wetting zone, and wetting front. The saturation and transition zones are fully saturated. The transmission zone is the ever-lengthening unsaturated zone of uniform water content. The wetting zone is the area where the transmission zone joins the wetting front. The wetting front is the line of delineation where the soil changes from wet to dry. Depth of the wetting front is an important factor for sustained plant growth. Grasses with laterally extending fibrous roots as well as a deep tap root are adapted to utilize precipitation from low precipitation events as well as subsurface water.

**Figure G-8.** Moisture profile during infiltration (Spaeth 2020).




K. Plant Available Water

(1) Wilting point, field capacity, and plant available water are important concepts that vary significantly with soil texture (figure G-9). These concepts are especially important in determining irrigation schedules for crops. Plant growth and yield are reduced at 40–60 percent of the plant available water (PAW) content (figure G-10) (Elliot and Ward 1995).

(2) For example, to determine the water needed to increase a loam soil from a critical water deficit (~50 percent) to field capacity, obtain upper and lower bounds for loam (English units, wilting point = 1.1 in, and field capacity = 3.2 in).

$$\theta \text{ paw} = (3.2 \text{ in} - 1.1 \text{ in}) = 2.1 \text{ in}$$

(i) The crop root zone is 2 ft. and PAW = (2.1) (2) = 4.2 in (106.6 mm)

(ii) If the critical deficit is 50 percent of PAW, then (0.5) (4.2) = 2.1 in of water is needed to raise the soil water content from the critical value to field capacity.

(iii) Wilting point is the moisture content of the soil (oven-dry basis) where plants wilt and fail to recover a turgid state in a dark environment. Wilting point is typically at 10–15 bars for crops. In rangelands, wilting point may exceed 30 bars for specific desert and semi-arid plants.

(iv) Field capacity is the percentage of water remaining in the soil two to three days after saturation and drainage has stopped.

(3) If significant erosion has occurred and topsoil with inherent levels of organic matter is lost, soil moisture holding capacity is compromised. Soil water retention is a function of soil physical properties and organic matter (Rawls et al. 1991; Wösten et al. 1988). The effects of organic matter on soil water retention cannot be overemphasized. Rawls et al. (2003) provide a detailed review the literature on the effects of organic matter on soil water retention. Some research using organic matter in regression models is contradictory, but there is agreement that organic matter "is an important factor when water contents at field capacity and wilting

point are measured directly" (Rawls et al. 2003). (See Section 645.0707(B), and Subpart F, Soil Health for discussions and information on organic matter and carbon dynamics on grazing lands).

**Figure G-9.** Plant available water capacities of different soil textural groups.

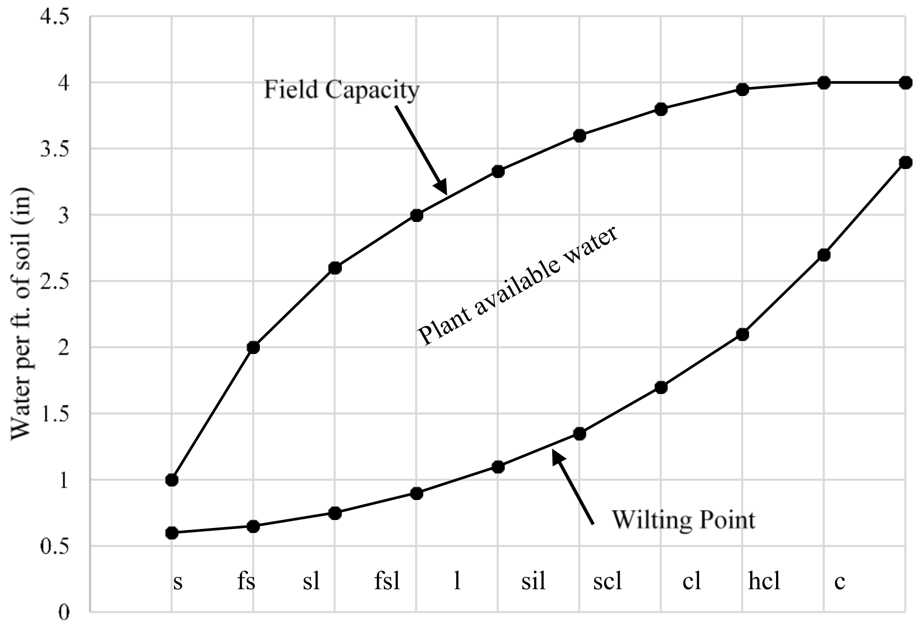
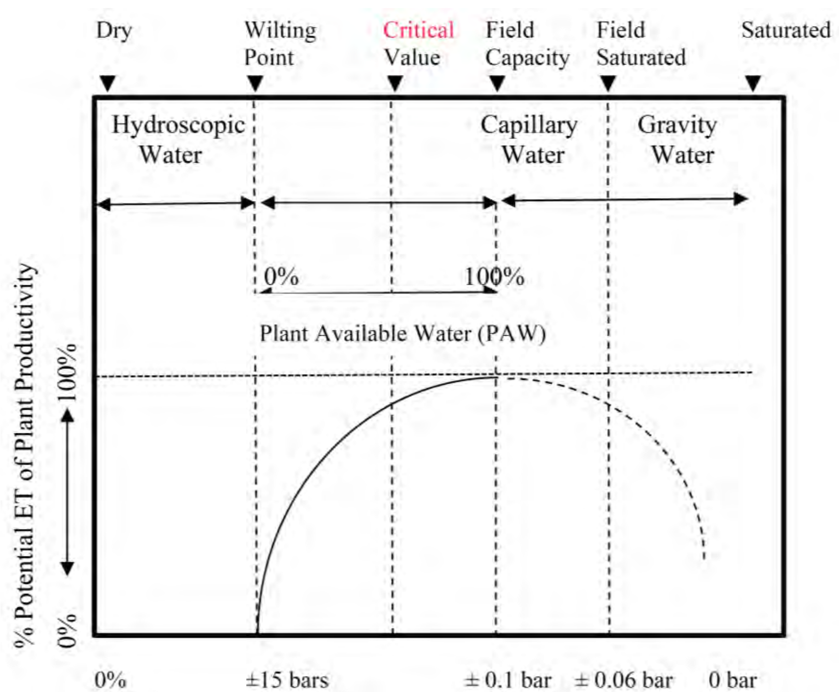



**Figure G-10.** Expected plant yield response with soil water content at 0 to 15 bars (wilting point). The critical value (40–60 percent) where plant production falls off due to waning available plant water (adapted from Ward and Elliot 1995).



L. Direct Surface Runoff

(1) Surface runoff or overland flow occurs when rainfall rate exceeds infiltration capacity, and the soil becomes saturated. The rate and distribution of runoff from a watershed are determined by a combination of physiographic, land use, and climatic factors. Runoff is closely linked to nutrient cycling, erosion, and contaminant transport. Runoff can be a sensitive indicator of ecosystem change, especially rangeland health determinations (hydrologic function and soil and site stability). Factors influencing runoff include:
(i) Form of precipitation (rain, snow, hail)
(ii) Type of precipitation (convective, orographic, cyclonic)
(iii) Seasonal distribution of precipitation
(iv) Intensity, duration, and distribution of precipitation
(v) Plant cover and biomass
(vi) Plant community types and the character of vegetative cover
(vii) Kind of vegetation as well as quantity of vegetation
(viii) Watershed topography and geology
(ix) Physical and chemical soil characteristics
(x) Evapotranspiration
(xi) Antecedent soil moisture
(xii) Degree of compaction i.e., land use practices

(2) High intensity convective storms are typically associated with runoff, as rainfall intensity and amount are greater than infiltration capacity. The dynamics of high intensity convective storms vary considerably across states and rangeland environments (Consult National Oceanic and Atmospheric Administration Atlas 14, precipitation frequency estimates, for local information). High return period storms > 5, 10, 25, 50, 75, 100-year frequency can initiate rills, gullies, and irreparable soil loss, especially when low cover and production, and soil compaction are present. On stable rangelands with adequate cover and proper management, long-term average soil loss is usually not a concern. However, erosion risk and potential during high intensity design storms that generate high runoff can be associated with significant erosion. Lower intensity frontal storms, where rainfall occurs at a low rainfall intensity (< 1 in/hr) rate, are conducive to higher amounts of water infiltrating and percolating through the soil.

M. Watershed Hydrograph

Various environmental processes and pathways determine streamflow. Hydrographs are used for analyzing the dynamics of surface runoff. A hydrograph shows the properties of streamflow with respect to time and has four component elements: channel precipitation, direct surface runoff, subsurface flow, and baseflow (figure G-11).

(i) Baseflow

Baseflow is that portion of precipitation which percolates into the soil profile and is released slowly and sustains streamflow between periods of rainfall and snowmelt. Baseflow does not respond quickly to rainfall (Spaeth 2020).

(ii) Subsurface Flow

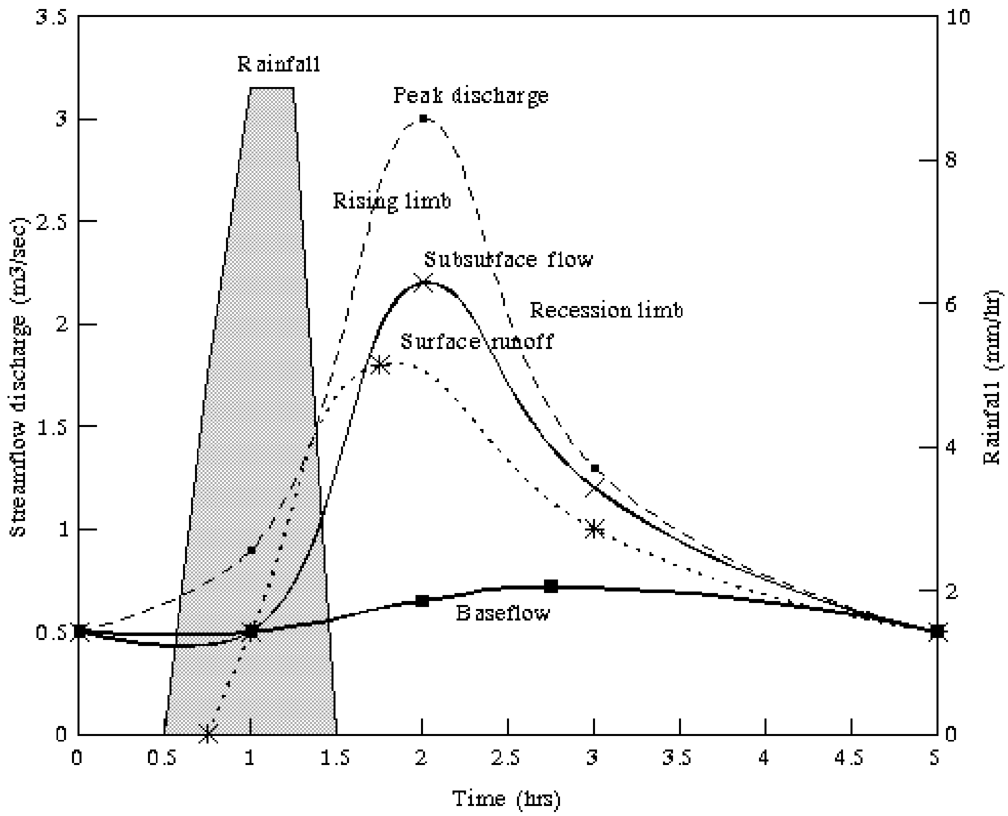
Subsurface flow is infiltrated water that is impeded by a restrictive layer in the soil (e.g., hardpan, caliche layer, bedrock). Subsurface water is diverted laterally and flows through the soil until it arrives at a stream channel over a short time period, where it is considered part of the storm hydrograph (Spaeth 2020).

(iii) Evaporation

Evaporation is the physical process where water transitions from a liquid to a gaseous state. Wherever water exists in a liquid state, evaporation occurs. The majority of water evaporation occurs from oceans, lakes, and other water bodies (>90 percent);

the remainder of evaporated water is from soil surfaces. Water evaporating from the soil surface is dependent upon energy associated with atmospheric conditions and vapor pressure gradients. As solar energy inputs to the soil surface layer increase, the vapor pressure of water and the gradient increase. The upper boundary layer of soil (0.5–1.0 inches) represents the evaporation layer.

**Figure G-11.** Example hydrograph of a watershed showing the relationship of water flow pathways (Spaeth 2020).

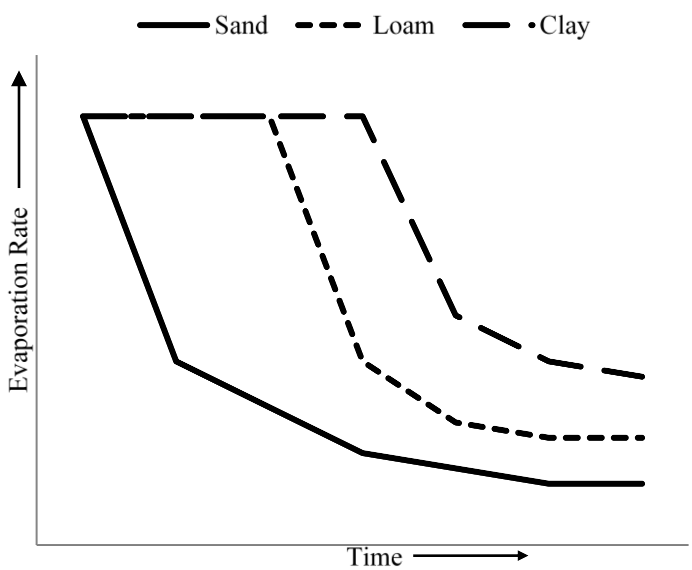



- Water evaporating from the soil surface is replaced by water moving upward in the soil profile by connecting water films around soil particles and through soil capillary pores. Water moves from zones of high potential (lower soil layers) to areas of lower potential (the upper soil surface). Soil hydraulic conductivity decreases as soil dries, and upward water migration decreases as soils become drier. In summary, as soil dries over time, water flow to the surface slows and cannot keep pace with atmospheric energy gradients at the soil surface. As subsoil water is lost during drying, evaporation is limited, regardless of surface atmospheric energy inputs. Water deficits occur sooner in lighter textured soils (sandy) compared to heavier textured soils (clayey) (figure G-12).
- The ionic effects of salts in soil lowers the vapor pressure of water, thereby reducing the vapor pressure gradient between the atmosphere and the soil solution. The result is lower evaporation potential. As salts precipitate in soils, pore-clogging can occur, which reduces the evaporative surface area and soil permeability.
- Managing vegetation cover and height is important in minimizing soil water evaporation losses. As soil surface temperatures rise, so does the vapor pressure

gradient. Soil surface evaporation is a factor that can be managed by prescribed grazing and maintaining minimum plant heights. Maintaining minimum plant stubble height (see state standards for Prescribed Grazing (528) and Forage and Biomass Planting (Code 512) standards) is not only important for insuring plant recovery and initiation of photosynthesis, but adequate plant cover and height also help buffer soil surface temperature, soil water evaporation, and soil erosion. Where these conservation practices cannot restore proper function and plant recovery, range and pasture seeding can be implemented.

- Evaporation rates vary with soil texture. Evaporation is highest with sand textures, lower for clay, over time. See section 645.0705 Hydrologic Water Budgets.

**Figure G-12**. Soil water evaporation with soil texture (Spaeth 2020).




(iv) Transpiration

- The process of water loss in plants is transpiration. When a plant is turgid, and water balance is sufficient (saturated), water vapor is transpired to the atmosphere. Most of the water adsorbed by the plant is transpired or lost as water vapor via stomata. More than 90 percent of the water in plant uptake is transpired and is lost to the atmosphere. If humans perspired as much, we would have to drink 20 gallons or more of water per day. Water is the basis of metabolic processes in the plant and is used in photosynthesis and synthesis of hormones, chlorophyll, and other plant pigments. The exchange of gases in photosynthesis requires moist cell surfaces. When the balance of water absorption by roots falls below transpiration rates, leaves may wilt and stomata close. Stomata remain closed at night when plants are restoring water balance.
- Transpiration rate is dependent upon water vapor pressure gradients between plant intercellular spaces and the atmosphere. As water vapor fills plant intercellular spaces, it then diffuses out to the atmosphere through stomata, lenticels (horizontal slit-like areas in the bark of woody stems or roots), or other plant openings that may be present. Any part of the plant anatomy can transpire water. High temperatures, bright sunlight, low humidity, high air pressure, and wind are associated with increased transpiration rates. Leaf size is an indication of transpiration potential because large leaves transpire more water compared to smaller leaves. Transpiration

increases about 20–30 percent for every 18° F rise in temperature. In rangeland plant environments, transpiration is generally a factor beyond control of land management.

(v) Evapotranspiration

Evapotranspiration (ET) is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. Transpiration from plants is the major component of water loss in semiarid and arid rangelands. Table G-8 gives estimated ET rates for various vegetation types. Evapotranspiration affects water yield and largely determines what proportion of precipitation input to a watershed becomes streamflow. Changes in vegetation composition that reduce ET result in an increase in streamflow and/or ground water recharge, whereas increases in ET have the opposite effect. Vegetation cover can reduce soil evaporation rates by shading and reducing wind velocity. The greater the vegetation cover, the greater the interception and transpiration loss, which usually offsets the benefits of reduced evaporation.

**Table G-8.** Average evapotranspiration rates for various vegetation types (from various sources).

| Plant Species or Plant Community | Evapotranspiration (% of total or inches per day) |
|---|---|
| Pinyon-Juniper | 63–97% of annual precipitation |
| Honey mesquite, Texas | 95% of annual precipitation |
| Chaparral, California, 23 in/yr ppt. | 80–83% of annual precipitation |
| Rio Grande Plains, S. Texas, Honey-mesquite Shrub clusters (shrub cluster) | 0.09 in/day |
| Low sagebrush community, springtime | 0.05–0.12 in/day under differing soil moisture and sunlight conditions (6-day average) |
| Wyoming big sagebrush/bluebunch wheatgrass, spring, Idaho, 12 in/yr ppt. | 0.07 in/day |
| Wyoming big sagebrush/bluebunch wheatgrass, summer, Idaho, 12 in/yr ppt. | 0.04 in/day |
| Low sagebrush/Idaho fescue, spring, Idaho, 13 in/yr ppt. | 0.09 in/day |
| Low sagebrush/Idaho fescue, summer, Idaho, 13 in/yr ppt. | 0.06 in/day |
| Mountain big sagebrush/grass, spring, Idaho, 19 in/yr ppt. | 0.10 in/day |
| Mountain big sagebrush/grass, summer, Idaho, 19 in/yr ppt. | 0.02 in/day |
| Mountain big sagebrush/grass, summer, Idaho, 30 in/yr ppt. | 0.12 in/day |
| Mountain big sagebrush/grass, fall, Idaho, 30 in/yr ppt. | 0.03 in/day |
| Forest, summer | 0.12–0.2 in/day |
| Open desert vegetation | 0.001–0.02 in/day |

## 645.0705 Hydrologic Water Budgets and Interaction with Precipitation, Runoff, Evaporation, Transpiration, Erosion, and Sediment Yield

A. The hydrologic cycle is the foundation for developing water budgets for various rangeland plant communities. Water is regarded as the limiting factor in forage production in rangelands. Discussing water budgets with land users is an excellent way to show how total rainfall is partitioned due to site vegetative status and management. In addition, a water budget can be an effective way to show land users the benefits of various rangeland conservation practices. A simplified equation for evaluating available water for plant growth is as follows:

$$\text{Available Water for Plant Growth} = P - R - G - E - T$$

where:

P = total precipitation
R = surface runoff
G = deep percolation and/or ground water flow
E = evaporation
T = transpiration

(B) Table G-9 is an example of a water budget for various stands of grass in Major Land Resource Area (MLRA) 106, Nebraska and Kansas Loess-Drift Hills.

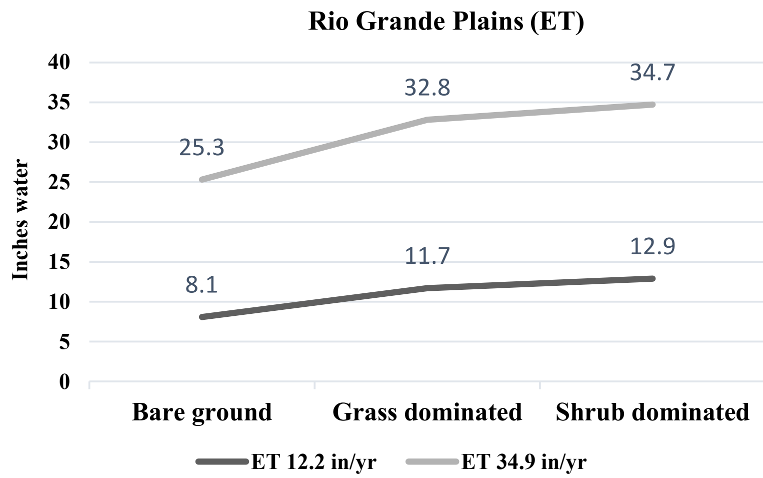
**Table G-9.** Water budget examples for MLRA 106, Nebraska and Kansas Loess-Drift Hills. Loamy site, 25 inches average annual precipitation for stands I, II, and III with different species composition (%). (Data from Rangeland Hydrology and Erosion Model, and Evapotranspiration Equations).

| Plant Species | Stand I (%) | Stand II (%) | Stand III (%) |
|---|---|---|---|
| Little bluestem | 30–50 | | |
| Big bluestem | 15–30 | | |
| Prairie dropseed | 10 | | |
| Porcupine grass | 40 | | |
| Sideoats grama | 5 | | |
| Grasses (Subdominants: Blue grama, Sedges, Prairie junegrass, Buffalograss) | 5 | | |
| Kentucky bluegrass | 0 | 75 | 25 |
| Smooth bromegrass | 0 | 25 | 75 |
| **Hydrologic Data** | **Stand I inches (%)** | **Stand II inches (%)** | **Stand III inches (%)** |
| Precipitation (in) | 25 | 25 | 25 |
| Infiltration | 19.3 (77) | 13 (52) | 17 (68) |
| Runoff | 5 (20) | 11.2 (45) | 7.5 (30) |
| Grass and litter interception | 0.13 (0.05) | 0.10 (0.04) | 0.15 (0.06) |
| Evapotranspiration (ET) | 18.1 (94) | 18.3 (95) | 18.3 (95) |
| Soil evaporation | 11.5 (60) | 11.5 (60) | 11.5 (60) |
| Plant transpiration | 6.5 (34) | 6.7 (35) | 6.7 (34) |
| Deep percolation | 0.6 (2.5) | 1 (4) | 2 (0.05) |
| Change in soil water (affected by antecedent soil moisture) | 0 | -1.4 | -0.6 |

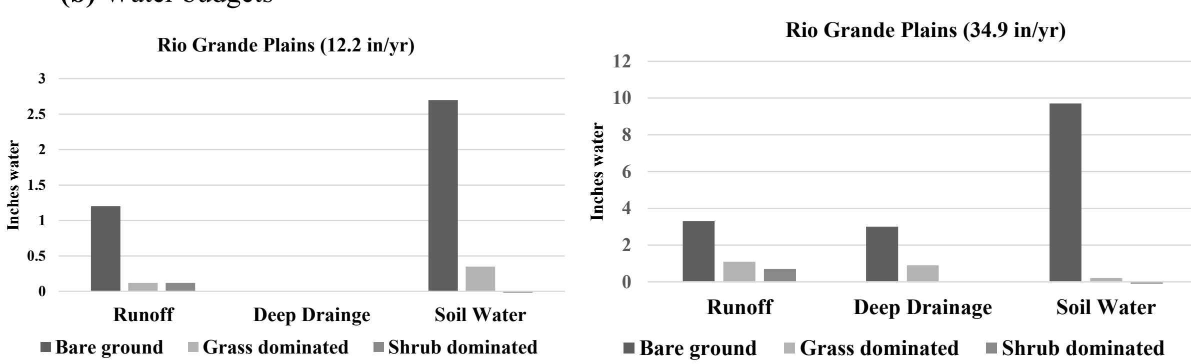
Stand I represents a tallgrass prairie reference state (historic plant community) dominated by native bunchgrasses. Stand II is dominated by Kentucky bluegrass (*Poa pratensis*), a sod forming species. Stand III is dominated by smooth bromegrass (*Bromus inermis*) with subdominant Kentucky bluegrass. Note the difference between native bunchgrasses and invasive sod forming grasses. Twenty percent of the total precipitation was runoff in Stand I (tall grasses), 45 percent (Stand II), and 30 percent (Stand III) dominated by Kentucky bluegrass and smooth bromegrass, respectively. C. In figure G-13, the pattern of evapotranspiration between the shrub clusters and grass interspaces were similar. However, ET rates were about three times higher the second year with increased rainfall rate (34.9 in $yr^{-1}$) (Weltz and Blackburn 1995). Surface water runoff and deep drainage from bare soil treatments were significantly greater than the shrub clusters and grass interspaces. Figure G-14 shows ET rates, water budgets, and sediment production for three cover conditions in the Texas Rolling Plains.

**Figure G-13. (a)** Evapotranspiration rates and **(b)** water budgets for bare soil areas, grass interspaces, and shrub clusters. Rio Grande Plain of Texas on a Miguel fine sandy loam soil with 1–3% slope for two years with significantly different annual precipitation rates (Weltz and Blackburn 1995).

**(a)** Evapotranspiration rates




**(b)** Water budgets

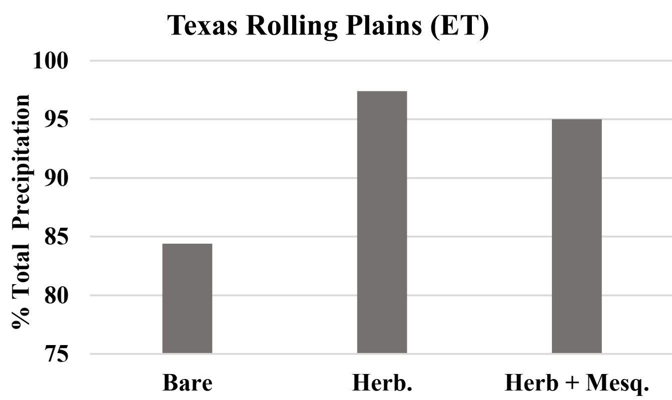



Notes:
Miguel fine sandy loam (1–3 percent)
Soil water was calculated as Precipitation–Runoff–ET–Deep Drainage.
Shrub clusters are honey mesquite (*Prosopis glandulosa*), brasil (*Condalia hookeri*), spiny hackberry (*Celtis pallida*), lime prickly ash (*Zanthoxylum fagara*), Agarito (*Berberis trifoliota*), Texas persimmon (*Diospyros texana*), Texas colubrina (*Colubrina texensis*), and wolfberry (*Lycium berlandieri*).

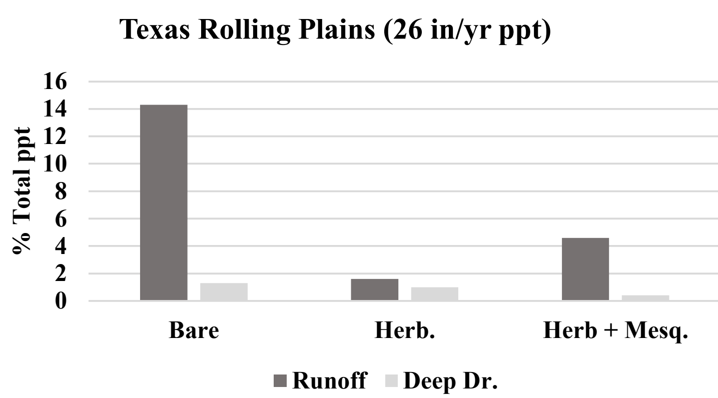
Grass clusters: thin paspalum (*Paspalum setaceum*), knotroot bristlegrass (*Setaria geniculate*), and windmillgrass (*Chloris verticillata*), red lovegrass (*Eragrostis secundifola*), red grama (*Bouteloua trifida*), threeawn (*Aristida* spp.), and southern sandbur (*Cenchrus echinatus*).

**Figure G-14. (a)** Evapotranspiration percent, **(b)** annual water balance differences between bare ground, herbaceous, and herbaceous plus mesquite vegetation composition from 1986 to 1988 on the Texas Rolling Plains, and **(c)** sediment losses for the same treatments (Carlson et al. 1990).

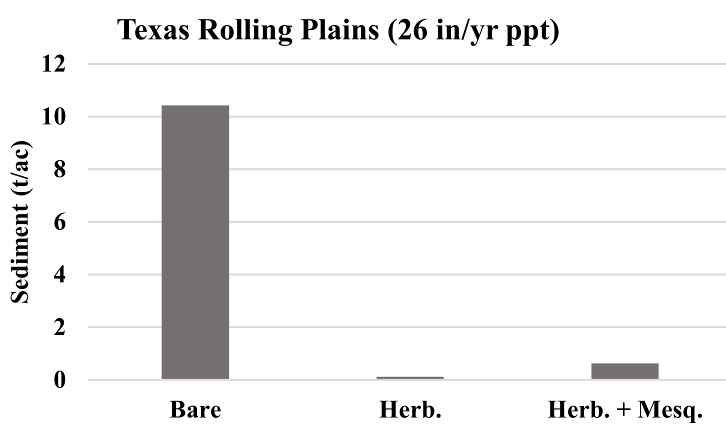
**(a)** Evapotranspiration as percent of total precipitation




**(b)** Water balances




**(c)** Sediment production



D. Runoff, interill erosion, and sediment losses were linked with rainfall amount, peak short-term storm intensity, and amount of bare ground (Carlson et al. 1990). On the bare and herbaceous treatments, mesquite trees were removed by cutting and stump treatment with diesel oil.

E. Evapotranspiration accounted for over 95 percent of water loss from vegetated sites. Runoff was lowest on herbaceous plots, followed by the herbaceous + mesquite plots. There was essentially no net change in deep drainage or evapotranspiration on sites where the herbaceous component increased in response to shrub removal.

## 645.0706 Water-Use Efficiency

A. The water requirement for a plant is the amount of water required to produce a given weight of above-ground dry matter. See Table G-10. An average value of water use efficiency for arid-land plants is 1,428 g of $H_2O$ lost per gram of biomass produced. Given that plant tissue is 50 percent C content, 0.042g C is released as $CO_2$ per gram of C fixed in plant biomass (Fischer and Turner 1978). For every pound of arid-land biomass, 171.12 gal of water is required; or for 1,000 lbs. of arid-land biomass produced, 171,121.2 gal of water is required. Water requirements for plants are affected by many factors such as available water, physiologic characteristics of the plant, ecotypic variations of plants, environmental demands, phenology, plant rooting depth, length of growing season, temperature, and nutrient availability. In some rangeland community types, the benefits of converting shrub lands to grass can be shown by comparing water-use efficiencies. There is considerable variability among studies to determine water use efficiencies; however, grasses tend to be more efficient in terms of water use compared to forage, legumes, and shrubs. Water use efficiency of productivity is defined as:

$$Wp = \frac{\text{Dry matter production (lbs.)}}{\text{Water consumption (gal)}}$$

**Table G-10.** Water requirements of specific plant species.

| Plant Species | Gallons of water needed for 1 lb dry weight. |
|---|---|
| **Plant Species in the Pinyon/Juniper type** | |
| Crested wheatgrass (*Agropyron cristatum*) | 68–85 |
| Western wheatgrass (*Pascopyrum smithii*) | 52–84 |
| Blue grama (*Bouteloua gracilis*) | 72 |
| Black grama (*Bouteloua eriopoda*) | 69 |
| Tobosa grass (*Pleuraphis mutica*) | 110–136 |
| Russian thistle (*Salsola australis*) | 12–32 |
| Fourwing saltbush (*Atriplex canescens*) | 185–234 |
| Broom snakeweed (*Gutierrezia sarothrae*) | 310–716 |
| **Water use efficiencies at Tifton, Georgia** | |
| Coastal bermudagrass (*Cynodon dactylon*) | 85 |
| Common bermudagrass (*Cynodon dactylon*) | 190 |

Controlled field conditions at Cheyenne, Wyoming. Water availability was maintained at 0.3 to 0.8 bars at 12-inch depth; soil was a fine, sandy, clay loam; organic matter ranged from 2–4 percent; (July 20 and Aug 29 harvest dates) (Fairbourn 1982).

| Range Grasses | July 20 | Aug. 29 |
|---|---|---|
| Blue grama *(Bouteloua gracilis)* | 245 | 180 |
| Slender wheat grass (*Agropyron trachycaulum*) | 520 | 262 |
| Western wheatgrass *(Pascopyrum smithii)* | 493 | 191 |
| Green needle grass (*Stipa viridula*) | 361 | 293 |
| **Pasture Grasses** | **July 20** | **Aug. 29** |
| Fawn tall fescue (*Festuca arundinacea*) | 493 | 219 |

| | | |
|---|---|---|
| Garrison creeping foxtail (*Alopecurus arundinaceus*) | 580 | 249 |
| Latar orchardgrass (*Dactylis glomerata*) | 361 | 253 |
| Regar bromegrass (*Bromus bieebersteinii*) | 493 | 267 |
| Thickspike wheatgrass (*Agropyron dasystachyum*) | 538 | 177 |
| **Legumes** | | |
| Alsike clover (*Trifolium hybridum*) | 366 | 233 |
| Dawson alfalfa (*Medicago sativa*) | 548 | 385 |
| Ladak alfalfa | 519 | 332 |
| Vernal alfalfa | 529 | 332 |

B. Studies at the Northern Great Plains Research Center in Mandan, North Dakota, showed that water use efficiencies of fertilized grasses generally increased. Comparisons among crested wheatgrass, smooth bromegrass, and native mixed grass prairie show that water use efficiency in response to nitrogen (N) fertilization was greatest for smooth bromegrass and least on mixed grass prairie. Under semiarid conditions, grass growth processes are controlled primarily by soil water availability and secondarily by N availability. Studies in the eastern United States (Pennsylvania) with cool and warm season grasses have shown that during years of evenly distributed precipitation, N was the main factor controlling yields, and water use efficiency accounted for 80 percent of the variation in yields of the species. When most precipitation occurred as large storm events or when precipitation was low or poorly distributed, soil water holding capacity was the major factor controlling yield, and water use efficiency accounted for about 40 percent of the variation in yields.

## 645.0707 Runoff and Erosion Dynamics

A. Runoff

(1) Overland flow or runoff begins when infiltration capacity is surpassed and when storage capacity of surface depressions is filled. In general, runoff varies with scale on the landscape. Runoff decreases as the size of the contributing area increases and provides more opportunities for infiltration. Runoff is closely tied to soil moisture content, compaction, condition or existence of soil aggregates, soil frost conditions, soil texture, porosity, as well as plant species, plant cover and root dynamics.

(2) Soil erodibility follows an annual cycle. It is highest at the end of a freeze-thaw period of late winter and lowest at the end of the summer rainy season when soils have been compacted by repeated rainfall.

(i) The Rangeland Hydrologic and Erosion Model (RHEM) (Nearing et al. 2011, Hernandez et al. 2017) is now available and has been proven effective for estimating surface runoff and soil erosion on rangeland uplands (Weltz and Spaeth 2012; Belnap et al. 2013; Hernandez et al. 2013, 2017; Al-Hamdan et al. 2015; Williams et al. 2016).

(ii) In arid and semiarid rangeland ecosystems, runoff is sporadic and interannual variations in runoff are quite high. Runoff is closely linked to chemical and nutrient cycling, erosion, salts, and contaminant transport. Runoff is a sensitive indicator of ecosystem change from one ecological state to another ecological state and response to disturbance (Pierson et al. 2011, Pierson and Williams 2016).

B. Erosion

(1) Soil erosion is the detachment of soil by wind and water. Variations in landscape, soil type, and available energy cause a continuum of detachment and deposition on rangeland, resulting in most soil particles moving only a few feet. Sediment production is related to runoff, which is the principle means of soil detachment and transport. Climate, vegetation, soil, and topography are the major variables affecting soil erosion from rangelands. In the western

United States, rangeland watersheds yield most of the sediment load, and forested watersheds produce the majority of streamflow.

(2) The key to developing more effective management systems requires an understanding that certain kinds of plants, vegetative growth forms, and vegetation clusters are more effective at stabilizing a site than others and provide early warning signals to rangeland degradation. In semi-arid and arid environments, alterations of the natural plant community—caused either by a natural event or anthropogenic causes—can lead to depletion of the original native plant species and replacement by exotic weedy species. Reduction of vegetative cover causes increased surface runoff and often leads to accelerated erosion. Rills and gullies develop, followed by larger flow concentrations. Further dissection of the land surface results in lower ground water tables, decreased infiltration of snowmelt and rainfall, and lower streamflows. Perennial streams can become ephemeral due to depletion of ground water storage, which has a deleterious effect on riparian vegetation.

(3) For every watershed and site within the watershed, there exists a critical point of deterioration due to surface erosion. Beyond this critical point, erosion continues at an accelerated rate, which cannot be overcome by the natural vegetation and soil stabilizing forces. Areas that have deteriorated beyond this critical point continue to erode even when human-caused disturbance is removed.

(4) What does 1mm of soil loss amount to in tons $ac^{-1}$, or Mg $ha^{-1}$? Several publications have provided estimates of average soil loss.

(i) How much is 1 mm of soil loss?

- 0.1 mm $yr^{-1}$ for our most recent geologic epoch (Wilkinson and McElroy 2007)
- 0.021 mm $yr^{-1}$ (the average erosion rate at 21 meters per million years (m/m.y.) (Summerfield and Hulton 1994).
- Loess and glacial till areas of Iowa, USA ~ 0.8–1.9 Mg $ha^{-1}$ $yr^{-1}$ (Ruhe and Daniels 1965, Walker 1966).
- On cultivated United States croplands, average estimated erosion rates are about 600 m/m.y. (0.6 mm $yr^{-1}$) (USDA NRCS 2000).

(ii) If 1 mm of soil erodes on a silt loam with a bulk density of 1.33 Mg $m^3$, what is the equivalent soil loss in Mg $ha^{-1}$ and United States tons $ac^{-1}$?

- For 1 mm soil depth = (1m)(1m)(0.001m) = 0.001 $m^3$
- Weight of soil 1 $m^2$ at 1 mm depth = (0.001 $m^3$)(Bulk density 1.33 Mg $m^3$) = 0.0013 Mg m3
- Weight of soil for 1 hectare at 1mm depth = (100m)(100m)(0.0013 Mg $m^3$) = 12.97 Mg $ha^{-1}$ (5.79 t $ac^{-1}$)

(5) Increases in erosion will occur on rangeland sites and in watersheds not protected by vegetation. Fine surface particles and organic matter are removed. Organic matter is rapidly decomposed on exposed soils, and raindrop impact further causes surface sealing, resulting in a more impermeable soil crust. The first stage of erosion is interrill erosion. Interill erosion (sheet erosion) combines detachment of soil from raindrop splash and transport by a thin flow of water across the surface. Minute rills form concurrently with the detachment of soil particles. As runoff becomes more concentrated in rills and small channels, the velocity, mass of the suspended soil, and intensity of turbulence increases. As kinetic energy of the runoff event occurs, the ability of the water flow to dislodge larger soil particles increases. In more arid areas with sparse vegetation cover and poor land use management, sheet and rill erosion is common. Rill erosion begins when water movement causing interrill erosion concentrates in discrete flow paths. Rill erosion produces the greatest amount of soil loss worldwide. Where soils are more resistant to sheet and splash erosion, erosion occurs mostly by rills and gullies. Sheet erosion is a more erosive process on sandy textured soils. Velocities of

6 in $sec^{-1}$ are required to erode soil particles 0.3 mm diameter. Velocities as low as 0.7 in $sec^{-1}$ will carry the particle in suspension.

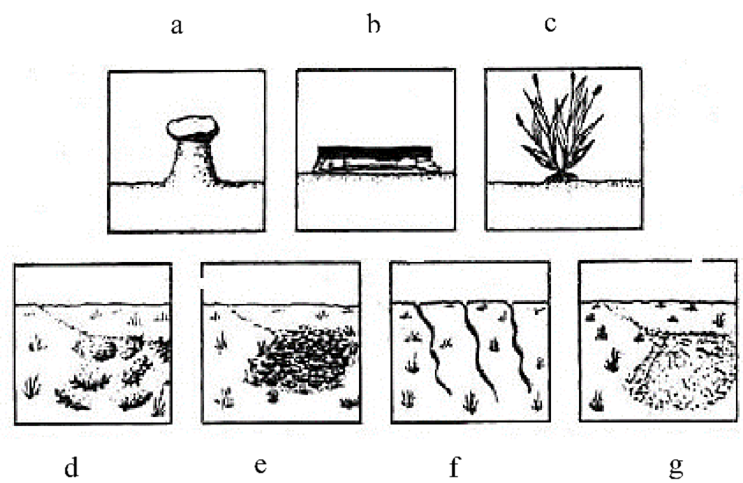
(6) Gully erosion occurs when runoff is concentrated at a nickpoint, where there is an abrupt change of elevation, slope gradient, and a lack of protective vegetation. See figure G-15. Gullies are recently channelized drainage features that transmit ephemeral flow, usually have steep sides and a head scarp (leading upslope area of exposed soil and rock), and are more than 30 cm wide and 60 cm deep (Selby 1982, Toy et al. 2002). These erosional features commonly form when a master rill deepens and widens its channel, especially where changes in slope or vegetation patterns occur on unconsolidated materials (Neary et al. 2012). Gullies may also form where debris and mud flows exit unstable drainage basins or where large subsurface drainage features collapse. The most common cause of gully formation is a loss in surface protection associated with a change in the overlying vegetation or soil disturbance on the hillslope. Headcuts are caused as water falls over the nickpoint and undermines this point and migrates upslope.

**Figure G-15.** Initiation nickpoints and headcuts associated with gully erosion on rangeland.

(7) Often, under normal climate and average precipitation regimes and intensities, erosion on rangeland can be difficult to detect. Long-term average erosion rates on rangeland are usually not informative as a measure of site erosion dynamics because they mask the accelerated erosion rates that occur during intense rainfall events. Attention to the effects of design storm dynamics is more important and relevant on rangelands, where 5 to 100-year storm frequencies with intense high-capacity short-term storms can initiate erosive events, especially rills and gullies. Pedestalling of plants, an indicator in the rangeland health matrix,

can be a warning sign of active erosion, where wind erosion, rills and gullies may not be readily apparent (figure G-16).

**Figure G-16.** Visual indicators of accelerated erosion on rangeland. **(a)** soil pedestal; **(b)** differential charring of woody litter is an indication of amount of soil eroded after fire; **(c)** pedestalled plant; **(d)** debris dams caused by accelerated runoff; **(e)** puddled depressions on soil surface where fine clays are deposited and form crusts, which have a cracked appearance during drying; **(f)** rill and gully formation; and **(g)** small alluvial fans deposited at slope transitions (adapted from Thurow 1991).




(8) Erosion can reduce productivity of the plant community so slowly that the reduction may not be recognized until the site has reached a threshold level. Increased runoff reduces available soil water which affects plant growth. Less plant growth means less residue. Less vegetation and residue provide less cover, which increases erosion. Because water erosion strongly relates to runoff, increased runoff also leads to increased erosion. Thus, the process advances exponentially, and reversing it may become physically and economically impossible, if it is not detected and controlled by proper management practices.

(9) Water erosion on range and pastureland can be determined in the field by a variety of indicators. Some of these factors are accounted for in Interpreting Indicators of the Rangeland Health (IIRH), Determining Indictors of Pasture Health (DIPH), and pasture condition scoring models. Examples of the indicators include:

- (i) Pedestalled soil, plants, rocks
- (ii) Base of plants discolored by soil movement from raindrop splash or overland flow
- (iii) Exposed root crowns
- (iv) Formation of miniature debris dams and terraces
- (v) Puddled spots on soil surface with fine clays forming a crust in minor depressions which crack as the soil surface dries and the clay shrinks
- (vi) Rill and gully formation
- (vii) Accumulation of soil in small alluvial fans where there are minor changes in slope
- (viii) Surface litter, rock or fragments exhibit some movement and accumulation of smaller fragments behind obstacles
- (ix) Eroded interspace areas between plants with unnatural gravel pavements
- (x) Flow patterns contain silt or sand deposits and are well defined or numerous
- (xi) Streambank erosion

(10) Soil surface characteristics, the dynamics of plant growth life and growth forms, individual plant species, and plant community type (ecological sites) have dynamic properties and

impacts on runoff and erosion (table G-11). Soil surface characteristics such as organic matter, bulk density, texture, structure, aggregate stability, porosity, and moisture conditions influence soil runoff and erosion by controlling the amount of infiltration and runoff from a site. Litter and vegetation reduce the soil's susceptibility to erosion by protecting the soil surface from raindrop impact, decreasing the velocity of runoff, encouraging soil aggregation, binding the soil with roots, and reducing soil compaction.

**Table G-11.** Measurements of Soil Loss from Various Land Uses and Types.

| Land Use | Location | Soil Loss (Tons/Ac) | Reference |
|---|---|---|---|
| Prairie dog towns | High Plains TX | 0.80 | Spaeth 1990 |
| Three awn grass/Texas tumblegrass | High Plains TX | 0.78 | Spaeth 1990 |
| Broom Snakeweed | High Plains TX | 0.47 | Spaeth 1990 |
| Buffalograss | High Plains TX | 0.07 | Spaeth 1990 |
| Blue grama | High Plains TX | 0.10 | Spaeth 1990 |
| Blue Grama/Buffalo | High Plains TX | 0.10 | Spaeth 1990 |
| Honey Mesquite/Sideoats grama/ Texas wintergrass | Rolling Plains TX | 0.62 | Carlson et al. 1990 |
| Mesquite removed/Sideoats grama/ Texas wintergrass | Rolling Plains TX | 0.11 | Carlson et al. 1990 |
| Denuded Honey Mesquite/Sideoats grama/Texas wintergrass | Rolling Plains TX | 10.4 | Carlson et al. 1990 |
| Natural ungrazed rangeland, Semi-arid to sub-humid | Avg. 17 data sources | 0.32 | van Oudenhoven et al. 2015 |
| Pastureland | Avg. 7 data sources | 1.89 | van Oudenhoven et al. 2015 |
| Abandoned rangeland, Semi-arid to sub-humid | Avg. 2 data sources | 1.20 | van Oudenhoven et al. 2015 |
| Silvo-pasture | Avg. 14 data sources | 1.49 | van Oudenhoven et al. 2015 |
| Restoration rangeland Semi-arid to sub-humid | Avg. 16 data sources | 0.06 | van Oudenhoven et al. 2015 |
| Sparse grassland | Alberta. Canada | 7.7 | Campbell 1970 |
| Grass and scrub | India | 1.60 | United Nations 1951 |
| Dry Woodland and Rangeland | Southern CA | 2.70 | Krammes 1960 |
| Dry Woodland and Rangeland after fire | Southern CA | 24.7 | Krammes 1960 |
| Woodland Protected | Texas | 0.05 | Smith and Stamey 1965 |
| Pinyon-juniper woodland Undisturbed | New Mexico | 0.14 | Ludwig et al. 2005 |
| Pinyon-juniper woodland | New Mexico | 0.45 | Disturbed, Ludwig et al. 2005 |
| Eucalypt savanna Undisturbed | NE Australia | 0.55 | Ludwig et al. 2005 |
| Eucalypt savanna | NE Australia | 0.79 | Disturbed, Ludwig et al. 2005 |
| Vegetation eliminated by Smelter fumes | Ontario | 26.1 | Pearce 1973 |
| Rural Roads Forest Roads | Idaho | 7.90 | Copeland 1965 |
| Forest Roads in a jammer unit | Idaho | 29.7 | Megahan and Kidd 1972 |
| **Grazing Systems** | | | |
| Low intensity grazed rangeland | Avg. 9 data sources | 0.61 | van Oudenhoven et al. 2015 |
| High intensity grazed rangeland | Avg. 22 data sources | 1.80 | van Oudenhoven et al. 2015 |
| Overgrazed degraded rangeland | Avg. 2 data sources | 4.41 | van Oudenhoven et al. 2015 |

## 645.0708 Soil Properties Affecting Hydraulic Processes

A. Soil Particle Size (Texture)

(1) Rangeland plant communities are multivariate in nature. No single variable acts alone—many variables interact and affect hydrologic dynamics. Soil texture is probably the most dominant physical property that is correlated with infiltration capacity. Soil texture provides a way to identify the contribution of sand, silt, and clay (soil test results may describe texture as soil particle size). In general terms, fine textured soils have more clay, whereas coarse-textured soils contain more sand. Technically, the United States Department of Agriculture has classified sand particles as being between 0.05 mm to 2 mm in size. Sand particles are visible to the naked eye. Silt particles are not visible to the naked eye, ranging from 0.002 mm to 0.05 mm. Clay particles are the smallest class of particles, < 0.002 mm. Surface area increases inversely to particle size. Clay particles have a large surface area per unit weight and have a tremendous capacity to absorb and store water. Very fine clay particles act as colloids, and if suspended in water do not settle out. Soil hydraulic properties for soil textural classes are shown in table G-12 and figure G-6 (Rawls et al. 1998). Infiltration rates can be higher, particularly in the initial stages of the process, where soils are well aggregated, and surface mineral crusting is minimal. Table G-12 shows approximate relationships between soil texture, water storage, and water intake rates under irrigation conditions.

(2) Infiltration rates that are slower than expected for certain soil textures are usually an indication of several causal factors. Soil structure, the arrangement of soil particles and pore spaces, may be altered by previous cultivation or other disturbances (grazing, compaction by machinery). Heavier-textured soils typically form aggregates, which are formed by biotic components such as roots, fungal hyphae, mycorrhizae, compounds formed by fungi and algae, and adhesive byproducts of organic matter decay, humic components, and microbial synthesis of mucilaginous compounds. Porosity (pore volume) is a physical soil attribute and is correlated with soil texture and the degree of soil aggregation. Some soil hydraulic properties are shown by soil texture in table G-12. Porosity and pore size, in addition to other soil physical attributes (texture, bulk density, structure), determine infiltrability of water into the soil.

B. Soil Organic Matter

(1) The global soil pool contains about as much of the carbon reservoir as plants and the atmosphere combined. See figure G-16. Carbon imbalance occurs from burning fossil fuels and open burning (fire). The largest carbon reserve is in carbonate rocks (75 million Pg). More carbon is emitted from the soil (62 Pg) than entering the soil (59–60 Pg) due to erosion and loss of organic matter. Land use changes have been estimated to produce 1.6–2 Pg C $yr^{-1}$. Throughout the world, grazing lands contain 10 to 30 percent of the world's organic carbon stores (Kimble et al. 2001); about 5 percent is contained in U.S. soils (Waltman and Bliss 1997). Significant losses of soil organic matter on rangeland have occurred over time and are attributed to cultivation and abandonment, overgrazing, introduction of exotic plant and animal species, invasive native species, and lack of proper rangeland management practices. Following cultivation, soil organic carbon losses of 20 to 40 percent occur over a 5 to 20-year period (Davidson and Ackerman 1993). Figure G-17 shows the decline in organic matter after cultivation on tallgrass prairie. The active soil organic matter (SOM) pool of organic matter is rapidly mineralized when cultivation begins. After 100 years of cultivation, about 56 percent of the total soil organic matter has been lost. Reseeding back to permanent native plants would slowly and continually begin to build organic matter content over time.

**Table G-12.** Estimation guides for soil hydraulic properties based on sample data (Rawls et al. 1998). The geometric mean of the Ks sorted according to soil texture and bulk density classes along with the 25 and 75th percentile.

| USDA Soil Class Texture | Sand (%) | Clay (%) | Porosity ($m^3$ $m^{-3}$) | Geometric Mean Ks (mm $h^{-1}$) | Ks 25th percentile (mm $h^{-1}$) | Ks 75 th percentile (mm $h^{-1}$) | Mean Capillary Drive Cd (mm) | Sample Size |
|---|---|---|---|---|---|---|---|---|
| Sand | 92<br>91 | 4<br>4 | 0.44<br>0.39 | 181.9<br>91.4 | 96.5<br>64.0 | 266.8<br>218.5 | 50 | 39<br>30 |
| Loamy Sand | 82<br>82 | 6<br>7 | 0.45<br>0.37 | 123.0<br>41.4 | 83.8<br>30.5 | 195.5<br>77.6 | 70 | 19<br>28 |
| Sandy Loam | 65<br>68 | 11<br>13 | 0.47<br>0.37 | 55.8<br>12.8 | 30.5<br>5.1 | 129.6<br>31.3 | 130 | 75<br>112 |
| Loam | 38<br>43 | 23<br>22 | 0.47<br>0.39 | 3.9<br>6.2 | 1.6<br>2.8 | 28.4<br>16.5 | 110 | 44<br>65 |
| Silt Loam | 18<br>21 | 19<br>20 | 0.49<br>0.39 | 14.4<br>3.4 | 7.6<br>1.0 | 37.1<br>9.9 | 200 | 61<br>46 |
| Sandy Clay Loam | 56<br>58 | 26<br>26 | 0.44<br>0.37 | 7.7<br>2.8 | 2.0<br>1.0 | 50.5<br>10.9 | 260 | 20<br>53 |
| Clay Loam | 29<br>35 | 35<br>35 | 0.48<br>0.40 | 4.2<br>0.7 | 2.2<br>0.2 | 13.1<br>3.8 | 260 | 20<br>53 |
| Silty Clay Loam | 10<br>10 | 34<br>32 | 0.50<br>0.43 | 3.7<br>4.9 | 2.3<br>2.3 | 10.4<br>14.0 | 350 | 26<br>33 |
| Sandy Clay | 51 | 36 | 0.39 | 0.9 | 0.3 | 2.5 | 300 | 14 |
| Silty Clay | 4 | 49 | 0.53 | 1.8 | 0.5 | 7.5 | 380 | 10 |
| Clay | 18<br>26 | 53<br>50 | 0.48<br>0.40 | 2.0<br>1.8 | 0.9<br>0.3 | 6.0<br>6.9 | 410 | 20<br>21 |

(2) Estimates are slightly different among authors (adaptations and data from Berner 1990, Schimel 1995, Batjes 1996, Falkowski et al. 2000, Pacala and Socolow 2004, Houghton 2007, Solomon 2007, Battin et al. 2009, Haddix et al. 2011, Pan et al. 2011, Lal 2018). Note: $10^6$ g=Mg=megagram (tonne); $10^{12}$ g=Tg=teragram; $10^{15}$ g=Pg=petagram (Adapted from Spaeth 2020).

(3) Carbon gains in rangeland soils occur early in soil formation and development, but eventually reach equilibrium or a steady state (Schlesinger et al. 1990, Chadwick et al. 1994, Li et al. 1994, Larcher 2003). In terrestrial ecosystems, once soil organic matter has reached equilibrium, during some years there is a positive buildup of organic matter. During other years a loss of organic matter may occur. However, the long-term average is constant or zero (Larcher 2003, Wolf and Snyder 2003). Development of soil organic matter in rangeland soils is dependent on the soil forming processes:

soil formation = function of (climate, potential biota—plants and animals, relief, soil parent material, and time)

**Figure G-16.** The global carbon cycle with representative carbon pools and reservoirs that interact with earth's atmosphere (units next to reservoir names are Pg C; Pg = $10^{15}$ g).

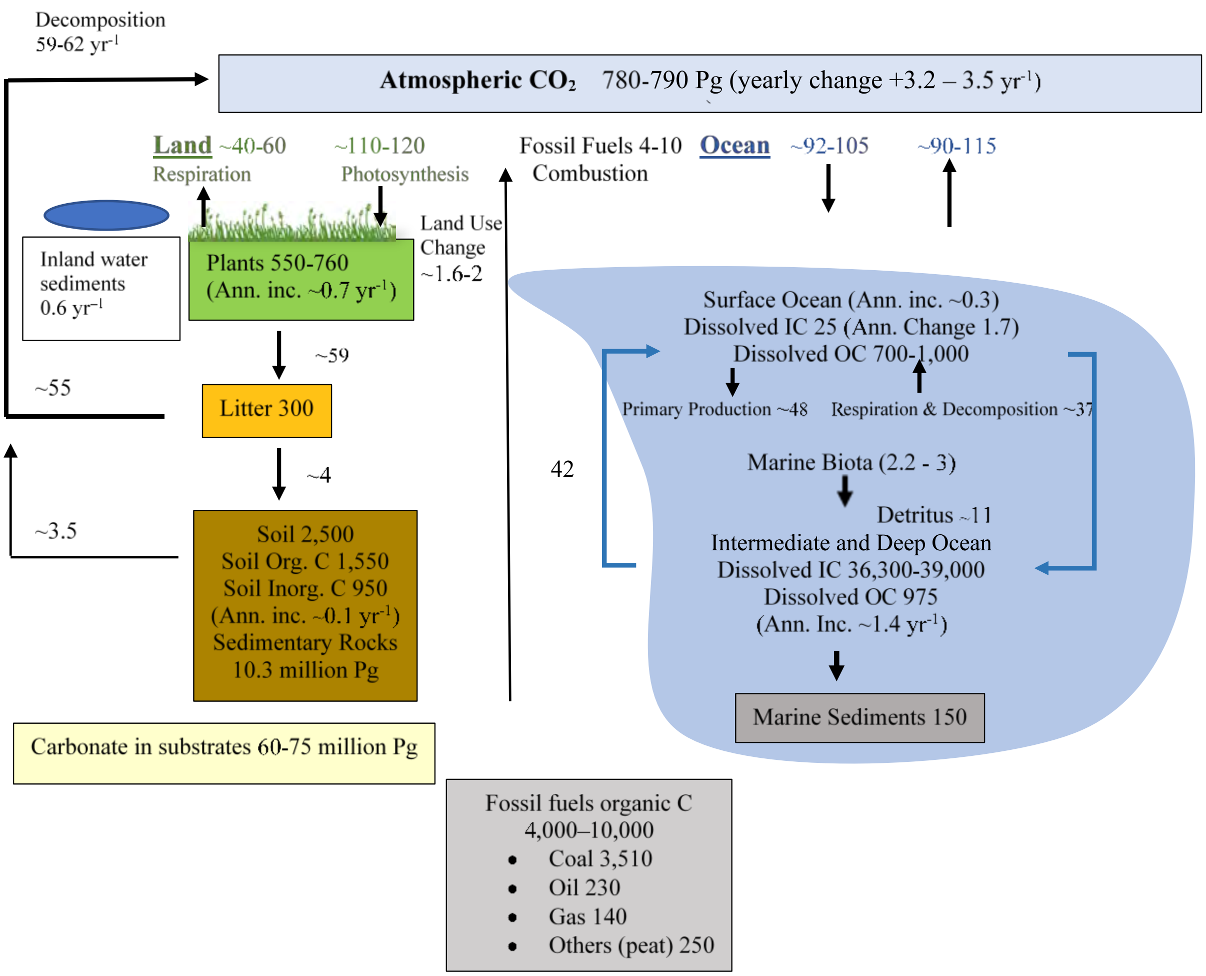
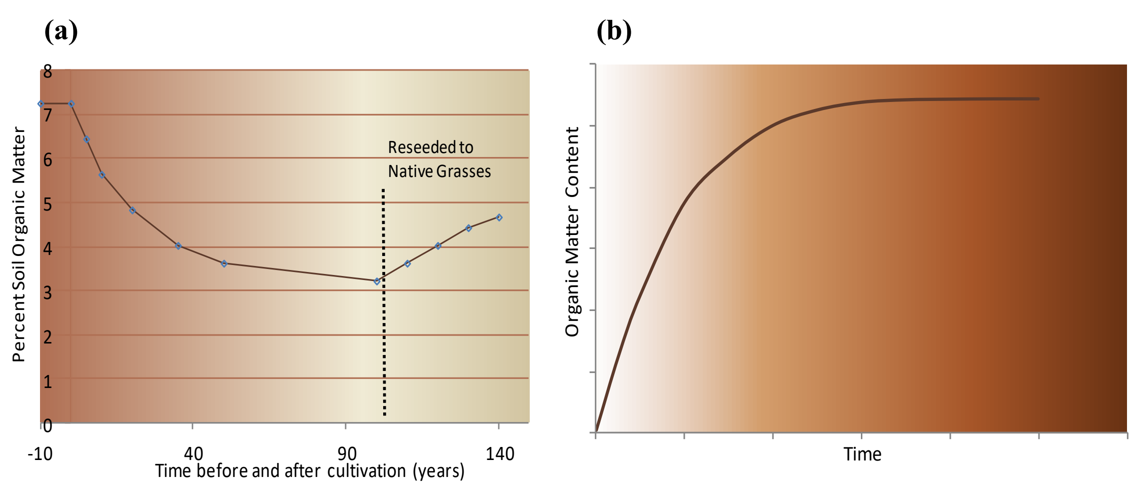



**Figure G-17.** **(a)** Tallgrass prairie converted to cropland with high historic organic matter content (7.5 percent). **(b)** Development of organic matter over time



Graph **(a)** shows progressive loss of organic matter in the upper 10 inches after cultivation. If field is seeded back to native grasses after 100 years, organic matter would slowly increase. Graph **(b)** With development of organic matter over time, the rate of accumulation is progressive until a constant level is reached**—**in equilibrium with climate, soil properties, plant community, and decomposition processes.

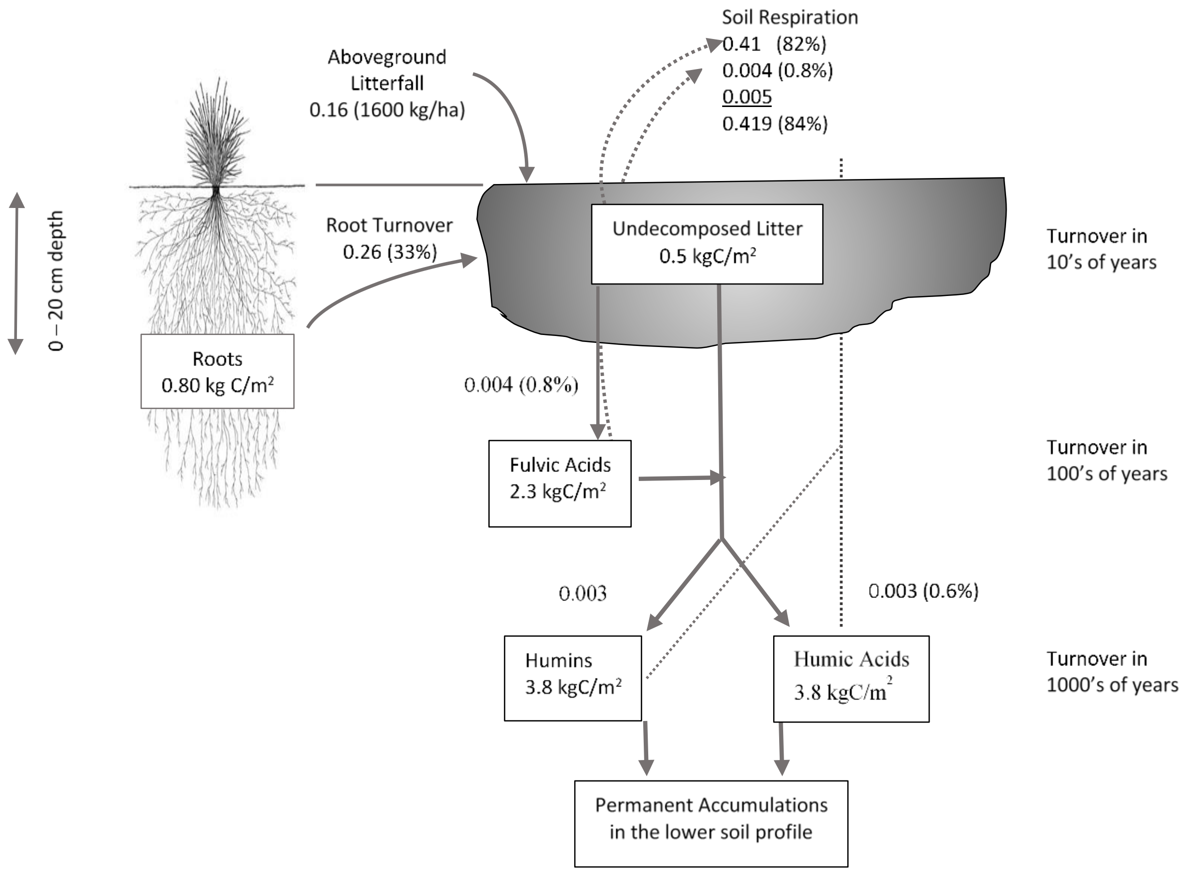
(4) Organic matter is an important and dynamic soil component in natural rangeland ecosystems. It is the foundation of a productive soil and is a principle underlying component of soil and site stability, hydrologic function, biotic integrity, and overall soil health. Soil organic matter provides important soil functions related to energy, nutrients, and biological diversity, which affect soil aggregation and subsequent infiltrability. The stratification and inherent amounts of organic matter with soil depth is an indication of proper function of soil and site stability, hydrologic function, and biotic integrity because of improved infiltrability, resistance to erosion, and a source of plant nutrients. The ramifications of organic carbon in soils and soil health are immense (Schnitzer and Khan 1989, Sylvia et al. 1998, Wolf and Snyder 2003, Paul 2007, Motuzova et al. 2011, Bj'orklund and Mello 2012, Wall et al. 2012).

(5) Soil organic matter consists of plant or animal products in various stages of breakdown (decomposition). Decomposition of plant material includes physical, chemical, and biological processes. Mineralization is a biological process in which organic substances are converted to inorganic substances by soil microorganisms. The common outputs are carbon dioxide ($CO_2$), energy, water, plant nutrients, and resynthesized organic carbon compounds. The rate of decomposition is determined by three major factors: soil organisms, the physical environment, and the quality of the organic matter. Bacteria and fungi are primarily responsible for mineralization of organic matter in soils. Microorganisms release enzymes that oxidize organic compounds in organic matter. The final end-products are nutrients in the mineral form.

(6) The rate of mineralization is influenced by biotic and abiotic factors, and nutrients released vary significantly among the different fractions of soil organic matter. On average, after one year, about 17 to 35 percent of the C in plant residue was incorporated into SOM (65 to 83 percent is lost to the atmosphere) (Schlesinger 1995, Himes 1998, Stewart et al. 2017). Schlesinger's 1995 model of detrital carbon dynamics at 0–20 cm soil depth on a grassland soil shows that about 84 percent of the above-ground litterfall and root turnover is lost through soil respiration (figure G-18). In grasslands, the vegetation grows rapidly; and at the same time, parts of the shoots and roots die off or are eaten. The annual increase in organic matter fluctuates between large positive and negative values, but the long-term average is approximately a zero gain (figure G-19 data from Kucera et al. 1967). Recovery of soil organic carbon in soil depends upon the soil type, initial carbon inventories, climate, field cultivation practices, and field management. Management practices capable of minimizing erosion and maximizing return of residue biomass are fundamental to the maintenance of organic matter in cultivated soils.

(7) Organic matter has a profound effect on soil physical and chemical properties, which subsequently affect hydrology. The interrelationships among all the related factors create a complex web that is dynamic with the environment. For example, from a physical point of view, soil organic matter influences and enhances soil structure, granulation, aggregate stability, and porosity, which are related to hydrologic factors such as infiltration capacity. Organic matter is highly correlated with infiltration, water holding capacity, and subsequent available water for plant growth, reduced runoff and erosion, deep percolation into the soil profile (which can recharge ground water and eventually aquifers), and subsurface lateral flow to streams and springs.

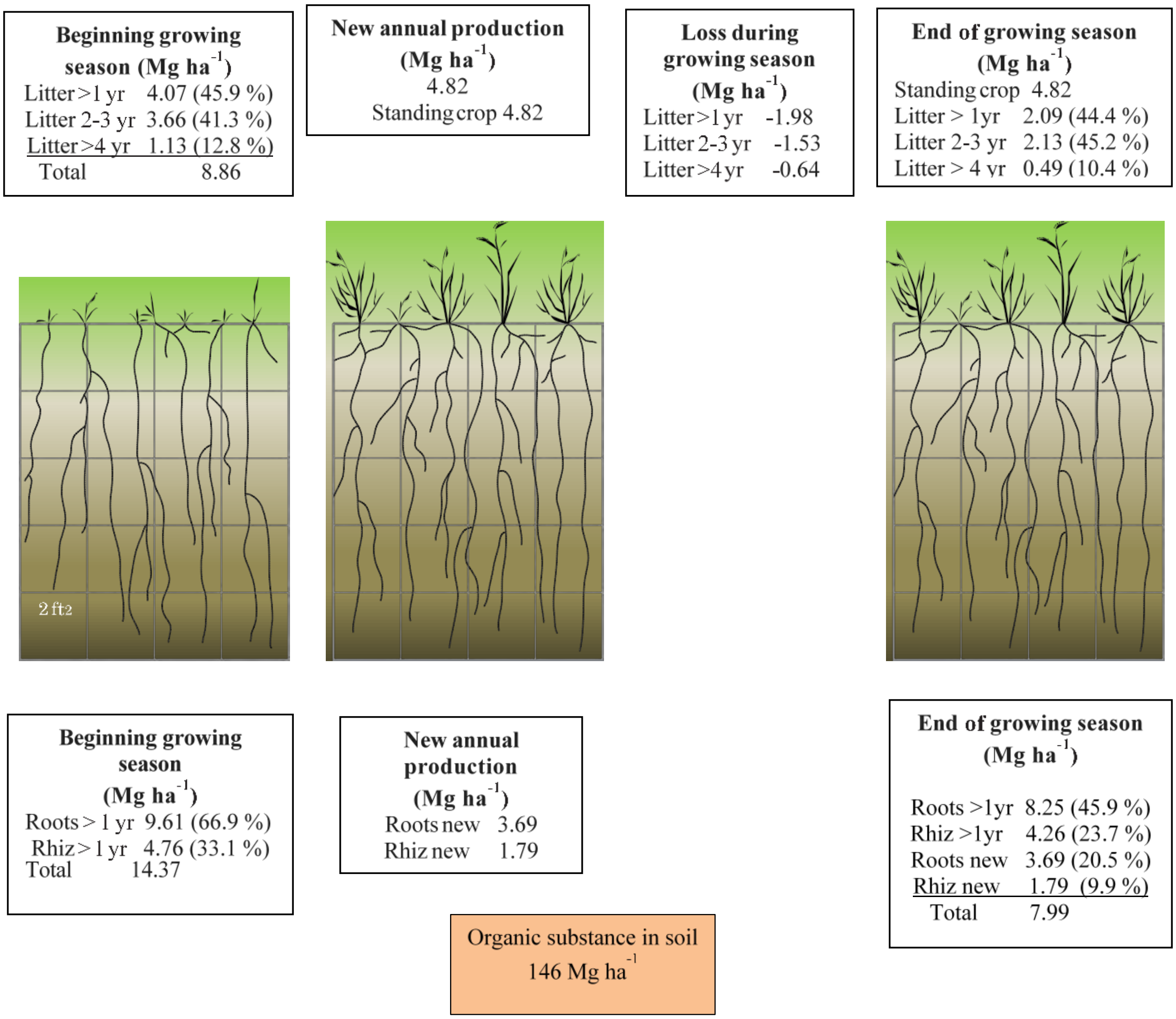
**Figure G-18.** Carbon dynamics (carbon pools and annual transfer) on a grassland (mollisols). (Adapted from Schlesinger 1995).




C. Soil Aggregate Stability

(1) Soil aggregation facilitates water infiltration, providing pore space (oxygen) and habitat niches for soil microorganisms, stabilization, and a buffer of soils to erosion. Soils that lack adequate residue cover are compacted by grazing or other means and have high amounts of bare ground. Such soils are more apt to have poor aggregations, soil crusting, lower water holding capacity, and higher runoff and erosion (Franzleubbers 2002a, Franzleubbers and Stuedeman 2002b). The stability of soil aggregates is often used as an index of soil and site stability and hydrologic function, as it represents the culmination of processes that bind the soil into discrete particles that resist deterioration upon wetting. Soil aggregate stability is an important concept to recognize because it is related to organic matter content and biological activity in the soil. Aggregate stability refers to how well soil aggregates hold together. Soil aggregates are soil particles that are bound together into larger particles as a result of biological activity in the soil, soil physical characteristics and chemistry.

**Figure G-19.** Content and turnover of organic dry matter in the Tallgrass Prairie. No grazing of large herbivores, only from insects and rodents (Data from Kucera et al. 1967).




(2) Soil microorganisms secrete compounds, fungi form hyphae (thread-like structures), and earthworms secrete a mucus (coelomic fluid that enables them to move more easily in the soil and lines their burrow paths to keep them from collapsing) that stabilizes and aggregates soil particles, essentially organic glues. Generally, soil aggregates < 0.25 mm are held together by older, more stable organic compounds, whereas larger aggregates (>0.25 mm) form from more recent biological activity and organic material. The larger aggregates are more fragile and less stable but are good indicators of soil health. Aggregate stability can be measured in the lab or in the field with test kits (Herrick et al. 2005). Tillage practices, hoof impact by livestock, and foot traffic can degrade aggregate stability.

D. Soil Structure

(1) Soil structure is a physical property of soil and is characterized by how the individual particles (sand, silt, and clay) and organic matter are arranged into larger aggregates called peds. See figure G-20. The peds break apart along natural weak points which have low tensile

strength. Soils covered by natural vegetation and undisturbed by previous tillage exemplify the inherent structure of the soil. Soil structure is identified by shape and appearance. The easiest structure to identify is single-grained where the soil particles consist of non-aggregated sand or loose windblown loess. Granular structure appears as small, rounded aggregates that are easily separated from the mass.

(i) Granular soil structure is characteristic of soil surfaces (A horizons) high in organic matter with earthworm activity.

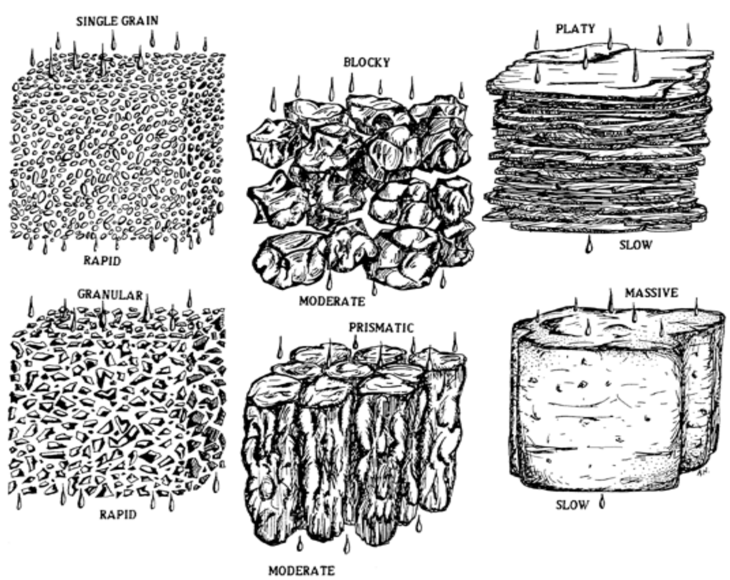
(ii) Platy structure has particles which are arranged in flattened planes and are usually arranged horizontally. During the soil forming processes, soil parent materials deposited by water and ice can develop a platy structure. Clay soils that are compacted by machinery can also develop a platy structure.

(iii) If soil peds are blocky, irregular, or cube like, the structure is blocky. There are two types of blocky structure: angular, block edges are sharp and distinct; and subangular, planes are rounded in appearance. Blocky structure is usually seen in B horizons but may also occur in the A horizon.

(iv) Columnar and prismatic structures appear as vertically oriented columns, which vary in height (subsurface horizons in arid and semiarid regions; poorly drained areas in humid regions). Columnar is differentiated from prismatic in that the top of the peds are more rounded. Prismatic or columnar structure is often associated with swelling clays and in some subsoils where sodium is present.

(v) The last structural type, massive, represents a soil condition where there is no evidence of the above structural types. The soil particles appear as a mass with no apparent pattern.

**Figure G-20.** Soil structural types found in mineral soils and associated infiltration rate.




(2) What happens to soil structure when rangeland has been previously cultivated or compacted by various disturbances such as machinery and heavy grazing? Several things begin to occur: reduction and damage to soil structure, soil aggregates are broken up and dispersed, and soil pores are aerated above the norm, which exposes, oxidizes, and accelerates the breakdown of soil organic matter. Farming operations that use heavy machinery (deep plows, heavy discs, chisels) can penetrate the subsoil, disturb, and alter soil structure. Rangelands with a cultivation history have undergone mixing of the surface and subsoil, which lead to a loss of organic matter, possibly bringing heavier clay particles and sodium (if in the subsoil horizon) to the surface, and development of plowpans (dense layers of soil caused by compaction

during mechanical disturbance, especially plowing). Soil surfaces of frequent and heavily disturbed soils tend to crust over after wet and dry cycles because of altered soil texture, soil physical properties, and loss of organic matter.

E. Bulk Density

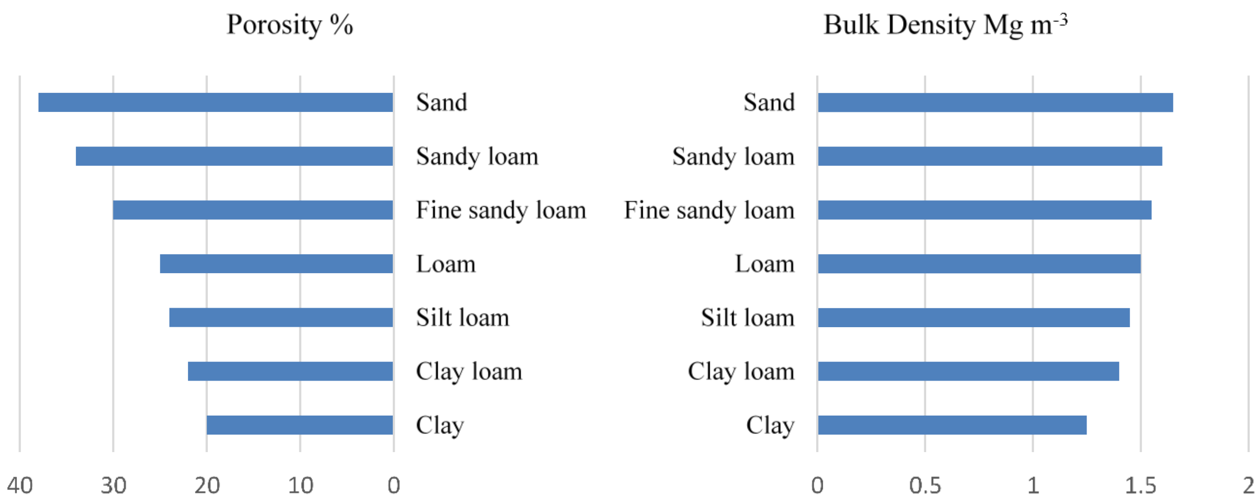
(1) Particle density and bulk density are two important factors that are inherently associated with particle size (texture) and degree of compaction (table G-13). Particle density (same as specific gravity) is the mass per unit volume of the individual particles. Particle density for coarse sand=2.65 Mg $m^{-3}$, silt = 2.79 Mg $m^{-3}$, and clay = 1.25 Mg $m^{-3}$. Particle density of soils with high organic matter is reduced (0.9 to 1.4 Mg $m^{-3}$). The SI unit for density is megagrams per cubic meter (Mg $m^{-3}$), which is numerically equivalent to grams per cubic centimeter (gm $cm^{-2}$). Bulk density can be a measure of soil compaction, although soils have predictable bulk density ranges with textural classes. Bulk density decreases as soils become finer textured (silt loams and clays). Bulk density tends to increase with soil depth due to a variety of factors such as textural changes from the original soil-forming materials, downward movement of clay, and gravity and weight of the soil compacting the material.

(2) There is a relationship between porosity, bulk density, and texture: pore space and bulk density in fine-textured soils (clays) is lower compared to coarse-textured sandy soils (figure G-21). As soils become compacted (machinery, grazing, foot traffic), there is less pore space and higher bulk density. Compaction is deleterious and negatively impacts crop and rangeland plant growth and production because it results in less water storage in the soil horizon.

**Table G-13. Average bulk density values for soil textural groups (USDA-NRCS 2018a)**
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr10/tr/?cid=nrcs144p2_074844

| Texture Terms: | Moist Bulk Density Mg $m^{-3}$ |
|---|---|
| COS (coarse sand) | 1.70–1.80 |
| S (sand) | 1.60–1.70 |
| FS (fine sand) | 1.60–1.70 |
| VFS (very fine sand) | 1.55–1.65 |
| LCOS (loamy coarse sand) | 1.60–1.70 |
| LS (loamy sand) | 1.55–1.65 |
| LFS (loamy fine sand) | 1.55–1.65 |
| LVFS (loamy very fine sand) | 1.55–1.60 |
| COSL (coarse sandy loam) | 1.55–1.60 |
| SL (sandy loam) | 1.50–1.60 |
| FSL (fine sandy loam) | 1.50–1.60 |
| VFSL (very fine sandy loam) | 1.45–1.55 |
| L (loam) | 1.45–1.55 |
| SIL (silt loam) | 1.45–1.55 |
| SI (silt) | 1.40–1.50 |
| SCL (sandy clay loam) | 1.45–1.55 |
| CL (clay loam) | 1.40–1.50 |
| SICL (silty clay loam) | 1.45–1.55 |
| SC (sandy clay) | 1.35–1.45 |
| C (clay (35–50%) | 1.35–1.45 |
| C (clay) (50–65%) | 1.25–1.35 |
| SIC (silty clay) | 1.40–1.50 |

**Figure G-21.** Comparison of average porosity and bulk density values with soil texture (Spaeth 2020).




## 645.0709 Vegetation Effects on Hydrologic Processes

A. Infiltration and runoff are regulated by the kind and amount of vegetation, edaphic, climatic, and topographic influences (Wood and Blackburn 1981). Vegetation is the primary factor that influences the spatial and temporal variability of soil surface processes which affect infiltration, runoff, and interrill erosion rates on arid and semiarid rangelands (Blackburn et al. 1992). As plant cover declines, infiltration decreases (Holechek et al. 2004). Each plant-soil complex exhibits a characteristic infiltration pattern (Gifford 1985). Hydrologic processes such as infiltration are not constant from one range or soil complex to another. Factors such as soil physical and chemical attributes, plant life growth forms, and storm dynamics can significantly change hydrologic dynamics among different ecological sites and within an ecological site.

B. Each plant community type must be evaluated in terms of what variables affect hydrology on the site. No single factor ever varies alone, especially with regard to hydrologic processes. Variables that affect site hydrology include:

(1) above- and below-ground plant morphology
(2) total production
(3) production of individual plant species
(4) total canopy cover
(5) canopy cover of individual plant species
(6) plant architecture
(7) grass growth form or habitat (sod vs. bunch caespitose)
(8) interspace
(9) shrub coppice
(10) soil physical properties
(11) soil chemical properties

C. Semiarid rangelands throughout the western United States have significant spatial and temporal variations in hydrologic and erosion processes. The spatial distribution of the amount and type of vegetation has been shown to be an important factor in modifying infiltration and interrill erosion rates on rangeland grass (Thurow et al. 1986, 1988; Spaeth et al. 1996a). In comparisons between permanent grass, cropland, and denuded forest, grass stands can have twice the infiltration capacity. See table G-14.

**Table G-14.** Infiltration capacity for various plant covers (Bonde and Subramanyam 1968).

| Cover Type | Infiltration Capacity |
|---|---|
| Established Grass | 5.1 in $hr^{-1}$ |
| Wheat | 3.6 in $hr^{-1}$ |
| Peas | 3.6 in $hr^{-1}$ |
| Fallow Land | 2.8 in $hr^{-1}$ |
| Denuded Forest | 2.4 in $hr^{-1}$ |

D. Plant life form, such as tall grasses, mid grasses, short grasses, forbs, shrubs, half shrubs, and trees and their compositional differences on a site greatly influence infiltration and runoff dynamics. Infiltration is usually highest under trees and shrubs and decreases progressively in the following order: bunchgrass, sodgrass, and bare ground (figure G-22) (Thurow et al. 1986). On the Edwards Plateau, Texas, shrub coppice zones showed highest interception and infiltration, followed by bunchgrass, then sodgrass (table G-15, figure G-23) (Blackburn et al. 1986). Infiltration rate was correlated to total organic cover and bulk density characteristics on the site. The amount of cover in the individual vegetation stands provided protection of soil structure from direct raindrop impact. Sediment production was related to the total aboveground biomass and bunchgrass cover of the site (Blackburn et al. 1986).

**Table G-15.** Summary of canopy interception, interrill erosion, runoff, and erosion from oak, bunchgrass, sodgrass, and bare ground dominated areas, Edwards Plateau, Texas. Based on 4 inches rainfall rate in 50 minutes (data from Blackburn et al. 1986). Tarrent silty clays overlying an undulating fractured caliche, slope (l–2 percent).

| Condition | Oak Motte | Bunchgrass | Sodgrass | Bare Ground |
|---|---|---|---|---|
| % Canopy Interception | 7 | - | - | - |
| % Grass and Litter Interception | - | 0.5 | 0.4 | 0.0 |
| % Litter Interception | 12 | - | - | - |
| Interill Erosion (lbs/ac) | 0.0 | 179 | 1,250 | 5,358 |
| % Surface Runoff | 0.0 | 24 | 45 | 75 |
| % Infiltration | 81 | 75.5 | 54.6 | 25 |

**Figure G-22.** Average infiltration rates for three vegetation types, Edwards Plateau, Texas (adapted from Thurow et al. 1986).

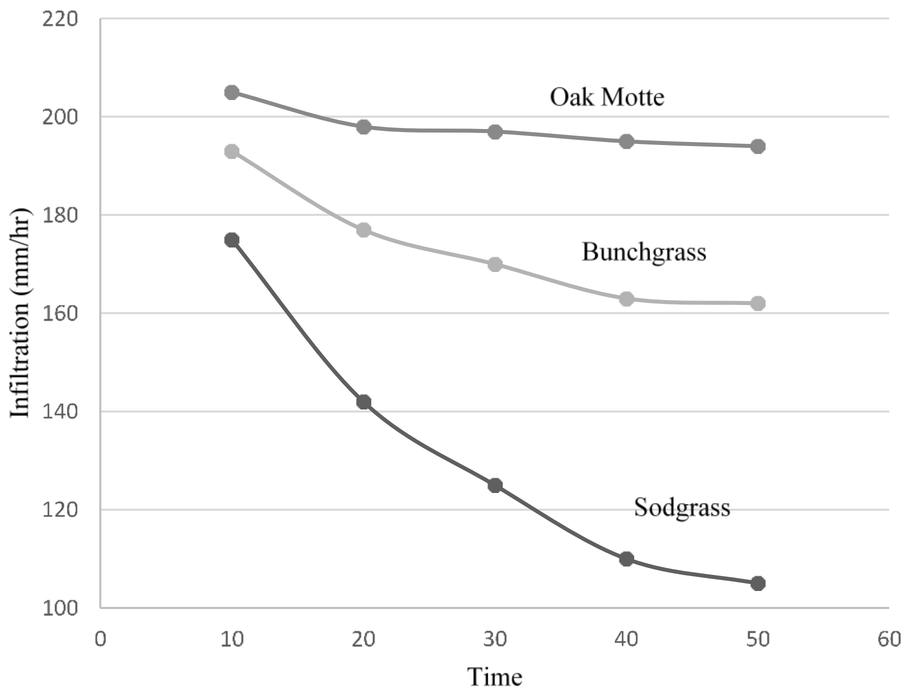
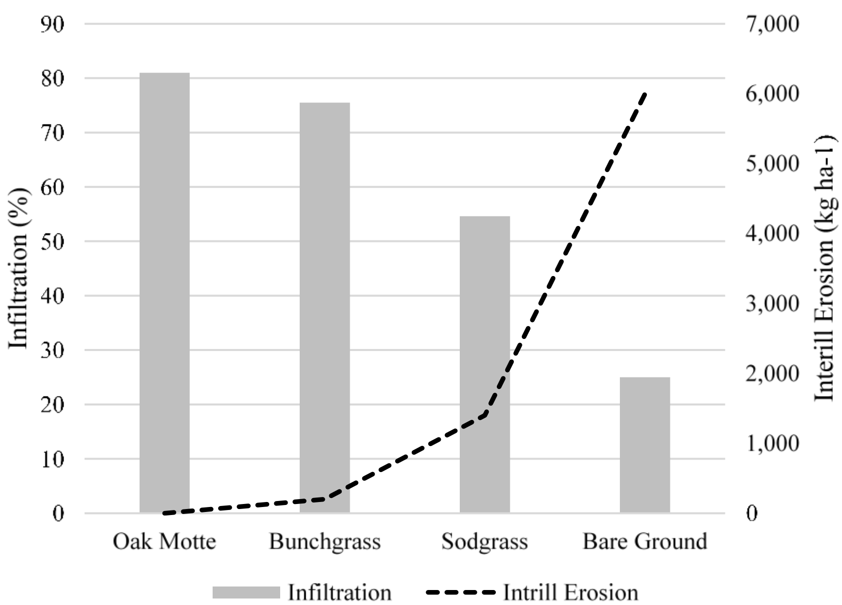


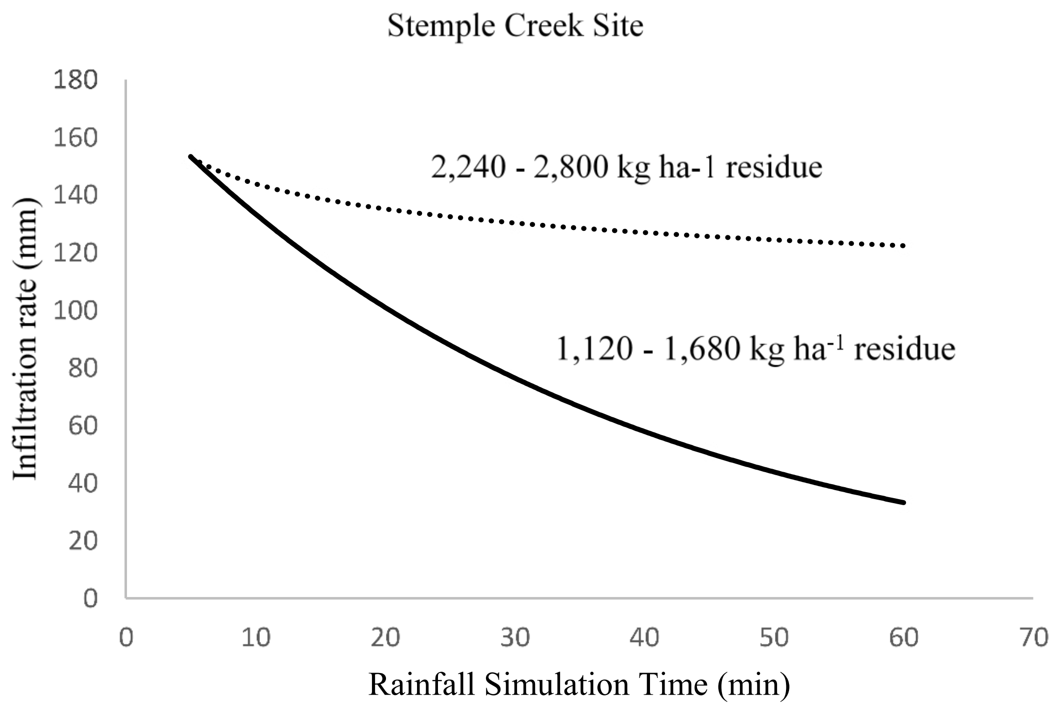

**Figure G-23.** Amount of infiltration and interrill erosion from oak, bunchgrass, sodgrass, and bare ground dominated areas on Edwards Plateau, Texas. Rainfall Simulation applied 4 in rain in 50 minutes. Tarrent silty clays overlying an undulating fractured caliche, slope (l–2 percent) (data from Blackburn et al. 1986).




E. Annual grasses can provide sufficient cover to protect the soil surface, but are vulnerable to wildfire, which usually denudes the site, causing high risk for accelerated runoff and high erosion rates. In California annual grass communities, foliar cover of grass species may be high. However, rainfall simulation experiments showed that the amount of biomass on the site (with high cover) was more closely correlated with higher infiltration and lower runoff than foliar cover (figure G-24) (Spaeth 2020).

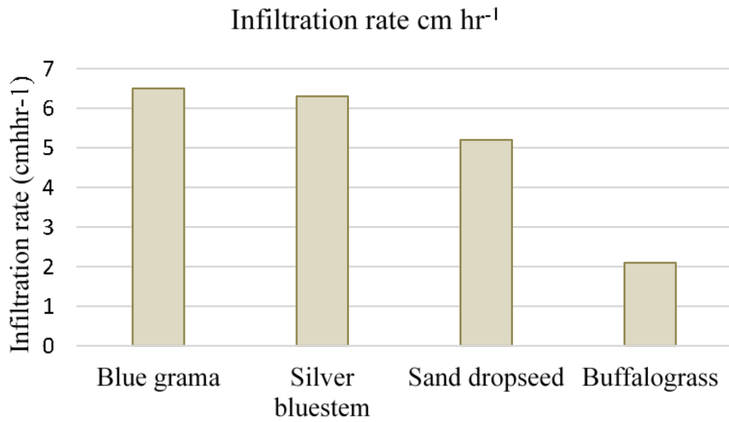
F. Levels of foliar cover necessary for site protection against accelerated soil erosion on rangelands vary from 20 percent in Kenya (Moore et al. 1979) to 100 percent for some Australian conditions (Costin 1959). Most studies indicate that cover of 50 to 75 percent is probably sufficient to prevent degradation from accelerated soil erosion processes (Wood and Blackburn 1981, Gifford 1985,Weltz et al. 1998, Pierson et al. 2011, 2016, Williams et al. 2014, and Cadaret et al. 2016 a, b).

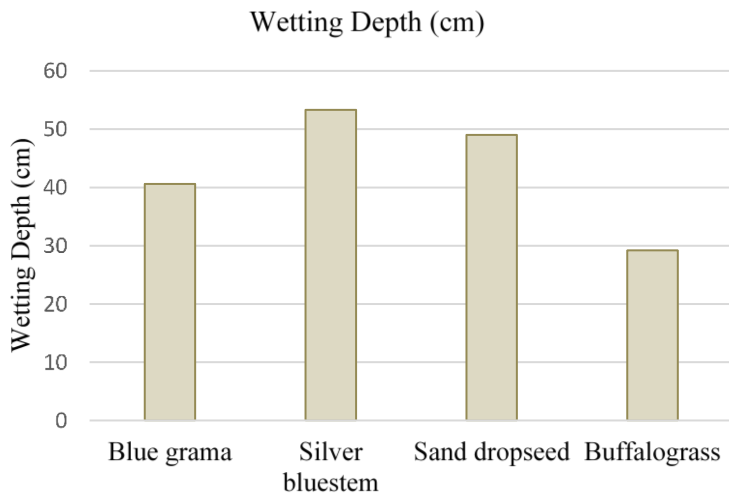
**Figure G-24.** Rainfall simulation infiltration rate vs. time at Stemple Creek site, California. Soil type identical, with two residue levels (Spaeth 2020). Foliar cover was near 100 percent on all plots.




G. Individual plant species, such as different grasses, forbs, and shrubs, also have a profound effect on hydrology and erosion dynamics (Spaeth 1996a, b). Field studies have documented infiltration capacity with individual species composition. Dee et al. (1966) found that water infiltrated three times faster in blue grama and silver bluestem (*Bothriochloa saccharoides*) stands than areas dominated by annual weeds such as summer cypress (*Kochia scoparia*) and windmill grass (*Chloris verticillata*) (figure G-25). Blue grama terminal infiltration capacity was also about three times higher than buffalograss stands, holding soil type constant. Wetting front was greatest under silver bluestem, most likely because of deeper rooting depth and macropores from root decay.

**Figure G-25.** Infiltration and wetting front experiments in shortgrass prairie, west Texas (Dee et al. 1966).




H. Mazurak and Conard (1959) evaluated infiltration capacity of different grass species as three locations in Nebraska (table G-16). Infiltration on western wheatgrass plots was highest at two locations. Big bluestem was associated with greater infiltration rates at two locations, and smooth bromegrass and buffalograss (sod forming species) were associated with low infiltration.

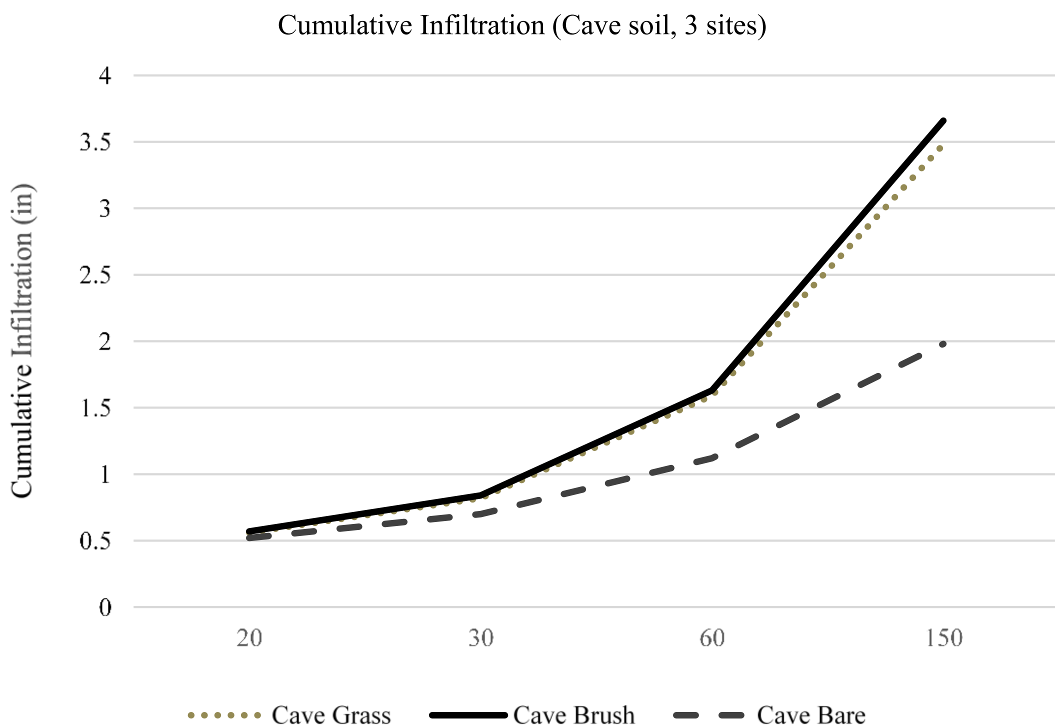
I. On the Walnut Gulch Experimental watershed in southeastern Arizona, Tromble et al. (1974) conducted a study of infiltration rates for three vegetation states on Cave and Hathaway gravelly loam soils: grass, brush, and bare ground. Dominant vegetation on the Cave site was whitethorn acacia (*Acacia constricta*), creosotebush (*Larrea divaricata*), sandpaper bush (*Mortonia scabrella*), tarbush (*Flourensia cernua*), yucca (*Yucca* spp.), common sotal (*Dasylirion wheeleri*), Mexican bluewood (*Condalia mexicana*), squawbush (*Condalia spathulata*), burroweed (*Haplopappus tenuisectus*), and various cacti. The grasses included black grama (*Bouteloua eriopoda*), fluffgrass (*Tridens pulchellus*), sideoats grama (*Bouteloua curtipendula*), wolftail (*Lycurus phleoides*), threeawn (*Aristida* spp.), and annuals. Dominant vegetation on the Hathaway soil was black grama, fluffgrass, curly mesquite (*Hilaria belangeri*), and a limited number of annuals. Shrubs encountered were burroweed, whitethorn, creosotebush, bear-grass (*Nolina microcarpa*), yucca, common sotol, and ocotillo (*Fouquieria splendens*). On the Cave gravelly loam, cumulative infiltration was very similar for the brush and grass states, compared to significantly lower cumulative infiltration for bare ground (figure G-26a). The Hathaway gravelly loam site exhibited the same trend for grass ungrazed and brush. Cumulative infiltration was significantly lower for the grazed grass site (figure G-26b).

**Table G-16**. Field experiments comparing infiltration rates of different grass species at three locations in Nebraska using ring infiltrometer at 60 min, values are cm $hr^{-1}$ averaged for 7 years (Mazurak and Conard 1959).

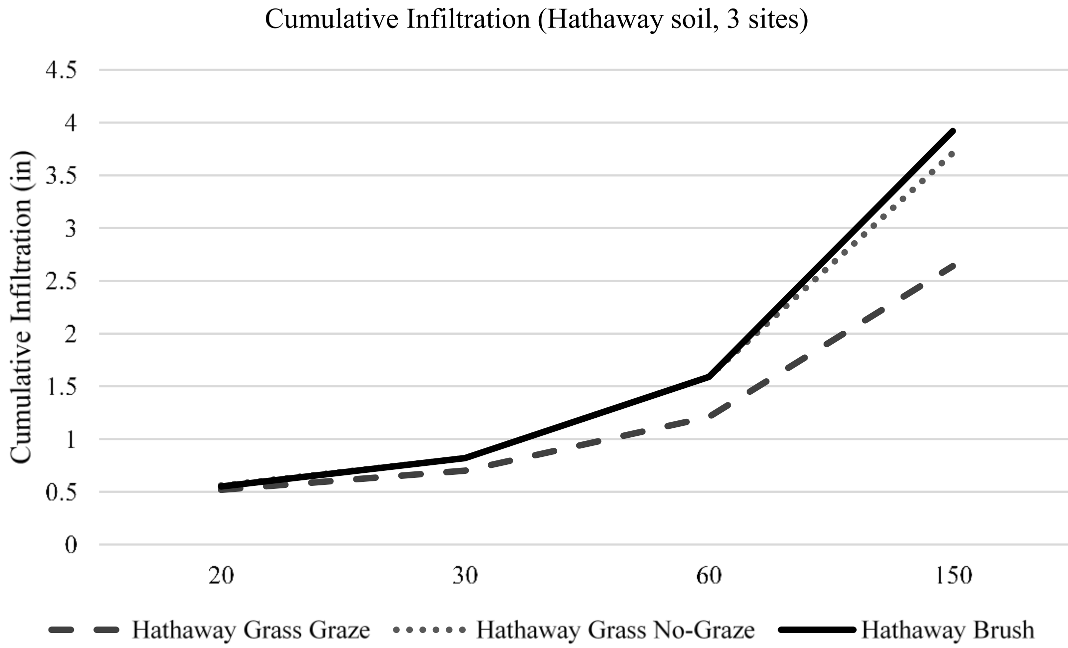
| Sharpsburg scl l (Lincoln, NE) | Holdrege vfsl (North Platte, NE) | Rosebud vfsl (Alliance, NE) |
|---|---|---|
| Western wheatgrass (12.2) | Big bluestem (5.7) | Western wheatgrass (6.9) |
| Crested wheatgrass (10.8) | Russian wildrye (5.0) | Desert wheatgrass (4.7) |
| Big bluestem (9.7) | Western wheatgrass (4.8) | Crested wheatgrass (4.1) |
| Desert wheatgrass (8.7) | Blue grama (4.7) | Russian wildrye (3.4) |
| Intermediate wheatgrass (8.6) | Sideoats grama (4.7) | Smooth bromegrass (3.8) |
| Buffalograss (8.2) | Desert wheatgrass (4.0) | Intermediate wheatgrass (2.9) |
| Smooth bromegrass (7.8) | Smooth bromegrass (2.8) | |
| Blue grama (7.4) | Buffalograss (2.4) | |
| Sideoats grama (7.0) | | |

**Figure G-26.** Average infiltration rates on two soil-vegetation complexes at the Walnut Gulch Experimental Watershed in southeastern Arizona. **(a)** cumulative infiltration (Cave soil, three sites) and **(b)** cumulative infiltration (Hathaway soil, three sites) (Tromble et al. 1974).

**(a)**



**(b)**




J. Some shrubs and half-shrubs are associated with coppice dunes or mounds composed of litter and wind-transported soil. Field experiments show that surface soil organic carbon, bulk density, percentage silt, and infiltration and interrill erosion rates are higher for shrub-coppice dunes and shrub-interspace areas compared to interspace (figures G-27 and G-28) (Blackburn 1975, Johnson and Gordon 1988, Blackburn et al. 1990, 1992; Pierson et al. 2001, 2002a, 2008).

**Figure G-27.** Infiltration curves for the big sagebrush community, Duckwater Watershed, Nevada. (data from Blackburn 1975).

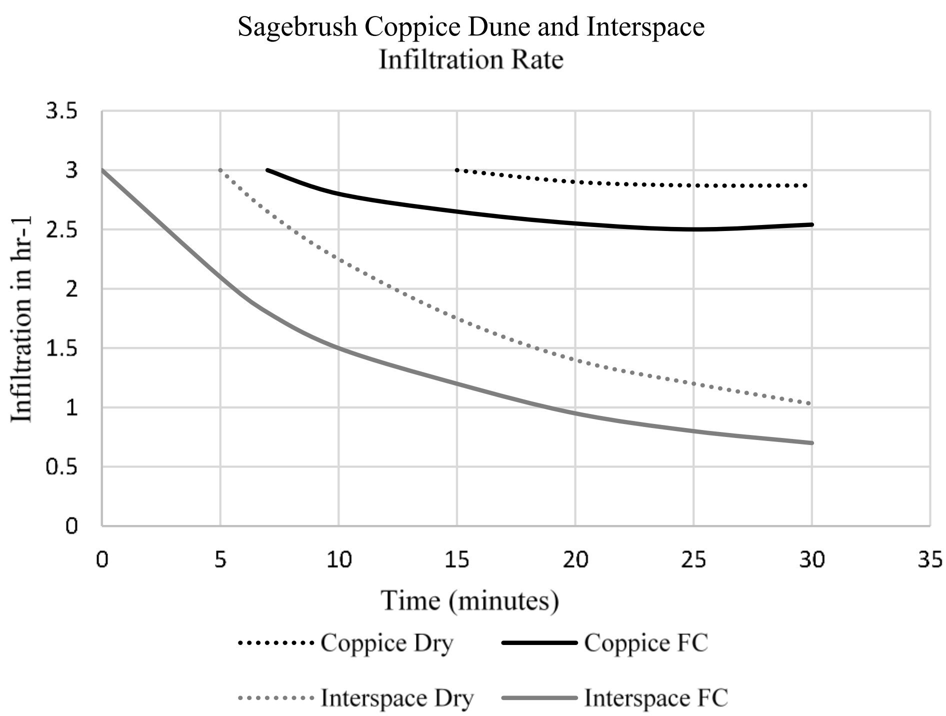
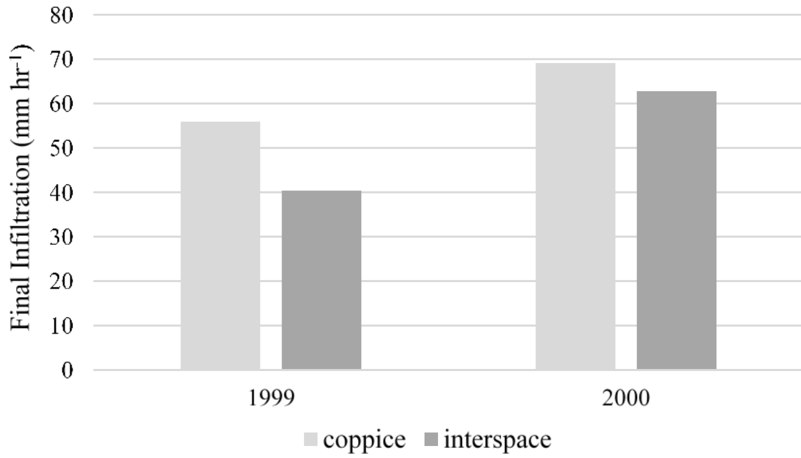
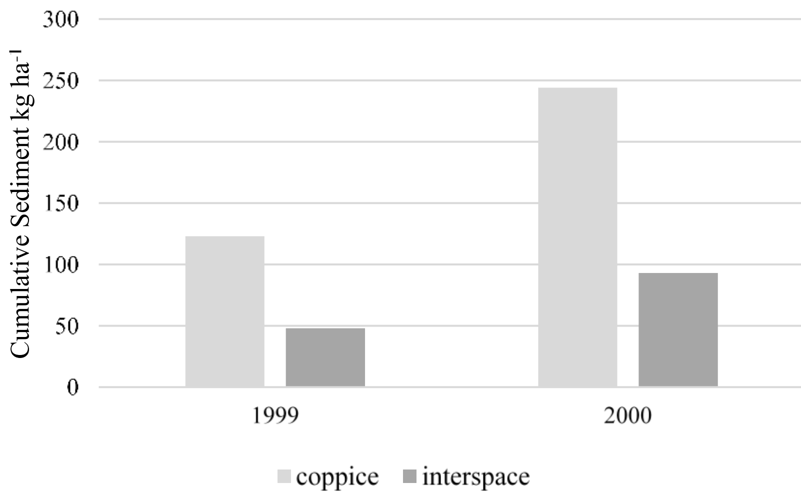


**Figure G-28. (a)** Average final infiltration rates on sagebrush coppice and interspace. **(b)** Cumulative sediment losses on sagebrush coppice and interspace. Mountain big sagebrush site, Denio, Nevada. (Pierson et al. 2001).

**(a)**




**(b)**




K. Vegetation patches (small clumps of grasses 0.5–2 $m^2$ to large tree groves 100–1,000 $m^2$) and other obstructions such as logs, rocks, and ant mounds on the landscape act as barriers and impediments that slow and trap runoff water, sediments, and nutrients from open interspace areas (Wilcox and Breshears 1995, Ludwig et al. 2005). In addition, when vegetation patch growth is enhanced, capturing water and nutrients, new biomass and woody growth further increases the capacity of the patch to intercept overland flow from subsequent rainstorm events (Ludwig et al. 2005). When grazing or other disturbances reduce vegetative cover in patches, not only is forage production reduced, but runoff and sediment losses can increase.

## 645.0710 Case Studies: Review of Vegetation Effects on Hydrology and Erosion

A. Tall grass prairie

Soils and vegetation data were collected along a line transect extending eight-tenths of a mile across a chalk flat range site in Gove County, Kansas (Linnell 1961). Infiltration was collected along the transect, using a ring infiltrometer. Soils were friable silt loams and light silty clay loams. Clay content was higher in the lower horizons. The dominant plant species were sideoats grama, buffalograss, salt grass, little bluestem, sand dropseed, and big bluestem. Average basal cover and above ground biomass were 16.4 percent and 2,348 lbs $acre^{-1}$ respectively. Infiltration rates varied considerably depending on the soil properties and vegetation. Infiltration was higher when little bluestem was dominant, compared to sideoats grama-dominated sites.

B. Short grass prairie

Water infiltrated three times faster in blue grama and silver bluestem (*Bothriochloa saccharoides*) stands than areas dominated by annual weeds such as summer cypress (*Kochia scoparia*) and windmill grass (*Chloris verticillata*) (Dee et al. 1966). Wetting front was greatest under silver bluestem, most likely because of deeper rooting depth. Infiltration rates were three times greater for blue grama (bunch grass growth form), compared to buffalograss (sodgrass growth form) (Spaeth 1990).

C. Short grass prairie, weedy species

Some weedy species such as broom snakeweed (*Gutierrezia sarothrae*) are associated with similar infiltration rates found in native grass stands (historic plant reference communities) in west Texas short grass prairie (Spaeth 1990). On a loamy ecological site in west Texas, infiltration rates in broom snakeweed stands were equal to reference state blue grama stands. The implication is that vegetation states within an ecological site or successional stage are not always correlated with hydrologic condition. Some half-shrub and shrub species develop coppice dunes beneath the plant, which capture additional organic matter and windblown silt.

D. Mixed grass prairie, clubmoss vs. mid grasses

In rainfall simulation studies near Killdeer North Dakota, runoff on soils at antecedent moisture with 17 to 25 percent composition by weight of clubmoss (*Lycopodium dendroideum*) had 0.28 in $hr^{-1}$ of runoff compared to near zero runoff on sites with native mid-grasses.

E. Mixed grass prairie

(1) Aase and Wight (1973) measured and compared infiltration rates between undisturbed mixed grass prairie and adjacent prairie sandreed (*Calamovilfa longifolia*) colonies. The predominant species in the mixed grass component were western wheatgrass (*Agropyron smithii*), fringed sagebrush (*Artemisia frigida*), blue grama (*Bouteloua gracilis*), sedges (*Carex* spp.), prairie junegrass (*Koeleria cristata*), and needle and thread grass (*Stipa comata*).

(2) Prairie sandreed colonies were interspersed in the mixed grass vegetation and measured 20 ft in diameter. According to the profile descriptions, sand content in the A horizon and clay content in the B horizon were higher under the prairie sandreed colonies. Statistically, only the clay content in the upper one to two inches was significantly different. Infiltration was almost four times higher (9.0 in $hr^{-1}$) in the prairie sandreed colonies than the surrounding vegetation mixed grass vegetation (2.4 in $hr^{-1}$). The authors attributed the higher infiltration rate to the vigorous growth form of prairie sandreed. Less raindrop impact on the soil surface caused less sealing of the soil surface. Soil texture may have been a secondary influencing

factor which influenced infiltration rates, as indicated from the small textural differences between the two plant communities.

F. Tap rooted and fibrous rooted plants

In the Boise river watershed, Pearse and Wooley (1936) compared the absorption rates of water between bare soil plots and vegetated plots. In general, plots with a single plant absorbed water 71 percent faster than bare soil plots. Compared to bare soil, a fibrous-rooted plant was associated with a 127 percent increase in infiltration, while a 51 percent increase in infiltration was noted for tap-rooted species.

G. Soil loss in relation to bare soil conditions

(1) On reclaimed grassland sites in South Dakota, a marked increase in soil loss was recorded when bare soil increased from 28 to 45 percent (Ries and Hoffmann 1986).
(2) Lane et al. (1987) conducted large plot rainfall simulation studies on five sites in semiarid and desert rangeland areas in Arizona and Nevada. Three treatments were evaluated: natural vegetation, vegetation removed, and bare soil conditions. Sites differed in plant communities, soils, and locations. When all data from both states were pooled, a 39 percent decrease in average infiltration rates was observed by removing the vegetative canopy cover. Also, when rock and gravel cover was removed from the clipped sites, an additional decrease of 34 percent in infiltration rate occurred. A 60 percent decrease in average infiltration rates occurred between the vegetated and bare soil areas. "Vegetative canopy cover and surface cover of rock and gravel exhibited comparable influences on final infiltration rates. Final infiltration rates decreased significantly as vegetative canopy cover and soil surface rock and gravel cover decreased" (Lane et al. 1987).
(3) Branson and Owen (1970) found that runoff on salt desert shrub watersheds in western Colorado were directly related to the percentage of bare soil within a watershed. As bare soil surfaces increased, runoff increased (r = 0.81); and as plant cover plus mulch increased, runoff decreased (r = -0.80).
(4) Lysimeter Study, Grass vs. Bare Soil: Hino et al. (1987) investigated the role of grass on infiltration processes and subsurface flow (table G-17). Lysimeter I, grass was planted (species not given, mean height was 24 inches); lysimeter II was bare soil. Soil was a loamy clay. The dimensions of the lysimeter were 7.4 ft. in length x 1.3 ft. in width x 2.3 ft. in depth. The lysimeters were inclined at a slope of 10 percent.

**Table G-17.** Water use by grass and bare soil.

| Treatment | Bare Soil | Grass Cover |
|---|---|---|
| Total water applied (mm) | 500 | 500 |
| Infiltration (mm) | 372 | 496 |
| Surface runoff (mm) | 128 | 4 |
| Evaporation/Transpiration (mm) | 194 | 354 |
| Ground water flow (mm) | 176 | 140 |

H. Impacts of plant cover, rock cover, slope, and soil Depth on infiltration on semiarid rangeland in New Mexico: On semiarid rangeland (slopes 16 –70 percent) in the Guadalupe Mountains of southeastern New Mexico, infiltrability was strongly influenced by vegetal cover and biomass. Plant cover was generally better correlated with infiltrability than plant biomass. Aerial cover was a better indicator of infiltrability than basal cover. "The relative importance of grasses, shrubs or litter was dependent on their respective abundance, especially grass" (Wilcox et al. 1988). On shallow soils, the impacts of soil depth became more acute as infiltration progressed. Rock cover was negatively associated with infiltrability because of low vegetal cover. A positive correlation was found between slope gradient and infiltrability, which may be due to increased interflow rates with increases in slope (Wilcox et al. 1988).

I. The importance of soil and vegetation and their influence on rangeland hydrology: Grazing management treatments have been investigated more extensively than any other issue in rangeland hydrology research (Blackburn 1984). Treatments such as grazing intensity and systems are often compared with respect to infiltration and sediment yield. Studies of this nature are often of limited value since the "real issue is not the practice itself, but how the practice alters the soil and vegetation components that influence the hydrologic relationships" (Blackburn et al. 1986).

J. Infiltration in various plant communities in Nevada: Infiltration rates of 29 plant communities and soils on five rangeland watersheds in Nevada varied considerably within and between watersheds. "Highest infiltration rates and lowest sediment production occurred on sites with well-aggregated soils free of vesicular porosity" (Blackburn and Skau 1974).

(1) On five watersheds in Nevada, Blackburn (1975) found that soil surface horizon morphology had the greatest influence on infiltration. On a scale of 1 to 5, 1 = sandy texture or well aggregated granular structure without vesicular pores, and 5 = strong platy structure having many vesicular pores, or clayey and massive. More sediment was produced from moist soils at field capacity than for dry conditions because soil surface instability was enhanced when it was saturated. Sediment production decreased on sites where organic matter, sand-sized particles, coppice dunes, and litter increased. Sediment production was usually greater as bulk density increased in the surface four inches.

(2) Invasive plants have contributed to rapid desertification and loss of ecosystem services in the last century. Extensive woody plant encroachment altered runoff and soil erosion across much of the drylands and significantly contributed to desertification. An example is the Great Basin region in western North America, where over 20 percent of Great Basin ecosystems have been significantly altered by invasive plants, especially exotic annual grasses and native conifers, resulting in loss of biodiversity. This land conversion has resulted in desertification and reductions in forage availability, wildlife habitat, and biodiversity (Pierson et al. 2011, 2013; Miller et al. 2013).

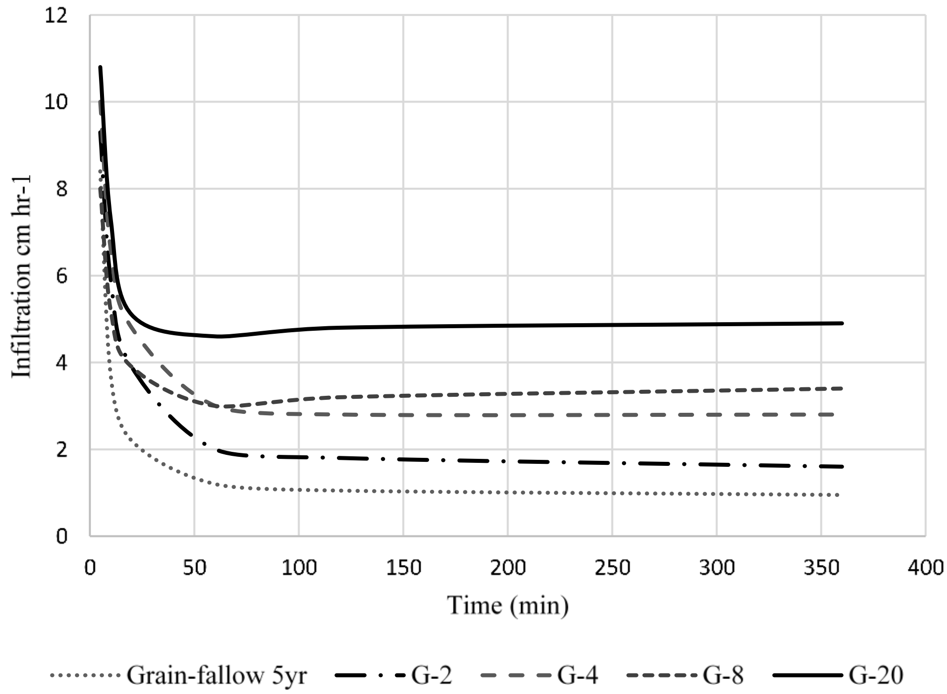
K. Mazurak et al. (1960) compared grain crop infiltration with various age-seeded perennial grass stands of intermediate wheatgrass (Agropyron intermedium) and smooth bromegrass (Bromus inermis). See figure G-29. Infiltration rates of grass seedings starting at age four years were significantly different from a grain-fallow system. Infiltration increased with age of grass stands, and the authors discussed possible effects that may be due to more developed root systems.

L. Water intake and plant cover on rangelands: "The more plant cover on rangeland soils, the more rainfall will be absorbed" (Rauzi 1960). Comparisons of infiltration rates on a silty soil near Newell, South Dakota showed that higher plant cover and good range condition (2,600 lbs $ac^{-1}$ biomass production) absorbed 1.43 in $hr^{-1}$ during a rainfall simulation test. In comparison, a low-cover condition (1,200 lbs $ac^{-1}$ biomass production) absorbed only 0.61 in $hr^{-1}$ of artificial rain.

(1) The amount of plant material on the soil surface is important in absorbing the impact of raindrops. Erosion and soil surface sealing are also reduced (Rauzi 1960). "Regardless of soil type, water-intake rates depend on the type of plant cover, the amount of standing vegetation, and the amount of mulch material on the ground" (Rauzi 1960).

(2) Infiltration is usually highest under trees and shrubs and decreases progressively by bunchgrass, sodgrass, and bare ground (Blackburn 1975, Wood and Blackburn 1981, Knight et al. 1984, Thurow et al.1986).

**Figure G-29.** Comparison of infiltration of grain crop with different age intermediate wheatgrass and smooth bromegrass pastures. Notes: plots hayed with 40 lbs ac$^{-1}$ ammonium nitrate in spring, not grazed. (Age of stand in years: G-2 = 2 yr. per. Grass; G-20 = 20 yr. per. grass).

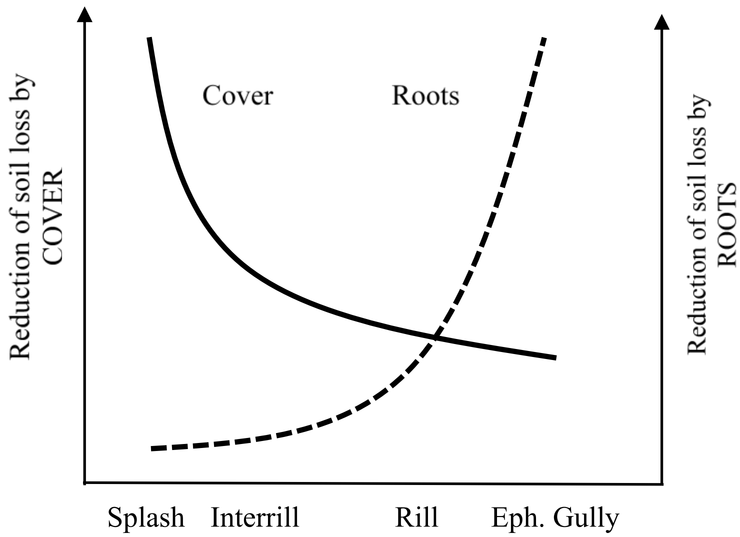



M. Runoff and vegetation relationships: "Runoff varies with the kind of vegetation as well as the quantity of vegetation" (Branson et al. 1981). Runoff quantities from different vegetation types are related to environmental complexes with major influential variables such as vegetation, soil, temperature, altitude, and precipitation zones (Branson et al. 1981). Rainfall events ranging from 1.5 to 3 in hr$^{-1}$ have 4 to 9 times more runoff on bare soil compared to areas with adequate plant cover (Branson et al. 1981).

N. Effect of roots on rangeland hydrology and erosion: In addition, biotic factors such as roots and soil flora can enhance infiltration rates and capacity (Pearse and Wooley 1936, Lipiec et al. 2006). It was found that infiltration rates in grass-covered soil can be higher (van Noordwijk et al. 1991, Mitchell et al. 1995) or lower (Gish and Jury 1983, Huat et al. 2006, Ng and Menzies 2014, Ng et al. 2016) than those in bare soil. Infiltration rates in grass-covered soil were lower when roots were actively growing, but they were higher when mature roots were decaying.

Based on the structural model (figure G-30) indicating the relative importance of vegetation cover and plant root density on the different water erosion processes (splash, interrill, rill, and ephemeral gully erosion), vegetation cover is the most important parameter for reducing splash and interrill erosion. In contrast, plant roots have greater influence of reduction of rill and ephemeral gully erosion.

**Figure G-30.** Structural model indicating the relative importance of vegetation cover and plant root density on different water erosion processes, i.e., splash, interrill, rill, and ephemeral gully erosion.




## 645.0711 Physical, Chemical, and Biological Crusts affect Infiltration (Spaeth 2020).

A. Physical and chemical crusts can be problematic in cropland soils and rangelands where these crusts alter ecosystem functions related to soil health. These crusts can form on the soil surface by raindrop impact on bare soil, evaporative processes forming chemical crusts, and compaction from various sources such as grazing and other related vehicular traffic. Vesicular crusts are common where aggregate stability breaks down, and gas bubbles form a crusty layer 1–10 mm thick. As raindrops impact bare ground, whatever remnant of aggregate stability remains is further dispersed to the inherent soil particles. The smaller soil particles wash into and block any existing soil pores and form a crust as the soil dries. As drying occurs, soil surface tension contracts the soil particles into a dense layer. This clogging action can reduce pore continuity and infiltration capacity by 90 percent (Belnap et al. 2001). The outcome results in low saturated hydraulic conductivity and increased runoff and soil erosion. As this process continues, poor soil structure, reduced pore space, consistently less and unstable soil aggregates, decreases in organic matter, and less microbial function become more pronounced. In contrast to physical soil crusts reducing hydrologic function, these crusts may have a positive influence on reducing wind erosion—at least temporarily. The presence and perpetuation of soil physical crusts creates an environment that is associated with low plant reproductive capacity, negligible seed germination; and on rangelands, this condition is highly conducive to the beginning of desertification.

B. Physical crusts can commonly form on silt, clay, and loam soils; and in some cases, salts either in the soil or irrigation water can promote clay dispersion. As aggregates are dispersed, clay particles permeate soil pores; and when soil begins to dry out, the soil surface forms a thin cemented layer, often with cracks, which inhibits water infiltration, exacerbating runoff and potential erosion (figure G-31). Soils with low organic matter are also more prone to developing physical crusts and soil sealing on tilled cropland. The formation of physical soil crusts is common after a rain event on freshly tilled and planted fields and often results in poor seedling emergence and the need to reseed.

**Figure G-31.** Physical soil crusts on cropland have reduced infiltration capacity and porosity, have higher density, and are an indication of high evaporation rates in the presence of sunlight (Belnap et al. 2009) (Courtesy of USDA-NRCS, Soil Health Division).

C. Biological Soil Crusts (Spaeth 2020)

(1) Biological crusts (also referred to as microphytic, microbiotic, crytogamic, and cryptobiotic), where prevalent, are comprised of various microorganism complexes (green algae, cyanobacteria, lichens, mosses, microfungi, and bacteria) (figure G-32). The impact of biological soil crusts on infiltration rates and soil erosion is poorly understood and often contradictory.

(2) Biological soil crusts can reduce infiltration rates and increase soil erosion by blocking flow through macropores, or they may enhance porosity and infiltration rates by increasing water-stable aggregates and surface roughness (Loope and Gifford 1972, West 1991, Eldridge 1993). Disturbance of the soil surface can disrupt biological soil crusts and result in enhanced wind erosion–and may or may not affect water erosion processes (Belnap and Gillette 1998, Eldridge and Koen 1998, Barger et al. 2006, Li et al. 2008, Belnap et al. 2009).
Li et al. (2008) evaluated the interactions between biological soil crusts and runoff on a hillslope with patchy shrub vegetation. They reported that in undisturbed areas 53 percent of the simulated rainfall became runoff from the crust patches, and 55 percent of this was redistributed and absorbed by the shrub patches. In addition, approximately 75 percent of the sediments, 63 percent of the soil carbon, 74 percent of the nitrogen, and 45 percent to 73 percent of the dissolved nutrients transported in runoff from the crust patches were transported to shrub patches. The disturbance of crust patches tended to result in the uniform distribution of water over the whole slope, with a corresponding reduction in the transport of runoff and nutrients from the crust patches to the shrub patches. The exact response on runoff and soil erosion is a function of site disturbance and level of development of the biological soil crusts (Belnap et al. 2013).

(3) When studies are evaluated based on biological crust type, the results indicate that biological crusts in hyper-arid regions reduce infiltration and increase runoff. Biological soil crusts have mixed effects in arid regions, and infiltration is increased and runoff reduced in semi-arid cool regions. Most research has shown that intact biological soil crusts are effective in reducing soil erosion and transport of sediment and associated contaminants (Belnap 2006).

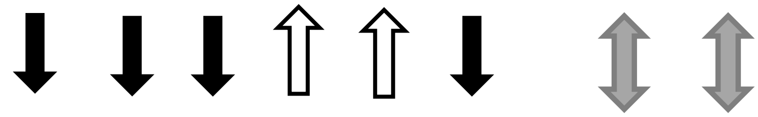
**Figure G-32.** Biological soil crusts comprised of algae, cyanobacteria, and nonvascular plants (mosses, lichens) have evolved in many rangeland ecosystems. Canyonlands and Arches National Parks are hosts to good examples of biological soil crusts that help stabilize soil interspaces around vegetation patches. (Courtesy of USGS Canyonlands Research Station).

## 645.0712 Grazing Effects on Hydrology and Erosion

A. A considerable number of studies and reviews concern grazing impacts on hydrologic processes on rangeland (Gifford and Hawkings 1978; Branson et al. 1981; Blackburn et al. 1981; Blackburn 1984; Warren et al. 1986a, b, c; Warren 1987; Savory 1988; Thurow 1991; Spaeth et al. 1996a, b; Weltz et al. 1998; Asner et al. 2004; Holechek et al. 2004). From a conservation-management perspective, the grazing management specialist should consider how grazing is affecting the soil surface, plant species composition, and ultimately hydrologic dynamics of the site, field, and watershed. Available water in the soil and ET regulate soil moisture, which ultimately determines the dynamics and function of the plant community (Stephenson 1990). Three elements in the hydrologic cycle are responsible for water loss, evaporation, transpiration, and runoff. Evaporation of water from the soil and runoff can be managed somewhat with vegetation management—including grazing intensity and timing. Figure G-33 shows how components of the hydrologic cycle change with managed grazing.

**Figure G-33.** Grazing and effects on the hydrologic cycle. Processes are divided into aboveground (AG) and belowground (BG) components. PPT=precipitation, Ps = spring snow melt, F = fog or cloud condensation, I = canopy interception, R = runoff, E = evaporation from soil surface, T = transpiration from plants, S = the change in soil moisture, and D = subsurface flow of water vertically and horizontally from plant roots. Note: Ps and F are not applicable in all rangeland environments (Adapted from Asner et al. 2004).

$$PPT + P_s + F = (I + R + E + T)_{AG} + (\Delta S + D)_{BG}$$



Direction of change with managed grazing

B. The amount of disturbance from hoof action by livestock on a site depends on soil type, soil water content, seasonal climatic conditions, and vegetation type. Repetitive and continuous high intensity trampling results in a cascading effect: bulk density increases (compaction), and soil aggregates degrade, especially on lighter textured soils. This results in lower infiltration, higher runoff, and greater potential for erosion. If intensive grazing occurs on wet soil, soil aggregate stability is further damaged, resulting in an impermeable surface layer and possible development of a physical crust. On some soils, a physical vesicular crust can occur, which impedes infiltration.

C. Grazing at any level triggers an immediate vegetation response and imposes either subtle or drastic changes in soil physical, chemical, and biological factors (figure G-34). Depending on the level of grazing (light to heavy), there are numerous implications that managers should be aware of (figure G-35). These changes may be entirely natural, as many rangeland plant communities evolved with ungulate grazing (Mack and Thompson 1982); or they may be disruptive, depending on the severity of the perturbation.

**Figure G-34.** Model depicting effect of grazing practices on soil surface and subsequent results on plant communities, hydrology, energy and nutrient cycles, and erosion and sedimentation dynamics.

Short- and Long-Term Effect of Grazing Practices and
Potential for Modification of

⇓

Soil Surface Properties

⇓

Plant Species Structure and Composition

⇓

Hydrology (Infiltration and Runoff)

⇓

Energy and Nutrient Cycles

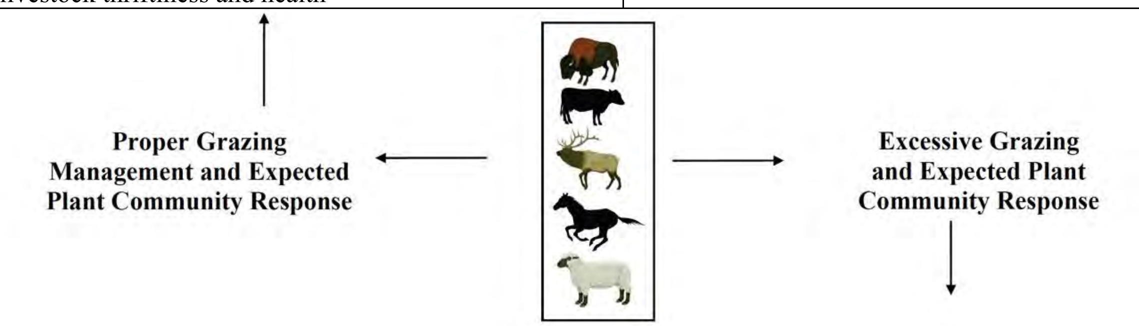
⇓

Erosion and Sedimentation Dynamics

D. Heavy use by livestock can compact the soil, have a negative impact on soil structure, mechanically disrupt soil aggregates, reduce soil aggregate stability, and destroy biological soil crusts which may be essential to erosional stability. Infiltration capacity is generally reduced with increased grazing intensity, mainly through vegetation removal and composition change, changes to soil structure, bulk density, and aggregate stability.

**Figure G-35.** Diagrammatic representation of grazing and the relationship to soil surface.

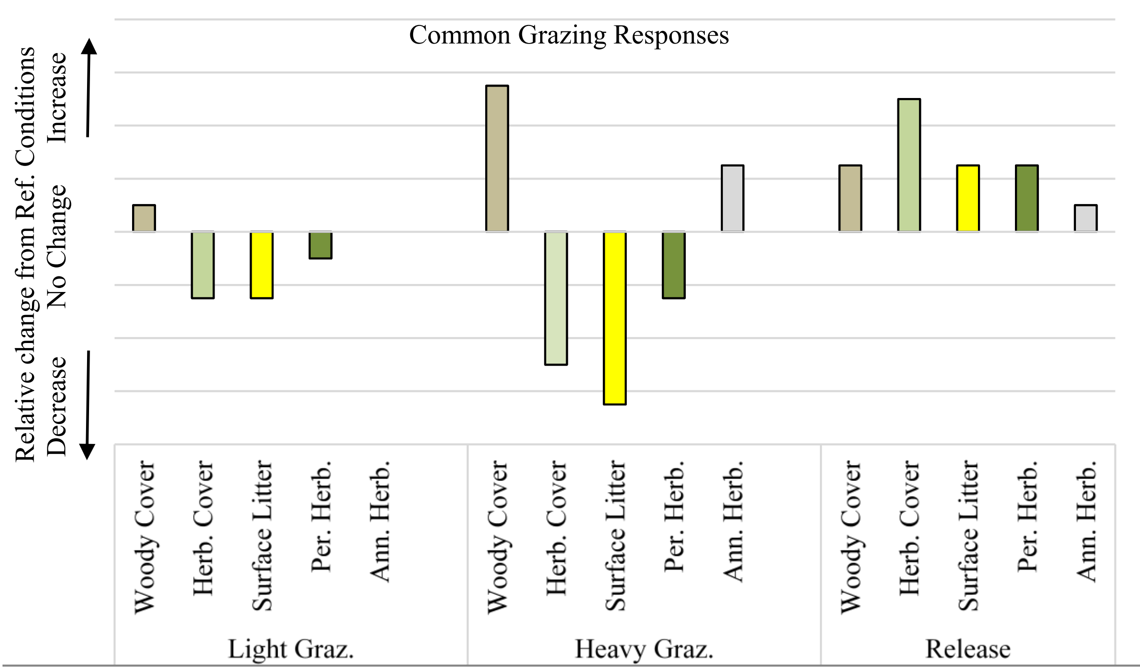
| Increase | Decrease |
|---|---|
| plant cover<br>soil organic matter<br>infiltration rate<br>soil water content<br>subsurface flow<br>aquifer recharge potential<br>ET potential<br>litter<br>soil microorganisms and/or biological crust response where present on ecological site<br>rangeland health<br>plant community integrity<br>enhances soil structure<br>soil aggregate stability<br>balanced nutrient and energy cycle<br>enhances wildlife habitat<br>livestock thriftiness and health | runoff<br>soil bulk density<br>soil detachment and erosion<br>erosion and sedimentation<br>site entropy<br>soil water evaporation |




| Increase | Decrease |
|---|---|
| runoff<br>soil bulk density (compaction)<br>soil detachment and erosion<br>erosion and sedimentation<br>site entropy<br>risk of a non-recoverable situation<br>soil water evaporation | plant cover<br>soil organic matter<br>infiltration rate<br>soil water content<br>litter<br>soil microorganisms and/or biological crust response where present on ecological site<br>rangeland health<br>plant community integrity<br>soil structure<br>soil aggregate stability<br>subsurface flow and aquifer recharge potential<br>soil surface stability<br>balanced nutrient and energy cycle<br>ET potential |

E. On rangelands, increases of woody plant cover have been associated with overgrazing, especially where the trend of increasing woody cover and biomass is already advancing (Archer 1994) (figure G-36). The main causal agents of woody encroachment are associated with fire suppression that enhances native woody plant densities, invasion and survival, atmospheric $CO_2$ enrichment that favors C3 (woody) plant growth, climatic pulses that favor shrub establishment, and overgrazing (Archer et al. 1995, van Auken 2000). Studies show that light grazing intensity results in slight increases in woody plant cover (Tobler et al. 2004) and a decrease in herbaceous biomass or cover and surface litter cover and biomass (Harris et al. 2003, Oba et al. 2003). In addition, perennial grasses can slightly decrease in production, although there is no clear and consistent trend (Mapfumo et al. 1999). Decreases of perennial grasses are more pronounced in settings with long-term heavy grazing (Asner et al. 2004) (figure G-36). The key to limiting loss of production of key forage species lies in proper management and consistent monitoring of vegetation composition.

**Figure G-36.** Responses of vegetation to light grazing, heavy grazing, and release from grazing. Bar graph shows relative responses from literature (Hendricks 1942, Archer 1994, Fuhlendorf et al. 2001, Pettit and Froend 2001, Asner et al. 2003, Cingolani et al. 2003, Friedel et al. 2003) (adapted from Asner et al. 2004).



## 645.0713 Influence of Livestock Grazing and Trampling on Hydrologic Characteristics

A. Many grasslands and rangeland plant communities evolved with ungulates, some more intensively grazed than others (table G-18) (Mack and Thompson 1982). Mack and Thompson (1982) characterized two grassland provinces dominated by perennial grasses, the *Agropyron* province (dominated by bunch or caespitose grasses) west of the Rocky Mountains and the *Bouteloua* province (dominated by rhizomatous/stoloniferous species) east of the Rocky Mountains. Before and after the Wisconsin glaciation*, Bison bison* were prolific and numerous throughout the *Bouteloua* province (may have exceeded 40 million animals at the time of European contact). In contrast, there is not much evidence of large herds of bison west of the Rockies (Durant 1970). Few prehistoric records of bison existed on the Columbia Plateau of Washington and Oregon, with a regional decline to extinction by 2500 BP.

**Table G-18.** Physiological characteristics and grazing tolerance of dominant species in the *Agropyron* and *Bouteloua* provinces in the United States.

| Species | Sensitivity to grazing | Growth Habit | Photosynthetic pathway | Flowering/veg. culm ratio | Meristem position |
|---|---|---|---|---|---|
| ***Agropyron* province** | | | | | |
| *Pseudoroegneria spicata* | very sensitive in late spring | caespitose, rhizomatous at higher elev. | C3 | high | elevates early |
| *Festuca idahoensis* | sensitive to light grazing | caespitose | | | |
| *Poa sandbergii* | sensitive to light grazing | caespitose | C3 | high | |
| *Poa pratensis* | delayed response if any | rhizomatous | C3 | low | at ground level throughout season |
| ***Bouteloua* province** | | | | | |
| *Bouteloua gracilis* | delayed response if any | tufted, but forming a sod | C4 | low | at ground level throughout season |
| *Pascopyrum smithii* | less sensitive than PSSP | rhizomatous | C3 | low | elevated early |
| *Bulbilis dactyloides* | delayed response if any | stoloniferous, extensive stolon-forming dense sod | C4 | low | at ground level throughout season |

B. With the introduction of livestock on United States grasslands and ranges came the irrevocable impact on plant composition change in more arid rangelands, especially the *Agropyron* province. These endemic grass species did not evolve with heavy grazing and therefore are sensitive to grazing pressure (Mack and Thompson 1982).

(1) In the *Bouteloua* province, one bovid essentially replaced the other. The main change that occurred with cattle herds is frequency of disturbance rather than the type of disturbance. In more recent times, fire frequency has also changed dramatically. In some locations it has been essentially eliminated, excepting the inescapable wildfires that occur.

(2) In the *Agropyron* province, dramatic changes occurred compared to the *Bouteloua* province, where the introduction of domestic cattle herds and changes in frequency of grazing rapidly changed the composition of many grazed native ranges with the introduction of Eurasian exotic annual grasses and forbs.

(3) The fragile arid rangelands were more susceptible to exotic annuals, as many of them are winter annuals. Cheatgrass (*Bromus tectorum*) was first collected in Pennsylvania, 1861;

Washington, 1893; Utah, 1894; Colorado, 1895; and Wyoming, 1900 (Yensen 1981). Field bromegrass (*Bromus arvensis)*, another common exotic annual C3 brome species, is also native to Eurasia and is also characterized as a winter annual that germinates in fall and survives throughout the winter as “rosettes” (Baskin and Baskin 1981). It is found in all states within the United States, with the exception of Hawaii and Alaska and in the Canadian provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and Prince Edward Island (USDA-NRCS Plants Database 2020). Medusahead wildrye (*Taeniatherum caput-medusae*)*,* is a Eurasian C3 introduction (Hungary through Ukraine to Tadzhikistan), and made its début in the United States in the 1880s near Roseburg, Oregon. The spread of medusahead has been slower than cheatgrass (Pyke 2000) but is now becoming increasingly prominent on western United States rangelands (Turner et al. 1963, Hilken and Miller 1980, USDA-NRCS 2018b). Unlike cheatgrass and field brome, medusahead has a high ash and silica content (72–89 percent), which makes it less palatable as the plant matures (Swenson et al. 1964).

C. By the turn of the century, irreversible changes to the ecological and biological structure of the *Agropyron* province was well underway. Native grass species could no longer recolonize disturbed areas, once the exotic annual grasses were present. With the advent of heavy grazing, the transformation from perennial bunchgrass was rapid; and when annual grass dominance occurs, ecosystem function can be compromised (Vitousek et al. 1997). On United States rangelands, non-native exotic plants can negatively impact biotic integrity, ecosystem resilience and stability, composition and structure, natural fire cycles, diversity, soil biota, vegetation production, forage quality, wildlife habitat, soil physical properties, organic matter dynamics, carbon balance, nutrient and energy cycles, and hydrology and erosion dynamics in many unique ways (Chapin et al. 2000, Evans et al. 2001, Pierson et al. 2002b, 2008; Ehrenfeld 2003; Ogle et al. 2004; Brooks et al. 2004; Norton et al. 2004; Belnap et al. 2005; Hooper et al. 2005; Boxell and Drohan 2009; Herrick et al. 2010; Davies 2011).

D. Modification of plant composition, cover, and biomass on a site can singularly or collectively affect infiltration dynamics and may accelerate erosion. Stocking rates that continuously exceed moderate stocking (continuous, season long, and intensive systems) will ultimately decrease infiltration and increase runoff, erosion, and sediment loss (Rhoades et al. 1964; Rauzi and Hanson 1966; Rauzi and Smith 1973; Gifford and Hawkins 1978; Owens et al. 1982; Blackburn 1984; Wood and Blackburn 1984; Warren et al. 1986 a, b, c; Warren 1987; Thurow et al. 1988; Naeth et al. 1990; Thurow 1991).

E. In general, the effects of livestock grazing on hydrologic resilience are associated with the degree to which grazing pressure affects surface soil conditions by altering the spatial and temporal variations in canopy and ground cover (Gifford and Hawkins 1978; Wood and Blackburn 1981;Thurow et al. 1986, 1988; Thurow 1991; Trimble and Mendel 1995; Spaeth et al. 1996a, b; Asner et al. 2004). Grazing pressure that substantially reduces vegetation and ground cover or compacts and disturbs surface soils will likely increase losses of water and soil resources through water and wind erosion processes (Greene et al. 1994, Trimble and Mendel 1995, Field et al. 2011). High intensity grazing, particularly over multiple years, can alter plant composition such that the biotic structure triggers long-term site degradation through abiotic-driven losses of water and soil resources (Warren et al. 1986 b, c; Schlesinger et al. 1990; Greene et al. 1994; Rietkerk and Van de Koppel 1997; Van de Koppel et al. 1997; Ludwig et al. 2007; Turnbull et al. 2008, 2012).

F. Grazing systems such as intensive rotation grazing (IRG), short-duration grazing methods, high intensity-short duration, or other forms of heavy stocking rotation systems (“mob grazing,” ultra-high stocking densities) have been purported in the popular literature to be advantageous to hydrology, animal performance, litter decomposition and organic matter dynamics, lessening carbon footprints, and cattle production profits. Weltz and Wood (1986) found that even short duration grazing had adverse impacts on both surface runoff and sediment yield. The intensive removal of standing biomass leaves the site at an elevated risk of erosion if intensive rainfall events occur before vegetation can regrow. Continuous intensive grazing systems over time can increase risk of deteriorating plant production, changes in native plant composition and loss of species diversity, which have ramifications beyond livestock production, such as pollinating species' dependence on preferred nectar plants. Intensive grazing systems can be especially damaging during drought periods because plants don't have the resources to regrow (Thurow et al. 1986 and Warren et al. 1986b). Before initiating intensive grazing, consideration should be given to the physiological response of the species to grazing (See Mack and Thompson, 1982; Briske and Richards, 1995; Dahl, 1995; and Dahl and Hyder, 1977).

G. In any agricultural endeavor where the manager is unequivocally convinced of a particular practice using anecdotal evidence, and the rangeland is in healthy condition, caution needs to be exercised with monitoring of the practice. Some intensive grazing systems as proposed by Goodloe 1969, Savory 1978, 1979; Savory and Parsons 1980, including those mentioned above, have been the subject to controversy with regards to effects on species composition and hydrology. Managers claim purported benefits supported by anecdotal evidence; however, under scrutiny of scientific experimental evidence, are the benefits sustainable and beneficial in the long term? With most intensive short duration grazing systems, livestock are concentrated in small paddocks for short periods of time, creating a concentrated herd effect with intensive trampling of the soil and plants. Proponents claim that the "hoof action" disturbs the soil surface and helps incorporate litter for microbial breakdown, enhancing soil surface organic matter and infiltration of rainfall. Hoof action may quicken contact of standing litter with the soil, but subsequent decomposition and overall soil organic matter would be about equal, with standing dead litter naturally collapsing and eventually falling to the soil surface. Different gases such as $CH_4$, $NH_4^+$, $NO_3^-$, $SO_4^{-2}$, $H_2S$, and $HPO_4^{-2}$, and especially $CO_2$ are emitted when organic materials begin to decompose as residues come in contact with the soil, and mineralization by soil microbes begins, coupled with adequate soil moisture and complementary temperatures, (Al-Kasi and Lal 2017). The rate of mineralization is influenced by biotic and abiotic factors, and nutrients released vary significantly among the different fractions of soil organic matter. On average, after one year, about 17 to 35 percent of the carbon added as plant residue is incorporated into SOM (Himes 1997 and Stewart et al. 2017).

H. Trampling intensity is correlated with compaction and changes in bulk density. Warren et al. (1986a) demonstrated experimentally that repeated high intensity trampling decreased soil aggregate stability and increased bulk density, which reduced infiltration rates and increased surface runoff and interrill erosion (table G-19). Trampling dry soil disturbed the soil surface and resulted in reducing the size of naturally occurring soil aggregates and increasing bulk density. When moist silty clay soils were trampled, soil aggregates were largely destroyed by compaction into the impermeable surface layer. In summary, Warren et al. 1986a found that infiltration rate decreased, and sediment production increased significantly on a silty clay soil, following trampling that typifies intensive rotation grazing systems. Warren et al. 1986a also found that 30 days' deferment from grazing was insufficient to allow for hydrologic recovery.

I. The amount of damage to a site from "hoof action" by livestock depends on soil texture, soil water content, seasonal climatic conditions, and vegetation type. In summary, repetitive and continuous high intensity trampling increases bulk density (compaction) and breaks down soil aggregates, resulting in lower infiltration, higher runoff, and a potential for erosion (Gifford and Hawkins 1978; Branson and Miller 1981; Warren et al. 1986 a, b, c; Greenwood and McKenzie 2001; Daniel et al. 2002; Teague et al. 2011; Asner et al. 2004). If this action occurs on wet soils, soil aggregate stability is damaged even more, resulting in an impermeable surface layer. Freeze-thaw cycles and wet-dry cycles can ameliorate surface soil compaction from livestock, depending on time since disturbance and soil texture (Weltz et al. 1989).

## 645.0714 Case Studies Livestock Grazing and Hydrologic Effects

A. Infiltration and erosion response to trampling intensity (Warren et al. 1986a)

(1) Warren et al. (1986a) state: "the idea that benefit can be derived from short-term, high intensity physical impact of livestock is the principal foundation upon which many proponents of intensive, rotational grazing systems base their support. The physical impact is believed to chip or churn the soil surface and break up surface crusting without compacting the soil, thus improving water infiltration and reducing erosion (Goodloe 1969, Savory and Parsons 1980). This study showed that repeated high intensity trampling, at levels typical of intensive rotational grazing systems, was detrimental to soil properties which are normally well correlated to infiltration rate and sediment production. The detrimental impact generally increased as stocking rate increased. Trampling on a dry soil did indeed, chip and churn the soil surface. However, the 'hoof action' reduced the size of naturally occurring soil aggregates and increased the density of the surface soil layer. Trampling on moist paddocks destroyed existing soil aggregates and led to the creation of a flat, comparatively impermeable surface layer composed of dense, unstable clods. Both of these conditions were detrimental to infiltration rate and sediment production."

(2) In summary, trampling activity by grazing animal hooves reduces infiltration by altering soil surface physical factors: bulk density or compaction, breakdown of soil aggregates, and reduction of porosity. Intense trampling as a result of doubled or tripled stock intensities in smaller paddocks for short periods of time (creating a herd effect) has been hypothesized as enhancing infiltration and reducing erosion. Research to date by rangeland hydrologists has not supported the idea that increased intensity of trampling enhances infiltration capacity (table G-19).

**Table G-19.** Mean infiltration rate and interrill erosion in relation to trampling intensity and water content on the Edwards Plateau, Texas. Simulated rainfall =15 cm in 45 minutes (Warren et al. 1986c). Symbols IX indicates moderate stocking intensity, 2X double the moderate intensity, 3X triple the moderate intensity, soil texture was silty clay.

| Infiltration Rate x | | | | |
|---|---|---|---|---|
| **Stocking Intensity** | **Before Trampling ($mm\ hr^{-1}$)** | **Trampled Dry ($mm\ hr^{-1}$)** | **Before Trampling ($mm\ hr^{-1}$)** | **Trampled Moist ($mm\ hr^{-1}$)** |
| 0 | 166 | 166 | 160 | 160 |
| 1X | 147 | 132 | 133 | 130 |
| 2X | 137 | 106 | 115 | 83 |
| 3X | 134 | 101 | 109 | 82 |
| **Interrill Erosion** | | | | |
| **Stocking Intensity** | **Before Trampling ($kg\ ha^{-1}$)** | **Trampled Dry ($kg\ ha^{-1}$)** | **Before Trampling ($kg\ ha^{-1}$)** | **Trampled Moist ($kg\ ha^{-1}$)** |
| 0 | 976 | 976 | 2,007 | 2,007 |
| 1X | 1,892 | 3,824 | 2,998 | 2,752 |
| 2X | 2,272 | 4,605 | 3,542 | 5,048 |
| 3X | 2,211 | 7,078 | 4,057 | 7,465 |

B. Comparison of grazing treatments on infiltration and interrill erosion, Sonora, Texas.

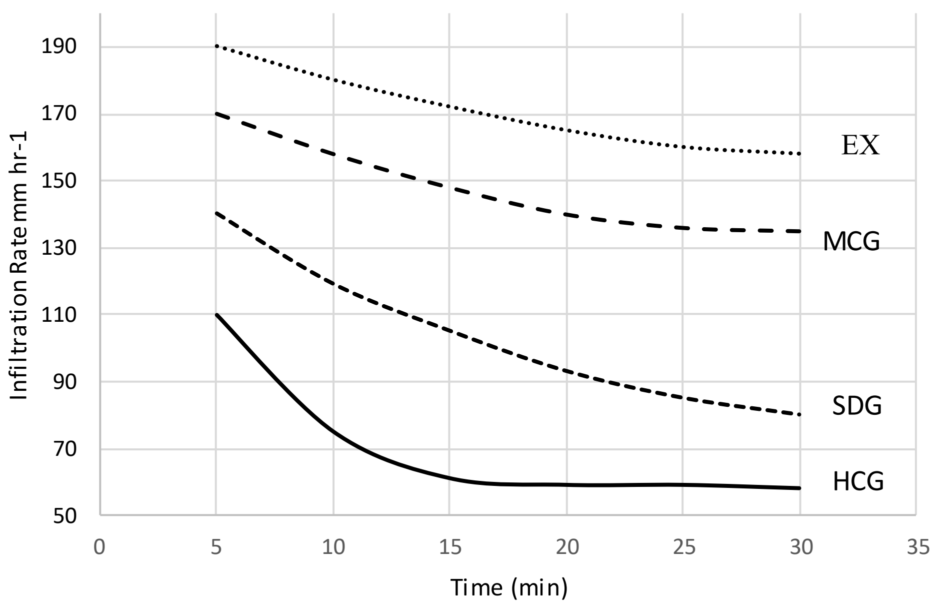
(1) The key components affecting infiltration rate – such as aggregate stability, bulk density, standing crop, litter biomass, and litter cover – are sensitive to grazing management systems (Thurow et al. 1988). It is imperative for the land manager and conservationists assisting in planning grazing systems to recognize temporal responses of infiltration and interrill erosion to the planned grazing system as unwanted shifts to alternate states (consult state-and-transition model in ecological site description).

(2) Thurow et al. (1988) reported that the infiltration rates and erosion for continuously grazed at moderate intensity (MCG) and at high intensity low frequency (HILF) were maintained at acceptable levels; however, infiltration rates decreased and interrill erosion increased on heavy continuous (HCG) and heavily stocked short duration grazing (SDG) pastures. Infiltration and erosion on HCG and SDG were not gradual but occurred in a more dramatic stair step pattern. See figure G-37. Infiltration and interrill erosion rates did not recover after drought conditions when normal precipitation patterns returned. Heavy stocking rates and climatic factors were the primary factors in reducing infiltration and increasing erosion.

C. Impacts of grazing in Utah.

West et al. (1984) reported, after 13 years of livestock deferment, desirable native perennial vegetation had not reestablished, despite a trend of increased precipitation over the length of the study. They concluded that the site had transitioned to a stable shrub-dominated site. The concept that removing livestock would return the plant community to the original sagebrush-native shrub-grass assemblage is unlikely. Therefore, direct manipulation of the site is mandatory if rapid return to the desired plant community is desired. Belnap et al. (2009) reported that grazed watersheds in southeast Utah had significantly more soil loss from wind than ungrazed watersheds. When comparing soil losses among the sites, they determined that biological soil crusts were the most important factor in predicting site stability, followed by perennial plant cover.

**Figure G-37.** Mean infiltration rates from four grazing treatments on Edwards Plateau, Texas (6-yr study). HCG = continuous grazed and heavily stocked at 1.75 x the moderate intensity; SDG = short duration rotation (14-pasture, 1-herd; 4 days on, 50 days rest); MCG = continuously grazed at moderate intensity; EX = livestock enclosure, no grazing (Thurow et al. 1988).




D. Infiltration rates and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas.

During the hydrology grazing study, infiltration rates decreased and interrill erosion increased in the heavily stocked short duration rotation (SDG) and continuously grazed and heavily stocked (HCG) pastures. Decreases and deterioration of infiltration and interrill erosion rates in these heavily stocked pastures tended to follow a stair-step pattern typified by decreasing grass basal cover, litter, and midgrass cover during drought, and an inability to recover to predrought levels during periods of above normal precipitation. In comparison, infiltration and interrill erosion rates in the moderately stocked pastures were able to recover from droughts and maintain initial or improved rates during periods of above-normal precipitation.

E. Infiltration rates and sediment production as influenced by grazing systems in the Texas Rolling Plains.

(1) Two production scale grazing treatments were sampled at Throckmorton, Texas to evaluate their impact on hydrologic processes. Treatments were yearlong continuous grazing, stocked at a moderate rate (MC); 16-paddock rotational grazing treatment, stocked at a heavy rate (RG-16); moderately stocked pasture three-herd deferred rotation treatment (DR-3); and ungrazed exclosure (EX). Sediment production was lowest in the exclosure. Compared to the RG-16 treatment (sediment = 63 kg $ha^{-1}$ and infiltration 82 mm $hr^{-1}$), sediment production was least (33 kg $ha^{-1}$) and infiltration rate greatest (89 mm $hr^{-1}$) in the MC treatment. As above-ground biomass and cover increased, infiltration rates increased, and sediment production decreased. The RG-16 treatment had higher sediment production and lower infiltration rates than MC treatment (Pluhar et al. 1987).

(2) Before grazing treatments, infiltration rates and sediment production in the RG-16 and DR-3 treatments were not significantly different from those in the MC treatment. However, subsequent grazing caused a significant decline in infiltration rates and a significant increase in sediment production in both treatments (as a function of removal of above-ground biomass, cover, and proportion of the area in midgrasses). Midgrasses had higher infiltration rates and lower sediment production than shortgrasses. This study is similar to the Weltz and Wood (1986) study: high intensity rotational grazing removes excessive amounts of above-ground biomass and increases the vulnerability of the site to accelerated soil erosion.

F. Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia.

(1) This study evaluated the impacts of livestock grazing on native plant species cover, litter cover, soil surface condition, surface soil physical and chemical properties, surface soil hydrology, and near ground and soil microclimate in remnant *Eucalyptus salmonophloia* woodlands in western Australia (loamy sand over clay) (Yates et al. 2000).

(2) Heavy grazing by sheep was "associated with a decline in native perennial cover and an increase in exotic annual cover, reduced litter cover, reduced soil cryptogam cover, loss of surface soil microtopography, increased erosion, changes in the concentrations of soil nutrients, degradation of surface soil structure, reduced soil water infiltration rates and changes in near ground and soil microclimate. The results suggest that livestock grazing changes woodland conditions and disrupts the resource regulatory processes that maintain the natural biological array in E. salmonophloia woodlands" (Yates et al. 2000).

(3) Intensive livestock trampling typical of multi-pasture rotational grazing systems had a negative impact on soil physical properties. The deleterious effects tended to increase as stocking rate increased. Trampling on dry soil caused disruption of naturally occurring aggregates and compaction of the surface soil layer. Trampling on moist soil disturbed existing aggregates and led to the creation of a flat, comparatively impermeable surface layer composed of dense, unstable clods. Bulk density was higher in heavily grazed woodlands, thus increasing soil penetration resistance and soil pore volume, a result associated with loss of perennial vegetation cover, biological soil crusts, and the impact of sheep trampling. Perennial vegetation provides a feedback mechanism where organic litter provides protection against raindrop splash and surface sealing effects.

G. Yearlong grazing on pastures in Coshocton, Ohio

On pastureland in Ohio, the highest annual soil loss values (1.12 t $ac^{-1}$) occurred on unimproved pastures grazed yearlong where cattle had direct access to riparian areas. Rotational summer grazing with >90 percent grass cover had trace amounts of soil loss (Owens et al. 1996).

H. Impact of cattle treading on hill land and soil damage patterns

"Animal treading (or trampling) in grassland ecosystems is known to affect the condition of both soil and vegetation. Much of this knowledge centers on dry and/or rangeland conditions where soils and vegetation are considered to be very fragile. Treading action can result in reduced soil water infiltration and increased water runoff" (Sheath and Carlson 1998). Soil surface damage was greatest on animal tracks and easy contoured areas. For rapid recovery of damaged paddocks, continued grazing of cattle during spring should be avoided (Sheath and Carlson 1998).

I. MOB grazing and effects on compaction, forage quality, and hydrology

Unfortunately, few scientific studies exist on mob grazing (MOBG). Most of the positive or negative claims about MOBG grazing are anecdotal and from the popular literature. Mob grazing is a more intensive type of rotational grazing and is characterized by ultra-high stocking densities, short durations (one day or less between rotations), and long rest periods (usually at least 45 days of growth). Highly intensive grazing treatments have more flexibility of management options in humid climates where there is adequate precipitation to regenerate forage species. Semiarid and arid rangelands are not conducive to long-term success from MOBG grazing. The scientific literature on intensive stocking systems on rangeland do not support the claims of increased infiltration, organic matter, and plant response. Many native perennial rangeland grasses are not as resilient to continual heavy grazing as introduced exotic forage grasses; therefore, careful monitoring is needed to assess the results.

J. Water and hydrologic processes are the main drivers in plant ecosystems. If hydrologic function is compromised, reducing infiltration and increasing runoff, all other systems will be altered, including nutrient, energy, and organic carbon cycles. Ignorance of these effects in high intensity grazing treatments is a "recipe for disaster" with sometimes unrecoverable consequences, including vegetation state change and impacts on livestock health.

K. Grazing affects vegetation stature and composition and soil surface factors, which can subsequently affect the hydrologic cycle (figure G-33). On a watershed scale at intensified levels, livestock grazing can initially decrease plant cover, cryptogamic crusts, soil aggregate stability, and soil organic matter, and increase compaction and soil crusting. Improper grazing intensities, over longer periods, can and often alters plant composition, which may seriously affect the hydrology of a watershed. With continuous heavy stocking, plant composition will ultimately change over time, perhaps subtlety at first where the manager does not notice immediate changes. Rangeland grazing and hydrology studies show that soil physical factors consistently change in many high intensity grazing treatment studies. Increases in bulk density and compaction and decreased soil aggregate stability are common with high intensity grazing treatments. If erosion is occurring at a higher than sustainable rate, the dynamics of the organic matter cycle may change, resulting in altering the stability of soil aggregates and soil microbial populations and activity associated with organic matter and soil health.

L. The literature is clear with respect to high intensity grazing: infiltration rates and capacity are reduced, water runoff is increased, and interrill erosion increases. The main factors associated with hydrologic decline on rangeland are due to changes in:

(1) Plant cover
(2) Plant species composition

(3) Accelerated erosion leading to decline in surface soil horizon dynamics
(4) Increased incidence of invasive species
(5) Decline in grazing intolerant perennial grasses (Mack and Thompson 1982)
(6) Reduced biomass production
(7) Deterioration of soil aggregates and soil biological crusts
(8) Increased bulk density
(9) Increased soil surface water evaporation
(10) Decreasing water holding capacity and available moisture
(11) Soil microorganism populations may change the balance between soil fungi and bacteria.
(12) Bacterial populations in the soil can be depressed by dry conditions, soil acidity, soil compaction, and lack of organic matter.

(i) Soil surface disturbance, especially tillage, has an adverse effect on fungi as it physically severs the hyphae, breaking up the mycelium. Soil microorganism populations are important indicators of soil health as they respond rapidly to environmental changes and site conditions because of their direct relationship with conditions of the site. Changes in microbial populations can occur and precede detectible changes of soil physical and chemical properties – an early warning system to soil degradation and decreasing soil health (Nielsen and Winding 2002).

(ii) Soil organisms are inherent to many soil processes such as organic matter and nutrient cycles, which are prominent aspects of range and pasture health. Plant vigor, productivity, and reproductive capability are "first responders" – factors associated with soil health, which are immediate indicators for identifying imbalances, an aspect that cannot be determined by soil physical and chemical measures alone.

M. Summarized findings of hydrology studies on range and pastureland:

(1) Species composition changes can have a positive or negative effect on hydrology, depending on the individual species involved.
(2) Hydrology studies consistently show that ungrazed areas and study exclosures have the lowest runoff rates compared to the grazing systems in the respective study areas and are often similar to light grazing.
(3) The reaction to the impact of trampling varies with stocking rate, soil type, soil water content, time of grazing and seasonal climatic conditions, and vegetation type.
(4) On heavier textured soils, trampling impact on wet soils can break down soil aggregates, and impermeable surface layers can develop (e.g., vesicular crusts and rainfall induced crusts).
(5) "Deferred Rotation Systems" with adequate rest periods generally maintain hydrologic parameters similar to ungrazed areas. Adequate rest periods vary with soil type and vegetation types. Soil surface conditions should be monitored on a site-specific basis.
(6) Watershed research data suggest that watershed conditions can be maintained and improved with light and moderate continuous grazing. On lighter textured soils, there is little hydrologic response between light and moderate continuous grazing on rangeland hydrology.
(7) Short duration high intensity grazing is associated with higher sediment production, compared to moderate continuous grazing. The reduced standing vegetation and plant cover, compaction, decreasing soil aggregate stability and porosity, and development of soil crusts associated with this system are the major causes of increased runoff and sediment production. No definite hydrologic advantage has been documented in the scientific literature for increased stocking density via manipulation of pasture size and numbers.

N. Caution needs to be exercised concerning short duration high intensity systems. The rangeland community type and the physiological response of species inherent species to defoliations needs to be carefully considered (See Mack and Thompson, 1982; Briske and Richards, 1995; Dahl, 1995; and Dahl and Hyder, 1977). Soil surface physical properties, mineral and microbiotic crusts, and plant species composition must be monitored carefully. Rangeland plant communities are unique, and plant/soil interactions are complex and are not consistent from one vegetation and soil type to the next. This makes it difficult for the land manager, since consistency in hydrologic response is not well documented for many plant/soil complexes. Frequent on-site monitoring is essential.

O. In Midwestern pasturelands, the majority of soil loss occurs when the vegetation is dormant. Large runoff events (usually a small percentage of the total number of rainfall events) produce most of the runoff volume and erosion; however, these events are usually the impetus for the initiation of rills and gullies and subsequent decline in hydrologic function.

P. Because grazing systems and hydrologic impacts vary, management specialists should consult references for particular grazing trials (Gifford and Hawkins 1978; Blackburn et al. 1980, 1981; Blackburn 1984; Wood and Blackburn 1981; Warren et al. 1986 a, b, c; Weltz and Wood 1986; Warren 1987; Holechek et al. 2004).

## 645.0715 Monitoring Prerequisites for Grazing Systems

The following factors should be observed or evaluated regularly to determine the effectiveness of grazing systems:

(1) Monitor forage quality
(2) Watch animal activity, signs of stress
(3) Monitor and evaluate species composition shifts, especially in native grass stands. Watch for the establishment or increase of invasive or less desirable species
(4) Consumption vs. trampling. High density stocking may be impacting desired consumption
(5) Evaluate impacts on soil surface dynamics
    (i) Soil temperature changes
    (ii) Soil moisture, accelerated drying of soil surface
    (iii) Excess litter
    (iv) Soil compaction
    (v) Physical changes in soil surface (structure, porosity, aggregate stability)
    (vi) Crust formation, especially in clayey soils
    (vii) Significant soil stability (aggregate stability) changes
    (viii) Soil organic matter depletion
(6) Noticeable decrease in infiltration capacity and increase in runoff.
(7) Changes in rangeland health assessments (soil and surface stability, hydrologic function, and biotic integrity).

## 645.0716 Soil Erosion and Sediment Production on Watersheds

A. A serious recurring problem in the United States and throughout the world is the loss of soil resources on productive and functioning watersheds as well as dysfunctional watersheds. Soil loss impacts both on-site and off-site watershed functions. On-site effects include the changes in soil structure, decline in organic matter and nutrients in the soil, and a reduction of available soil moisture (Morgan 1995, Gregersen et al. 2007, Brooks et al. 2013), with overall negative impacts on productivity and decline in value of natural resources within watershed landscapes (Ffolliott et al. 2013). Loss of the soil resources from otherwise productive and well-functioning watersheds is often a recurring problem confronting hydrologists and watershed managers. Sediment is the product of soil erosion, and its source can be from upland sheet and rill erosion, gully erosion, soil mass movement, or channel erosion. Sediment yield is the amount of eroded soil that moves from a source to a downstream control point, such as a reservoir, per unit time.

B. Sediment yield from watersheds depends on inherent watershed characteristics: geology, topography, vegetation, land use and management, condition of vegetation, conservation measures, and storm dynamics and streamflow which produce and transport sediment (Anderson 1957). Sediment that is deposited in a stream channel is dependent on:

(1) The proximity of the source of the erosion to the channel
(2) Shear forces acting on soil and rock
(3) Size and distribution of sediment particles
(4) Transport of sediment from one part of the watershed to another and eventually into a major stream channel

C. Not all of the eroded soil that accumulates as sediment in water courses is transported through and out of the given watershed in response to storm events. Eroded soil can be deposited at the base of hillslopes, on stream terraces, or buffered in riparian zones before deposition to a stream channel (Neary et al. 2012, Brooks et al. 2013). Off-site effects commonly include increases in sediment loads and loss of nutrients such as nitrogen and phosphorous that are transported with sediment to stream channels (Dunne and Leopold 1978, Morgan 1995, Brooks et al. 2013). The consequences of sediment and nutrient loads from upland watersheds are reductions in river flow capacity, thus increasing risk of flooding in river basins and pollution that impacts water quality. The consequent increases of sediment in streamflow from upland watersheds often reduces the capacity of rivers to deliver high-quality water to downstream users, increases the risk of flooding, reduces or blocks the flow of water through irrigation systems, and shortens the expected operational life of downstream reservoirs. Increased soil erosion and sedimentation rates can also impact a variety of ecosystem services from watersheds, such as water supply quality, ground water and aquifer recharge, effective nutrient cycling, and biodiversity of plants and animals.

D. The NRCS plays an important role in assisting landowners with preventing accelerated and unacceptable rates of soil erosion, resulting in decreased sedimentation to water courses. Many conservation practices are implemented to prevent or reduce detrimental impacts to the environment and watershed.

E. Sediment delivered to rivers from agricultural watersheds, including cropland and pastureland, ranges from 1 to 30 percent of the estimated erosion (Robinson 1988). It is estimated that about eight percent of all erosion from cropland is deposited in estuaries and the ocean; however, cropland soil erosion is highly variable from site to site (Office of Technology and Assessment 1982). Smaller watersheds generally have higher sediment delivery ratios than larger watersheds. In the United States, estimates suggest that between 5 and 10 percent of water eroded soil ends up in the Gulf of Mexico or oceans (Robinson 1988).

F. Average sediment delivery ratios (SDR) for various sized watersheds are:

(1) 25-acre watershed: 30–90 percent (SDR)
(2) 2,400-acre watershed: 10–50 percent (SDR)
(3) 10,000 $mi^2$: 5 percent (SDR)

G. Examples of watershed and sedimentation case studies are given below:

(1) Nichols and Renard (2006)
  (i) Walnut Gulch Experimental Watershed is located in the transition zone between the Sonoran and Chihuahuan Deserts in southeastern Arizona. The experimental watersheds ranged in size from 35 ha to 92 ha and are underlain by a coarse-grained Quaternary and Tertiary alluvium shed from the Dragoon Mountains. See table G-20.
  (ii) Sediment yield from semiarid grazed watersheds (cattle) can be erratic due to variability of precipitation and runoff (table G-21).

(iii) Soil textures were not listed in their paper; however, to derive an estimate in tons $ac^{-1}$ sediment: Watershed I with a soil bulk density of 1.7 Mg $m^3$
$(1.7 \text{ Mg m}^3) \times (0.4 \text{ m}^3 \text{ ha yr}^{-1}) = 0.68 \text{ Mg ha yr}^{-1} (0.4047) = 0.275 \text{ tons ac yr}^{-1}$

**Table G-20.** Walnut Gulch Experimental Watershed, southeastern Arizona, USA. (Lane et al. 1998).

| Watershed Features | Area ($km^2$) (acres) | Runoff (mm) 1973–76 | Sediment yield (t $km^2$ $yr^{-1}$) | Sediment concentration (%) |
|---|---|---|---|---|
| Hillslope, brush, Tombstone Pediment, ungullied | 0.0018 (0.4) | 12.7 | 151.0 | 1.19 |
| Grass, Tombstone Pediment, ungullied | 0.0186 (4.6) | 19.7 | 51.2 | 0.26 |

**Table G-21.** Sediment yield from desert watershed in southern Arizona.

| Drainage area (ha) | Dominant Vegetation Type | Period of Record | Years of Records | Volume of Accum. Sediment ($m^3$) for Years of Record | Sediment Yield ($m^3$ $yr^{-1}$) | Sediment Yield per Hectare ($m^3$ ha $yr^{-1}$) |
|---|---|---|---|---|---|---|
| 92.2 | Black Grama, Curly Mesquite | 1973–1984 | 29 | 1,057 | 36 | 0.4 |
| 35.2 | Whitethorn Acacia, Creosote Bush, Tarbush | 1966–1984 | 35.9 | 2,936 | 82 | 2.3 |
| 84.2 | Black Grama, Curly Mesquite | 1962–1996 | 39.9 | 5,667 | 142 | 1.7 |
| 43.8 | Whitethorn Acacia, Creosote Bush, Tarbush | 1956–2002 | 45.6 | 5,658 | 124 | 2.8 |

(2) Trimble (1997)
San Diego Creek, which drains a 288 $km^2$ basin in Orange County, California supplies sediment to Newport Bay, which is considered to be one of the primary estuarine wildlife habitats in the state. An initial channel study indicated that from the late 1930s to the early 1980s channel erosion supplied more than one-fourth of all sediment yield. From 1983 to 1993, stream channel erosion comprised about two-thirds of the total sediment yield.

(3) Spomer et al. (1986) working in
- (i) Dry Creek Basin in south central Nebraska
- (ii) 20 $mi^2$ watershed area; 65 percent of land area is steep; 35 percent is relatively level
- (iii) 33 percent cropland, 66 percent rangeland
- (iv) High gully erosion rates
- (v) Approximately 60 percent of eroded soil reached the watershed outlet

(4) Coote (1984) working in
- (i) Prairie landscape in Manitoba and Saskatchewan, Canada
- (ii) Delivery of eroded soil to streams was estimated to be about 5 percent

(5) Lowrance et al. (1986) working in
- (i) Forest, Crop Watershed in Turner County, Georgia
- (ii) 34 percent of the watershed area was row crops, 59 percent forested
- (iii) About one percent of eroded soil was delivered to streams

H. Estimates of sediment delivery should be tempered by judgment and consideration of other influencing factors such as soil texture, relief, type of erosion, sediment transport system, and deposition areas and precipitation intensity and duration.

## 645.0717 Hydrologic Effects of Range Improvement Practices

A. Rangeland management practices that promote increased production usually increase transpiration, while surface runoff and water yields are reduced (Boughton 1970). Many researchers have reported increases in infiltration following mechanical range improvement practices, such as root plowing, vibratilling, and pitting by creating a macroporous surface which is able to store more water (Branson et al. 1966, Wight 1976, Tromble 1976, Neff and Wight 1977, Gonzales and Dodd 1979, Bedunah 1982, Bedunah and Sosebee 1985).

B. Bedunah and Sosebee (1985) studied the results of site manipulation on infiltration on a mesquite/buffalograss community in west Texas. Seven treatments were applied: foliar spray, shred, control, grub between trees, grub trees, Kleingrass (*Panicum coloratum*) planting, and vibratill. Vibratilling resulted in the highest infiltration rates. Shredding trees was ranked second for increasing infiltration rates. The shredding treatment was associated with increases of litter and standing crop. Removal of mesquite trees by foliar spraying, mechanical grubbing, or planting to Kleingrass did not increase water infiltration rates, compared to the control treatment.

C. In the last 150 years, proliferation of trees and shrubs on rangelands worldwide has had a significant impact on land cover at the expense of perennial grasses (Archer et al. 2011). With shrub encroachment, estimates suggest that for every millimeter of precipitation above 300 mm, aboveground net primary production increases by 0.6 g C $m^{-2}$ $yr^{-1}$ (Barger et al. 2011). Research from the Walnut Gulch Experimental Watershed and the Jornada Experimental Range have demonstrated significant differences in hydrology and water erosion between grasslands and shrublands (Wainwright et al. 2000). In general, splash detachment and inter-rill erosion rates are higher in shrublands compared to grassland sites (Abrahams et al. 1988, Parsons et al. 1991). However, there are interesting dynamics in shrub coppice zones with significant litter accumulations under the canopy. Higher infiltration rates, greater organic matter and nutrient accumulation, greater aggregate stability, lower bulk density, and greater biological activity are associated with coppice mounds (Pierson and Williams 2016).

D. When grass production is lost due to woody plant encroachment, grass cover often declines rapidly. Above and belowground productivity, litter inputs, rooting depth, distribution, biomass changes, hydrology, microclimate, and energy balance are altered as woody plant encroachment progresses (Archer et al. 2011).

E. Brush management on rangeland can be accomplished by one or more means such as mechanical removal, prescribed burning, herbicides, and selecting the proper class of grazing animal. Brush control on watersheds increases available water to other usually more desirable forage plants, which can include seeding as part of the management action; and increase runoff water for off-site use by replacing deep-rooted shrubs with more shallow-rooted grasses or forbs which consume less water. Overall broad sweeping conclusions about the hydrologic impacts of brush control are difficult because of the interactions of climate, weather, vegetation composition before and after treatment, soil type, shrub control methods, density of and type of shrubs, understory vegetation, timing of shrub control, and management after treatment. Brush control impacts will vary over time and from one rangeland plant community type to another because of these natural variations. Improvements in hydrologic response following brush control depends upon the factors listed above.

## 645.0718 Riparian Vegetation and Grazing

A. Riparian zones occur along the interface between aquatic and terrestrial ecosystems. Riparian ecosystems generally make up a minor portion of the landscape in terms of land area but are extremely important components in the planning and management of the rangeland or pastureland unit. It is important to recognize that management and condition of the transitional zone (inactive floodplains, terraces, meadows, etc.) and upland sites are critical to the health of riparian ecosystems because these are areas of runoff and recharge. Excessive runoff and gully erosion on uplands ultimately has a profound impact on the riparian zone and stream corridor.

B. A well-planned grazing system that provides periodic rest can alleviate many of the problems associated with livestock in riparian areas. Continuous season-long grazing is the most damaging grazing regime to riparian sites because livestock congregate and spend most of their time in riparian zones. Riparian zones, compared to more rugged, steep upland sites in the western United States, provide available and easily accessible water, forage, and shade. Excessive livestock impacts, such as heavy grazing and trampling, affect riparian-stream habitats by reducing or eliminating riparian vegetation, changing streambank and channel morphology, increasing stream sediment transport, and lowering of the surrounding ground water tables.

C. Livestock are perceived as a major cause of riparian degradation in the West, which has resulted in increased concerns from resource users. In addition to forage for livestock, riparian areas are generally one to two percent of the summer range land area but produce about 20 percent of the summer forage. Riparian areas have high value for fisheries habitat, wildlife habitat, recreation, transportation routes, precious metals, water quality, and timing of water flows.

D. Rehabilitation of riparian zones can include rotational grazing schemes, complete exclusion of livestock, changes in type or class of animal, and techniques to improve livestock distribution (salt placement, development of watering areas away from the riparian zone, fencing, herding, alternate turnout dates, etc.). Rest-rotation is one of the most practical means of restoring and maintaining riparian zones. Under moderate stocking, rest-rotation can improve riparian vegetation and physical stability. Where livestock grazing is compatible in a particular riparian area, grazing management practices must allow for regrowth of riparian plants and should leave sufficient vegetation cover for maintenance of plant vigor and streambank protection.

E. Streamside use of herbaceous forage in riparian areas in summer-grazed pastures should be used judiciously (not more than 50 percent by weight). In the intermountain region, riparian plant communities have limited regrowth potential after mid-summer. In riparian zones, “Rule of thumb” stubble heights proposed by some grazing guides (e.g., 4.0 inches) may or may not be adequate for certain species. State technical guides should be consulted for the dominant species on the site. Fall grazing should be monitored carefully because little or no regrowth potential remains. Utilization should be monitored on a per weight basis for native species or by height of stubble (as per state technical guides).

## 645.0719 Fire Dynamics on Hydrology and Erosion

A. Periodic fire is a natural disturbance that has formed and been part of the evolution of many rangeland plant communities and has been part of their evolution (Fuhlendorf et al. 2012) (Table G-22). Interruption and alteration of natural fire regimes since European settlement has resulted in altered rangeland ecosystems. In many rangeland ecosystems, the historic plant community was maintained by fire, and subsequent removal of fire has resulted in community threshold transitions, often with the consequence of woody plant invasion and loss of plant cover, resulting in increased erosion and loss of production for livestock and wildlife. In many rangeland ecosystems, most herbaceous plant species recover within 2–3 years postfire, irrespective of season of burn. However, there are always exceptions in rangeland ecosystems where fire is inherently infrequent (Fuhlendorf et al. 2012). There is always associated risk of excessive runoff and erosion is always associated with either prescribed fire or wildfires. Landowners and producers must weigh out the benefits versus the risk. However, risk of soil erosion is less on prescribed burns because current climate forecasts can be evaluated, plant root systems remain intact, and plants resprout quickly, and affected land areas are usually much less than when wildfires consume large areas of land.

B. Wildfire frequency intervals can be more frequent than natural fire frequencies in some rangeland plant communities and have a significant effect on runoff and hydrology. Wildfire, especially on rangelands where fire has been previously repressed, can have devastating effects on the environment. If high intensity rainfall events occur after severe burn events, there is high risk of accelerated runoff and flooding, debris-flow events, high erosion rates and sedimentation in water courses, damage to property, and loss of life. Pierson and Williams (2016) state: "the degree to which fire increases runoff and erosion rates and the associated risks is highly variable and depends on many factors." The dynamics and effects of runoff and erosion in response to fire is highly dependent on the intensity of the burn, fuel type, soil, climate, time of burn, topography, and vegetation. Fire has a dramatic effect on vegetative and ground cover and may also physically and chemically affect soils as fire intensity and temperatures increase.

- (1) Fire effects on hydrology:
  - (i) Reduced infiltration, increased runoff, and soil surface protection
  - (ii) Alteration of physical, chemical, and biological factors
  - (iii) Exacerbation, alteration, and formation of soil water repellence (hydrophobicity)
- (2) Fire and erosion effects:
  - (i) Increased rain splash and soil erosion
  - (ii) Altered concentrated flow processes

C. For example, fire temperatures have varying effects on organic matter. Humic acids and organic compounds (long-chain aliphatic hydrocarbons) are lost at temperatures below 212°F. At temperatures between 212°F and 390°F, nondestructive distillation of volatile organic substances occurs, and at temperatures between 390°F and 570°F about 85 percent of the organic substances are destroyed by destructive distillation. The duration and temperature of the fire can distill organic material and other substances downward into the soil and form a non-wettable hydrophobic layer. Fuels that burn quickly (e.g., grass) or very hot (brush piles) generally do not form a hydrophobic layer in the soil. Water repellent layers in the soil are most common in shrub communities where fires burn from five to 25 minutes. This situation is inherent in chaparral communities where 90 percent of the decomposed organic matter is usually lost as smoke and ash, and the remaining material is distilled downward and condensed in the soil.

**Table G-22.** Fire frequency comparisons and fire regime characteristics in range and forest plant communities. LANDFIRE Rapid Assessment Vegetation Models. Courtesy U.S. Forest Service. https://www.fs.fed.us/database/feis/fire_regime_table/fire_regime_table.html

| Vegetation Community | Fire Severity* | % of Fires | Mean Interval (yrs) | Minimum Interval (yrs) | Maximum Interval (yrs) |
|---|---|---|---|---|---|
| **Pacific NW Grassland** | | | | | |
| Bluebunch wheatgrass | Replacement | 47% | 18 | 5 | 20 |
| | Mixed | 53% | 16 | 5 | 20 |
| Pacific NW Shrubland | | | | | |
| Mountain big sagebrush (high elev) | Replacement | 100% | 20 | 10 | 40 |
| Wyoming big sagebrush steppe | Replacement | 89% | 92 | 30 | 120 |
| **California Shrubland** | | | | | |

| Vegetation Community | Fire Severity* | % of Fires | Mean Interval (yrs) | Minimum Interval (yrs) | Maximum Interval (yrs) |
|---|---|---|---|---|---|
| California grassland | Replacement | 100% | 2 | 1 | 3 |
| Chaparral | Replacement | 100% | 50 | 30 | 125 |
| **California forested** | | | | | |
| Coast redwood | Replacement | 2% | ≥1,000 | | |
| | Surface or low | 98% | 20 | | |
| **Southwest grassland** | | | | | |
| Desert grassland with shrubs and trees | Replacement | 85% | 12 | | |
| | Mixed | 15% | 70 | | |
| Plains mesa grassland | Replacement | 81% | 20 | 3 | 30 |
| | Mixed | 19% | 85 | 3 | 150 |
| **Northern and Central Rockies Forested** | | | | | |
| Douglas-fir (cold) | Replacement | 31% | 145 | 75 | 250 |
| | Mixed | 69% | 65 | 35 | 150 |
| Grand fir-Douglas-fir-western larch mix | Replacement | 29% | 150 | 100 | 200 |
| | Mixed | 71% | 60 | 3 | 75 |
| Ponderosa pine (Black Hills, low elevation) | Replacement | 7% | 300 | 200 | 400 |
| | Mixed | 21% | 100 | 50 | 400 |
| | Surface or low | 71% | 30 | 5 | 50 |
| **Plains Grassland** | | | | | |
| Central Tallgrass prairie | Replacement | 75% | 5 | 3 | 5 |
| | Mixed | 11% | 34 | 1 | 100 |
| | Surface or low | 13% | 28 | 1 | 50 |
| Northern mixed-grass prairie | Replacement | 67% | 15 | 8 | 25 |
| | Mixed | 33% | 30 | 15 | 35 |
| Southern shortgrass or mixed-grass prairie | Replacement | 100% | 8 | 1 | 10 |
| **Northeast Woodland** | | | | | |
| Pine barrens | Replacement | 10% | 78 | | |
| | Mixed | 25% | 32 | | |
| | Surface or low | 65% | 12 | | |
| Eastern woodland mosaic | Replacement | 2% | 200 | 100 | 300 |
| | Mixed | 9% | 40 | 20 | 60 |
| | Surface or low | 89% | 4 | 1 | 7 |

*Fire Severities

**Replacement:** Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.

**Mixed:** Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.

**Surface or low:** Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area.

The thickness and depth of a hydrophobic layer depends on the intensity and duration of the fire, soil water content, and soil physical properties. Hydrophobic layers form in dry soils more than in wet soils, and coarse-textured soils are more likely to become water repellent than fine-textured soils (Pierson et al. 2001, 2002a, 2008). In sagebrush ecosystems, water repellency was generally greater on unburned hillslopes and had a greater impact on infiltration capacity than fire effects (Pierson et al. 2008). Fire-induced reduction on infiltration was the result from the combined effect of canopy and ground cover removal and the presence of naturally occurring water repellent soils. Pierson et al. (2008) summarized: “removal of ground cover likely increased the spatial connectivity of runoff areas from strongly water repellent soils. The results indicate that for coarse-textured sagebrush landscapes with high pre-fire soil water repellency, post-fire increases in runoff are more influenced by fire removal of ground and canopy cover than fire effects on soil water repellency, and that the degree of these impacts may be significantly influenced by short-term fluctuations in water repellent soil conditions."

D. Fire-induced hydrologic vulnerability is generally low where canopy and ground vegetative cover is minimal. In high intensity burns, the risk of accelerated runoff, sheet-rill and gully erosion risks increase exponentially, especially with land slope increases. Hydrologic studies on plots and hillslopes show that runoff and erosion can increase after fire from 2 to 40 times greater on small simulation plots and more than 100-fold on large plots to hillslope scales, compared to unburned treatments (Pierson and Williams 2016).

## 645.0720 Rangeland Models Associated with Hydrology and Erosion

A. The Rangeland Health Model is based on the qualitative assessment of 17 indicators that determine the preponderance of evidence for Hydrologic Function, Site Stability, and Biotic Integrity. All three of these rangeland health attributes relate to watershed management and should be considered in planning and monitoring rangeland. The Rangeland Health Model can be used in conjunction with quantitative assessments of rangeland (production, foliar cover, bare ground, invasive species). The model is useful in detecting subtle changes, which may indicate if a site is near or has passed a threshold to an alternative state. Once a resource manager has been properly trained, a high degree of repeatability and reliability can be achieved.

B. Interpreting Indicators of Rangeland Health V5 (Pellant et al. 2020) is available for use by NRCS for estimating historical surface runoff, soil erosion, and sediment yield, or future risks at the hillslope scale for conservation planning and assessing the sustainability of rangelands. Specific classes are offered by NRCS to provide training on this tool.

C. Rangeland Hydrology and Erosion Model (RHEM)

(1) RHEM was developed as a coordinated project between three USDA agencies: Agricultural Research Service (ARS), NRCS, and the United States Forest Service (USFS) (Wei et al. 2009, Hernandez et al. 2017, Nearing et al. 2011, Hernandez et al. 2017). The RHEM model is designed for government agencies, land managers, and conservationists who need sound, science-based technology to model and predict runoff and erosion rates on rangelands and to assist in assessing rangeland conservation practice effects. RHEM is a process-based erosion prediction tool specific for rangeland application and is based on fundamentals of infiltration, hydrology, plant science, hydraulics and erosion mechanics. RHEM can be used to evaluate runoff and erosion as a consequence of plant species and growth form changes from disturbances such as fire, brush management, and climate change. RHEM will also evaluate the statistical risk from various storm events (2, 5, 10, 25, 50, 75, and 100-yr). Outputs of RHEM include average precipitation, number of storms producing runoff, runoff, soil loss, and hydrology and erosion risks for the design storm events. The RHEM model can be accessed at the USDA-ARS Southwest Watershed Research Station web site: https://apps.tucson.ars.ag.gov/rhem/login.

(2) Model Functionality:
- (i) Model and evaluate conservation practice and systems benefits
- (ii) Evaluate conservation program benefits
- (iii) Assist in developing conservation system guides
- (iv) Conservation planning, check site parameters with planned management practices
- (v) Assist in developing hydrologic function sections for ecological site descriptions
- (vi) Watershed planning
- (vii) National Resource Inventories—assessment of rangeland hydrology and erosion
- (viii) Training tool to teach interactions between climate-soils-plants-management
- (ix) Use in "Market-based approaches"

(3) Importance: benefits for NRCS customer
- (i) Provide a quantitative tool for evaluating the effectiveness of conservation practices.
- (ii) Model and predict rangeland hydrology and erosion for current and future conditions.
- (iii) Identify ecological site thresholds and identify critical site issues that may still be rectified.
- (iv) Provide data and tools to support market-based approaches.

(4) Benefits for field staff

RHEM outputs can be linked with other NRCS web-based technologies. This information can be used in many NRCS programs and planning activities (i.e., predict rangeland hydrology and erosion at the field and watershed level scale).

(5) Benefits for area and state offices

All items above, and for use in developing Conservation guidance sheets, Ecological Site Descriptions, and Rangeland Health Reference Sheets.

(6) National benefits

NRCS program evaluation, evaluating conservation priorities, NRI, and conservation benefits analysis. RHEM can be used to support activities across all missions in the agency strategic plan and carrying out Farm Bill initiatives.

(7) Several publications, handbooks, and RHEM ESD guide documents have been produced to assist in using the RHEM model and writing ecohydrology sections for ecological site descriptions or evaluating benefits of conservation.
- (i) NRCS Handbook: Title 190, Rangeland Processes Handbook, Part 646, "Hydrology and Soil Erosion.
- (ii) NRCS Handbook: Title 190, Rangeland Hydrology and Erosion Model Handbook, Part 647, "RHEM Guide."
- (iii) Rangeland Hydrology and Erosion Model Guide and Discussion for: Short Grass Prairie Ecological Site, West Texas. Discusses the Deep Hardland Loamy 16–21" PZ (R077CY022TX) Major land resource area (MLRA): 077C-Southern High Plains, Southern Part Ecological Site, Texas.
- (iv) Rangeland Hydrology and Erosion Model Guide and Discussion for: Post Oak Savanna Ecological Site with Ash Juniper Encroachment, Central Texas. Discusses Deep Redlands 29–35" PZ (R081CY358TX). Major land resource area (MLRA): 081C eastern part of the Edwards Plateau region of central Texas.
- (v) Rangeland Hydrology and Erosion Model Guide and Discussion for: Mountain Big Sagebrush and Bluebunch Wheatgrass, with western Juniper Encroachment and cheatgrass Invasion, Southeast Oregon. Discussion for South Slopes 12–16 in PZ (R023XY302OR); Major Land Resource Area (MLRA): 23 Malheur High Plateau, Southeast Oregon.
- (vi) Rangeland Hydrology and Erosion Model Guide and Discussion for: Desert Grassland Ecological Site with Invasive Grass and Shrub Encroachment, Southeastern Arizona. Discusses the Limy Slopes 12–16" PZ ecological site (Site ID: R041XC308AZ) Major land resource area (MLRA): 041-Southeastern Arizona Basin and Range.

## 645.0721 Appendix G-A.

A. Ecological Site Development: Ecohydrology

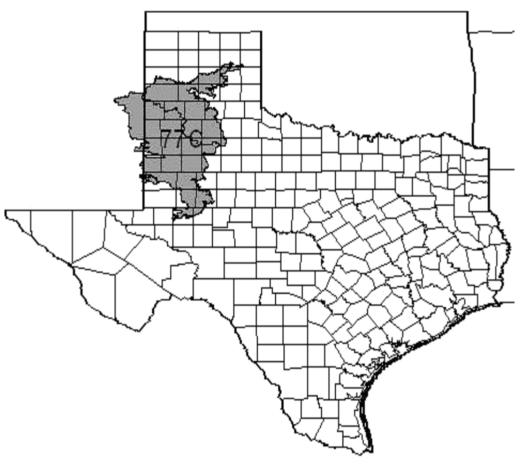
Ecological site descriptions (ESD) support discussions on ecohydrology. The following fact sheet guide "Rangeland Hydrology and Erosion Model (RHEM) guide and Discussion for: Short Grass Prairie Ecological Site, west Texas" is an example of a detailed ecohydrology narrative and discussion with RHEM outputs to illustrate hydrology and erosion dynamics with state-and-transition model changes.

B. Rangeland Hydrology and Erosion Model guide and Discussion for: Short Grass Prairie Ecological Site, west Texas

(1) General Background

(i) The Ecological Site for this example is a Deep Hardland Loamy 16–21" PZ (R077CY022TX); Major land resource area (MLRA): 077C-Southern High Plains, Southern Part Ecological Site (ES). See figure G-A-1.

**Figure G-A-1.** Location of Major Land Resource Area and example of Reference plant community.




(ii) MLRA 77C is characterized by nearly level plains with numerous playa depressions, moderately sloping breaks along drainageways, and a steep escarpment along the eastern margin. This site occurs on the large nearly level to moderately sloping, well drained, moderately permeable soils formed in calcareous, loamy colluvium and slope alluvium derived from the Ogallala Formation of Miocene-Pliocene age. A few ancient drainage ways dissect this plateau, and relatively shallow closed depressions are scattered throughout the area. The elevation ranges from 2,800 feet to 4,500 feet above sea level. Slopes range from 0 to 5 percent. The site is extensively used for cultivated cropland, as well as rangeland. The climate is semi-arid dry steppe. Mean annual precipitation is 21 inches. This site consists of very deep, well drained, moderately permeable soils that formed in loam and clay loam loess deposits. These are very well-developed soils on old stable landforms and are moderately alkaline throughout. The soils have dark colored loam subsurface layers. Parent material is Eolian deposits from limestone origin. There are no surface fragments greater or less than three inches on the soil surface.

(2) Ecological Site Description

(i) The reference plant community (figure G-A-2) is shortgrass prairie grassland dominated by blue grama (*Bouteloua gracilis,* Bogr, 60–70 percent composition by weight) and buffalograss (*Bulbilis dactyloides,* Buda, 15–25 percent composition by weight). Other shortgrass species and a variety of forbs comprise the remaining plant composition. Typically, forbs contribute around five to eight percent of the total production. A few woody species, cholla cactus (*Cylindropuntia imbricata*, prickly pear (*Opuntia* spp.), broom snakeweed (*Gutierrezia sarothrae,* Gusa) or occasional yucca (*Yucca* spp.) will be present, usually only one to two percent of the total plant community. Although honey mesquite (*Prosopis glandulosa*) is not a native component species on this ecological site, it can be invasive. The Deep Hardland ecological site can exhibit high plant species richness and diversity (Spaeth 1990).

(ii) With continued heavy grazing pressure, the plant community shifts to a more equal distribution of blue grama (25–50 percent) and buffalograss (15–30 percent) (figure G-A-2, phase 1.2). In community phase 1.2 the soil can become more compacted, and subsequently rainfall infiltration capacity is reduced and runoff increases. Further long-term grazing pressure can result in a transition to State 2.1 where buffalograss dominates the stand. Once buffalograss dominates the stand, transition to State 1 can be long-term (decades) because of the ecohydrologic dynamics of buffalograss (see RHEM modeling results and discussion, this appendix). The dominant buffalograss, state 2.1, also occurs as a transition from State 4.1, which results from prairie dog colonization and abandonment. This transition may take decades and depends on climate and management of the site.

(iv) Combinations of long-term heavy grazing pressure and drought can facilitate the increase of the native half shrub broom snakeweed. Sandier soil pockets and components within the ecological site are also more conducive to broom snakeweed invasion (Spaeth 1990). This low-growing (less than 0.5 m tall) suffrutescent plant is poisonous and is considered undesirable by many landowners because it suppresses growth of other native grasses and forbs. Allelopathy may be a factor, as it is correlated with reduced grass and forb production, which enhances its own life cycle (Lowell 1980). Plant diversity is low in stands with dominance of broom snakeweed (Spaeth 1990).

(v) Mesquite and cholla cactus can be invasive on this ecological site (State 5.1). Once this state becomes established, gains momentum, and woody densities increase, more stringent applications of conservation practices will be necessary (Brush Management, Prescribed Burning and Grazing). The economic inputs to convert State 5.1 to 2.1 can be high.

(vi) Black-tailed prairie dogs (*Cynomys ludovicianus*), often referred to as “ecosystem engineers” and “keystone species” (Lawton and Jones 1995, Power et al. 1996) in shortgrass prairie can have a profound effect on grassland structure, composition, and ecosystem dynamics (Winter et al. 2002, Fahnestock et al. 2003). Where prairie dogs are abundant, grassland vegetation can be altered dramatically with extensive and persistent burrow systems. Prairie dogs have intrinsic biological value in grasslands. Colonies can provide refugia for subdominant grasses, forbs, and shrubs (Coppock et al. 1983). Soil structure and chemistry can be modified. Nutrients can be altered (Whicker and Detling 1988), and modifications in habitat can benefit other grassland animals (Clark et al. 1982, Lomolino and Smith 2003). Although the disturbance regime can be extreme in active prairie dog colonies, floristic richness can be high, even greater than State 1.1 (Bonham and Lerwick 1976, Klatt and Hein 1978, Coppock et al. 1983, Martinsen et al. 1990, Spaeth 1990, Fahnestock and Detling 2002). Soil surface physical and chemical condition changes created by prairie dog colonization also have a significant effect to decrease infiltration capacity, soil water storage, and increase runoff and erosion (see RHEM modeling results and discussion, this appendix).

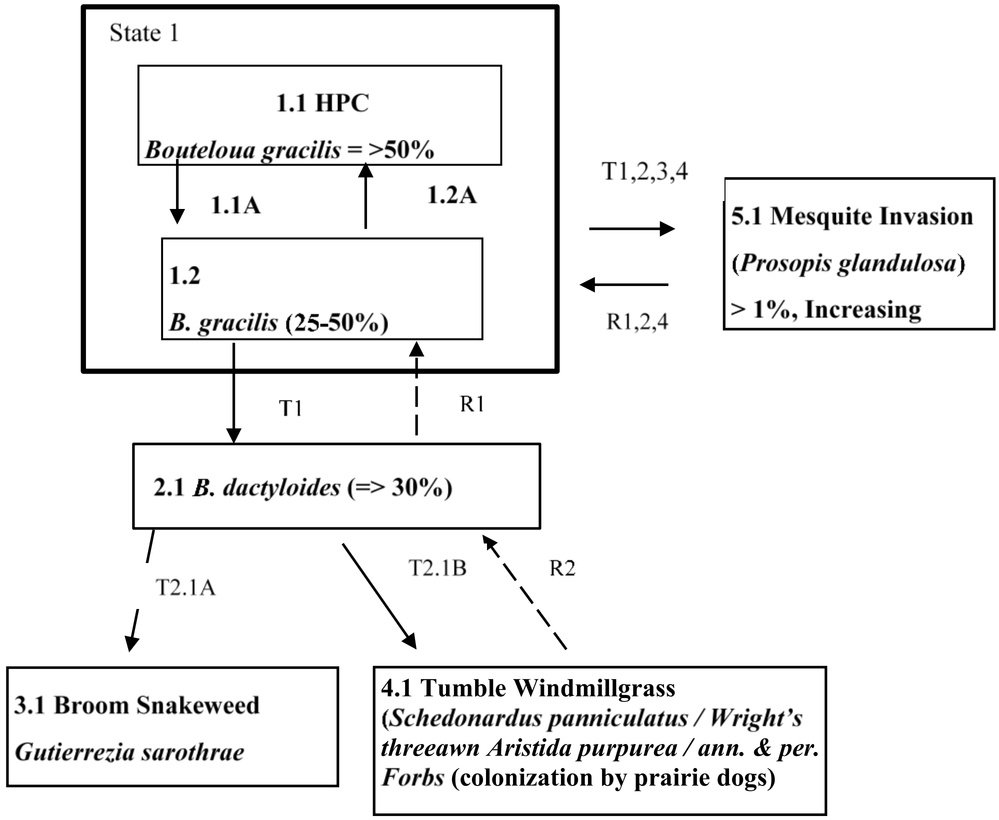
(3) Soils

Existing soil texture components in the Deep Hardland Loamy Ecological Site include loam, silty clay loam, and clay loam.

(4) Climate
Ecological Site Description/Climate Description: Climate is semi-arid dry steppe. Summers are hot with winters being generally mild with numerous cold fronts that drop temperatures into the single digits for 24 to 48 hours. Temperature extremes are the rule rather than the exception. Humidity is generally low and evaporation high. Wind speeds are highest in the spring and are generally southwesterly. Canadian and Pacific cold fronts come through the region in fall, winter, and spring with predictability, and temperature changes can be rapid. Mean average precipitation is 21 in, most of which comes in the form of rain and during the period from May through October. Snowfall averages around 15 inches but may be as little as eight inches or as much as 36 inches. Rainfall in the growing season often comes as intense showers of relatively short duration. Long-term droughts occur on the average of once every 20 years and may last as long as five to six years (during these drought years moisture during the growing season is from 50 to 60 percent of the mean). Based on long-term records, approximately 60 percent of years are below the mean rainfall and approximately 40 percent are above the mean. May, June, and July are the main growth months for perennial warm-season grasses, whereas forbs make their growth somewhat earlier. Average frost-free days are 205; freeze-free days 210.

(5) Modeling Results and Discussion
(i) Modeling inputs are shown in table G-A-1.
(ii) Figures G-A-4 through G-A-9 provide an overview of plant communities and summary of precipitation, runoff, sediment yield, and soil loss rates for the annual average and 2, 5, 25, 50, and 100-year runoff recurrence intervals. For the Deep Hardland Loamy Ecological Site, hydrology and soil loss is highly variable across the respective states. As management and climate affect cover, production, and species composition, significant changes occur over time with respect to ecological changes (species composition) and hydrology. The decline of foliar plant cover and production affect the hydrologic regime. However, plant life/growth forms on a site greatly influence infiltration and runoff dynamics, such as tall grasses, mid grasses, shortgrasses, forbs, shrubs, halfshrubs, and trees, and their compositional differences. Infiltration is usually highest under trees and shrubs and decreases progressively in the following order: bunchgrass, sodgrass, and bare ground (Carlson et al. 1990, Thurow 1991, Weltz and Blackburn 1995).

**Figure G-A-2.** State and transition diagram for ecological site Deep Hardland site near Muleshoe, Texas (photos by NRCS).




Legend

| | |
|---|---|
| 1.1A | Lack of prescribed grazing, heavy grazing use |
| 1.2 A | Prescribed grazing, above average spring, summer precipitation |
| T1 | Traversed threshold, transition from State 1 to 2; lack of prescribed grazing, drought, prairie dog use |
| R1 | Restoration from State 2.1 to 1.2, tenuous, time factor could be decades; climate pulse—above average summer precipitation; prescribed grazing; periodic deferment from grazing |
| T2.1A | Traversed threshold to State 3 due to stand deterioration, significant broom snakeweed increases > 2% cover |
| T2.1B | Traversed threshold to State 4 due to prairie dog colonization, significant bare ground increase |
| R2 | Restoration from State 4.1 to 2.1 is tenuous, time factor could be decades, climate pulse—above average summer precipitation; prescribed grazing; periodic deferment from grazing |
| T1234 | From any state, 1, 2, 3, 4: Mesquite invasion > 1%, increasing comp. of Cholla and prickly pear cactus |
| R124 | Restoration from State 5.1 to 1.2 will require one or more of the following conservation practices (brush management, prescribed burning, and prescribed grazing). |

(iii) Individual plant species also have a profound effect on hydrology and erosion dynamics, such as different grasses, forbs, and shrubs (Spaeth 1996 a, b). Field studies have documented infiltration capacity with individual species composition. Dee et al. (1966) found that water infiltrated three times faster in blue grama and silver bluestem (*Bothriochloa saccharoides*) stands than areas dominated by annual weeds such as summer cypress (*Kochia scoparia*) and windmill grass (*Chloris verticillata*). Blue grama terminal infiltration capacity was about four times higher than buffalograss stands, holding soil type constant.

**Table G-A-1.** RHEM model inputs for evaluation of hydrologic impact of transitions from one ecological state to another ecological state for Deep Hardland Loamy 16–21" PZ (R077CY022TX) site. Representative soil series is a Berda loam in the surface horizon.

| Input Parameter | Reference State 1.1 | State Phase 1.2 | State 2.1 | State 3.1 | State 4.1 |
|---|---|---|---|---|---|
| Soil Texture | Clay | Clay | Clay | Clay | Clay |
| Soil Water Saturation (%) | 25 | 25 | 25 | 25 | 25 |
| Slope Length (ft) | 100 | 100 | 100 | 100 | 100 |
| Slope Shape | Linear | Linear | Linear | Linear | Linear |
| Slope Steepness (%) | 2 | 2 | 2 | 2 | 2 |
| Foliar Canopy Cover (%) | | | | | |
| Bunch Grass Foliar Cover (%) | 90 | 45 | 0 | 25 | 5 |
| Forbs and/or Annual Grass Foliar Cover (%) | 5 | 5 | 5 | 10 | 5 |
| Sodgrass Foliar Cover (%) | 5 | 50 | 90 | 10 | 5 |
| Woody Foliar Cover (%) | 0 | 0 | 0 | 0 | 90 |
| Ground Surface Cover % | | | | | |
| Basal Cover (%) | 10 | 6 | 5 | 1 | 1 |
| Rock Cover (%) | 0 | 0 | 0 | 0 | 0 |
| Litter Cover (%) | 30 | 20 | 5 | 0 | 10 |
| Biological Crusts Cover (%) | 0 | 0 | 0 | 0 | 0 |

- Figure G-A-3 shows comparative infiltration rates derived from rainfall simulation experiments for various ecological states and phases (Spaeth 1990). Initial infiltration capacity from the onset of rainfall to 25 minutes was slightly different for the reference state, blue grama (Bogr), and perennial broom snakeweed (Gusa) stands. However, long term infiltrability (near-saturated hydraulic conductivity) were the same. The Gusa stands had infiltration rates similar to the reference Bogr stands (representative of high similarity index), indicative of low similarity index values, higher percentage of bare ground, low graminoid and forb cover, and high sub-shrub cover. This demonstrates that the Gusa stands still maintain adequate hydrologic function, representative of low biotic integrity and similarity index with significant changes in plant functional groups (graminoid-to-woody), high composition of invasive plants, and loss of native grass cover. However, soil loss was higher in Gusa stands compared to the reference stands (1.1 Bogr and 1.2 Bogr/Buda) due to higher bare ground under snakeweed canopy (figure G-A-5). What factors may be responsible for the near identical infiltration curves for the reference Bogr sands and the Gusa stands? The answer most likely is due to the morphology of the plants and coppice dune formation, if present. Field studies show that infiltration capacity in bunchgrass stands have inherently higher rates compared to sodgrass stands (Mazurak and Conard 1959; Dee et al. 1966; Spaeth 1990; 1996a, b; Pierson et al. 2002b).
- Some shrubs and half-shrubs are associated with coppice dunes or mounds composed of litter and wind-transported soil. Coppice dunes form under broom snakeweed plants, which create a zone of high infiltrability and low runoff. Field experiments show that surface soil organic carbon, bulk density, percentage silt, and infiltration and interrill erosion rates are significantly higher for shrub-coppice and shrub-interspace areas (Blackburn 1975; Johnson and Gordon 1988; Blackburn et al. 1990; 1992; Pierson et al. 2001, 2002b, 2008).

(iv) Infiltration capacity of state phase 1.2 is different from the reference community 1.1, where blue grama is the dominant species (figures G-A-3 and G-A-4). State phase 1.2 is representative of increasing buffalograss, where the ratio of blue grama and buffalograss is close to 1:1. As buffalograss increases in the stand, infiltration capacity decreases. This is also evident in state 2.1 where buffalograss occurs almost in a monoculture (figure G-A-2). Dominant stands of buffalograss (state 2.1; figure G-A-2) are common around the periphery of active prairie dog colonies and in pastures where grazing has been consistently heavy. Buffalograss is a short shoot plant (grazing tolerant plant with protected meristematic tissue, growing points) that is more tolerant to drought and hot temperatures than blue grama (Weaver 1954) and reproduces sexually (seed) and vegetatively (surface runners-stolons). Research shows that buffalograss also exhibits a dense shallow fibrous root system (root pan) that is correlated with significantly reduced infiltration capacity (Spaeth 1990, 1996a, b).

In some grass stands, where roots are found in the inter-aggregate pores, water repellent compounds form on soil aggregates and soil structural peds as a result of decaying organic matter and the production of humic and fulvic acids (Bisdome et al. 1993, Dekker and Ritsema 1996). Ritsema et al. (1998) state that water repellency is considered a plant-induced soil property. Sources of water repellent compounds include accumulated plant derived organic matter from mulch, decomposing roots and plant material, and root exudates (Doerr et al. 1996, Czarnes et al. 2000). Particulate organic matter contains plant and microbial produced compounds such as waxes (Franco et al. 2000, Schlossberg et al. 2005); humic acids (Spaccini et al. 2002); a presence of a protective water-repellent lattice of long-chain polymethylene compounds around soil aggregates (Shepherd et al. 2001); aliphatic C present in organic matter (Ellerbrock et al. 2005); mycorrhizal and saprobic soil fungi (Bond and Harris 1964, Paul and Clark 1996, Hallett and Young 1999, White et al. 2000, Rillig 2004); basidiomycete fungi (Bond and Harris 1964, Fidanza 2003); fungal proteins such as hydrophobins (Rillig 2005, Rillig and Mummey 2006); and fatty acids, fulvic acids, extracellular enzymes, polysaccharides (Bisdom et al. 1993, Kostka 2000, Eynard et al. 2006).

(v) State 4.1 was produced by prairie dog colonization. Although plant cover is minimal in active colonies, plant species diversity can be greater than all the contrasting states associated with this ecological site (Spaeth 1990). In state 4.1, infiltration capacity is significantly reduced, and erosion potential is higher than any of the other states represented in this ecological site (figures G-A-3, G-A-4, G-A-5). In summary, the extent of vegetation cover and individual plant species (within a life/growth form or contrasting growth habit) can be primary factors that influence spatial and temporal variability of surface soil processes controlling infiltration and interrill erosion rates on rangeland.

(vi) Table G-A-2 and figure G-A-10 show the risk assessments for the five states depicted in the state and transition diagram (figure G-A-2). Interpretations are as follow: there is a 50 percent chance that soil loss (X) will be less than 0.49 t/ac in the Bogr state, a three percent chance in Bogr/Buda, and zero percent in Buda, Gusa, and Arol/Scpa. There is a 30 percent chance that soil loss will be within 0.49 and 0.72 t/ac in the Bogr state, six percent in Bogr/Buda. In the Bogr/Buda state, there is a five percent chance that soil loss will exceed 1.03 t/ac, whereas the probability of soil loss exceeding 1.03 t/ac is high in Bogr/Buda (70 percent), Buda (97 percent), Gusa (100 percent), and Arol/Scpa (100 percent).

**Figure G-A-3.** Comparative infiltration on five ecological states associated with a Deep Hardland Loamy Ecological Site, Berda loam soil in west Texas. Reference State 1.1 Bogr = blue grama; State phase 1.2 Bogr/Buda (blue grama and buffalograss); State 2.1 Buda = buffalograss; State 3.1 Gusa = perennial broom snakeweed; and State 4.1 Arol = perennial threeawn, Scpa = Texas tumblegrass.

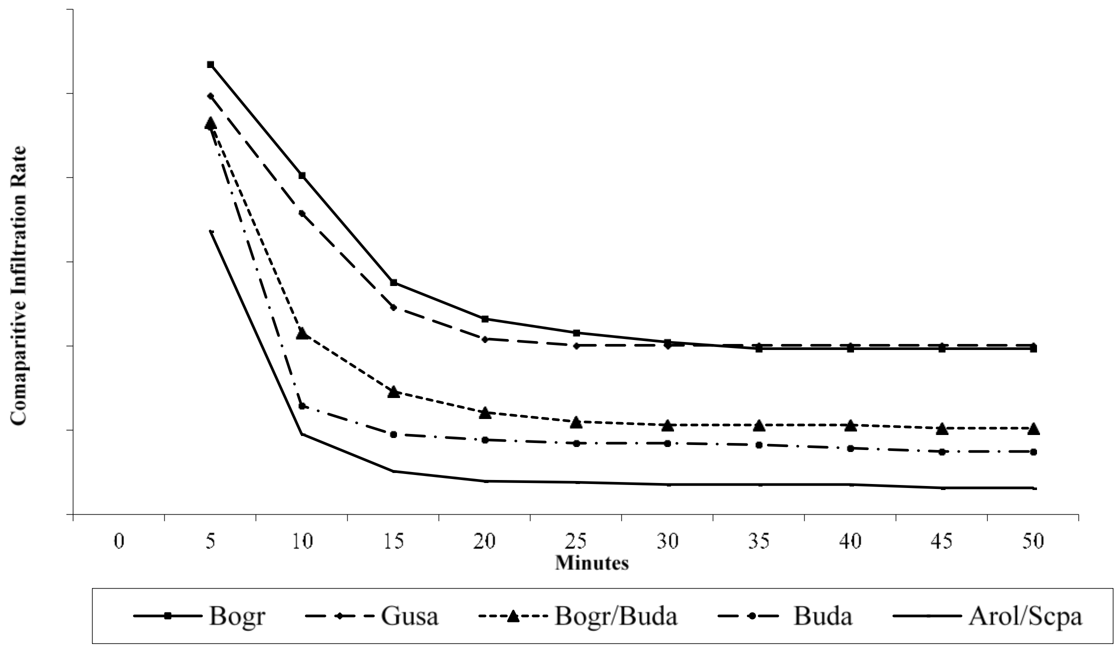



**Figure G-A-4.** Rangeland Hydrology and Erosion Model estimated average annual precipitation and runoff for Deep Hardland Ecological Site by ecological state near Muleshoe, Texas.

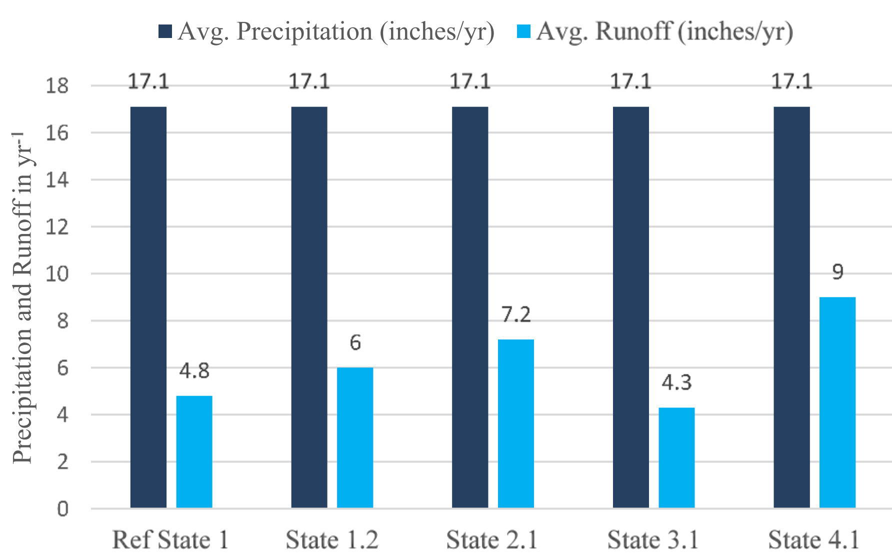


**Figure G-A-5.** Rangeland Hydrology and Erosion Model estimated average annual sediment yield and soil loss for Deep Hardland Loamy Ecological Site by ecological state near Muleshoe, Texas.

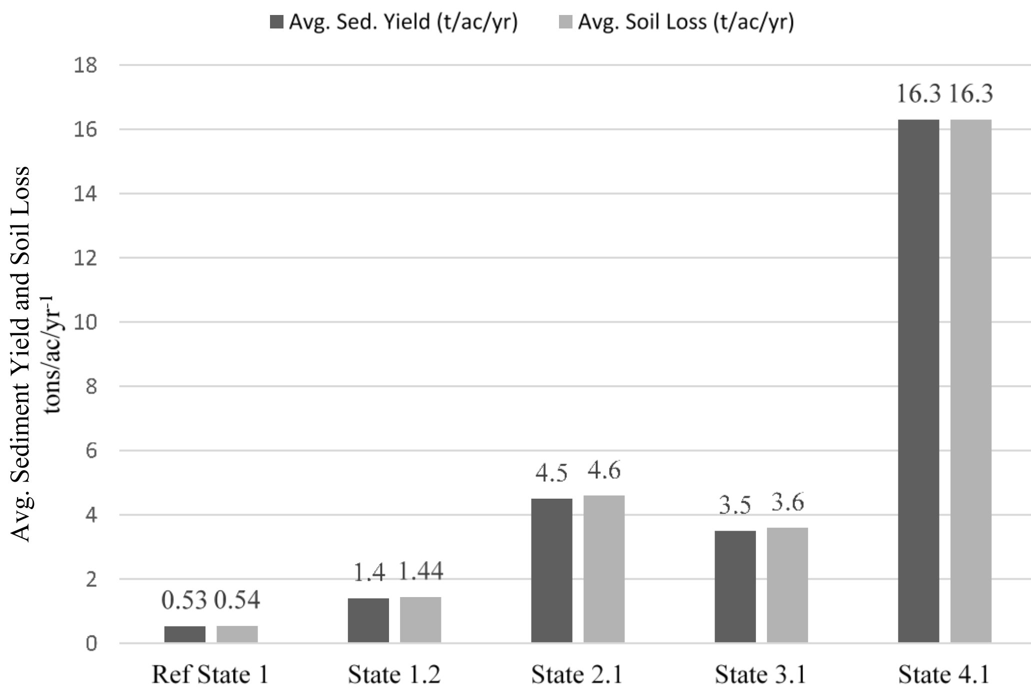



**Figure G-A-6.** Rangeland Hydrology and Erosion Model estimated storm return period precipitation for Deep Hardland Loamy Ecological Site by ecological state near Muleshoe, Texas.

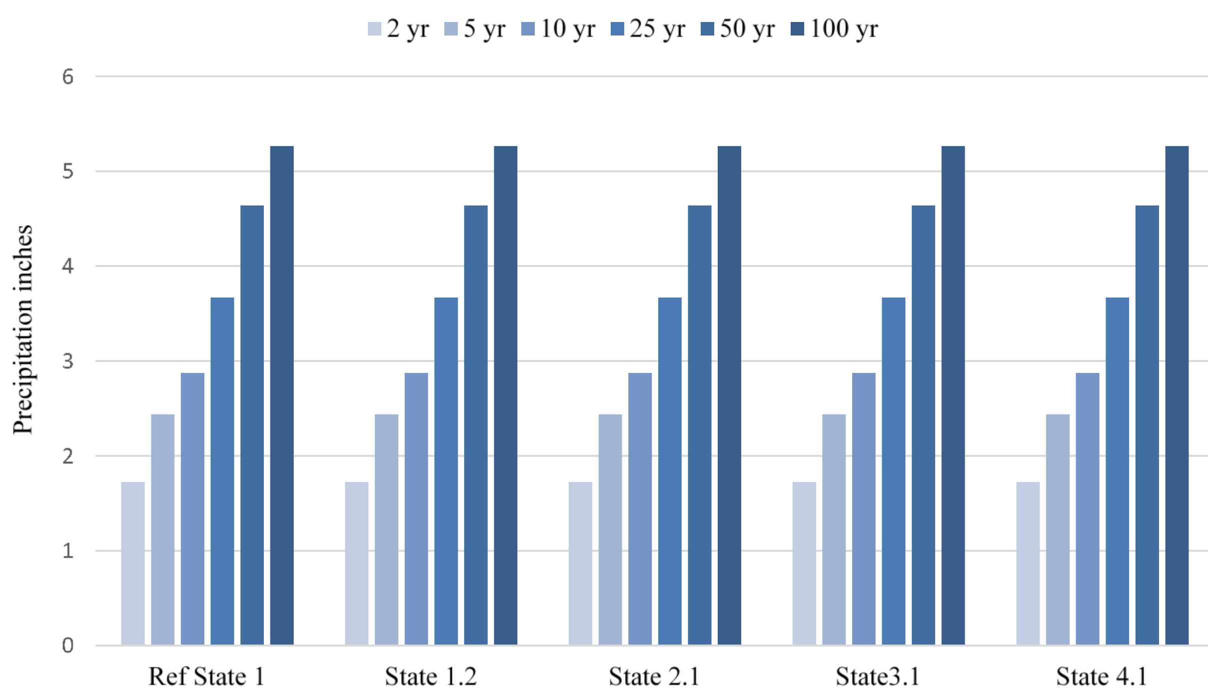


**Figure G-A-7.** Rangeland Hydrology and Erosion Model estimated storm return period runoff for Deep Hardland Loamy Ecological Site by ecological state near Muleshoe, Texas.

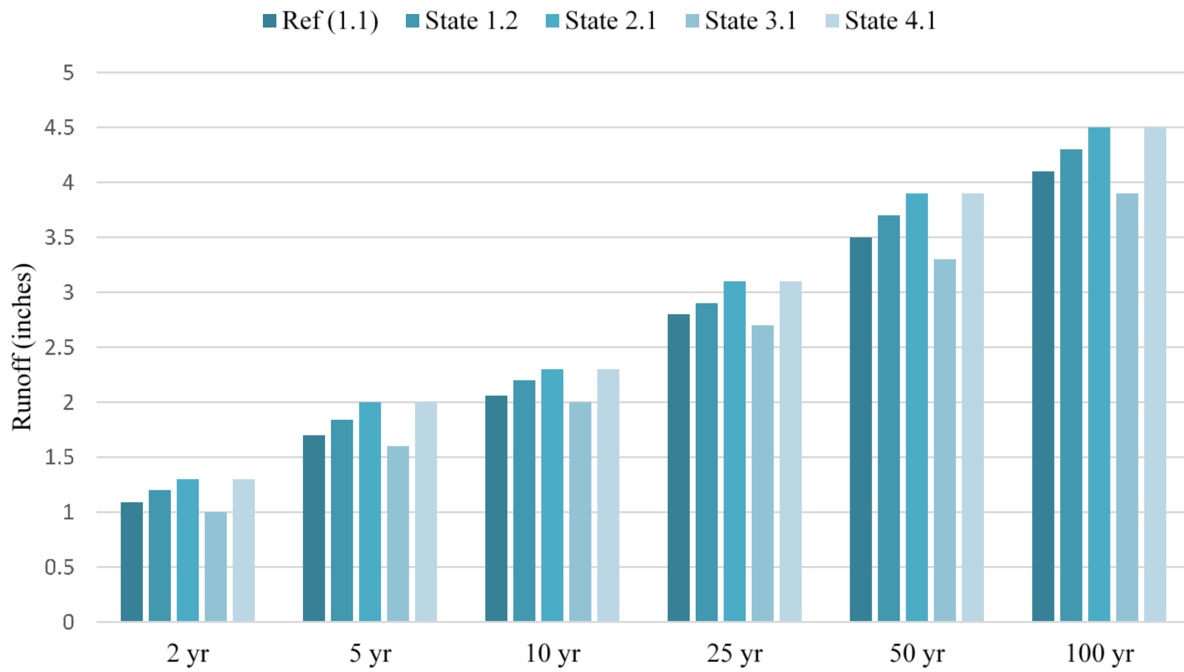



**Figure G-A-8.** Rangeland Hydrology and Erosion Model estimated storm return period soil loss for Deep Hardland Loam Ecological Site by ecological state near Muleshoe, Texas.

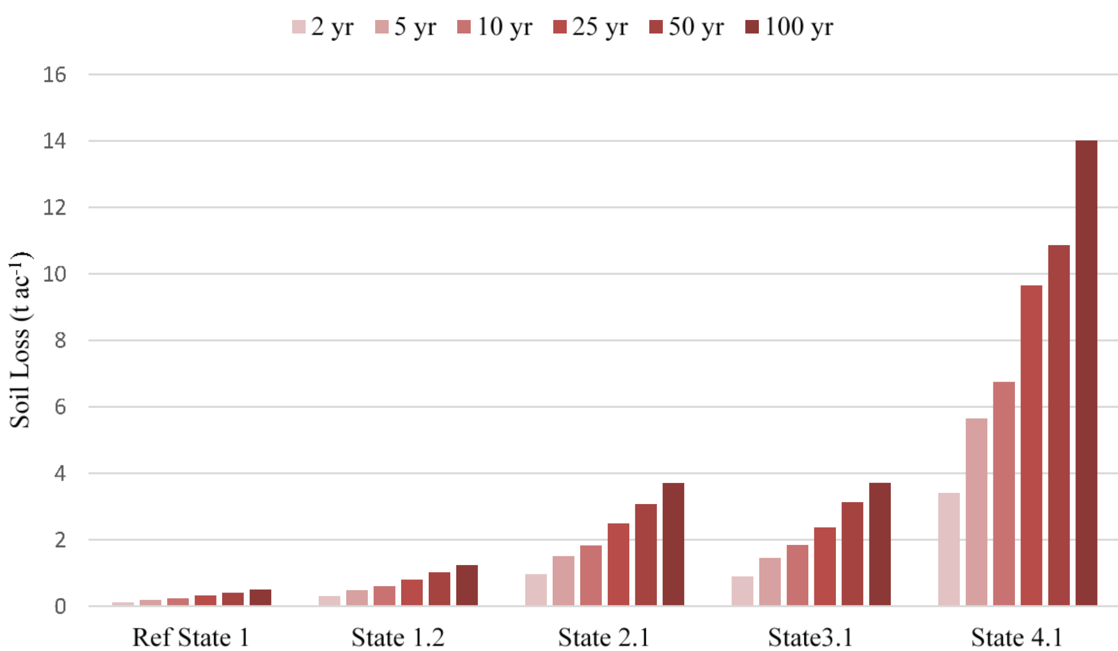


**Figure G-A-9.** Rangeland Hydrology and Erosion Model estimated storm return period sediment yield for Deep Hardland Loam Ecological Site by ecological state near Muleshoe, Texas.

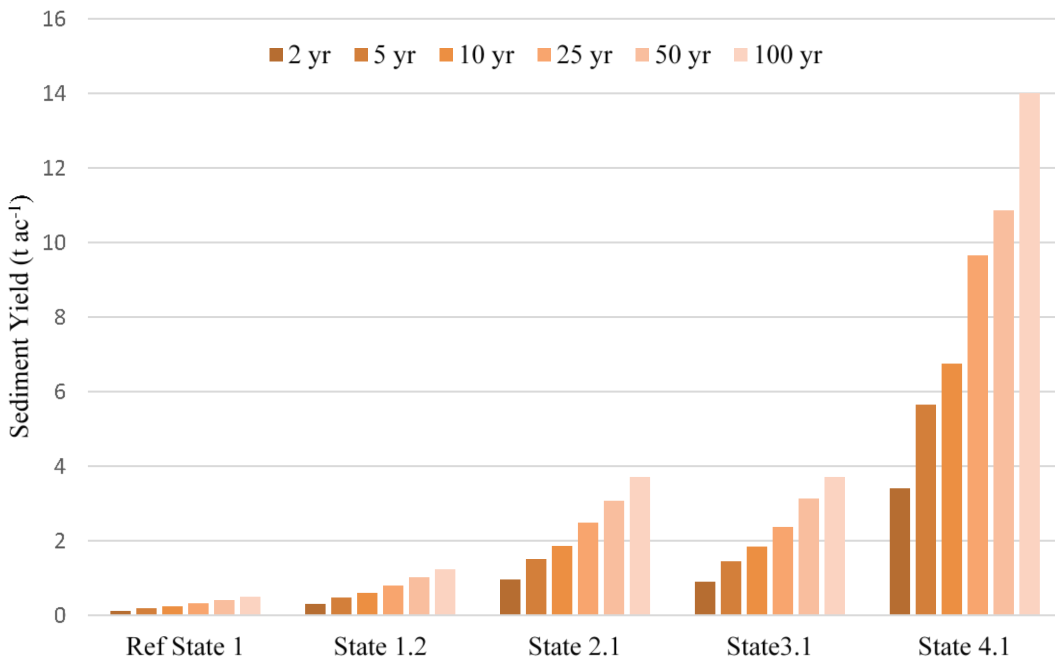


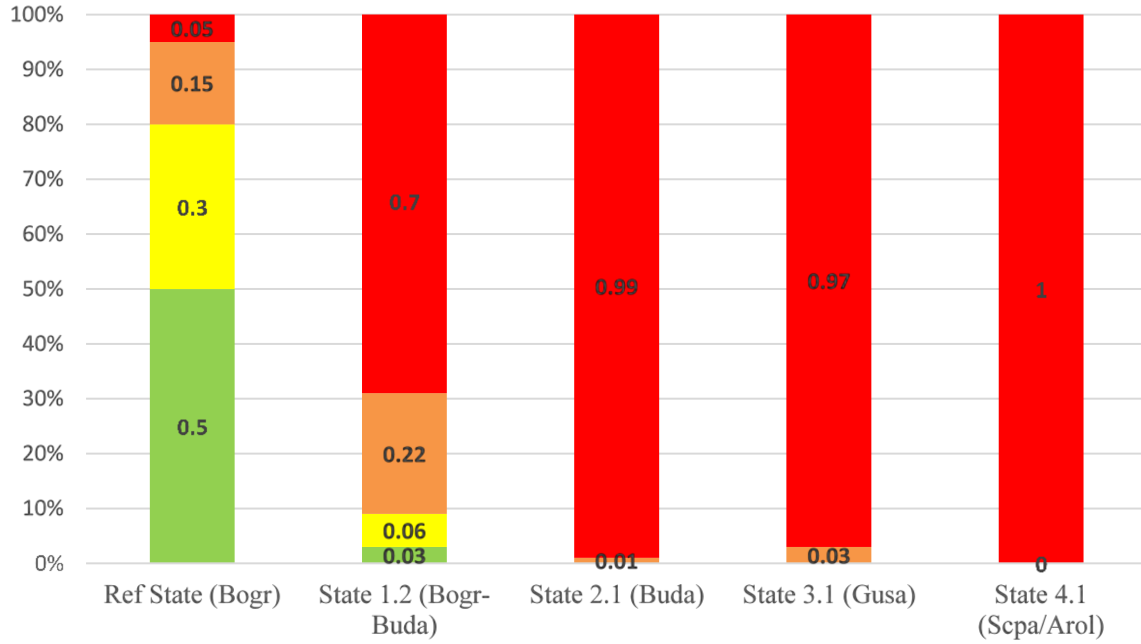

**Table G-A-2.** Risk Assessment of Accelerated Soil Erosion (ton $ac^{-1}$)

| Range of Annual Soil Loss (ton $ac^{-1}$) | 1.1 Bogr | 1.2 Bogr/Buda | 2.1 Buda | 3.1 Gusa | 4.1 Arol/Scpa |
|---|---|---|---|---|---|
| Low X < 0.49 | 0.50 | 0.03 | 0 | 0 | 0 |
| Medium 0.49 <= X < 0.72 | 0.30 | 0.06 | 0 | 0 | 0 |
| High 0.72 <= X < 1.03 | 0.15 | 0.22 | 0.01 | 0 | 0 |
| Very High X > 1.03 | 0.05 | 0.70 | 0.97 | 1 | 1 |

**Table G-A-3.** Frequency Analysis by annual soil loss (ton/ac/year) by return period for Deep Hardland Loam Ecological Site.

| Return Period | State 1.1 Bogr | State 1.2 Bogr-Buda | State 2.1 Buda | State 3.1 Gusa | State 4.1 Arol-Scpa |
|---|---|---|---|---|---|
| 2 | 0.118 | 0.306 | 0.962 | 0.899 | 3.388 |
| 5 | 0.190 | 0.480 | 1.504 | 1.445 | 5.592 |
| 10 | 0.239 | 0.599 | 1.853 | 1.834 | 6.680 |
| 20 | 0.301 | 0.756 | 2.328 | 2.309 | 8.274 |
| 30 | 0.328 | 0.878 | 2.613 | 2.557 | 9.685 |
| 40 | 0.360 | 0.910 | 2.733 | 2.677 | 10.330 |
| 50 | 0.370 | 0.918 | 2.758 | 2.781 | 10.782 |
| 60 | 0.409 | 1.024 | 3.074 | 3.135 | 10.869 |
| 70 | 0.425 | 1.057 | 3.164 | 3.193 | 11.881 |
| 80 | 0.434 | 1.076 | 3.220 | 3.212 | 12.976 |
| 90 | 0.461 | 1.146 | 3.428 | 3.434 | 13.604 |
| 100 | 0.492 | 1.224 | 3.663 | 3.699 | 13.915 |

**Figure G-A-10.** Probability of occurrence for yearly soil loss for all scenarios using erosion classes of Low (50 percent), Medium (80 percent), High (95 percent), and Very High (>95 percent).




(6) Summary

(i) Analysis of the RHEM simulation runs on the Deep Hardland Loamy 16–21 inch precipitation ecological site provides a basis for interpreting the impacts of vegetative canopy cover, surface ground cover, and topography on dominant processes in controlling infiltration and runoff, as well as sediment detachment, transport and deposition in overland flow at each state. Our results suggest that RHEM can predict runoff and erosion as a function of vegetation structure and behavior of different plant community phases and amount of cover for the different states.

(ii) Significant differences in estimated annual soil erosion rate occur between the ecological states on this ecological site. The drivers are plant composition, largely the interaction between the two dominant C4 grass species, blue grama and buffalograss. As buffalograss increases in the stand, infiltration capacity will decrease. The causative factors are associated with root morphological differences between blue grama and buffalograss and the degree of water repellency found in buffalograss stands. Water repellent compounds appear to be associated with stands of buffalograss, although more research is needed to confirm the dynamics. Prairie dog activity has a profound effect on biotic integrity, hydrologic function, soil and surface stability, and similarity index calculations. A high degree of bare ground and significant changes in plant composition are associated with prairie dog colonization and runoff and soil loss can be extreme. Broom snakeweed stands and the reference state, blue grama, exhibit the highest infiltration capacity on this site. However, broom snakeweed stands have significantly higher soil loss (wind and water) because of a depauperate understory and a high percentage of bare ground in shrub interspaces.

(iii) High-intensive convective storms can have a significant impact on this site. During 5, 10, 25, 50, and 100-year storms, where there is a high short burst of rainfall, a significant amount of runoff and soil loss will occur (figures G-A-6 and G-A-9).

(iv) Management of this site should strive to maintain a higher ratio of blue grama to buffalograss. The threshold where increasing buffalograss begins to affect infiltration capacity is around 30 percent (Spaeth 1990). Infiltration experiments have also shown that plant-related variables such as cover, biomass, and species composition largely influence infiltration dynamics during the early phases of rainfall (0–15 minutes), whereas soil-related variables such as bulk density, aggregate stability, and porosity influence infiltration as storms progress > 15 minutes.

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# Part 645 – National Range and Pasture Handbook

## Subpart H – Livestock Nutrition, Husbandry, and Behavior

### 645.0801 General

A. Successful conservation and efficient use of grazing lands depend on correlation of the treatments and management of forage plants with the management of the animals that harvest the plants. NRCS conservationists who work with livestock producers must be thoroughly familiar with locally adapted and customary livestock husbandry and livestock management principles and practices applicable to advise customers on proper and efficient use of grazing resources. NRCS will not provide technical advice or assistance to livestock producers on matters relating primarily to animal breeding, genetics, animal health problems (except when animal health is related to forage resources) or make nutritional recommendations such as feed rations. However, conservationists should acquire enough information about these matters so that they can communicate effectively during the planning process and to adequately discuss livestock health, nutrition, and behavior with livestock producers.

B. The 2018 Farm Bill states "livestock means all animals raised on farms, as determined by the Secretary" [16 USC 3801 (a) (17)]. For purposes of this document livestock will be separated into ruminants and non-ruminants. The ruminant section will include cattle (further separated into beef and dairy), sheep, and goats; non-ruminant section will include horses, swine, and poultry. It is important to understand non-ruminant fermenters (i.e., swine, poultry) will obtain most of their nutrition from feedstuffs supplied. Swine and poultry can obtain approximately 5–20 percent of their nutritional needs from forages, the balance must be obtained from grain or other feedstuffs (i.e., vegetable or bakery waste, or brewery grains). Refer to feed management technical notes for specific animal nutritional needs.

C. Genetic factors, age of animal, sex of animal, body composition of animal, physical activity, and lactation (where appropriate) are also discussed in this subpart for animals.

### 645.0802 Nutrition

A. One of the greatest challenges associated with successful livestock management combined with integrating grazing management and forage production is animal nutrition. Understanding the complex issues of animal nutritional demand, forage nutritional values, and grazing management influence on forage nutritional values and production is the key to successful planning and management on grazing lands.

B. Developing a good feeding and management program is important for managers to meet livestock goals and herd performance objectives. Many factors affect the requirements of animals and the extent of nutrient utilization. The effect of genotype, physiological state, and environment on voluntary feed consumption is mediated by the animals' metabolism, and consumption is generally dependent upon forage quality.

C. When animals graze, the energy contained in those plants is used for maintaining body functions (respiration, blood flow, and nervous system functions), for gain of tissue in growing animals, and for products (milk, wool).

D. The synthesis of protein in the animal's body, which forms muscle, organs, soft body tissue, and animal products, should be the main objective of animal nutrition. Different kinds of animals and various breeds have different nutritional requirements during the year and acquire different values from forages and supplements. See exhibit 1 for kinds of animals (beef and dairy cattle, sheep, goats, and horses) and representative breed types.

(1) Ruminants

(i) Basic nutritional requirements include energy (i.e., carbohydrates), protein, minerals, vitamins, and water. Energy is responsible for maintenance and growth functions and the generation of heat. Protein grows tissue and performs other vital functions. Vitamins such as A and E, calcium, phosphorus, and selenium may be fed free choice as a mineral supplement (Rinehart, ATTRA 2008).

(ii) Different types of animals and various breeds have different nutritional requirements during the year and acquire different values from forages and supplements.

(2) Non-ruminants

(i) Basic nutritional requirements like ruminants include–energy, protein, minerals, vitamins, and water. However, non-ruminant animals are not able to obtain all their nutritional needs from forages alone. Providing concentrates to their diet is very important to ensure maintenance and growth.

(ii) Pastured swine and poultry will need supplementation other than forage, since they are nonruminants

- Refer to the State and federal regulation on food waste if being fed to pastured swine.
- The particle size of grain fed to pastured swine and poultry is important since particle size affects breakdown and utilization.

E. The bulk of dry matter in plants is made up of three groups of organic compounds:

(1) Proteins
(2) Carbohydrates
(3) Fats

F. Carbohydrates, proteins, and fats are the fuels that animal cells are capable of converting into various forms of energy. This energy is used for mechanical work of muscles, synthesis of macromolecules from simpler molecules, and for providing heat. Heat energy is referred to as a calorie (cal). Inorganic matter includes salts minerals, and trace elements.

## 645.0803 Maintenance, Growth, and Production

A. Maintenance requirement for energy is the amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal body (7th NRC Beef). Maintenance is comprised of the following processes or functions: body temperature regulation, essential metabolic processes, and physical activity. The selection of animals for lean tissue growth has resulted in some extreme conditions that present interesting models of animal growth and also demonstrate how genetic selection can be used to direct the partitioning of nutrients for tissue growth (Mitchell, 2007). Partition of nutrients for pigs and sheep were prioritized first for brain and CNS (central nervous system), then by bone, muscle, and fat (Hammond, 1944; Mitchell, 2007). Factors affecting maintenance and voluntary intake include genetic factors, age of animal, sex of animal, body composition of animal, physiological, and environmental factors.

B. **Large Ruminants: Beef Cattle**

(1) Genetic factors

(i) Genetic variations in ruminants can influence feed consumption. Animals with higher potential for feed consumption exhibit enhanced tissue metabolism as indicated by a higher basal metabolism and maintenance requirement. Under optimal conditions and environment, feed intake should be affected by the animal's genetic potential to use energy. For example, the Brahman breeds have a lower basal net energy requirement than European breeds, and a dairy cow has more soft tissue to maintain than a beef breed, making its basal net energy requirements higher.

(ii) Voluntary feed intake is affected by genotype interactions with type of diet and various components of the environment. Rapidly growing, slowly maturing livestock (Hereford, and Angus) are more efficient producers of protein than are slower growing, early maturing animals (Simmental and Charolais).

(2) Age of the animal

Age has a pronounced effect on basal metabolism. As the animal gets older, the basal metabolism goes down. The portion of energy derived from the oxidation of protein instead of fat decreases with age. Younger animals require more protein and energy to maintain condition and growth, so basal metabolism is high.

(3) Sex of the animal

The expenditure of energy is different between sexes. The basal metabolism rate is higher for males than it is for nonpregnant females of the same age and size. In domestic animals, castration results in a 5 to 10 percent depression in basal metabolism. Indications are that sex hormones can increase the metabolism and nutritional requirements of both sexes.

(4) Body condition of the animal

(i) Body condition scoring (BCS) allows producers of livestock to evaluate animals with a scoring system that reflects reproductive performance. For cattle, it is best used at calving time to assign a score. This percentage of body fat in livestock at different stages of the production cycle is important in determining their reproductive performance and overall productivity. Goals should be set for BCS scores at the time of breeding because it can affect conception rates. BCS should not be used for steers or feeder cattle, muscle scoring will be used for those animals.

(ii) Several factors affect body condition scores:

- Climatic conditions
- Stage of production
- Age
- Genetics
- Birthing date
- Weaning date
- Forage management

(iii) The amount and kind of supplemental feeding required to meet performance are influenced by the initial body reserves of protein and fat which also influences overall body condition score. Body condition scoring or the right condition rating is a guide for evaluation of the nutritional status of the animal. This rating is a more reliable guide than live weight or shifts in body weight. Live weight can be mistakenly used as an indication of body condition and fat reserves because the fill of the gut and the products of pregnancy prevent weight from being an accurate indicator of condition.

(iv) BCS are numbers to suggest the relative fatness or body composition of the animal. It can be a simple indicator of available fat reserves which can be used by the animal in periods of high energy demand, stress, or suboptimal nutrition scores range from 1 to 9 for beef cattle.

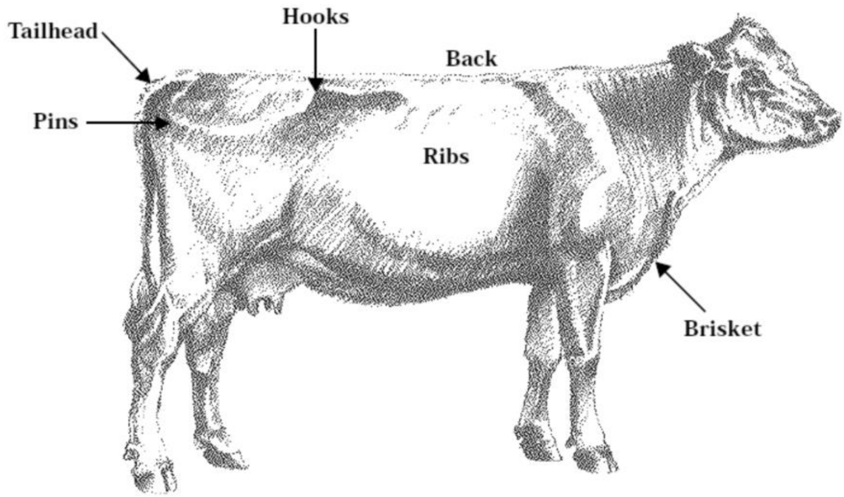
(v) Cattle: A body condition score of 5 or more (at least 14 percent body fat) at calving and through breeding is recommended for good reproductive performance for beef cows. A body condition score of 5.5 is recommended for first calf heifers to compensate for the additional nutrient requirements plus growth.

BCS and pregnancy rate. Cows that are thin following calving have a longer period between calving and re-breeding, as compared to a cow that is adequately conditioned. The impact on pregnancy rate of a thin body condition at calving is negative unless enough time is allowed to recover body tissues.

(vi) Description of body condition scores

Cattle: The different BCS ratings are described in table H-1. Figure H-1 shows the reference points for body condition scorings.

**Figure H-1.** Reference points for body condition score for cattle




Reference points for body condition score

**Table H-1.** Description of body condition scores for cattle

| Body score | Description of cow condition |
|---|---|
| 1 | Severely emaciated. Bone structure of shoulder, ribs, hooks and pins is sharp to the touch and easily visible. Little evidence fat deposits or muscling |
| 2 | Emaciated. Little evidence of fat deposition but some muscling in the hind- quarters. The backbone feels sharp to the touch. |
| 3 | Very thin, no fat on the ribs or brisket, and some muscle still visible. Back- bone easily visible. |
| 4 | Thin, with ribs visible but shoulders and hindquarters still showing fair muscling. Backbone visible. |
| 5 | Moderate to thin. Last two or three ribs cannot be seen unless animal has been shrunk. Little evidence of fat in brisket, over ribs or around the tailhead. |
| 6 | Good smooth appearance throughout. Some fat deposits in brisket and over the tailhead. Ribs covered and back appears rounded. |
| 7 | Very good flesh, brisket full. Fat cover is thick and spongy, and patchiness is likely. Ribs very smooth. |
| 8 | Obese, back very square, brisket distended, heavy fat pockets around tailhead. Square appearance. |
| 9 | Rarely observed. Very obese. Animal's mobility may be impaired by excessive fat. |

(5) Physiological state

(i) Pregnancy–Nutrient needs for reproduction generally are less critical than during rapid growth but are more critical than for maintenance alone. If nutrient deficiencies occur prior to breeding, animals may be sterile, have low fertility, silent estrus, or fail to establish and maintain pregnancy. Underfeeding during growth causes delayed maturity and underfeeding and overfeeding of protein cause reduced fertility. Energy needs for most species during pregnancy are most critical during the last third of the term. Pregnant animals have a greater appetite and spend more time grazing and searching for food than the nonpregnant animal. Nutritional deficiencies in the pregnant animal, especially protein deficiencies, first affect the weight of the female and not the newborn. However, health and vigor of the calf may be affected.

(ii) Physical activity– Maintenance requirements of livestock are increased by activity. As a general guideline, the maintenance of an animal is increased by about 0.9 Mcal/day for cows in grazing situations compared to those in a dry feedlot. Cows that are required to graze over wide areas or on steep slopes require additional energy, so adjustments are necessary to maintain energy requirements. The cost is also higher for larger animals than for smaller animals. Animals walking on a horizontal surface expend about 1.7 to 2.5 joules of energy per meter per kilogram of body weight. Animals walking with a vertical change (increased slopes) expend 12 to 20 times more energy than those on slopes of less than 15 percent. Work activities result in an increased energy demand for the portion of work done and the efficiency with which it is accomplished. Carbohydrates are more efficient sources of energy for work than fats.

(iii) Lactation–Lactation results in more nutritional stress in mature animals than in any other production period except heavy, continuous muscular activity. During the year, high production cows and goats produce milk with a dry matter content equivalent to 4 to 5 times that of the animal's body and can reach as high as 7 times body dry matter. High producing cows can give so much milk that they cannot consume enough feed to prevent weight loss (attributed to mobilization of fat stores/reserves during periods of lactation. Milk is 80 to 88 percent water, so water is a critical nutrient to maintain lactation. All nutrient needs are increased during lactation. In cow's peak lactation occurs in mature animals from 30 to 45 days after parturition and then gradually tapers off. Therefore, the peak demands for nutrients follow the typical milk flow characteristics for the species concerned. Limiting the water or energy intake of the lactating animal results in a marked drop in milk production, whereas protein limitation has a less noticeable effect. Peak milk production in 2-year-old cows occurs at about 30 days and lasts for shorter periods. Deficiencies of minerals do not affect milk composition but result in rapid depletion of the lactating animal's reserves. The effects of nutrient deficiencies during lactation often carry over into the next pregnancy and the next lactation.

(6) Environmental factors

(i) The climatic conditions browsing, and grazing animals are exposed to can significantly affect the animal's intake. Some domestic animals' body temperature exceeds that of the environment. This relationship results in heat flow from the animal to the environment. Within a range of ambient temperatures, the heat produced by normal metabolism of a resting animal is minimal and is enough to cover this heat loss.

(ii) Animals lose heat by conduction, convection, and radiation from the body surface and evaporation of water from the body surface, lungs, and oral surfaces. The rate heat is lost from the body is determined by the difference between body surface temperature and the surrounding environmental temperature. The body temperature is greatly influenced by the insulation of subcutaneous fat, skin thickness, and skin covering or hair length. Insulation benefits are also greatly reduced by air movement or when the body surface is wet. Most animals have a much better means of protecting themselves from the cold than in a hot climate.

(iii) Thermoneutral zone–When the animal is in the thermoneutral zone (TNZ) no physiological processes are activated that require the expenditure of a considerable amount of energy to maintain normal body temperature. In the TNZ, body temperature is physiologically regulated by the constriction or dilation of the peripheral blood vessels and by some sweating. Little energy is required by these processes, and intake is not affected when temperatures are in the animal's TNZ. When the ambient temperature is below the lower critical point of the TNZ, body temperature is regulated by shivering. Table H-2 shows typical TNZ's for different species.

**Table H-2.** Typical thermoneutral zones

| Species | Temperature (ºF) |
|---|---|
| Cattle | 41– 68 |
| Calves | 50– 68 |
| Sheep | 70– 88 |
| Goats | 50– 68 |

(iv) Low temperatures–Temperatures below the thermoneutral zone may have stimulated or depressed intake rates, depending upon precipitation. Rain, snow, and muddy conditions depress intake because of decreased grazing time. Dry, cold conditions can generally stimulate intake.

Nighttime cooling allows animals to shift their grazing times to night, which can reduce grazing time lost during the day.

(v) High temperatures–In a hot climate the animal must cool itself by increasing evaporation from the body surface, by more rapid respiration and panting, finding shade, or by immersing itself in water. The actual temperature that may cause heat stress is reduced by high humidity (which reduces evaporative cooling rate), a high level of feeding, feeding any ration that produces a high protein or high fiber for ruminants, or restriction of water consumption. Evaporation is the only way an animal can cool itself (other than immersion in cool water) if the environmental temperature exceeds body temperature.

Voluntary consumption of feed has been reported to decrease by 50 percent in the first 8 days after exposure to heat loads and decreases to only 10 percent reduction after 17 to 24 days as the animal adjusts to the high temperatures. Above the upper critical point, animals pant and increase their rate of respiration in addition to sweating. Animals that do not tolerate heat can have intake reduced as much as 35 percent at temperatures of 95°and no nighttime cooling. At the same temperature with nighttime cooling, intake is reduced only 20 percent.

(7) Forage quality and quantity

(i) Forage intake is affected by several factors:

- Body weight
- Forage quality
- Forage quantity
- Stage of production
- Supplemental feeding strategy
- Genetics
- Environmental conditions

(ii) Quality–Intake is most influenced by the quality of forage. As the quality declines, intake is drastically reduced. Different species and animals digest nutrients with different efficiencies. The greatest differences are between monogastric species and ruminants. The greatest variations occur in the digestion of roughages. Sheep have a higher digestion coefficient than cattle of feeds with digestibility greater than 66 percent digestible organic matter (DOM). Below 66 percent, cattle tend to have a higher digestibility than sheep, which indicates a higher capacity to digest fiber. Crude fiber tends to depress digestibility. The stage of maturity of forage plants also influences their digestibility: As the plant matures, the cell wall content increases, the soluble cell content decreases, and the plant becomes less digestible.

(iii) Although native forage quality generally deteriorates as the growing season progresses, recent research suggests that farmers and ranchers can compensate for poor forage quality by planting introduced forages and integrating year-long livestock grazing practices (such as bale and winter grazing). Adoption of alternative practices could also offset the adverse environmental impacts of a period of confined feeding of grains by reducing greenhouse gases associated with fertilizer and fuel use, and potentially curtailing run off water pollution. Such as a switch to pastured or range fed beef could offer alternative cattle production systems that may generate environmental and economic benefits: https://www.ucsusa.org/sites/default/files/attach/2017/11/reintegrating-land-and-livestock-ucs-2017.pdf

C. **Large Ruminants: Dairy Cattle**

(1) Genetic Factors

(i) Milk production is expressed phenotypically and may or may not be transferred to the offspring, this is the challenge for a dairy breeder to determine which cows and bulls to breed in order for the genetic trait to be transferred to offspring (Kiplagat et. al., 2012). Crossbreeding has been common in the United States by crossing a Jersey sire with a Holstein heifer or cow due to the ease of a Jersey's high calving ease (Armstrong and Heins, 2020). Crossbred animals tend to have increased fertility, longevity, and health, known as hybrid vigor. Pasture based producers typically have Jersey breeds due to their ability to withstand heat stress in reproductive performance (Probert, 2012).

(ii) The most popular breed in the United States is the Holstein breed. They are known for their high productivity and large body frame; due to this it takes them longer to replenish body condition and return to estrus after calving compared to other breeds and even crosses such as the Holstein/Friesian breeds. Those characteristics can present a challenge for seasonal operations where they must calve on a 12-month interval (Probert, 2012).

(2) Age of Animal

Growing heifers require similar dry matter intake as beef heifers; DMI will change during late gestational period (NRC, 2001). It is important to ensure heifers receive adequate nutrition to be fertile and cycling by 13-15 months old and continued growth occurs, so they are large enough at calving time (Dinsmore, 2021).

(3) Sex of Animal

Regulation of nutrient partitioning to support fetal development and subsequent milk synthesis is complex. From studies with dairy cattle, described how homeorhesis comes into play during pregnancy and lactation to support growth of the conceptus, the gravid uterus, the mammary gland, and, with the onset of lactation, the nutrients needed for milk synthesis (Bauman and Currie, 1980).

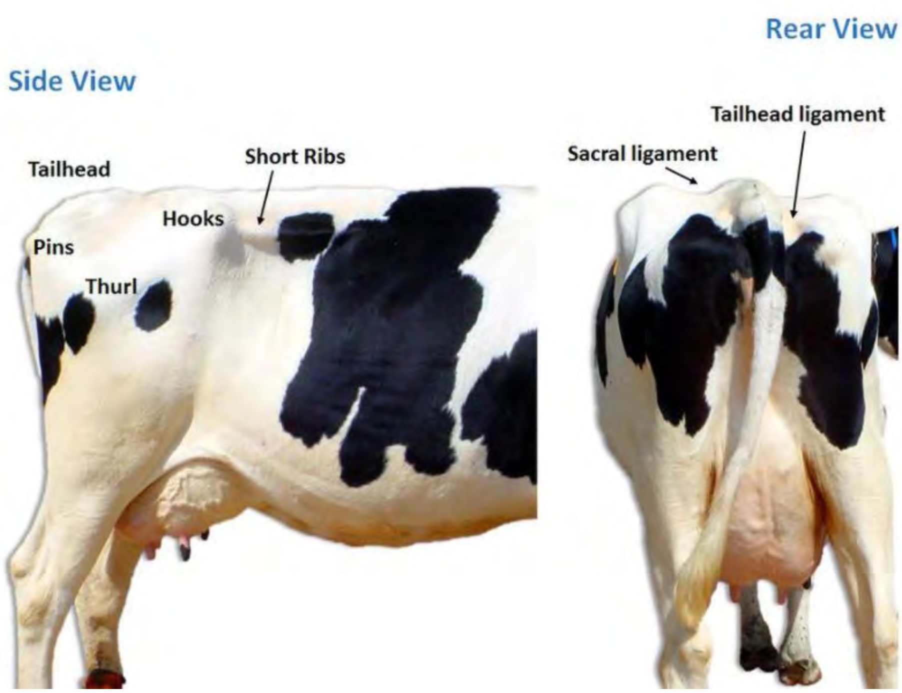
(4) Body Condition of Animal

Body condition scoring (BCS) for dairy cattle is on the same scale as beef cattle, 1 to 5. Typically, dairy cattle on pasture will have a lower BCS compared to confinement (Washburn and Mullen, 2014). Holsteins on pasture may experience a difficult time maintaining body condition score and drawing up on reserves more frequently than other breeds, such as Jerseys. Figure H-2 provides the side and rear view of the dairy cow; the BCS is measured using this area to focus on assigning the score. Table H-3 provides the suggested range for BCS by stage of lactation (Heinrichs et al., 2016). It is important to note that heifers will have a different BCS range for pre-breeding to calving. Ensuring the BCS is within range for the dairy cow is important to ensure reproduction and milk production are not impacted.

(5) Physiological State

(i) Pregnant pasture-based systems, particularly seasonal dairies using batch calving and lower input systems, can affect success in maintaining seasonal breeding and calving in Holstein and other breeds in those systems (Probert, 2012; Washburn and Mullen, 2014). There is a proportional increase in nutrient requirements during late pregnancy as the fetus grows exponentially and in preparation for lactation (Voth, 2018; Sguizzato, et al., 2020). Bell, et al., (1995) found the rates of increase of cow and fetus were linear or quadratic from 190d gestation to 270d of gestation. The crude protein increased from 62 and 117g/d, respectively.

**Figure H-2.** Side and rear view of dairy cow for body conditioning scoring (Heinrichs et al. 2021).




https://extension.psu.edu/body-condition-scoring-as-a-tool-for-dairy-herd-management#:~:text=Body%20condition%20scoring%20in%20dairy,indirect%20estimate%20of%20energy%20balance.

**Table H-3.** Cow BCS range

| Stage of Lactation | DIM[1] | BCS Goal | BCS Min | BCS Max |
|---|---|---|---|---|
| Calving | 0 | 3.50 | 3.25 | 3.75 |
| Early Lactation | 1 to 30 | 3.00 | 2.75 | 3.25 |
| Peak Milk | 31 to 100 | 2.75 | 2.50 | 3.00 |
| Mid Lactation | 101 to 200 | 3.00 | 2.75 | 3.25 |
| Late Lactation | 201 to 300 | 3.25 | 3.00 | 3.75 |
| Dry Off | >300 | 3.50 | 3.25 | 3.75 |
| Dry | -60 to -1 | 3.50 | 3.25 | 3.75 |

[1]Days in milk

Adapted from Heinrichs, et al., 2016.

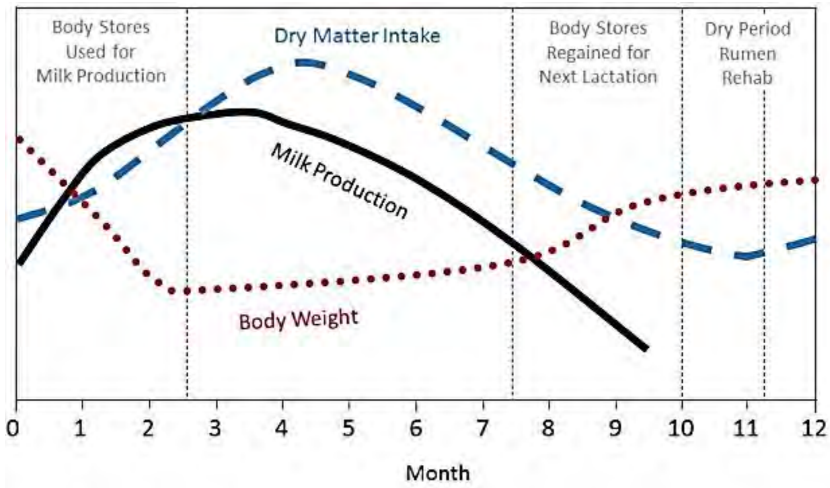
(ii) Physical Activity

- Pasture-based dairy cows will expend more energy than most confinement systems due to multiple circumstances:
  - the distance from the milking parlor to the pasture
  - grazing systems may have topography changes
- Pastured cattle will spend more time eating compared to the confinement fed cattle (NRC, 2001).NRC noted for a grazing 600kg (1,323 lb.) cow walking 0.5km (0.3mi) to and from the milking parlor 2 times per day (2km (1.2mi) total) the extra Net Energy allowance was 0.54 Mcal or about 5 percent increase in maintenance requirement. The additional increase does not include foraging in the pasture, walking to and from watering trough or if the pasture is hilly.
- Energy requirements will change along the dairy cow's production cycle, as is illustrated in Figure H-3. It provides an illustration of intersection between peak milk production and the start of increase for dry matter intake. At the same time there is a decrease in the cow's body weight to compensate for not only maintenance but milk production.
- Then there is a notable increase in body weight at the end of lactation, marked with a decrease in dry matter intake. If the forage does not provide sufficient energy and protein during peak production, then it is imperative that supplementation is provided. High producing cows require a higher plane of nutrition regardless of type of system; energy is the most limiting in pasture-based systems.

(iii) Lactation

- There are 3 main stages of lactation
  - early (14-100d)
  - mid (100-200d)
  - and late (200-305d)
- https://smallfarms.oregonstate.edu/sites/agscid7/files/feedingmilkingcow_1.pdf. Pastured dairy cattle typically have lower production per cow than nongrazing dairies, however, pastured dairies can be economically competitive due to lower operating and overhead costs (Washburn and Mullen, 2014).

**Figure H-3.** Energy requirements for a dairy cow (Heinrichs et al. 2021).




https://extension.psu.edu/body-condition-scoring-as-a-tool-for-dairy-herd-management#:~:text=Body%20condition%20scoring%20in%20dairy,indirect%20estimate%20of%20energy%20balance.

(6) Environmental Factors

(i) Feed

- Providing supplementation in an intensive grazing system can be challenging compared to confinement systems due to less control of the forage component with a grazing system. This reduces the consistency of nutrient intake from day to day and the variability in milk production Table H-4. The most limiting factor for dairy cattle is energy from forage alone.
- However, recent research has suggested that pasture based dairy cows may play a major role to supply healthier foods within systems with a reduced reliance on fossil fuels and chemical inputs, while also delivering environmental, biodiversity, and animal welfare benefits. (Delaby L., J.A. Finn, G. Grange, and B. Horan. (2020). Pasture-Based Dairy Systems in Temperate Lowlands: Challenges and Opportunities for the Future. Front. Sustain. Food Syst. 4:543587. doi: 10.3389/fsufs.2020.543587).

(ii) Water

Cattle obtain their water demand through three sources: drinking, ingestion of water contained in feed and water produced by the body's metabolism. Loss of water occurs through milk production, urine and fecal excretion, sweat and vapor loss from lungs (NRC, 2001). Lactating dairy cows will require 30 to 50 gallons/day. Water intake is very important since it reduces digestion of feed and feed intake, which then reduces milk production. It takes between 4 and 4.5 pounds of water to produce 1 pound of milk (Himmelmann and Amaral-Phillips). As temperatures increase so will water requirements.

(iii) Temperature

Heat and cold stress require the cow to increase the amount of energy used to maintain body temperature which requires an increase in the amount of energy the cow needs (Qi et al., 2015). Dairy cattle outside in adverse winter conditions will have a higher DMI and yet they grow slower or produce less milk due to the energy going to maintenance rather than production (Young, 1981). In 1981 the NRC estimated mild to severe heat stress requires increase maintenance requirements by

7 to 25 percent, respectively. Tucker et al. (2008) found Holstein Friesian cattle had a lower minimum body temperature when there was more protection from solar radiation using various levels of shade protection. Mild heat stress can occur at 65$^{o}$ (Thomas, 2012), providing shade will minimize the production losses.

**Table H-4.** Lactation milk yield for Holsteins grazing and non-grazing farms.

| Location | Grazing lb/cow | Non-grazing lb/cow | Difference |
|---|---|---|---|
| New York (2000) | 17,107 | 19,006 | 1,899 |
| New York (2001) | 16,295 | 19,105 | 2,810 |
| Northeast USA | 16,227 | 18,218 | 1,991 |
| Maryland (2000) | 17,000 | 19,400 | 2,400 |

D. **Small Ruminants: Goats**.

(1) Goats have grown in consumer demand between 1999-2002 (Schweihofer, 2011) and United States research in this area is still growing, but not at the same rate as other ruminants. Developing countries have conducted more research in this area compared to the United States.

(2) Genetic Factors

Avondo et al., (2008) found Mediterranean type DM intake was strongly correlated with body weight and less correlated with milk production. Conversely, Alpine breeds' intake level was strongly correlated with milk production or body weight and weakly correlated with dietary characteristics. Silanikove observed differently with Black Bedouin breed, less affected by diet fiber content compared to Saanen goats, attributed to the higher microbial density and degradation rate for the Black Bedouin. The dairy breeds such as Nubian and Alpine will lactate for approximately 284 days, the volume and composition of milk is impacted by genetics, but diet consumed is greatly influential (Van Saun et al., 2008).

(3) Age of Animal

Dairy kids require approximately 21 percent higher energy needs than adult goat's maintenance requirements. Lactating does have the highest requirement for energy than any age (Rashid, 2008). Regardless of age, goats tend to forage on grasses high in protein and digestibility, then will browse if the browse is overall higher (Luginbuhl, 2000). For specific weight gain of 0.11 lb/day the NRC recommends an additional 0.03 lb of protein, 0.22 TDN, 0.002lbs Ca, 0.002 lbs of P. Increasing the weight gain to 0.22 lb per day requires doubling of the protein and TDN, however, Ca and P requirements remain the same (National Research Council, 2007; Spencer, 2018. Refer to table H-5).

(4) Body Condition of Animal

Similar to sheep, goats body condition scoring is on a scale of 1-5; 1 being emaciated and 5 being overweight and the 5-point check applies to goats (see figure H-4). Does should have a BCS of 3 to 3.5 to ensure fertility and good health when going into lactation.

**Table H-5.** Required Nutrient Concentrations: Daily Goat Rations per animal

| Body Weight (lbs.) | Dry Matter (lb./head) | % Body weight | Total Protein (lb.) | TDN (lb.) | Calcium (lb.) | Phosphorus (lb.) | Vitamin A (IU) | Vitamin E (IU) |
|---|---|---|---|---|---|---|---|---|
| Maintenance | | | | | | | | |
| 22 | 0.63 | 2.80 | 0.05 | 0.35 | 0.002 | 0.002 | 400 | 84 |
| 45 | 1.08 | 2.40 | 0.08 | 0.59 | 0.002 | 0.002 | 700 | 144 |
| 67 | 1.46 | 2.20 | 0.11 | 0.80 | 0.004 | 0.003 | 900 | 195 |
| 90 | 1.81 | 2.03 | 0.14 | 0.99 | 0.004 | 0.003 | 1200 | 243 |
| 112 | 2.13 | 1.90 | 0.17 | 1.17 | 0.007 | 0.005 | 1400 | 285 |
| 134 | 2.44 | 1.82 | 0.19 | 1.34 | 0.007 | 0.005 | 1600 | 327 |
| 157 | 2.76 | 1.80 | 0.21 | 1.50 | 0.009 | 0.006 | 1800 | 369 |
| 179 | 3.05 | 1.70 | 0.23 | 1.66 | 0.009 | 0.006 | 2000 | 408 |
| 202 | 3.32 | 1.64 | 0.26 | 1.81 | 0.009 | 0.006 | 2200 | 444 |
| 224 | 3.58 | 1.60 | 0.28 | 1.96 | 0.011 | 0.008 | 2400 | 480 |
| Additional Requirements for Late Pregnancy | | | | | | | | |
| -- | 1.56 | -- | 0.18 | 0.87 | 0.004 | 0.003 | 1400 | 213 |
| Additional Requirements for Growth: Weight Gain at 0.11lb/day | | | | | | | | |
| -- | 0.40 | -- | 0.03 | 0.22 | 0.002 | 0.002 | 500 | 108 |
| Additional Requirements for Growth: Weight Gain at 0.22lb/day | | | | | | | | |
| -- | 0.79 | -- | 0.06 | 0.44 | 0.002 | 0.002 | 500 | 108 |
| Additional Requirements for Growth: Weight Gain at 0.33lb/day | | | | | | | | |
| -- | 1.19 | -- | 0.09 | 0.66 | 0.004 | 0.003 | 800 | 162 |

Spencer, 2018

(5) Sex of Animal

(i) Developing and breeding bucks should be provided 1lb/d of a 16 percent protein mixture if forage or browse is limited or low protein (<10 percent; Luginbuhl et al., 2000). Aregheore (1994) found significant differences in growth rate for West African Dwarf goats between bucks and does when three different crop residues were fed, which indicated bucks had a higher rate. There was no impact on the voluntary intake for either sex. It is important to note those crop residues were in a tropical setting, but overall sex of the animal has an impact on growth rate.

(ii) FAMACHA© Scoring: FAMACHA© is an acronym for FAffa MAllan Chart, Faffa Mallan was the scientist who developed the chart shown in figure H-5. This technique is used to determine if the animal is anemic due to worms, specifically a symptom from barber pole worm. The scoring is based on a scale of 1 through 5, 1 being that the eye lid is bright red indicating low chance of worm infestation and indicates the producer should not deworm. A score of 3 is where it is questionable whether producer should deworm, and the producer will then move to a Five Point Check. The five-point check will include:

- eye (FAMACHA© score)
- back (body condition score)
- tail (dag scoring)
- jaw (bottle jaw)
- nose (nasal discharge)

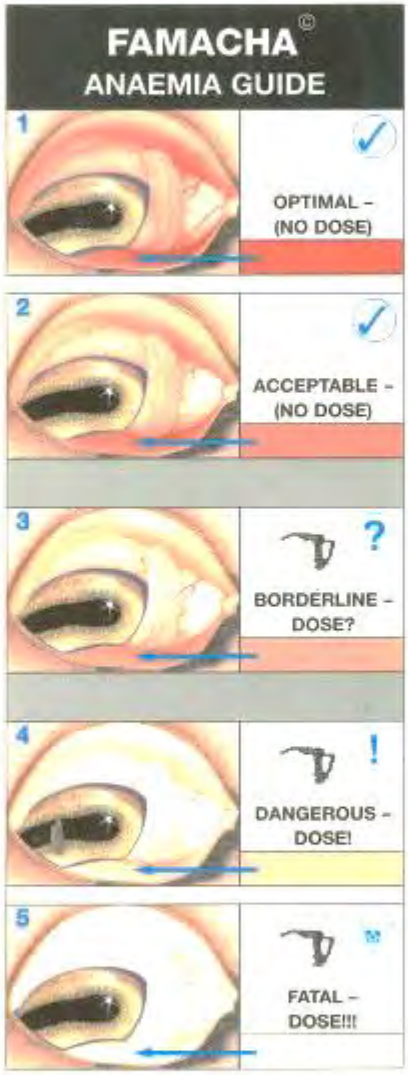
**Figure H-4.** Body Condition Score Description for Goats (Viera et al. 2015).

| | Very thin | Normal | Very fat |
|---|---|---|---|
| General condition | Raw or slightly-raw boned goat, with backbone and some ribs visible. | Backbone not prominent but still visible and ribs difficult to assess visually. | Backbone and ribs not visible. Goat has a rounded appearance, sometimes with abdominal fat deposits visible. |
| Rump region |  |  |  |
| | Hip and pin bones are prominent.<br><br>The line that connects the hip bone and the thurl assumes a markedly concave shape.<br><br>There is little muscle and/or fat between the skin and bone structures. | Hip and pin bones still visible, but not prominent.<br><br>The line that connects the hip bone the thurl assumes a slightly concave or straight shape.<br><br>It is possible to realize some muscle and/or fat between the skin and bone structures. | Hip and pin bones are difficult to identify.<br><br>The line that connects the hip bone the thurl assumes a slightly or markedly convex shape.<br><br>All the rump region is coated by muscle and fat, contributing to the rounded appearance of the goat. |

(iii) A score of 4 indicates a must for deworming and a score of 5 is critical condition for the goat. A score of 5 the animal will need to be dewormed and monitored due to a high likelihood of death. These five-point checks will need to be conducted multiple times throughout the year. It is also recommended the producer conduct fecal egg counts to determine success of deworming. If an animal continues with re-infection of worms, the producer may need to consider culling the animal.

(iv) It is important to also consider the condition of the pasture. Pastures should be rested for at least 30 days and no more than 45 days to break the worm cycle, specifically the *Haemonchus contortus* (also known as the barber pole worm). Grazing height and stocking rate need to be controlled to avoid ingesting worms due to overgrazing. A stubble height of 4 inches should be achieved to reduce the chance of goats consuming worms that typically reside near the soil surface.

**Figure H-5.** FAMACHA© Scoring for goats (https://www.extension.purdue.edu/extmedia/AS/AS-573-W.pdf)( NCSU https://content.ces.ncsu.edu/forage-needs-and-grazing-management-for-meat-goats-in-the-humid-southeast#).




(6) Physiological State
  (i) Management and needs of goats depend on if the animal is being raised for milk, meat, or hair.
  (ii) Pregnant does are pregnant for approximately 150 days, roughly 5 months, which is affected by breed, kid weight, environment, and parity (Stewart and Shipley, 2014). Goats produce fat internally, which makes it difficult during pregnancy to have enough room to meet their nutritional needs (See table H-6), so it's important to monitor does (Penn State University; https://extension.psu.edu/programs/courses/meat-goat/nutrition/feeding-the-doe/early-pregnancy-or-maintenance).
  (iii) Angora goats managed for mohair will require an increase in protein and TDN, this will be dependent upon the annual fleece yield for those animals (Spencer, 2018).
  (iv) Physical Activity

Similar to other livestock, goats' nutrient requirements will be dependent upon several factors, such as age, sex, production type (hair, dairy, meat), etc. (See tables H-6 through H-9). It is important to meet the goats' nutritional needs to ensure they are producing desired product and healthy. Growing kids require 21 percent higher rate for carbohydrates than adult goats (Rashid, 2008). Lactating does, growing kids, and mohair goats will have the highest energy and protein requirements (Rashid, 2008). Diary does require higher level of nutrition than non-dairy does. For example, a 132-lb doe's maintenance requirement for dairy doe is 0.72 lbs/d TDN compared to a 0.60 lbs/d for non-dairy and will consistently be greater throughout different cycles of breeding, gestation, and lactation (Schoenian, 2014).

**Table H-6.** Daily Nutrient Requirements for Meat Producing Goats.[1, 2]

| Nutrient | Young Goats[3], Weaning (30 lb) | Young Goats[3], Yearling (60 lb) | Does, Pregnant (early) (110 lbs) | Does, Pregnant (late) (110 lbs) | Does, Lactating (avg. milk) (110 lbs) | Does, Lactating (high milk) (110 lbs) | Bucks (80–120 lbs) |
|---|---|---|---|---|---|---|---|
| Dry matter, lb | 2.0 | 3.0 | 4.5 | 4.5 | 4.5 | 5.0 | 5.0 |
| TDN, % | 68 | 65 | 55 | 60 | 50 | 65 | 60 |
| Protein, % | 14 | 12 | 10 | 11 | 11 | 14 | 11 |
| Calcium, % | 0.6 | 0.4 | 0.4 | 0.4 | 0.4 | 0.6 | 0.4 |
| Phosphorus, % | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |

[1]Nutrient Requirements of Goats in Temperate and Tropical Countries, 1981. National Research Council.
[2]Pinkerton, F. 1989. Feeding Programs for Angora Goats. Bulletin 605. Langston.
[3]Expected weight gain > 0.44 lb/day.

(v) Lactation

Energy intake is the limited factor for milk production and will draw upon body reserves during early lactation to meet those requirements if feed intake lags nutrient demand (table H-7). Mid and late lactation and dry period can be made up during those periods to replace the stored energy (Sahlu and Goetsch, 1998). Upon kidding, the amount of grain may adjust upward 1-2 pounds grain, maybe more if nursing multiples (PSU; https://extension.psu.edu/programs/courses/meat-goat/nutrition/feeding-the-doe/early-pregnancy-or-maintenance). If a doe is a high milking goat grazing lush forage in early lactation it may be needed to provide a mineral with 20-25 percent magnesium oxide to reduce grass tetany (Luginbuhl et al. 2000). Also, if the forage or browse is limited or low in protein, they should be fed 1.0 lb/d of a 16 percent protein mixture.

**Table H-7.** Nutrient Requirements of Mature Does (Rashid, 2008), dry matter basis.

| **Production Stage** | DMI, % of BW | % CP | % TDN |
|---|---|---|---|
| Maintenance | 1.8–2.4 | 7 | 53 |
| Early gestation | 2.4–3.0 | 9–10 | 53 |
| Late gestation | 2.4–3.0 | 13–14 | 53 |
| Lactation | 2.8–4.6 | 12–17 | 53–66 |

**Table H-8.** Dry Matter Intake, Total Digestible Nutrient (TDN), and Crude Protein (CP) for a doe in late pregnancy with two kids. Nutrient Requirements of Small Ruminants, NRC 2006.

| Live Weight (lb.) | Dry Matter Intake, Lb. | TDN % | CP % |
|---|---|---|---|
| 66 | 2.23 | 79.21 | 15 |

(7) Environmental Factors [Source: Nutritional Feeding Management of Meat Goats. JM Luginbuhl. Oct. 8, 2015 (Revised: Sept. 17, 2020) North Carolina State University Extension].

(i) Feed

- Feeding may be the highest expense of any meat goat operation. Goats raised for meat need high quality feed in most situations and require an optimum balance of many different nutrients to achieve maximum profit potential. Because of their unique physiology, meat goats do not fatten like cattle or sheep, and rates of weight gain are smaller, ranging from 0.1 to 0.8 lb/day. Therefore, profitable meat goat production can only be achieved by optimizing the use of high-quality forage and browse and the strategic use of expensive concentrate feeds. This can be achieved by developing a year-round forage program allowing for as much grazing as possible throughout the year.
- The goat is not able to digest the cell walls of plants as well as the cow because feed stays in its rumen for a shorter time period. Trees and shrubs, which often represent poor quality roughage sources for cattle because of their highly lignified stems and bitter taste, may be adequate to high in quality for goats. This is so because goats avoid eating the stems, don't mind the taste, have the ability to detoxify tannins, and benefit from the relatively high levels of protein and cell solubles found in the leaves of these plants. On the other hand, straw, which is of poor quality due to high cell wall and low protein, can be used by cattle but will not provide even maintenance needs for goats because goats don’t utilize the cell wall as efficiently as cattle. In addition, goats must consume a higher quality diet than cattle because their digestive tract size is smaller with regard to their maintenance energy needs. Relative to their body weight, the amount of feed needed by meat goats is approximately twice that of cattle. When the density of high-quality forage is low and the stocking rate is low, goats will still perform well because their grazing and browsing behavior allow them to select only the highest quality forage from that on offer. Thus, they are able to perform well in these situations, even though their nutrient requirements exceed those of most domesticated ruminant species.
- Goats require nutrients for body maintenance, growth, reproduction, pregnancy, and production of products such as meat, milk, and hair. The groups of nutrients that are essential in goat nutrition are water, energy, protein, minerals, and vitamins. Goats should be grouped according to their nutritional needs to more effectively match feed quality and supply to animal need. Weanlings goats, does during the last month of gestation, high lactating does, and yearlings should be grouped and fed separately from dry does, bucks, etc. which have lower nutritional needs. When pasture is available, animals having the highest nutritional requirements should have access to lush, leafy forage or high-quality browse. In a barn feeding situation such as during the winter months, these same animals should be offered the highest quality hay available. Whether grazed or barn fed, goats should be supplemented with a concentrate feed when either the forage that they are grazing or the hay that they are fed do not contain the necessary nutrients to cover their nutritional requirements. Total digestible nutrients (TDN) and protein requirements are shown in table H-9. To give producers an idea where these requirements fall, low quality forages contain 40 to 55 percent TDN, good quality forages contain from 55 to 70 percent TDN, and concentrate feeds contain from 70 to 90 percent TDN.
- Because of a goat’s preference for trees and shrubs they are very effective in targeted grazing programs where shrubs or small trees need to be reduced either for invasive plant control or fuel (i.e. vegetation) reduction programs in wildland urban

interface areas for wildfire prevention. (Lovreglio, Raffaella & Ouahiba, Sahar Meddour. (2014). Goat grazing as a wildfire prevention tool: A basic review. iForest - Biogeosciences and Forestry. 7. 10.3832/ifor1112-007.) Ingham, C.S. (2014). Himalaya Blackberry (Rubus armeniacus) Response to Goat Browsing and Mowing. Invasive Plant Science and Management, 7(3):532-539.

**Table H-9.** Daily Nutrient Requirements for Meat Producing Goats. [1, 2]

| Nutrient | Young Goats[3] | | Does (110 lb) | | Bucks (80-120 lb) | |
|---|---|---|---|---|---|---|
| | Weanling (30 lb) | Yearling (60 lb | Pregnant (Early) | Pregnant (Late) | Lactating (Avg Milk) | Lactating (High Milk) |
| Dry matter, lb | 2.0 | 3.0 | 4.5 | 4.5 | 5.0 | 5.0 |
| TDN, % | 68 | 65 | 55 | 60 | 65 | 60 |
| Protein, % | 14 | 12 | 10 | 11 | 14 | 11 |
| Calcium, % | 0.6 | 0.4 | 0.4 | 0.4 | 0.6 | 0.4 |
| Phosphorus, % | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |

1 Nutrient Requirements of Goats in Temperate and Tropical Countries. 1981. National Research Council.
2 Pinkerton, F. 1989. Feeding Programs for Angora Goats. Bulletin 605. Langston University.
3 Expected weight gain > .44 lb / day.

(ii) Temperature

Like most mammals, goats can do a fairly good job of thermoregulation by eating additional food for energy, sweating, and panting (in extreme situations). In cold temperatures, goats can huddle to some extent to share body heat with each other and remain somewhat comfortable. The body temperature (rectal) of the goat ranges from 101.5 to 104°F. The thermoneutral zone of the goat is between 50 and 68 degrees.

(iii) Water

Production, growth, and the general performance of the animal will be affected if insufficient water is available. Water needs vary with the stage of production, being highest for early lactating does, and during times when the weather is warm, and forages are dry. In some instances, when consuming lush and leafy forages, or when grazing forages are soaked with rainwater or a heavy dew, sufficient water requirements for maintenance may be provided by feed alone. . Because it is difficult to predict water needs, goats should always have access to sufficient high-quality water. Clear, flowing water from a stream is preferable to stagnant water; the latter may contain excessive levels of blue-green algae, which may be toxic. Nitrate in drinking water should also be of concern because it is becoming the predominant water problem for livestock. Safe levels in drinking water are as follow (in parts per million): less than 100 for nitrate nitrogen, or less than 443 for nitrate ion, or less than 607 for sodium nitrate.

## E. **Small Ruminants: Sheep**

(1) Genetic Factors

(i) Feed is a major cost in sheep production, Lee et al., (2001) estimated heritability of intake of mature ewes under pasture grazing conditions were low in Merinos, but much higher (0.4) in crossbred ewes (Fogarty et al., 2006). Merino sheep were found to have genetic and phenotypic correlations between feed intake and various production traits (Lee et al., 2002).

(ii) Improving ewe reproductive performance has been associated with greater profitability and life cycle efficiency than enhancing wool production or lamb growth (Wang and Dickerson, 1991; Borg et al., 2007; Murphy et al., 2020). Fogarty et al., (2009) studied heritability of feed intake of mature non-lactating and non-pregnant Merino ewes grazing pasture. The group found heritability for relative digestible dry matter intake was much higher than previous heritability for pasture intake for Merino sheep (0.32 and 0.12, respectively).

(2) Age of Animal
Intake changes in growing livestock as its size increases (Lewis and Emmans, 2010). The quantity of protein is more important than quality of protein since the rumen converts protein from amino acids (http://www.sheep101.info/201/nutritionreq.html). Young growing lambs and lactating ewes will have the highest requirements for protein due to muscle development and milk protein development, respectively. Energy and protein requirements on average are 15 percent higher for yearlings than for adult sheep due to yearlings' growth. Forage alone most likely will not meet the nutritional requirements for yearlings, which is similar for older ewes since their digestibility decreases with age (Ward and Gifford, 2017).

(3) Sex of Animal
- (i) Prior to breeding (~10–14d) ewes will need to increase their energy intake, also referred to as flushing. Young rams require a higher plane of nutrition following the breeding season to replenish its condition (Greiner, 2005).
- (ii) Entire ram lambs (not castrated) will grow faster, specifically Hampshire Down, Dorset, Suffolk, Charollais, Vendeen, or Texel-cross breeds. This can favor earlier slaughter, however, there could be a stronger flavor or taint to the meat (Hunt, 2015).

(4) Body Condition of Animal
- (i) Throughout the production periods, producers should know the condition of their sheep, such as breeding, late pregnancy, and lactation. Weight at a given stage of production is the best indicator, but there is a wide variation in mature size between breeds and individuals, which makes body condition scoring an acceptable method to use (Thompson and Meyer, 1994).
- (ii) Body Conditioning Score (BCS) can influence the response of an ewe to seasonal cues. Ewes with higher BCS display longer breeding rates because they are more likely to display estrus and experience a later onset of seasonal anestrous. However, it is unlikely manipulating BCS could shift the timing of the breeding season significantly. See figure H-6 (https://www.tandfonline.com/doi/pdf/10.1080/00288233.2013.857698).
- (iii) Research trials at Oregon State University indicated an ewe BCS at lambing influenced total pounds of lamb weaned per ewe. If the BCS was 3 to 4 at lambing she lost fewer offspring and weaned more pounds of lamb than those with a score of 2.5 or less (Thompson and Meyer, 1994). Refer to tables H-10 and H-11. Data suggest there is an effect of BCS on return to service but there may be a genotype differences for the minimum BCS and the rate of return to service. There may be a minimum BCS above which the return to service rate decreases, there is also evidence that there is an upper limit to BCS above which conception rates can decrease. It appears that a BCS of 2.5–3.5, depending on breed, will result in a higher pregnancy rate, than a low or high BCS. A low or high BCS will negatively impact pregnancy rates. (https://www.tandfonline.com/doi/pdf/10.1080/00288233.2013.857698)
- (iv) See also the FAMACHA Scoring for Goats.

**Figure H-6.** Body Condition Score and Description for Sheep (Bactawar, B. UF/IFAS Duval County Extension Service, University of Florida. https://extadmin.ifas.ufl.edu/nflag/livestock/sheep/sheep-nutrition/).

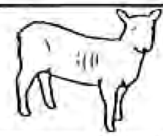
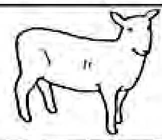
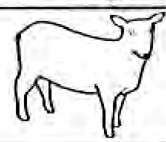
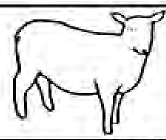
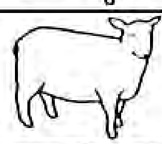
| Score | | Description | |
|---|---|---|---|
| 1 |  | Spine sharp, back muscle shallow, | Lean |
| 2 |  | Spine sharp, back muscle full, no fat | |
| 3 |  | Spine can be felt, back muscle full, some fat cover | Good Condition |
| 4 |  | Spine barley felt, muscle very full, thick fat cover | Fat |
| 5 |  | Spine impossible to feel, very thick fat cover, fat deposits over tail and rump | |

**Table H-10.** Optimum BCS values at various stages of production (Thompson and Meyer, 1994).

| Production Stage | Optimum Score |
|---|---|
| Breeding | 3–4 |
| Early–Mid Gestation | 2.5–4 |
| Lambing (singles) | 3.0–3.5 |
| Lambing (twins) | 3.5–4 |
| Weaning | 2 or higher |

(v) It is important to also consider the condition of the pasture. Pastures should be rested for at least 30 days and no more than 45 days to break the worm cycle, specifically the *Haemonchus contortus* (also known as the barber pole worm). Grazing height and stocking rate need to be controlled to avoid ingesting worms due to overgrazing. A stubble height of 4” should be achieved to reduce the chance of sheep consuming worms that typically reside near the soil surface.

**Table H-11.** Body weight by breed for ewes.

| Breed | Classification | Approximate Mature Weight–Ewes[1] |
|---|---|---|
| Coopworth | Medium wool, meat | 150 |
| Dorset | Short wool, meat | 140 |
| Finnsheep | Medium wool, meat | 120 |
| Katahdin | Hair, meat | 135 |
| Polypay | Medium wool, meat | 140 |
| Ramboulliet | Fine wool, meat | 150 |
| Romanov | Black wool, meat | 130 |
| Shropshire | Short wool | 150 |
| St. Croix | Hair, meat | 130 |
| Targhee | Medium wool, meat | 150 |

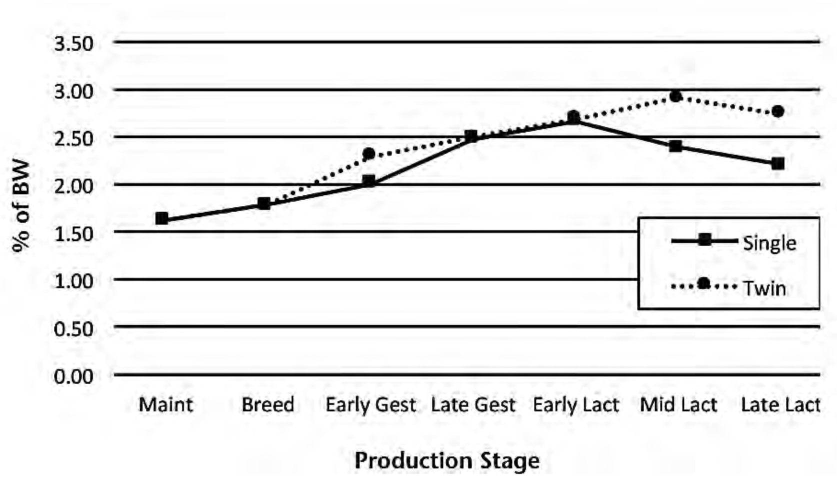
[1]Ram body weight is 1.55 to 1.75 times the ewe body weight.

(5) Physiological State

(i) Pregnant

Nutritional needs of an ewe will change largely with her stage and level of production (Ward and Gifford). Her energy needs are critical during breeding, just before lambing, and lactation, (figure H-7). shows the change in intake requirements over the ewes' productive year. Ewes should be at 3 or higher BCS to provide adequate energy for lactation. A 3+ BCS in the last part of gestation will be less prone to metabolic disorders (i.e. ketosis and pregnancy disease) compared to excessively thin or fat ewes. Fat or thin ewes may have low lamb birth weights and lamb vigor (Greiner, 2012). A low score could be due to nutrition or health concerns, such as parasites.

**Figure H-7.** Dry Matter intake of a 175-lb ewe (Ward and Gifford, 2017)



(ii) Physical Activity

The animal's basic maintenance requirements will vary based on age, exercise, climate, and body composition. Physical activity in grazing sheep can expend 10 to 100 percent more energy than sheep in drylots (New Mexico State University https://aces.nmsu.edu/sheep/sheep_nutrition/ewe_nutrition.html), the amount expended will depend upon topography and distance traveled to water and feed. Dry ewes will be able to maintain their nutritional requirements on pasture; however, supplementation may be needed during pregnancy and lambing, especially if used for dairy production. If the ewes are being used for milk production, they need a nutrition program with emphasis on body condition.

(iii) Lactation

A ewe will lose weight during early lactation. Weight loss will then taper off during mid-lactation and will regain weight at late lactation (Table H-11; Ward and Gifford, 2014). When an ewe has multiple lambs, the producer will need to prevent too much weight loss during lactation. It is recommended to either supplement or allow the lambs to creep feed.

(6) Environmental Factors

(i) Feed (Source: Sheep Nutrititon; Marcy Ward and Craig Gifford, Circular 685, College of Agriculture, Consumer and Environmental Sciences, New Mexico State University, 2017).

- Nutrition represents the largest cost in sheep production. A producer must know the animal's nutritional requirements during the different phases of production, the nutrient composition of available feedstuffs, and how to provide the available feedstuffs to meet the animal's requirements.
- Understanding the changes in nutritional requirements for sheep throughout the year will allow producers to fine-tune their nutrition program to reduce costs while maximizing production. Nutrition should be managed to support optimal health, be efficient and economical, and must minimize the potential for nutrition-related problems.
- The nutritional needs of a sheep do not stay the same. Instead, they vary largely with the stage and level of production. Energy needs are very critical (such as during breeding, immediately before lambing, and while lactating, during the various stages of growth and production). Other nutrients, such as energy, protein, vitamins, and minerals, will follow the same requirement pattern. Intake and nutrient demand will also increase with each additional need for production.
- One of the most reliable sources of information regarding sheep nutrition is Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids (2007), produced by the National Research Council (NRC). Requirements and diets of grazing sheep can vary greatly with changing forage quality and availability. However, if producers follow the NRC guidelines, the flock's nutritional requirements will be met as closely as scientifically possible at this time.
- Maintenance of the ewe is generally thought of in terms of her nutritional requirements when dry because at that time her requirements are the lowest of the year. Feed levels can be lowered to reduce the feed cost during the early stages of gestation and when ewes are dry. However, wool production is a continuous process that must be considered as part of the nutritional requirements throughout the year. The ewe's mature body weight will also affect how much feed she will need to simply maintain her condition. A ewe's nutritional priorities can be ranked: first is to maintain herself, second is to grow, third is for lactation, and last is reproduction. That means if the requirements for the first three stages of production are not met,

she will not reproduce. Therefore, proper nutrition is critical before, during, and after the breeding season. Ewes that have not had a properly balanced diet, including adequate phosphorus and vitamin A for example, may have a poor lamb crop percentage.

- **Gestation** is broken up into two phases: early and late. It is important to note that the nutritional requirements change throughout gestation. Therefore, feeding management may be fine-tuned to reduce costs and prevent ewes from becoming too fat or too thin.
  - Early Gestation (0–50 days)
    A ewe's nutritional requirements are only slightly higher than they are for maintenance. The goal should be to maintain good body condition in order to sustain the pregnancy. Significant weight loss at this time could result in early embryonic loss.
  - Late Gestation (105 days–lambing)
    -- Fetal growth is the greatest during the last 50 or 60 days of gestation.
    -- The nutritional status of the ewe should increase by approximately 20%.
    -- It is critical not to increase feeding overnight, but rather slowly over time before ewes reach this stage of pregnancy.
    -- If feed and body weight are not managed correctly at this stage, ewes can experience metabolic disorders shortly before or right after lambing.
- **Lactation** can be broken into stages: early, mid, and late. This can also help in management strategies for nutrition, weaning, and time of breeding. If the ewe's requirements are not adequately met for lactation, she will rapidly decline in her daily production. Once ewes experience a decline in milk production, due to interruptions in nutrition or water or reduced demand from the lamb, they will not regain their previous production level.
  - Early lactation
    The ewe's nutritional requirements continue to climb during early lactation. This period is generally considered to be the first 14 to 21 days after lambing. Additional protein and energy are required in order to maintain reasonable milk production.
  - Mid lactation
    The ewe peaks in her lactation cycle approximately 21 days after lambing. She requires both the greatest levels of energy and digestible protein during this time. Milk production gradually declines after this time as the lambs start to use more forage in their diet. Mid lactation is generally considered to be from 21 to 60 days after lambing.
  - Late lactation
    Late lactation is considered to be from day 60 to day 90 of lactation. By day 60, milk production is so low that it is no real benefit to the lamb(s) as a source of nutrition. Therefore, most production systems will wean their lambs at 60 days of age. If ewes are asked to milk too long, it could impede their ability to gain weight or to rebreed.
- **Young Lambs**
  - As with all growing animals, young lambs require a more nutrient-dense diet to properly meet their growth requirements. Lamb nutrition management can start before they are weaned. It is common in many sheep operations to creep feed lambs while they are still on the ewe. Creep feeding provides additional supplementation that the ewe cannot provide.

- Nutrition should be a priority with young growing ewe lambs. Separate management of these young animals may be necessary to optimize growth, genetic potential, and profitability. Additional supplementation is generally needed because native forages often fall short of meeting growth requirements.

- **Nutrition of the ram** should also be considered. A producer's goal should be to increase a ram's body condition prior to the breeding season since they tend to lose significant weight during the breeding season. If rams are over-conditioned, however, it may impact their libido and stamina for adequate breeding rates.
- On range and pasture lands, sheep will consume, in order of preference, forbs, grasses and shrubs and have been effectively utilized to control invasive species such as spotted knapweed, leafy spurge and yellow starthistle. Sheep on range or pasture can also be used as an alternative enterprise by taking value from wool, lambs or by contract grazing on other parcels of rangeland to control noxious weeds (Rinehart, L. 2008. Pasture, Rangeland and Grazing Management. A publication of ATTRA-National Sustainable Agriculture Information Service).

(ii) Temperature

The normal body temperature of the sheep is between 100.9° and 103.8°F. This temperature is in line with the normal body temperature of many other mammals. The thermoneutral zone (TNZ) for sheep, however, is between 70° and 88°F. This TNZ is almost 20 degrees higher than for most other farm animals. This higher TNZ is probably an adaptation to account for the amount of, and the insulating properties of the wool worn by the animal. The length and density of the fleece also affects energy requirements. Wool plays an important role in protecting sheep from both heat and cold. The insulating properties of wool help to cool the sheep in the heat of summer and keep body temperatures warmer in winter. Without wool, a sheep's energy requirements would be higher. Finer wool breeds, for example, tend to be more adaptable to hotter, dryer climates. The more extreme the weather, the more nutrition the animal will require for maintenance. Using wind breaks, shade structures, and providing dry ground helps minimize reduced performance due to weather.

(iii) Water

Though there is no specific requirement for water, it is fundamental for life, health, and production. Clean, fresh water is a daily necessity for sheep and lambs. Sheep will consume anywhere from ½ to 5 gallons of water per day, depending upon their physiological state, the content of water in their feed, and environmental conditions. Requirements increase greatly during late gestation and lactation. Stage of production (growing, lactating, dry, etc.), air temperature, and water quality all affect water intake. It is imperative that fresh, clean, reliable water sources are made available at all times. Drought and also excessive moisture can greatly impact water quality. It is therefore important to monitor water quality through regular testing.

F. **Non-ruminants: Horses**

(1) Genetic Factors

(i) The grouping of horses includes horses, ponies, mules, and donkeys. Mules are a sterile cross between a female horse and a male donkey and are typically used as work animals. Ponies are actually breeds of small horses; ponies may be used as work animals or as pleasure animals.

(ii) Horses are large breeds of the species *Equus Ferus Caballus* and appear in many forms and have had many uses over the ages. Horses range from huge draft animals weighing over a ton to horses used for riding that weigh closer to a thousand pounds.

(2) Age of Animal

Foals are usually weaned at between 4 and 7 months of age, and actually begin eating small amounts of grass and grain at after 4 months of age. Horses can live to over 30 years of age with 20 to 25 years being the norm. Mares can become sexually mature at 12 to 15 months of age and stallions at 15 months of age. Mares can be bred at two years of age, though three years is more generally accepted. Mares can be bred and produce offspring throughout their adult life though time between foals may increase as the animal ages. Gestation period is generally between 320 and 380 days with smaller breeds adhering to the shorter time period. Stallions that will not be kept for breeding should be gelded between six and twelve months of age before they begin to exhibit stallion-like behavior such as aggression or unruliness.

(3) Sex of Animal

A newborn horse of either sex is called a foal. A young female that has not had a foal or is under three to four years old is called a filly. A mare is a female that has reached three or four years of age. A colt is a young male usually under three years old. A gelding is a male that has been altered by surgical removal of the testes to eliminate the aggressive behavior of a stallion. A stallion is an adult unaltered male.

(4) Body Condition of Animal

(i) The body condition of horses based on the degree of fat cover is a good indicator of a horse's general health. The body condition score (BCS) allows one to assess if the horse is too thin, too fat, or about right. See figure H-8. Horses are scored on a scale from 1 (poor) to 9 (extremely fat) in six areas where they deposit fat – neck, withers, spinous processes (part of back vertebrae that project upwards) and transverse processes (portion of vertebrae that projects outward), tail head, ribs, and behind the shoulder. The subjective assessment is based on visual and physical (palpation) of the specified body regions including the hooks (tuber coxae and hip joints) and pins (tuber ischia and lower pelvic bones). Comparisons of relative degree of fatness can be made within or between horses. Categorization of body condition as underweight (BCS ≤ 3, 1–9-point scale), moderate (BCS 4–6), overweight (BCS ≥ 7) or obese (BCS ≥ 8) can be used as an aid in the management of body condition for optimal health and performance

(ii) Advantages of the body condition score are:

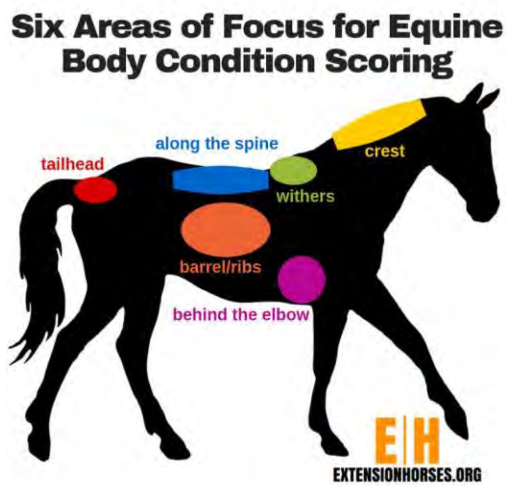
- Integration of all body areas
- Easy to perform
- Allows for classification of horses into underweight, overweight, or obese categories
- Cutoff values available to imply risk for disease
- Disadvantages of the body condition score are

(iii) Disadvantages:

- The method only assesses subcutaneous fat
- Bias between evaluators may influence results
- The score can be influenced by coat length, gut fill, muscle mass, pregnancy, etc.
- The score may not be comparable between different breeds or body types

Source: https://www.extension.iastate.edu/equine/body-condition-score

**Figure H-8.** Body Condition Scoring for Horses.




Source: Body Condition of Horses. CANR.MSU.Edu

(5) Physiological State

(i) Pregnant

- Mares can be bred at two years of age, though three years is more generally accepted. Mares can be bred and produce offspring throughout their adult life though time between foals may increase as the animal ages. Gestation period is generally between 320 and 380 days with smaller breeds adhering to the shorter time period. In feeding broodmares, consider several important factors: A good source of supplemental information for this area can be found at: Nutrition of the Broodmare, Cooperative Extension Service, University of Kentucky College of Agriculture. ASC 112. August 1988.
- Nutrient requirements of the particular class of horse being fed. Horses being worked, or large breeds, will require more and better feed than horses at rest. Mares, in the first and second trimester of pregnancy can probably get all or most of their nutritional needs from pasture and forage. As pregnancy progresses additional nutrients need to be provided.
- Physiological events involved in pregnancy. The physiology of the horse changes dramatically throughout pregnancy. Not only are there hormonal, structural, and physiological changes in the mare that need to be considered, but also consideration needs to be made for these same things in the developing foal. The foal grows from a single cell to around 45 to 50 pounds in less than a year of gestation, and this puts tremendous strain on all of the mare's physiological and anatomical systems.
- Nutrient content of the feed. The pregnant mare's nutrient needs are not much different from those of the mature horse at maintenance during the first two trimesters. Therefore, you can feed a pregnant mare a maintenance diet during early gestation. During the last trimester and during lactation, nutrient needs increase to meet the needs of the growing fetus and the newly born foal. If you are feeding a good quality alfalfa or legume hay, you may not need grain supplementation to meet the mare's nutrient requirements. However, feeding concentrate during the last 90 days of pregnancy is common and is a good practice to ensure adequate nutrition.

(ii) Physical Activity

As physical activity of the horse increases, its nutrient needs also increase. Mature animals, not performing work (work is draft, carriage, ranch, racing, pregnant, or lactating, among others) probably need little more than pasture and supplemental forage to remain in good physical condition. As the amount of physical activity increases, pasture and forage need to be supplemented with additional energy, protein, vitamins and minerals. These additional items may be supplied as whole feeds, concentrates, grain mixes, and mineral blocks, among other forms.

(iii) Lactation

Lactation is a period of substantial physiological stress. The lactating mare's nutrient needs are greater than those of any other class of horse with the possible exception of the horse in intense training. During this time the mare must recover from the stress of parturition, produce milk and re-breed. The lactating mare has an increased requirement for water, protein, energy, calcium and phosphorus. A normal, healthy mare will produce about 3 percent of her body weight in milk per day, during the first 3 months of lactation and 2 percent in late lactation. This means a 1000-lb mare will produce roughly 30 lbs of milk per day during early lactation and roughly 20 lbs per day during late lactation. Failure to meet the mare's nutrient needs during lactation will have more effect on her body condition than on milk production.

(6) Environmental Factors

(i) Feed

Because most horses in the US are kept through adulthood, they spend most of their lives needing energy for maintenance, with little additional energy needed for the small amount of work that they are doing. In most cases adult horses only need pasture or forage with very little supplementation. Working horses (draft, ranch, racing, pregnant or lactating) will need additional supplementation through grain, vitamins, and minerals. Pasture and range condition and makeup are very important to the health and wellbeing of the animals kept on them. Forage quality is important with working horses needing higher quality forages like alfalfa, and nonworking horses finding lower quality orchard or mixed grass hay sufficient.

(ii) Temperature

The horse is a warm-blooded animal like cattle, sheep, and even humans. If the horse receives sufficient energy from the food that it eats, it can withstand temperatures and weather conditions of most extremes. The "thermoneutral zone" (TNZ) for horses is about 41 to 77°F and for foals is around 60 to 72°F. This is the temperature range within the body that does not consume extra energy to maintain the internal body temperature. If the body has to set up mechanisms to warm up (shivering or slowing down of the respiratory rhythm) or to cool (sweating, increased breathing rhythm), it means that the horse is out of its comfort zone. The lower limit of this zone is the lower critical temperature and the upper limit is the upper critical temperature. Heavier breeds of horses (more body mass and greater degree of deposited fat) can withstand lower temperatures better than lighter breeds. The reverse is also true with lighter breeds able to withstand higher temperatures.

(iii) Water

An idle, 1,100-pound horse in a cool environment will drink 6 to 10 gallons of water per day. That amount may increase to 15 gallons per day in a hot environment. Horses that are being worked will drink more accordingly. Horses on fresh pasture that is high in moisture may have most of their water needs met by the grass that they eat. Quality of water is important for a healthy horse. The best indicator of water quality is total dissolved solids (TDS). The TDS sums the concentration of all substances dissolved in the water. The safe upper limit of TDS for horses is 6,500 ppm (parts per million or mg/L). Water below 1,500 ppm TDS is considered fresh water. Water greater than 5,000 ppm TDS is considered to be saline. Water quality can also be assessed by odor, color, and temperature. Odor is affected by the amount of sulfates, manure or rotting vegetation. An increase of any of these can affect palatability and voluntary intake (source: Water Quality for Horses, Iowa State University, Equine Extension).

G. **Non-ruminants: Poultry**

(1) Genetic Factors

(i) Three types of poultry are important commercially in the U.S. These are laying hens, meat type chickens, and turkeys.

(ii) Laying hens and meat type chickens are as different in breeding and function as are beef and dairy cattle. Poultry have been bred for quick growth and heavy production. Changes to the genetics of the bird can happen very quickly because hens reach laying age at about 5 months of age (7 months for turkey hens). Within another 3 to 5 months a generation of offspring will have grown and matured, providing data on which birds are the best producers. For instance, in 1980, it took 7 weeks to raise a 4-pound broiler, while in 2020 a 7-pound bird can be raised during the same time period. The same type of increase in production is exhibited in turkeys and laying hens.

(2) Age of Animal

Chickens and turkeys can live 5 years or more, but because production level falls as the birds get older, it is not economically feasible to maintain the birds to this age. Commercial laying hens are usually put into lay at 5 months of age and are rarely allowed to lay past two years of age. Turkey breeding hens start to lay at about 7 months and are rarely allowed to lay more than 8 to 10 months. Broiler breeding hens start to lay at 5 to 6 months and lay for about a year. Broiler chicks are marketed at a particular age based on the market the birds go to, with some birds for the fast-food market being harvested at 4 weeks, and roasters being harvested at as much as 10 weeks of age. Tom (male) turkeys are often grown to 25 weeks of age and 30 pounds and the meat from these large birds is processed into products such as turkey ham and pastrami. Turkey hens usually grow for 15 weeks and reach 12 to 18 pounds and are marketed as whole birds.

(3) Sex of Animal

The sex of the animal is most important with commercial egg layers. Because these birds are usually a light breed (usually White Leghorn), that has been bred solely for egg production, the male has little value and is usually sacrificed at hatching. Meat birds are often raised separated by sex to address a particular market to which the birds will be directed. With both meat type chickens and turkeys, males grow bigger and faster than females and sexes may need to be fed differently requiring different nutrients at a given time.

(4) Body Composition of Animal

(i) Poultry grow quickly and generally have a good ratio of lean-to fat. The dressing percentage for a commercial broiler is generally between 70 and 75 percent, compared to about 60 percent for a beef animal. Since laying hens, and breeding hens and roosters (and Tom turkeys used for breeding) are the commercial poultry that are used as adults, sometimes diets and feeding regimens need to be adjusted to keep the animals from becoming too fat. A high degree of fat can reduce egg production, fertility, and breeding ability.

(ii) Physiological State

The physiological state of a laying hen is always in flux. A hen in high production lays an egg about every 26 hours. About an hour after she lays, the hen ovulates, and lays again in another 26 hours. Hens on natural light usually lay before noon and rarely ovulate after about 3 pm in the afternoon. Because of this it is almost impossible for a hen to lay an egg a day. Egg production is largely a function of photoperiod, with hens needing 12 to 14 hours of light to be stimulated to develop an ovum, ovulate, and lay an egg. If the hen experiences decreasing daylength, she assumes winter is coming, and chicks she might hatch would not survive cold weather, so egg production will fall and eventually cease. For this reason, commercial hens never experience decreasing daylength; generally artificial lights are provided set to the time of the longest day of the year. The hen goes through all the same hormonal and physiological changes in the 26-hour period, that most other domestic animals experience in a 28-day (or longer) ovulatory cycle.

(iii) Physical Activity

Unlike most mammals, chicks are born active and with the ability to eat similar diets to the adult. Where they differ is that the chicks cannot thermoregulate and must be provided with warmth for the first two to three weeks of their life (chicks raised outdoors may need added warmth for a longer period of time). Correct environmental temperature of young chicks will affect their growth and production as they mature.

(6) Environmental Factors

(i) Feed

Both turkeys and chickens belong to the same taxonomic subfamily of Phasianidae (pheasants) which also includes quail and grouse, among others. All of these birds are characterized as ground living (though they may roost in trees) and spend much of their time scratching and pecking for seeds, worms, and insects. Very little of these animals' nutritional needs are met by forage and pasture, per se, but the seeds and insects that the pasture houses make pasture an attractive alternative for raising poultry. Around 5 to 10 percent of the birds needs can be met by eating grass or other plants, but since around 70 percent of the variable cost of raising poultry is for feed, this small amount attributed to pasture can have a sizable effect on the profit picture of the operation. If poultry are pastured, recommended stocking rates need to be followed and birds will be rotated frequently to prevent poultry waste from becoming a serious environmental problem (Fukumoto and Replogle (1999), Lee et al (2010), and Fanatico (2006). However, with proper management, there are significant benefits for soil health from pastured poultry. As birds roam freely on pasture, the manure is distributed back into the soil creating a nutrient-rich material for grass and pasture crops to utilize, which in turn provides food. Fukumoto and Replogle (1999) concluded that a properly managed pastured poultry operation would result in a decreased need for land application of fertilizers.

(ii) Temperature

Body temperature for both chickens and turkeys ranges between 105 to 107°F. Chicks are hatched at about 103°F, with temperature increasing each day for about 3 weeks until the normal range is reached; when normal is reached, chicks no longer need supplementary brooding heat. For most poultry, the TNZ is between 60 and 75° F. This zone represents the temperature range where heat production is lowest. As temperatures increase towards 85° F, the birds will adjust their behavior and decrease feed intake and production. These changes help prevent the bird's core body temperature from increasing. When air temperature increases towards 100° F, the birds' core body temperatures will increase to lethal temperatures unless relief is provided. Shade, ventilation, evaporative cooling, and providing feed late in the day (or at night when it is cooler) can all help to manage mortality due to high temperature.

(iii) Water

Water is the most important nutrient for poultry. Birds generally drink approximately twice as much water as the amount of feed consumed on a weight basis. During periods of extreme heat stress, water requirements may easily quadruple. Although the importance of providing adequate access to it is well accepted, the importance of good water quality is becoming ever more apparent. High levels of bacterial contaminants, minerals, or other pollutants in drinking water can have detrimental effects on normal physiological properties resulting in inferior performance. Drinking water should be clear, tasteless, odorless, and colorless. Poultry will do better on water that is slightly acidic than they will on water which is alkaline. Total Dissolved Solids (TDS) should have an absolute maximum of 2,999 ppm. (Source: Water Quality for Poultry, Auburn University Extension, June 2019).

H. **Non-ruminants: Swine**

(1) Genetic Factors

There are eight major breeds of swine that are commonly raised in the United States. Different breeds are better used for specific applications. Producers typically raise breeds that best fit their needs based on their qualities and physical characteristics. These eight breeds are: Berkshire, Chester White, Duroc, Hampshire, Landrace, Poland China, Spotted and Yorkshire. The modern pig grown commercially for meat is a fairly lean individual. Nevertheless, it will respond to a low-protein or high-fat diet by depositing more fat. Certain breeds such as the Chinese Meischan, the Gottingen minipig, and the feral Ossabaw have a much greater propensity for obesity. Obese lines of pigs have been developed by genetic selection for obesity-related traits such as maximal backfat thickness (Hetzer and Harvey, 1967; Mitchell, 2007 – reword). There are several reports where these breeds or genetic lines of obese pigs have been utilized as models for studies related to human obesity [see review by Mersmann (Mersmann, 1991; Mitchell 2007)].

(2) Age of Animal

Modern commercial swine have been bred for very fast growth, maturity, and harvest. From breeding of the sow to birth takes around 4 months, then around another 6 months are needed to produce a 260-pound market hog. Ten months is all that is needed for the entire life cycle of a modern commercial market pig. In many instances, producers who raise hogs on pasture use heritage breeds that have not been bred for the most efficient production. These animals grow slower, may grow at a less efficient rate of feed conversion, and may yield a carcass with a higher ratio of fat to lean. These animals seem to do better on pasture, and many consumers claim that the meat has more flavor. These animals may take over a year from breeding to market rather than the 10 months needed for commercial hogs.

(3) Sex of Animal

Swine sexes are further differentiated by size, gender, and ultimate use. Boars are adult males usually over one year in age, typically used for breeding. Sows are adult females used for breeding. Gilts are young females being raised for market or inclusion in the breeding herd. Barrows are young castrated males raised for market. If barrows are left intact, and reach sexual maturity, aggression can become a problem within the herd, and meat can have an "off" flavor when consumed.

(4) Body Composition of Animal

(i) Market swine have changed significantly over the years in response to market demand for less fat in meat. In the past, market hogs with 25 to 40 percent carcass fat were not unusual. In today's commercial operations, body fat percentage closer to 15 percent is not unusual. By the same token, in the past to achieve market weight without a large degree of fattiness, hogs were marketed at around 220 pounds. Today's pigs may be marketed at up to 280 pounds without being overly fat. This achievement to larger animals that are much leaner has been the result of breeding, nutrition, and management. See figure H-9.

(ii) Because producers of hogs on pasture often raise heritage breeds, those animals can be more typically higher in fat. The increased amount of exercise on pasture coupled with the low-calorie level of the small amount of forage eaten by pigs can moderate fat percentage somewhat.

(5) Physiological State

(i) Pregnant

- A sow will become sexually mature at 5 to 6 months of age, and the gestation period is about 115 days. The sow can produce about 2.5 liters per year. The purpose of the breeding herd is to consistently produce a targeted number of high-quality weaned pigs in an efficient manner and at low cost. The objective of the feeding program for gestating sows is to achieve an appropriate, targeted sow weight gain during gestation that will allow optimum litter development and prepare the sow for lactation.
- During gestation the pregnant sow requires nutrients and energy to maintain her bodily functions, for weight gain and to supply the developing litter (NRC 1998). Maintenance represents 75-85 percent of the total energy requirement of the pregnant sow. Maternal weight gain represents approximately 15-25 percent of the energy requirement of the sow. The composition of the maternal bodyweight gain will vary with parity, the amount of weight gained and the composition of the diet fed. Therefore, the energy cost per lb. of maternal gain can vary from 1.4-2.3 Mcal ME/lb (source: https://swine.extension.org/feeding-the-gestating-sow/; E-extension, August 28, 2019).

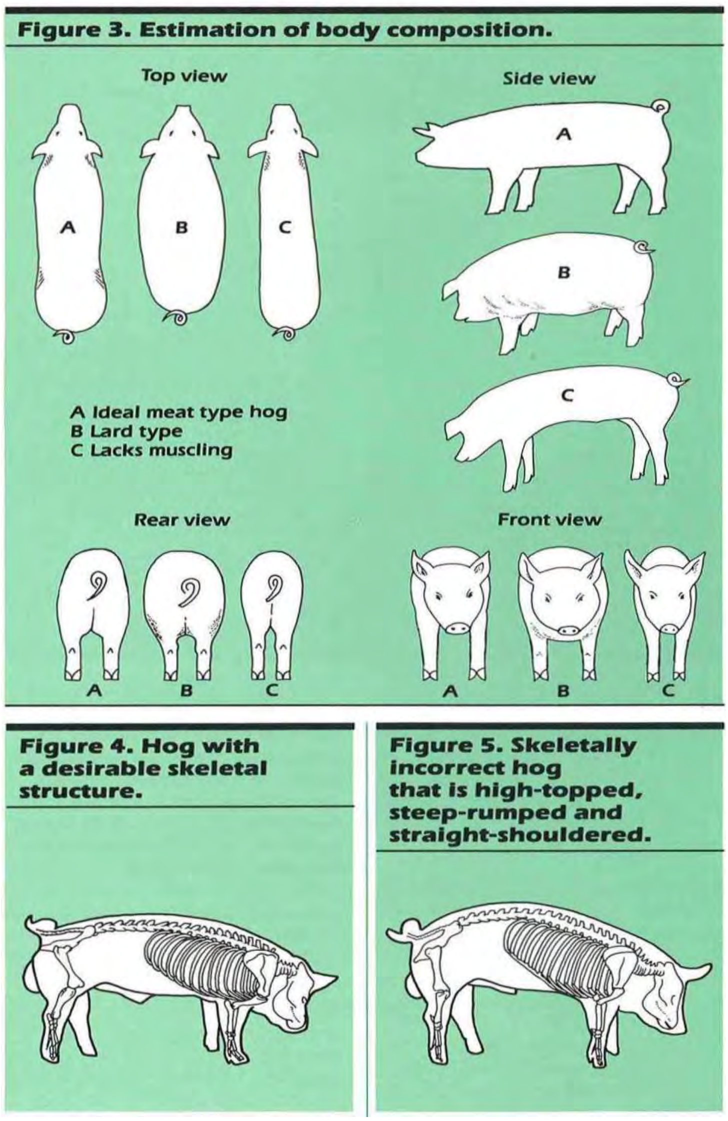
(ii) Physical Activity

Physical activity at all levels of production increases the need for food for the animal. Modern swine approach the best feed conversion of farm animals, falling behind chickens and turkeys, but feed conversion continues to improve.

(iii) Lactation

Sows require significantly more nutrients in lactation than in gestation to care for their litters without sacrificing body condition. The sow needs all the nutrients she can get during lactation. The more the sow eats the better potential she has for greater milk production, heavier litters at weaning and shorter time to return to estrus. The demand for energy and protein increases immediately following farrowing. Feeding sows *ad libitum* immediately allows them to consume the nutrients they require before they begin losing condition. On average, each sow consumes between 14 and 15 pounds of feed per day during the lactation period. Allowing the sows to eat what they need during lactation helps them to fulfill their needs on their own. This helps to minimize body weight loss during lactation, which, in turn, helps maximize piglet growth rates and optimize reproductive performance (https://www.purinamills.com/swine-feed/education/detail/sow-gestation-vs-lactation-rations).

**Figure H-9.** Hog body composition.




Source: 4-H 1064: 4-H Market Hog Project; Michigan State University Extension;

(6) Environmental Factors

(i) Feed

Swine are single stomached animals with a relatively short gastrointestinal tract. Feed must be digested and absorbed relatively quickly before it is expelled as waste. Because of this, swine must rely more on concentrated feedstuffs that are high in relative nutrients, than they do on grass and plants. Even pigs in the wild rely more on roots, nuts, seeds, worms, and insects for most of their nutrient needs than they do grass and plants. Though pigs need a concentrated diet, they can get at least some of their nutrition from grasses and forage. The growing hog can get up to 10 percent of its nutrient needs from pasture. Highly digestible plants or plants like legumes that are high in protein can supply a greater percentage of the nutrient needs of the animal. Most outdoor swine herds suffer from internal parasites that persist in soil; therefore, the producer needs to develop a rigorous parasite control program as part of a whole-herd health program.

(ii) Stocking rates

Stocking rates depend upon soil fertility, quality of pasture and time of year. Recently, several researchers (Rinehart 2018, Kephart et al 2019 and Pietrosemoli and Green 2015) have developed recommended stocking rates for pastured swine; however, pastured swine production systems can present significant environmental risks if not adequately managed. The environmental impacts of outdoor swine production are related to the natural behavior of swine and include deterioration of vegetative ground cover, soil compaction, high nutrient input, irregular nutrient distribution and nutrient losses to ground water and to the atmosphere (Pietrosemoli et al. 2012). Becchetti et al (2015) lists some of the management tools and approaches to help minimize the impact of swine. These tools include vegetative filter strips, hog proof fencing (permanent and electric), appropriate location of planned heavy use areas, and selecting appropriate vegetative cover for slowing, capturing, and filtering run-off. In addition, straw wattles and berm-and-swale systems can also be used to prevent overland flow and erosion from entering sensitive areas.

(iii) Temperature

The body temperature of a market pig is about 102°F. The thermoneutral zone (TNZ), the zone of temperatures at which the pig can maintain this body temperature without stress from being too hot or too cold is between 50° and 75°F. If temperature is greater than this range the pig will try to cool by decreasing food consumption, decreasing activity, finding shade, finding water, wallowing in mud, etc. If the temperature is lower, the animal increases activity, bunches together with other animals, finds protection from wind, and eats more food.

(iv) Water

- Water consumption ranges from less than 0.5 gal/ pig/day for newly weaned pigs to greater than 1.5 gal/pig/day for grow-finish pigs. Warm temperatures can quickly increase the consumption of water to much higher levels. High quality drinking water is an essential component for the health and efficient production of pigs.
- Many factors can affect the quality of water, including microbiological, physical and chemical factors. As a guideline, drinking water for animals should contain fewer than 100 total bacteria per milliliter and fewer than 50 coliforms per milliliter. Water should be clear and odorless. The acceptable range of pH is from 6.5 to 8.5. Total Dissolved Solids (TDS) for water for swine consumption should be less than 6,999 ppm. (Source: Guidelines for Water Quality in Pigs, North Carolina State University, Animal Science Facts No. ANS 00-811S, June 2000).

## 645.0804 Maintaining a Balance Between Livestock Numbers and Available Forage

A. The objective of most grazing management programs is to make optimum use of forage resources while maintaining or improving the resources. To accomplish this, a proper balance must be maintained between the number of animals using the forage and the amount and quality of forage produced.

B. No two years have exactly the same weather conditions. For this reason, year-to-year and season-to-season fluctuations in forage production are to be expected on grazing lands. Livestock producers must make timely adjustments in the numbers of animals or in the length of grazing periods to avoid overuse of forage plants when production is unfavorable and to avoid waste when forage supplies are above average. Timing of grazing and stock density should be managed to avoid overgrazing and yet achieve optimum proportion of plants grazed. In a rotation system, accomplishing this by changing the duration of grazing versus increasing stock density for the same grazing period can make overgrazing less likely to happen, especially when the producer has less experience with intensive grazing.

C. Avoidance of overgrazing is paramount and especially crucial during periods of rapid growth. Grazing management for the higher proportion of plants grazed can be implemented faster during periods of slow plant growth or dormancy, as the likelihood of overgrazing at this time is less. As producers gain experience with higher stock densities, shorter grazing periods can be implemented. Grazing a higher portion of plants helps to keep the vegetation more vigorous and reduces the buildup of old growth material. A livestock, forage, and feed balance sheet is useful in summarizing livestock and forage resources for use in planning and follow-through work.

D. The animal unit (AU) is a convenient denominator for use in calculating relative grazing impact of different kinds and classes of domestic livestock and of common wildlife species. (see table H-12). AU is generally one mature cow of approximately 1,000 pounds and a calf as old as 6 months, or their equivalent. An animal unit month (AUM) is the amount of forage required by an AU for 1 month. AU equivalents vary somewhat according to kind and size of animals.

(1) NRCS has elected to use 26 pounds of oven-dry weight or 30 pounds air-dry weight (as-fed) of forage per day as the standard forage demand for a 1,000-pound cow (one animal unit).
Forage consumption is affected by many factors and varies with individual animals. Some of these factors include:

- forage quality (crude protein and digestibility)
- standing crop
- age of the animal
- supplementation
- topography
- animal breed type
- animal species
- physiological stage
- weather factors
- watering facilities

(2) The National Research Council has calculated the requirements for a 1,100-pound dry beef cow to be 17.6 pounds per day. This is a calculated value based on a confined animal, and not what a 1,100-pound, free ranging, dry cow could eat to fill or capacity. Research has validated intake rates for beef cows as low as 1.5 percent of the body weight to a high of 3.5 percent. No single rate is always correct.

A free ranging 1,000-pound lactating cow grazing forage that is about 7 percent crude protein and 58.5 percent digestible would consume about 25 pounds of forage per day. If the forage quality is increased to 10 percent crude protein and 70 percent digestibility, forage intake would increase to about 32 pounds per day.

(3) Intake and stocking rates for lactating dairy cows are calculated at 3 percent of their body weight. Dry dairy cows are calculated using the 2.6 percent of body weight used by beef cattle. Table H-12 is a guide to AU equivalents.

**Table H-12.** Animal-unit equivalents guide (can be adjusted by actual weights).

| Kinds / classes of animals | Animal-unit equivalent | Forage consumed, day | Forage consumed, month | Forage consumed, year |
|---|---|---|---|---|
| Cow, dry | 0.92 | 24 | 727 | 8,730 |
| Cow, with calf | 1.00 | 26 | 790 | 9,490 |
| Bull, mature | 1.35 | 35 | 1,067 | 12,811 |
| Cattle, 1 year old | 0.60 | 15.6 | 474 | 5,694 |
| Cattle, 2 years old | 0.80 | 20.8 | 632 | 7,592 |
| Horse, mature | 1.25 | 32.5 | 988 | 11,862 |
| Sheep, mature | 0.20 | 5.2 | 158 | 1,898 |
| Lamb, 1 year old | 0.15 | 3.9 | 118 | 1,423 |
| Goat, mature | 0.15 | 3.9 | 118 | 1,423 |
| Kid, 1 year old | 0.10 | 2.6 | 79 | 949 |
| Deer, white-tailed, mature | 0.15 | 3.9 | 118 | 1,423 |
| Deer, mule, mature | 0.20 | 5.2 | 158 | 1,898 |
| Elk, mature | 0.60 | 15.6 | 474 | 5,694 |
| Antelope, mature | 0.20 | 52 | 158 | 1,898 |
| Bison, mature | 1.00 | 26 | 790 | 9,490 |
| Sheep, bighorn, mature | 0.20 | 5.2 | 158 | 1,898 |
| Exotic species (To be determined locally | | | | |
| Swine 55 pounds or more* | 0.40 | ND** | ND | ND |
| Swine < 55 pounds* | 0.10 | ND | ND | ND |
| Turkey* | 0.018 | ND | ND | ND |
| Broiler* | 0.008 | ND | ND | ND |
| Laying Hen* | 0.012 | ND | ND | ND |

*Animal units here calculated from 40 CFR 122.23 EPA CAFO definitions

** ND: No Data found for these animals

(i) Some examples of computing animal unit equivalents are:

- 40 mature sheep = 8 animal units (40 x .2)
- 40 mature white-tailed deer = 6 animal units (40 x .15)
- 40 mature bulls = 54 animal units (40 x 1.35)

(ii) Livestock and wildlife summary and data sheet (exhibit 1) is a field tool to collect the data necessary for inventory, husbandry, and nutritional information.

E. Ability of cattle to adjust to fluctuating forage quality

The stomach of the domestic cow reaches full size and maturity by the time the animal is 4 to 5 years old. The size of the stomach and associated organs is dependent upon the nutritional level of the plants the animal grazes during this growth and development period. In areas where the nutritional level of plants is low, the stomach of a mature cow may become large enough to hold 40 to 50 pounds of air-dry forage per day to meet the nutritional needs of the animal. In areas where the nutritional level of vegetation is high, the cow's stomach is small because only 20 to 30 pounds of air-dry forage is required per day. The significance of these factors to livestock operators is:

(i) If the nutritional level of vegetation is low, more pounds of forage are needed per day to support the animal.

(ii) If domestic animals of any age are moved from a pasture of low-quality vegetation to one of high- quality vegetation, the performance response of the animals should be excellent.

(iii) If a mature animal is moved from a pasture of high-quality forage to one of low-quality forage, the digestible protein fraction of the forage the animal must consume rapidly decreases. The performance of the animal will be poor during this time lag. The young animal's performance may not become satisfactory until the animal reaches maturity.

F. Chemical factors affecting forage quality

Depending on the livestock type, animals grazing plants and within plant communities may encounter plant species that can cause low gains, poor reproduction, lowered consumption rates, and toxicity syndromes that can result in death. Toxins that affect animal intake include:

(i) Selenium—A mineral that accumulates by plants growing on soils with high content of this material. Usually only a small amount of plant material is toxic.

(ii) Glycosides—These toxins are in several groups. The most common form is prussic acid or hydro-cyanic acid (HCN). The materials result from cyanogenic glucosides. HCN is released from plants following freezing, wilting, or crushing.

(iii) Alkaloids—These molecules are thought to be utilized for plant defense and to prevent herbivory. Alkaloids will typically interfere with animal nervous systems. Animals generally cannot be treated to prevent these reactions.

(iv) Grass tetany

This condition is caused by a deficiency of calcium and magnesium caused by rapid growing plants during cold and cloudy weather, or a diet low in magnesium during a period of high need for this mineral.

(v) Copper

Should not be part of the mineral mix since it is toxic to sheep (U of ME).

G. Intake

(1) Intake declines as forage availability decreases. According to nutrient requirements for cattle (NRC), intake declines by 15 percent when forage availability drops below 1,000 pounds per acre. However, when forage availability is above this amount, then digestibility normally controls intake. Studies vary greatly, and reports range from 120 pounds per acre to 5,000 pounds per acre. This indicates that although forage availability is an important factor with regards to intake, it has a wide variety of conditions that change between types of animals and kinds of forage.

(2) Herbage intake has been expressed as components of animal behavior by the following equations. These equations provide a conceptual approach to understanding the characteristics of a pasture on the intake behavior and their interactions with animal variables.

(i) Daily herbage intake = Grazing time x Rate of biting x Intake per bite

(ii) Intake per bite = Bite volume x Bulk density of herbage in grazed area Bite volume = Bite depth x Bite area

(3) Biting rate and grazing time are often regarded as the main changes animals adjust if intake quantity is limited per bite. Animals increase grazing time to adjust for intake limitations.

Increasing grazing time is a short-term response and generally does not compensate for reduced intake.

H. Nutrient needs of animals

(1) Animals have a biological priority for nutrients as shown in table H-13. It is interesting in this summary that the animal naturally gives priority to feeding parasites and maintaining its existing condition, rather than prioritizing new growth and new life. The animal really does not give priority to the parasites—the parasites “take” from the animal and leave the animal the residual to meet its needs. This is one reason a parasite control program is so important to producers.

**Table H-13.** Biological priority for nutrients

| Breeding female | Bull | Steer |
|---|---|---|
| Parasites | Parasites | Parasites |
| Maintenance | Maintenance | Maintenance |
| Fetus development | - | - |
| Lactation | - | - |
| Growth | Growth | Growth |
| Reproduction | Reproduction | - |
| Fattening | Fattening | Fattening |

(2) Protein content

(i) Protein is required by rumen micro-organisms to digest forages; therefore, if protein is inadequate, intake will be reduced. Proteins are the principal constituents of the organs and muscles. Protein deficiency is also a major problem. If an animal has an energy deficiency, a lack of protein in its diet aggravates the condition. Protein supplement is often mistakenly advocated when total energy (carbohydrates and fats) intake should be increased. In many range- land areas in fair to excellent range condition, and where adequate dry roughage is available, protein supplement is the only winter supplement needed. See part H(8) for the importance of fecal sampling.

(ii) The qualitative protein requirement is greater for growth than for maintenance and is affected by sex, species, and genetic makeup within species. Most animals tend to eat to satisfy energy requirements. A shortage of protein or energy in the diet prevents the animal from using fully their potential for growth. As the growth rate of muscles and bones is limited, excessive energy intake is converted to fat. Protein is diverted to energy only when it is provided in excess of the metabolic requirement or calorie intake is sufficient.

(3) Carbohydrates

(i) The primary function of carbohydrates and fats in animal nutrition is to serve as a source of energy for normal life processes. The dry matter in plants consists of 75 to 80 percent carbohydrates. Carbohydrates are the major constituents of plant tissues, and the energy in most plants is available largely as carbohydrates. This energy provides the animal the nutrition for growth, maintenance, and production. Energy deficiency is a major problem and usually occurs when animals do not get enough to eat. Increasing the animals' total feed intake can bring about dramatic recovery from many so-called minor element deficiencies and diseases.

(ii) Maintenance requirements for dry animals are significantly less than those for lactating animals. About 20 days after an animal gives birth, the megacalories of energy required are 150 percent of those required before parturition. The needs of mother and offspring immediately before weaning are 200 percent of those of the dry mother.

(4) Vitamins and minor elements

In addition to carbohydrates, proteins, fats, minerals, and water, vitamins (organic compounds) are required by animals in small amounts for normal body functions, maintenance, growth, health, and production, and they regulate the use of major nutrients. Vitamins must be provided to animals for many metabolic reactions within cells. If the vitamins are not available, biochemical reactions cannot take place and such symptoms as loss of appetite, poor appearance, reduced growth, and feed utilization may occur.

(5) Minerals

(i) Minerals have three functions:

- Calcium and phosphorus are the main constituents of bones and teeth.
- Present as electrolytes in body fluids and soft tissues.
- Trace elements are integral components of certain enzymes and other important compounds. These trace elements serve as activators of enzymes.

(ii) Animals derive most of their mineral nutrients from forages and concentrate feeds they consume. The concentrations of minerals in forage depend upon the following factors:

- Species of plant
- Composition in the soil where plant is growing
- Stage of maturity
- Climatic conditions
- Agricultural treatments such as fertilizer and irrigation

(6) Importance of water on nutrition

(i) Water is a major component of the animal's body and is influenced by several such factors as species, age, and dietary conditions that effect the amount in the body. Animals are more sensitive to the lack of water than food. If water intake is limited, the first indication is feed intake is reduced. As water intake becomes severely limited, weight loss is rapid, and the body dehydrates. Dehydration with a loss of 10 percent is considered severe, and a 20 percent water loss results in death.

(ii) Insufficient or poor-quality water causes poor livestock performance. Water requirements are influenced by diet and environmental factors. Water consumption is generally related to dry matter intake and rising temperature (table H-14, figure H-10, and table H-15). As the temperature increases, water consumption increases and feed intake decreases. The three sources of water are:

- drinking water
- water contained in foods
- metabolic water

(iii) Green forages and silage contain 70 to 90 percent water and make significant contributions to the animal needs. Concentrates and hay contain about 7 to 15 percent water.

(iv) Metabolic water is produced by metabolic processes in tissues through the oxidation of nutrients within the body. The utilization by the body of ingested food substances and of tissue reserves yields among other things quantities of metabolic water. As the complete combustion of 100 gm. of fat produces about 110 gm. of metabolic water, whereas 100 gm. of carbohydrate yields only 55 gm. of water, fat reserves and fatty foods are believed to be particularly valuable as a protection against desiccation. This contention would appear to be supported by the fact that many animals which exist in deserts have large reserves of fat. (Mellanby, K. 1942).

(iv) Water quality and quantity are extremely important and can affect the animal's feed intake and animal health. Low quality water normally results in reduced water and feed consumption. New sources of water should be tested for nitrites, sulfates, total dissolved solids, salinity, bacteria, pH, pesticide residue, and other contaminants. Table H-16 is a suggested guide for water quality standards for livestock.

(v) Nitrites can kill animals if ingested in high enough dosages. They are absorbed into the blood stream and prevent the blood from carrying oxygen, thus the animal dies from asphyxiation. Nitrates at lower amounts cause reproductive problems in adults and lower gains in young animals. High sulfates and high total dissolved solids cause diarrhea. Toxicity caused by saltwater upsets the electrolyte balance of animals. Bacterial causes calf losses, reduced feed intake, increased infections, and diarrhea. Acidic water (< 5.5) or alkaline water (> 8.5) can cause acidosis or alkalosis. These affected animals usually go off feed, get infections easier, and have fertility problems. Pesticides are not directly harmful to livestock, but the meat or milk produced by them may be contaminated if not broken-down during digestion or eliminated from the animal.

**Table H-14.** Expected water consumption of various species of adult livestock in a temperate climate*

| Animal | Gal./day |
|---|---|
| Beef cattle | 6–18 |
| Dairy cattle | 10–30 |
| Sheep and goats | 1–4 |
| Horses | 8–12 |
| Adult and market swine | 1.5-3 |
| Adult and market poultry | 2X weight of feed consumed |

*During heat stress situations, these upper limits can increase dramatically

**Table H-15**. Water requirements for swine by size of animal. Source: PSU Extension Swine Production Manual. June, 2005. https://extension.psu.edu/swine-production.

| Animal | 12-30 lb | 30-75 lb | 75-100 lb | 100-240 lb | Sow & Boar | Lactating Sow |
|---|---|---|---|---|---|---|
| Intake (quarts/day/head) | 1 | 2 | 5 | 6 | 8 | 10 |

**Figure H-10.** Water requirements of Indian and European cattle as affected by increasing temperatures (source: Winchester and Morris 1956).

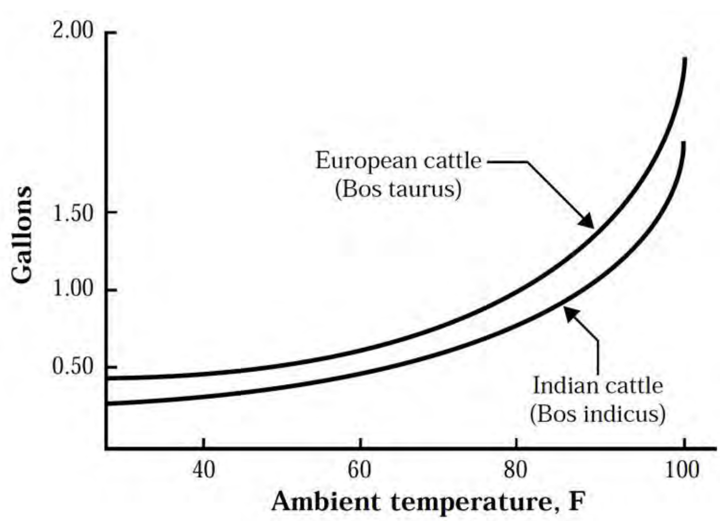


**Table H-16.** Water quality standards for livestock

| Quality category | Limit to maintain | Upper limit production |
|---|---|---|
| Total dissolved solids (TDS), mg/L | 2,500 | 5,000 |
| Calcium, mg/L | 500 | 1,000 |
| Magnesium, mg/L | 250 | 500+ |
| Sodium, mg/L | 1,000 | 2,000+ |
| Arsenic, mg/L | 1 | ? |
| Bicarbonate, mg/L | 500 | 500 |
| Chloride, mg/L | 1,500 | 3,000 |
| Floride, mg/liter | 1 | 5 |
| Nitrate, mg/liter | 200 | 400 |
| Nitrite | none | none |
| Sulfate | 500 | 1,000 |
| Range of pH | 8.0–8.5 | 5.6–9.0 |
| Salinity threshold concentrations in PPM | | 6,435 for horses<br>7,150 for dairy cattle<br>10,000 for beef cattle<br>12,900 for sheep |

(7) Nutritional deficiencies in animals

(i) The two primary causes of nutritional deficiencies in animals are those resulting from poor management and feeding practices and those caused by low-quality forage resulting from mineral deficiencies in the soil. Nutritional deficiencies resulting from low-quality forage can be corrected rapidly by supplemental feeding. Inadequate protein is probably the most common of all nutrient deficiencies because most energy sources are low in protein and protein supplements are expensive. Correcting soil deficiencies by applying the needed minerals requires time for the soil and plants to respond before the nutritional deficiency is corrected. This is seldom an economically feasible option to supply minerals needed by grazing animals.

(ii) Nutritional profile of a cow year

Producers need to be aware of the nutritional requirements of livestock and how requirements change throughout the year as well as the changes in animal unit equivalents (AUE). Animal size, stage of production, production goals, environmental factors, and body condition influence the requirements through the year. Example 1 profiles of a 1,000-pound Hereford cow for a year. In the example, 1 month represents each quarter of the cow year.

(8) Fecal sampling

Application of Near Infrared Reflectance Spectroscopy (NIRS) analysis of fecal samples gives the manager the opportunity to review nutrient composition of the forage plants ingested by the animals. The analysis provides the manager a percent crude protein and percent digestibility in the fecal sample. This offers information to make necessary adjustments to feed amount and types.

**Example 1.** Nutritional profile of a cow year

**Period 1. (May)**
80 to 90 days post calving.
Most critical period in terms of production and reproduction.
Nutrient requirements are greatest during this period. If nutritional requirements are not meet during this period, the results are:

- Lower milk production
- Lower calf weaning weight
- Poor re-breeding performance

Animal unit equivalent = 1.00
Dry forage consumption = 26.00 oven dry weight pounds of forage per day. Calf is 0.06 AUE, and consumes 1.8 pounds of forage per day

**Period 2. (August)**
Cow is now pregnant and lactating.
Animal unit equivalent = 0 .9546 for this animal and 0.051 for the 90-day calf
Forage consumption = 23.98 oven dry weight pounds of forage per day for cow and 1.35 pounds of forage for the calf.
With a 200-day old calf, 6.9 pounds of forage.

**Period 3. (November)**
Post weaning and mid gestation. Animal unit equivalent = .91
Forage consumption = 23.8 oven dry weight pounds of forage per day

**Period 4. (February)**
50 to 60 days prior to calving. Fetal growth at maximum.
Animal is fed 1.5 pounds of 20 percent breeder cubes, 2.0 pounds of grade 2 corn, and 16 pounds alfalfa hay. Animal can graze free choice in the pasture.
Animal unit equivalent from the concentrates = .123, the hay is .54 and the forage in the pasture represents .23 for this animal during this period.
Consumption = 3.2 pounds of concentrate, 14.1 pounds of hay, and 5.9 pounds of dry forage per day from the pasture.

Young animals also have higher requirements to meet growth requirements plus maintenance.

## 645.0805 Feedstuffs

The composition of feedstuffs is broken into six fractions, five of which are determined by chemical analysis and the sixth (nitrogen-free extract) is determined by calculation of the differences of the other five. The six fractions are water, crude protein, crude fat, crude fiber, nitrogen-free extract, and ash. The actual feed values of a feed cannot be determined by only chemical analysis. Allowances for losses during digestion, absorption, and metabolism must be made., as well as overall cattle performance.

(1) Water content is determined for a feed by placing it in an oven at 105 degrees until dry or by drying in a microwave oven. Water content is used for analytical comparison of different feeds.
(2) Crude protein is calculated from the nitrogen content of the feed determined by the Kjeldahl procedure. Proteins contain an average of 16 percent nitrogen, so the crude protein is determined by multiplying the nitrogen figure by 100/16 or 6.25.
(3) Crude fat is determined by extracting the sample with ether. The residue after the evaporation of the solvent is the ether extract or crude fat.
(4) Crude fiber is determined by subjecting the ether extracted sample to successive treatments with boiling dilute acid and base. The insoluble residue remaining is the crude fiber.
(5) Nitrogen-free extract is made up of carbohydrates, such as sugars and starch.
(6) Ash is determined by burning the feed at a temperature of 500 degrees Celsius, which removes the organic compounds. The residue represents the inorganic compounds of the feed or the ash content.

## 645.0806 Husbandry

A. Supplementing forage deficient in nutrients. The purpose of supplemental feeding on grazing lands is to correct deficiencies in protein or other essential nutrients in the forage.

B. Protein supplement. The amount of protein supplement required per animal each season varies tremendously. Once protein supplemental feeding is initiated, the feeding rate must be sufficient to meet most of the animal’s requirements and it must be continued until protein levels of available forage become adequate to meet the requirements of the animal. Insufficient amounts of protein supplement may be more detrimental to the animal’s performance than no protein supplement. The micro-organisms in the stomach of a ruminant adjust to break down the low-quality proteins in dry mature forage. Introducing insufficient amounts of a supplement containing highly soluble protein alters the kinds and numbers of rumen microflora, so they become less effective in utilizing the less soluble protein of mature forage. The total amount of digestible protein used by an animal may thus be less than if no supplement had been fed.

(1) An example for feeding protein to cattle is 41 percent crude protein (CP) cottonseed cubes or 43 to 48 percent CP soybean meal (use caution in feeding cottonseed in excess due to toxicity, especially for immature lambs, calves, kids, and piglets). Feeding these protein supplements, coupled with adequate amounts of dormant vegetation, is generally an efficient method of providing supplements to cattle. If any supplement mixture other than the two mentioned is fed, consideration should be given to the following:
   (i) Cost per pound of digestible protein in mixtures, compared with that of cottonseed or soybean derivatives.
   (ii) Quality of the product.
   (iii) Effectiveness of mixture in balancing the needs of the animal with the kind of vegetation grazed.
   (iv) Possible detrimental effects of the mixture to domestic animals and big game animals.

(v) Value of added trace elements and vitamins in mixture.

(vi) Labor requirements.

(2) Feed additives

(i) A feed additive is an ingredient or combination of ingredients added to the basic feed mix or parts thereof to fulfill a specific need. Additives are used to stimulate growth or other types of performance or to improve the efficiency of feed utilization or be beneficial to the animal's health or metabolism. The various groups of additives classified as drugs include: antibiotics, nitrofurans, sulfa compounds, coccidiostats, wormers, and hormone-like compounds. Some additives reduce impacts on GHG emissions, refer to CPS 592 Feed Management.

- Antibiotics–These compounds are produced by micro-organisms that have the properties of inhibiting the growth or metabolism of organisms that may be toxic to animals. Two antibiotics approved in recent years are monensin (refer to label; especially if rotating cattle or goats with other livestock; fatal in sheep, turkeys and horses) and lasalocid, which are rumen additives. These additives shift the rumen volatile fatty acid production to propionic acid and a reduction of methane production, which results in more efficient and improved gain in growing and adult animals on pasture or forage.
- Feeding protein supplements–Methods of feeding protein supplements include:
  - Mixing salt with protein supplement to control intake.
  - Blending urea with molasses.
  - Use of protein blocks.
  - Use of range cubes or pellets (soybean or cotton-seed).
  - Use of cottonseed or soybean meal.

(ii) General feeding rules are:

- Substitute 3 pounds of corn silage for 1 pound of alfalfa-grass hay.
- Substitute 3 pounds of alfalfa-grass hay for 1 pound of grain.
- During winter feeding, provide warm drinking water in cold areas so that energy from the animal's body is not needed to warm the water. Livestock will drink more water, which improves general health and performance.
- Livestock shelter structures should be considered when weather stress is a factor; reducing impacts of weather stress will improve animal performance and feed efficiency.

  If riparian areas are used for winter protection, exercise caution or install measures to avoid excessive physical damage to the woody vegetation and streambank.

(3) Minerals and vitamins

(i) In some areas livestock may need minerals, such as phosphorus, calcium, or magnesium, and trace elements including manganese, selenium, molybdenum, copper, and iodine. To be effective, the minerals should be made available to both mother and off- spring.

(ii) Phosphorus supplements include dicalcium phosphate, steamed bone meal, or polyphosphate mixtures. They are normally fed in a mixture of one part of salt to two parts of supplement. If phosphorus is supplemented, calcium needs of the animals are generally satisfied. The calcium to phosphorus ratio needed by cattle is 2-parts calcium to 1-part phosphorus. Calcium is usually readily available, and supplemental minerals being fed should be at a 1 to 1 or 1.5 to 1 ratio, depending on livestock type.

(iii) Magnesium is very unpalatable and must be mixed with an enticer for animals to consume it.

(iv) Copper, depending on livestock type, is often needed as a trace mineral in peat soils, as found in some marsh rangelands.

(v) Vitamin A is often needed if animals graze mostly dormant, dry vegetation. The intramuscular injection is effective in providing enough amounts of vitamin A. It generally provides vitamin A for a 3-month period.
(vi) Local needs should be established, as applicable, relative to the kinds and amounts of minerals required.

C. Proper location of salt, minerals, and supplemental feed

Properly locating salt and minerals (and supplemental feed if required) in properly fenced and watered pastures encourages good distribution of grazing. They should be placed in areas to ensure that all parts of the pasture are uniformly grazed. Portable feeders permit salt and minerals to be moved from place to place in the pasture, thus making it possible to adjust grazing use according to utilization patterns. Salt and minerals should not be placed adjacent to livestock water. The number of salting locations needed depends on the size and topography (tables H-17 and H-18) of the pasture and on the number and kind of livestock using the pasture.

**Table H-17.** Approximate number of animals at one salting location to provide enough salt and minerals on different terrain.

| Animal number | Type of terrain |
|---|---|
| 40 to 60 cattle<br>125 to 200 sheep or goats | Level to gently rolling range |
| 20 to 25 cattle<br>100 to 150 sheep or goats | Rough range |

**Table H-18.** General salt requirements for grazing animals.

| Animal | Pounds per month |
|---|---|
| Cows | 1.5 to 3 |
| Horses | 2 to 3.5 |
| Sheep and goats | 0.25 to 0.5 |

## 645.0807 Control of Livestock Parasites and Diseases

Effective control of parasites living in and on livestock is needed for efficient livestock production. Some tools that aid in controlling parasites and diseases are:

(1) Grazing system designed to use grazing units or pastures during different seasons, periods, or months in subsequent years or in the same year aid in disrupting the cycle of internal parasites.
(2) Resting pastures for a minimum of 20-day periods and grazing plants no closer than 4 inches from the ground to break stomach-worm life cycles. Longer rests may be needed for more sensitive animals like goats and sheep.
(3) Clean water.
(4) Calving, lambing, or kidding at a period of the year when losses from parasites can be reduced.
(5) Adequate control programs to reduce parasite problems.
(6) Cattle dusters, backrubbers, and other insect-control devices. (These devices often help to improve grazing distribution and to control livestock movement.). For goats and sheep use the FAMACHA score card and change up the active ingredient.

## 645.0808 Regulating the Breeding Season for Efficient use of Forage

A. Controlled breeding program. For efficient use of forage, a breeding program should be compatible with the existing (or planned) forage production program. By controlling the time of breeding, the period of optimum growth for the animals to be marketed can be synchronized with the period of peak quality and optimum growth of forage. The local climate is often the limiting factor when attempting to correlate the breeding and forage production programs. Although NRCS personnel are not to make an issue of this fact, they should call to the attention of livestock producers the opportunities that controlled breeding provide, especially where it could result in an improvement in the duration and timing of grazing.

(1) Advantages of controlled breeding are:
(i) Offspring are generally heavier at a given age and are in a better bloom at market time if they can graze throughout the growing season.
(ii) Females are usually in better condition when they go onto mature forage. The herd winters with less care, and the need for supplemental feed is reduced.
(iii) Animals are more uniform in size and quality at market time and generally demand better prices.
(iv) Barren and sterile animals can be identified and eliminated rapidly.

(2) Disadvantages of noncontrolled breeding. Many livestock producers leave males and females together throughout the year. The disadvantages are:
(i) Less efficient use of vegetation.
(ii) Lower calving and lambing rates and greater difficulty in culling slow breeders.
(iii) Higher labor costs.
(iv) Greater feed costs.
(v) Less efficient marketing because of nonuniformity in size of animals.
(vi) Greater difficulty in manipulating livestock in planned grazing systems.
(vii) Greater chance of adverse weather, both heat and cold, deterring optimum offspring growth.

B. Factors in planning a breeding program

(1) The following factors need to be considered in planning a program of controlled breeding:
(i) Birth of offspring should be scheduled to occur when adverse climatic conditions are likely to be minimal.
(ii) Variability in breeds and in the ability of their young to adjust to adverse climatic conditions.
(iii) Parturition should occur when the chances of seasonal diseases and parasite problems are less likely.
(iv) Female to male ratio; more bulls may be required for a 2- to 4-month breeding season to ensure adequate female exposure to available breeding males.

(2) Breeding season for ewes and nannies: Ewes and nannies are generally bred within a 60-day period (three heat cycles). Lambs and kids should be old enough at the time of vegetation green-up date to enable them to use the increased milk produced by their dams and to take advantage of the forage. If controlled breeding is practiced, one buck (ram) or billy is generally enough for every 25 to 30 ewes or nannies.

(3) Breeding season for cattle
(i) The opportunity for a uniform calf crop may be obtained if the breeding period is limited to 60 to 90 days (3 to 4 heat cycles). Calving times should meet the operator's objectives and correspond to the forage availability, supply, and nutrient content. Calving periods can start 60 to 90 days before the grass green-up date. The calves can take full advantage of increased milk production, and the cows will be in condition to

breed back. Breeding should start within 85 days after calving, or calves will be born progressively later each year.

(ii) If controlled breeding is practiced, one sire is generally adequate for every 20 to 25 females. The number of cows per bull ranges from 15 to 30 depending on the age, condition, management, libido, and semen quality of the bull; the size, condition, and topography of the pasture; and the distribution of the water supply.

(iii) Artificial insemination may be used in the cattle industry. A follow-up bull is generally used with each 100 cows to breed those that fail to conceive after one or two services.

(4) Reproduction characteristics. Table H-19 gives the reproduction characteristics of domestic animals. Table H-20 shows the ages of puberty for animals.

The practice of breeding for two calving and lambing seasons consists of dividing the breeding herd into two groups. One group is bred to calve or lamb in the fall and the other in the spring. Advantages include the need for fewer males and reduced labor requirements. This practice also permits two marketing periods.

(5) Additional factors in livestock breeding and selection

(i) All livestock should be bred, raised, and performance tested under the environmental conditions in which they are to be used. Because of the effects of heterosis, crossbred females usually reach productive ability at an earlier age, reproduce more regularly, and live longer, more productive lives than straight breeds of similar quality. Improved milking and mothering ability is another advantage of planned crossbreeding programs.

(ii) In selecting breeding animals for range and pasture, the following significant qualities should be considered. The list, however, is not in order of importance. For example, in Louisiana marshes we recommended that the most important quality is hardiness or environmental adaptability.

- Disposition
- Fertility
- Weight
- Rate of gain
- Conformation
- Hardiness, or environmental adaptability
- Milk production capability

**Table H-19.** Reproduction characteristics of domestic animals

| Species | Heat period | Heat cycle (days) | Gestation period (days) | Females per male (number) |
|---|---|---|---|---|
| Horses | 6–7 days | 22 | 336-340 | 15-30 |
| Cattle | 12–18 hours | 19.5 | 283 | 25 average |
| Sheep | 29–36 hours | 17 | 142-150 | 25 or more |
| Goats | 24–26 hours | 20–22 | 151 | 25 or more |

**Table H-20.** Ages of puberty for domestic animals (U.S. conditions)

| Animals | Age of puberty |
|---|---|
| Horses | Second spring (yearling) |
| Cows | 5 to 13 months (depending on breed and condition) |
| Sheep | First fall |
| Goats | 7 to 8 months |

## 645.0809 Animal behavior

A. Knowledge of animal behavior is important to understanding the whole animal and its ability to adapt to various environments and management systems. The value and performance of animals can be increased when managers can apply their knowledge of animal behavior. The behavior of animals is a complex process that involves the interactions of inherited abilities and learned experiences to which the animal is exposed. Changes in behavior of the animal allow for adjustments to external or internal change in conditions. They also improve efficiency and survival.

(1) Behavior is a function of its consequences, and consequences of behavior depend upon heredity and environment. Managers that understand the behavior of animals can adjust their management and even train animals to be more efficient and effective in the areas they graze.

(2) Animals have instinctive reflexes and responses at birth and also learn by habituation to respond without thinking. Their responses to certain stimulus become established as a result of continued habits. Animals are also conditioned by responding to positive and negative responses. Animals learn or develop behavior patterns through various processes of trial and error, reasoning, and imprinting. The two kinds of conditioning are:

(i) Classical conditioning —learned association between a positive stimulus and a neutral stimulus. For example, when an animal sees you carry feed to them and then reacts the same way when the animal hears the door open in the barn where the food is kept.

(ii) Operant conditioning—learning to respond a certain way as a result of reinforcement when the correct response is made. Livestock avoiding an electric fence is operant conditioning.

B. Systems of behavior.

Animals exhibit several major systems or patterns of behavior:

(i) sexual
(ii) care-giving
(iii) care-soliciting
(iv) agnostic
(v) ingesting
(vi) eliminative
(vii) shelter-seeking
(viii) investigative
(ix) imitative behavior

C. The systems of behavior that most affect the animal well-being and productivity are ingesting, eliminative, and diet selection.

(1) Ingesting behavior

(i) Ingesting behavior is when animals eat and drink. Ruminants graze and swallow their food as soon as it is well lubricated. After they have consumed certain amounts they ruminate. Cattle usually graze for 4 to 9 hours a day and sheep and goats for 9 to 11 hours a day. Animals usually graze, then rest and ruminate.

(ii) Sheep rest and ruminate more than cattle. Cattle ruminate 4 to 9 hours a day and sheep 7 to 10 hours a day.

(iii) Cattle, sheep and horses have palatability preferences for certain plants, and have difficulty changing from one type of vegetation to another. Most animals prefer to graze the lower areas, especially near the water.

(iv) Age of the livestock and weather can also affect their grazing behavior. Cattle graze less when temperatures are low, and younger animals graze even less than older ones.

Colder temperatures also delay starting grazing times. Table H-21 shows the activities of a cow on winter range.

**Table H-21.** Behavior of a cow on winter range

| Activity | Hours |
|---|---|
| Grazing | 9.45 |
| Ruminating, standing | 0.63 |
| Ruminating, lying | 8.30 |
| Idle, standing | 1.11 |
| Idle, lying | 3.93 |
| Traveling | 0.58 |
| **Total** | **24.0** |

(2) Eliminative behavior
Cattle, sheep, and goats eliminate their feces and urine indiscriminately. Cattle defecate 12 to 18 times per day and horses 5 to 12 times per day. Both urinate 7 to 11 times per day.

(3) Diet selection
Herbivores are able to select a balanced diet, when given choices, even though their nutritional requirements vary with age, physiological state, and environmental conditions. The behavior of animals affects their response to nutrients in foods (intake and digestibility). As long as forage intake is not limited because of the quantity of forage, the primary factor influencing animal performance is forage digestibility. The behavior of animals affects their response to toxins in foods (toxicity).

## 645.0810 Exhibits

**Exhibit 1.** Livestock and wildlife summary and data sheet

| Kind | Number of animals | Breed type | Class | Animal unit eq. or weight | Average body condition score | Age | Breeding age | Breeding period | Calving date | Grazing demand months | Roughage demand months | Supplement kind and Amount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 125 | Angus | Cow | 980 | 4.5 | 5–10 | 2.5 yrs | May–July | Feb–Apr | Mar–Nov | Dec–Feb | 20% protein |
| Cattle | 30 | Angus | Heifer | 600 | 5.0 | 2 | 2.5 yrs | May–July | Feb–Apr | Mar–Nov | Dec–Feb | 20% protein |
| Cattle | 7 | Angus | Bull | 1500 | 4.5 | 5 | 2.5 yrs | May–July | | Mar–Nov | Dec–Feb | 20% protein |
| Cattle | 100 | Xbreed | Steer | 500 | 4.0 | 1 | | | | Mar–Nov | | |
| Deer | 50 | mule | Mature | 175 | | | | Nov | May | Jan–Dec | | |
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| **Total** | **287** | | | **201AU** | | | | | | **9 mon.** | | |
| **Total AUMs** | | | | | | | | | | **1817.25** | | |

**Worming schedule**
**Vaccination dates**
**Growth hormones**
**Shearing date**

Livestock and wildlife summary and data sheet

| Kind | Number of animals | Breed type | Class | Animal unit eq. or weight | Average body condition score | Age | Breeding age | Breeding period | Calving date | Grazing demand months | Roughage demand months | Supplement kind and Amount |
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**Worming schedule**
**Vaccination dates**
**Growth hormones**
**Shearing date**

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# Part 645 – National Range and Pasture Handbook

## Subpart I – Wildlife Management on Grazing Lands

### 645.0901 General

A. Wildlife occurrence and populations (numbers) are generally dependent on land use patterns in the region. Wildlife, in the broadest sense, represents all fauna, with the exception of domesticated or caged animals. Many State agencies subdivide the responsibilities of the State fauna between

(1) birds and mammals as wildlife
(2) cold-blooded aquatic species as fish
(3) invertebrates as insects

B. NRCS implements an inclusive concept of the term "wildlife," which includes aquatic fauna (fish and aquatic invertebrates) as wildlife. The wildlife habitat potential on grazing lands is dependent on the site potential, the adjacent land use and condition, and the habitat condition on the grazing operation. Willing landowners can strategically manipulate the vegetative communities with equipment, herbicides, or grazing intensity to improve the quality of the wildlife habitat. It is worth noting that those same tools (equipment, herbicides, and grazing) can result in degradation of habitat. For example, mowing too often or at the wrong time of year benefits non-native grass species that are common to the United States: smooth brome, old-world bluestems, cheat grass, Bahia grass, Bermuda grass, and fescue. If wildlife habitat is identified as a resource concern, the conservation planner uses information from the resource inventory, coupled with understanding of the client objectives, to identify opportunities for habitat improvement. These opportunities are presented to the land managers as alternatives.

C. The discipline of wildlife management involves population management (hunting or take restrictions, stocking, etc.), habitat management, and people management. The management of wildlife is the responsibility of the State Game and Fish agency (or similar entity), the U.S. Fish and Wildlife Service, or the National Marine Fisheries Service. The NRCS role is limited to providing technical assistance with the assessment and management of habitat. On most grazing lands, the operation relies on revenue from the sale of livestock, and profitability is a consideration of any decision. However, particularly on native grasslands, the management techniques for sustainability of forage production are also beneficial to those wildlife species that evolved on native grassland habitats. Conservation planning on grazing lands might include implementation of conservation practice standards directly for wildlife (e.g., Wildlife Habitat Planting; Code 420), or the conservation planner addresses wildlife concerns by presenting alternatives that will minimize the impacts of the installation of non-wildlife conservation practices. That assistance may or may not include a specific wildlife habitat management plan, as part of the overall conservation plan. Regardless, any wildlife habitat management planned and applied is the ultimate decision of the land manager in keeping with his or her overall objectives related to their grazing operation.

D. When it is the desire of the manager of grazing lands to improve existing wildlife habitat, a wildlife habitat management plan or actions are included as components of the conservation plan and should be developed and implemented in association with the client's grazing strategy. Wildlife habitat potential varies widely on different types of grazing lands. On grasslands supporting primarily native grasses and forbs, and on grazed forest (i.e., silvo-pasture), the plant community can often, but not always, be more easily managed to allow for moderate and high-quality habitat. However, many of these native grasslands have been invaded by noxious or invasive species, such as smooth brome, cheatgrass, and old-world bluestems. Erosion, soil compaction, or overuse may also result in a monoculture of native plants, drastically limiting both the value and the potential to produce quality wildlife habitat.

E. The implementation of wildlife habitat management plans on pasture is also made more difficult. As with other intensively managed land uses, the target condition often includes implementing “best management practices” to mitigate the impacts of pasture management to resident wildlife, along with establishing some set-aside habitat of higher quality. Most NRCS State offices have developed documents that provide wildlife “BMPs” for pasture and hayland. By policy (National Biology Manual), if wildlife is identified as a resource concern, the mitigation measures on pasture (e.g., delayed mowing, mowing patterns, and deferment) are those needed to meet the minimum score of 50 percent on the State approved wildlife habitat evaluation guide (WHEG). Assistance in the application of a State NRCS WHEG is available from NRCS area or State biologists. In some States, partner biologists are available to provide support to the conservation planner and client to meet their objective to create, maintain, limit impacts, or improve wildlife habitat.

F. Assessment and planning of wildlife habitat are unique to most other planning considerations because wildlife are free ranging, by definition, typically acquiring significant life needs on adjacent lands, not under the control of the client. This may include lands in adjacent States and countries for migratory wildlife species. Thus, a single farm or ranch very rarely provides all of the life needs of a local wildlife population. Additionally, wildlife habitat is commonly of secondary concern on grazing lands, adding complexity to the planning process.

G. When wildlife habitat management has been identified by the client as an objective, herbivorous wildlife species may need to be considered because they can affect forage resources available for livestock management. Wildlife species and domestic livestock are selective consumers, with diets depending on morphological and physiological adaptations of the species. Diet composition for wildlife varies by season and location in response to the variability of the quantity and quality of food sources available.

H. Some species of wildlife have become so greatly reduced in number or extent and are threatened with extinction. When threatened and endangered (T&E) species are of concern, NRCS shall follow agency policies to assure that the NRCS technical or financial assistance meets the mandates of the law.

## 645.0902 Technical Assistance to Landowners and Managers

A. NRCS policy and procedures for assisting land managers, local units of government, and others in planning and applying wildlife habitat management on private and other non-Federal land are in the National Biology Manual.

B. Technical assistance is provided according to the provisions in the National Planning Procedures Handbook (NPPH) and the nine-step planning process. The NPPH aids NRCS planners in providing alternatives and assistance during the conservation planning process to address all resources recognized by NRCS, including wildlife, on all land units. Procedures for providing wildlife management assistance are described in the following sections.

(1) Determine objectives

(i) Each farm and ranch operation is different, and seldom are the long-range plans and objectives of different landowners the same. A good understanding of the livestock, wildlife, economics, and management aspects of the ranch or farm is the foundation to effective decision making. The planner needs to ask the landowner or manager which wildlife species or guild they want to target with their management efforts. The planner should also determine if their interest is to apply a more holistic approach to wildlife habitat, where the target is not a particular species of wildlife but rather to create vegetative conditions similar to the natural state (e.g., a rich and diverse native plant community infused with periodic disturbance patterns). Additionally, the intensity and extent of the management must be identified in the conservation planning process because the landowner may wish to manage the grazing lands with wildlife as a primary purpose, as a secondary purpose, or only as a consideration. The landowner's objectives should be clearly defined.

(ii) The planner will want to discuss the present capability and potential opportunity for producing and sustaining wildlife populations on the farm or ranch. Some operations are too small or lack the habitat to fully maintain local wildlife populations on the farm or ranch. In these situations, inventorying opportunities to provide part of the life requirements of local wildlife populations and migrants might be part of the planning process. For most wildlife management inventories, presented alternatives, and plans, the consideration of habitats on adjacent lands is required. Neither livestock grazing nor wildlife production can be maximized without affecting the other, and tradeoffs are necessary to optimize either or both. Wildlife management on grazing lands is best accomplished by viewing the livestock as a tool to manage the habitat, and always with profitability of the operation as an essential decision-making component.

(2) Inventory the wildlife habitat components

(i) Terrestrial and Wetland Wildlife. The quantity, quality, availability, and distribution, both seasonally and spatially, of all habitat elements (food, cover, water, and space) determine the habitat quality for a given area of land. There are two general types of wildlife habitat assessments.

- Some NRCS State Offices have approved a few single-species wildlife habitat evaluation guides (WHEGs) to assess habitat conditions (e.g., sage grouse, monarch butterfly). If well designed, these species-based WHEGs are designed to not only identify habitat limitations for the species, but also identify conservation practice standards available to treat the identified habitat limitations. When one or more of these factors are limiting for the target wildlife species, they should be identified, and the conservation plan tailored to remove the limiting factor(s).
- The other type of WHEG is a general wildlife habitat assessment based on land use. These land use-based assessments identify the habitat quality for wildlife in general. The interest and intensity of any inventory depends on the current land use and landform. For example, travel corridors used by upland wildlife typically warrant more consideration than would a large cropland field. Riparian areas always warrant high consideration for wildlife because they serve as corridors and provide unique habitat, being the interface between terrestrial and aquatic systems. Like cropland, improved pastures typically do not require any on-site inventory.

(ii) Plant community information. If wildlife habitat management is identified as an objective of the land manager, the planner will:

- Determine the habitat condition for rangeland, grazed forest, native or naturalized pasture, and "improved" pasture. When available, state-and-transition models associated with Ecological Site Descriptions can inform the planner about whether a particular management will move the plant community toward or away from the desired plant community.
- Appraise the condition and potential for wildlife habitat, giving special attention to food, cover, water, and space, and to their location and season of availability, for the target species or guild.
- Identify and quantify plant species of value to the target species.
- Consider vegetative structure, as it relates to the habitat type and condition.

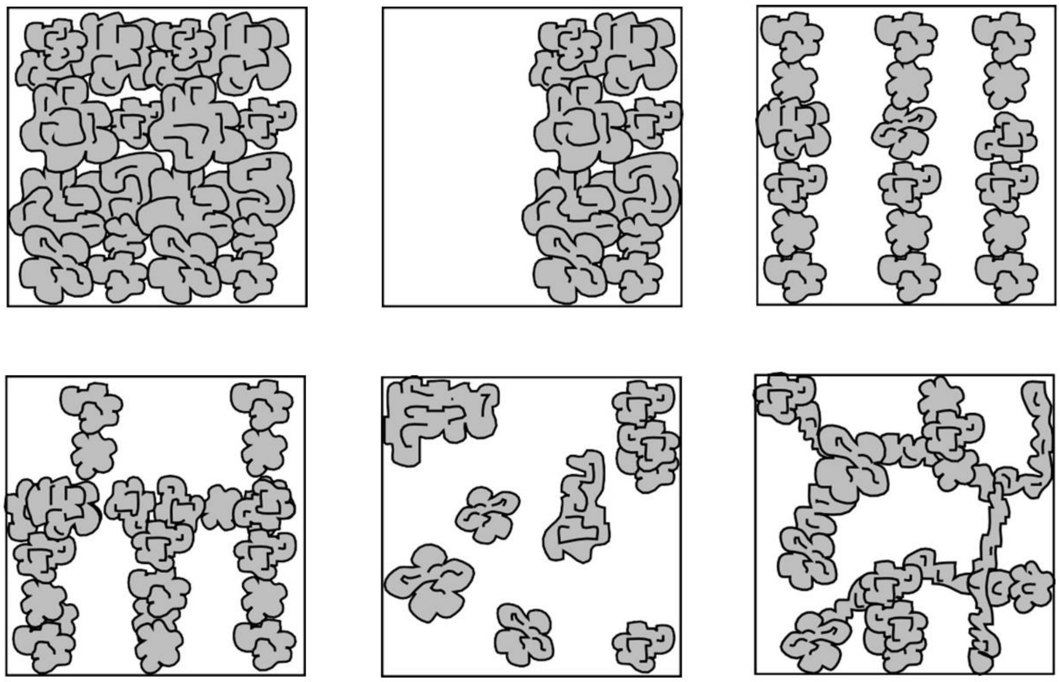
- Consider the objectives of the livestock operation and identify where competition for life needs of target species is occurring.
- Consider other spatial needs, such as interspersion of habitat types, and travel corridors between specific land use cover types and ecological sites. Each wildlife species or guild prefers different levels of species richness, abundance, and evenness. Some prefer edge (where two plant communities adjoin), while other wildlife species (interior species) prefer large blocks of similar habitat. Many species are particularly sensitive to the occurrence of woody plants. Others have very limited mobility (e.g., reptiles and amphibians), living their entire life in a very small habitat area. Because different species have vast variability in preferred habitat characteristics, the identification of the target species or guild is essential.

    As an example, in semi-arid and arid systems, brush management (Code 315) is a common conservation practice standard implemented with wildlife as a consideration. Figure I-1 below provides six different brush management approaches. A specific brush management design will benefit some species and will be detrimental to others. None are better or worse for "wildlife," as the term includes all species of fauna. Each species has a different preference for habitat, including the occurrence and interspersion of woody and grassland habitats. To this point, removal of all brush on a field or operation might be the preferred alternative for some species of wildlife (e.g., lesser prairie-chicken). If available, Ecological Site Descriptions can assist the conservation planner, if the objective is to promote habitat that resembles the historic reference conditions.

(iii) Animal information

- The interactions between species of wildlife and domestic livestock can present the land manager with a complexity of challenges and opportunities. For example, geese can impact grazing lands during winter along the Gulf Coast. Wintering elk and other big game can have similar impacts on some areas in the Rocky Mountain region.
    - Wildlife can also assist farmers and ranchers in reaching their goals. For example, in southern rice fields, winter flooding for waterfowl habitat can reduce red rice populations in a field.
    - The term "competition" is generally used to refer to any interaction that results in a negative outcome for one or more species. Competition for forage and habitat may occur between wild and domestic grazing animals. However, some grazing animals (wild or domestic) are more adaptable in their choice of forage and habitat than others.
- All wildlife species require food, cover, water, and space. To further the planning process, available information should be collected on the requirements of each target wildlife species and the forage utilization of livestock. Gaining as much of these details will provide the landowner with the proper technical assistance.
- Wildlife habitat elements need to be present in a pattern favorable to the target species within the livestock operation business model. Seasonal variations may occur.

**Figure I-1.** Six alternative designs of brush management on grazing lands. Each design will impact wildlife species in different ways. Not provided below is removal of all brush in the planning unit, which might be the most advantageous design for some species.



- Since wildlife species belong to the people of the State, the State wildlife department within each State has the responsibility of administering and managing the State's fish and wildlife resources. If wildlife population management is identified as a concern by the land manager, they should be encouraged to contact federal, State, and local wildlife agency personnel to determine what course of action may be possible within their State.
- NRCS responsibility is to present alternatives to improve habitat or mitigate impacts to local wildlife. The level and scope of habitat management on grazing lands, presented as alternatives to the client, are limited by the interests and abilities of the land manager to implement habitat improvement projects.

(iv) Infrastructure

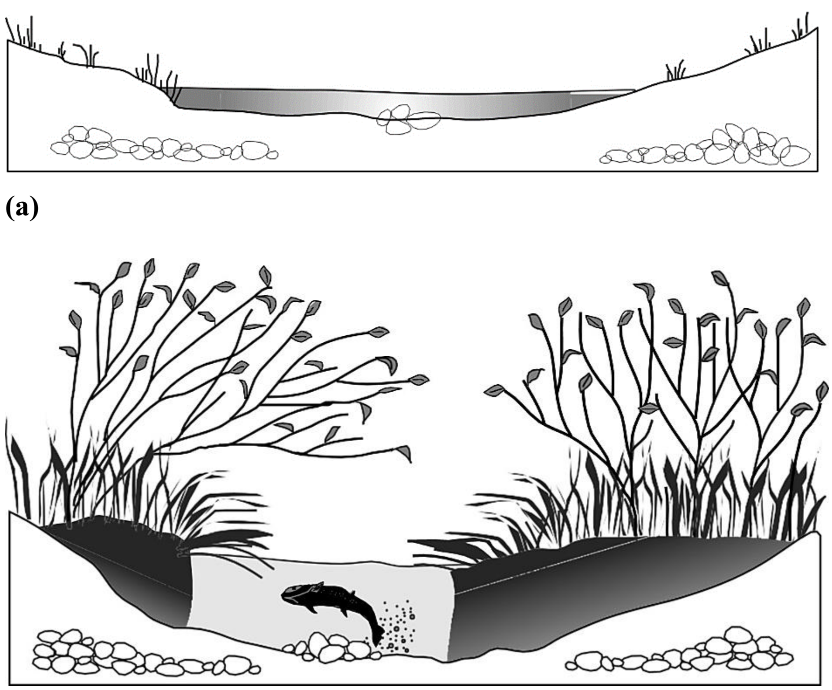
- Water is an essential element to all wildlife species. Some are more dependent on surface water than others. In general, adding artificial water for wildlife is not necessary and can actually lead to an increase in non-desirable plant and animal species distribution and abundance. For example, adding artificial water can increase the occurrence and populations of skunks and racoons into areas where they did not naturally occur (as both require surface water), thereby increasing predation of ground nesting birds adapted to nesting in large blocks of grassland habitat far from free water. When the land manager identifies a target species that relies on surface water, and their home range lacks such a source, then providing a water source may be warranted.
- An inventory of livestock watering facilities can assist in the identification of the potential for wildlife death in some watering facilities, which can have a detrimental impact on the water quality of the livestock water.

- Some wildlife species are particularly sensitive to livestock fencing (e.g., pronghorn antelope). Inventory fences to identify types that are prone to snare, entangle, or limit movement of wildlife. Fencing can often be retrofitted using Conservation Practice Standard, Structures for Wildlife (Code 649), to safely accommodate wildlife movement.

(v) Fish habitat.

- The management of a fish population is dependent upon the availability of water of sufficient depth, temperature, and quality, for the target fish species, coupled with adequate habitat structure. Proper planning and control of grazing are necessary to manage the fish habitat in streams and ponds adjacent to or contained within grazing lands. Management of grazing to assure water quality in receiving waters is necessary not only in the riparian area but also in the upland areas of the watershed. Detailed information is available in the NRCS National Biology Handbook.
- Riparian areas (figure I-2) are extremely important habitat for fish in the receiving waters. Lack of proper management can severely degrade fish and wildlife habitat when the stream channel is altered through trampling and removal or destruction of streamside vegetation.

**Figure I-2.** An altered stream channel in an overused riparian area **(a)** in contrast to a stream channel in a well-managed riparian area **(b)**.



**(a)**

**(b)**

- Streambanks with adequate undercuts, deeper water, and overhanging vegetation that shades the water and lowers the water temperature are desirable for many fish species. The fish population is severely depleted or eliminated where the streambank is altered and has fewer undercuts and less overhanging vegetation and where the water is shallow and has a high sediment load, lower oxygen levels, and a higher temperature. Most fish that live in streams and many that live in ponds depend on the riparian vegetation to:
  - stabilize the banks
  - keep sediment out of the channel

  - supply food in the form of associated insects
  - provide shade to keep the stream from getting too hot
  - provide large woody debris to form pools and hiding cover
  - provide energy to the stream in the form of leaves and other plant material that falls into the stream
  - keep pollutants and nutrients out of the water
- Grazing management can improve water quality in ponds and streams by reducing sediment yields from the drainage area and managing the desired vegetation around the shoreline. Excessive animal numbers can stir sediment, muddy the water by wading and drinking, and increase pollutant levels. Mismanaged grazing around the shoreline can remove valuable shade and cover vegetation for aquatic life.
- A properly planned grazing system must account for the needs of the fish population and its habitat. The intensity, duration, and timing of grazing in the riparian areas, as well as in the entire watershed, should be planned and controlled to meet the objectives. The proper location of fences, mineral supplements, and water developments can be facilitating practices that enhance the manager’s ability to implement a planned grazing system that is ecologically sound while maintaining desirable water quality.

(3) Analyze the needs for improving, restoring, or maintaining wildlife habitat

(i) The planner may use wildlife habitat evaluation guides, ecological site index and transition models, consultation with wildlife professionals, and other appropriate habitat evaluation procedures for the target wildlife species or guild. These tools can assist the NRCS planner and land manager in understanding which habitat elements are lacking.

(ii) Habitat patch size requirements for the target species is an important consideration when identifying conservation planning alternatives.

(ii) Grazing animals, both domestic and wild, select a wide variety of plants from the three major vegetation classifications: grass, forbs, and browse. The vegetation of an area is affected differently by different classes of livestock and different types of wildlife because of differences in foraging behavior.

(iii) The planner can use the technical information from (i) above to assist the landowner or manager in determining whether the area of interest is currently improving, being maintained, or deteriorating, and why. This determination normally includes an evaluation of current and past timing and utilization of plant species and evidence of satisfactory recovery periods to promote vigorous, healthy plant communities capable of sustaining wildlife.

(iv) The planner may also assist the landowner or manager to identify dietary overlap between major wildlife species and livestock. Dietary overlap may be found during critical seasons and may affect breeding, animal development, and survival for the wildlife species. It can also have detrimental impacts to the overall productivity of the livestock. The magnitude of the diet overlaps and the plant and animal species involved should be considered.

(v) As the kinds and amounts of vegetation decrease, competition increases. Competition for plants can also vary as physiological stages of the plants change.

(vi) Some livestock producers may be willing to sacrifice short-term livestock performance and profit to improve wildlife habitat. In these situations, livestock have the potential to serve as an effective tool to shift the plant community to a condition more suitable to the target wildlife species or guild.

(4) Develop and evaluate alternatives

Utilize the information acquired in the inventory to recommend alternatives to improve habitat, where needed. The planning process includes developing and evaluating alternatives to maintain, improve, or develop the desired wildlife populations and habitat. Alternatives are presented for habitat components that are determined to be limiting during the inventory process. This includes plant and animal resources as well as water resources. The grazing lands manager decides which alternative fits within their business operation goals. The NRCS planner will:

- Help the landowner or manager clarify the goals and objectives so that appropriate treatment alternatives are considered in the planning process.
- Provide information on the habitat needs and wildlife potential of the land. Examples of such treatment are:
  - Manipulating kind and class of livestock, season of use, and intensity of use with a prescribed grazing system to provide required food and cover at critical times and locations for wildlife.
  - Planning systems for brush management, such as prescribed burning, to obtain a desirable combination of herbaceous and woody species.
  - Using seed mixtures that produce plants beneficial to wildlife.
- Help the landowner or manager select alternatives to meet their wildlife habitat objectives, while retaining profitability of the grazing lands operation.

(5) Provide follow-through assistance and evaluation

The planner will:

- Provide technical assistance to the landowner or manager in their installation of conservation practice standards.
- Assist the landowner or manager in checking habitat periodically to evaluate trend in habitat components. If appropriate, selection of habitat monitoring protocols can be shared with the client to assist them in determining when adaptive habitat management actions are needed (e.g., weed control, prescribed fire, rest or deferment).
- In follow-up assistance, particular attention should be given to priority areas identified in the planning process (e.g., riparian areas, hedgerows, stream crossings).

# Part 645 – National Range and Pasture Handbook

## Subpart J – Prescribed Burning

### 645.1001 Introduction

A. Fire has played a key role in the formation and maintenance of most ecosystems in North America and the world. Research on rangelands in the United States has revealed that woody shrubs and trees increase, and herbaceous vegetation decreases with long-term fire removal. Periodic fire on rangelands is required to maintain or increase herbaceous vegetation (Fuhlendorf, S.D., et.al, 2011). When executed properly, prescribed burning is a safe and effective way to apply a natural ecological process, promote ecosystem health and reduce the risk of wildfire. Figure J-1 shows some typical prescribed burns.

**Figure J-1.** Prescribed burns.

*Photo Courtesy of Noble Research Institute*

B. NRCS has technical responsibilities to assist private landowners and managers to use prescribed burning as a conservation resource management alternative. Fire can positively affect multiple ecological conservation resource concerns such as soil health, plant structure and composition, plant productivity and health, wildlife habitat, and facilitates distribution of grazing and browsing animals. Prescribed burning can also reduce plant pest pressure, invasive species, and wildfire hazards from biomass accumulation (NRCS CPS 338, 2020). Figures J-2, J-3, and J-4 show planning a burn, starting a burn, and controlling a burn.

**Figure J-2.** Prescribed burn training.

**Figure J-3.** Starting a prescribed burn.

*Photo Courtesy of Noble Research Institute*

**Figure J-4.** Prescribed burn mop-up.

C. The opportunities to utilize prescribed burning certainly present several serious responsibilities. Prescribed burns must be conducted safely, with good control, and must meet the stated management objectives. Successful prescribed burning requires training, careful planning, and skilled execution, performed in a patient and deliberate method (Wright and Bailey, 1982).

D. NRCS supports and encourages the use of prescribed burning to meet specific resource management objectives. Burning is also practiced at Plant Materials Centers for the development, evaluation, and production of conservation plant materials. Employees acting in accordance with all Federal, State, and local laws and within the scope of their work accept no greater or less liability than that associated with the performance of any other assigned duty. Additional information about liability is provided later in this subpart. Any questions concerning liability should be referred to the appropriate State conservationist. The national policy for prescribed burning is in the General Manual, Title 190, Part 413 – available online at NRCS eDirectives - Part 413 - Prescribed Burning (usda.gov).

E. The national conservation practice standard for prescribed burning is in Title 450, National Handbook of Conservation Practices, Conservation Practice Standard (CPS) Prescribed Burning (Code 338). National practice standards are available online at https://directives.sc.egov.usda.gov/34544.wba. The standard does not, and is not, intended to preempt or supersede requirements established by local, State, Tribal, or Federal agencies, but is intended to serve as a baseline for effective planning and implementation of prescribed burns.

> **Warning:** *Reading this or any other material on prescribed burning does not by itself prepare one for planning or using fire as a conservation practice. You must first gain experience and job approval authority by participating on prescribed burns, attending instructive workshops, and following NRCS's prescribed burn training requirements according to policy.*

F. Differentiation of Fires

(1) Wildfire – A wildfire, brushfire, wildland fire or rural fire is an unplanned, unwanted, uncontrolled fire in an area of combustible vegetation starting in rural areas, forests, wilderness areas and urban areas (Wikipedia).

(2) Controlled Burn – A "controlled fire" is ignited intentionally by humans with a desire to control it; however, the fire likely has inadequate planning, preparation, labor, and equipment

to contain it. A controlled fire is typically what is referenced by the media when a "controlled burn" escapes and becomes a wildfire (Porter 2021).

(3) Prescribed burn – A prescribed burn is thoughtfully planned with written prescriptions that describe the following. The prescribed burn is only ignited when all the procedures and considerations are in adherence to the burn plan prescriptions (Porter 2021). Figure J-5 shows a technician monitoring a burn.
   (i) the objectives of the burn unit
   (ii) firebreaks
   (iii) fuel considerations
   (iv) acceptable weather parameters
      - wind speed and direction
      - temperature
      - relative humidity
      - smoke management
   (v) labor and equipment required
   (vi) notifications to neighbors and civil authorities
   (vii) ignition procedures
   (viii) contingency plans
   (ix) mop-up and monitoring procedures.

## 645.1002 Prescribed Burning Objectives

A. Fire is part of the ecological process that falls right behind sunlight and precipitation in importance of shaping North American forests and grasslands (Pyne 1982, Axelrod 1985).

B. Prescribed burning is an alternative conservation practice used to meet land management objectives and treat resource concerns utilizing a natural process. NRCS practice standard purposes for prescribed burning are to:

(1) Manage undesirable vegetation to improve plant community structure and composition
(2) Manage pests, pathogens, and diseases to reduce plant pressure
(3) Reduce wildfire hazards from biomass accumulation
(4) Improve terrestrial habitat for wildlife and invertebrates
(5) Improve plant and seed production, quantity, and/or quality
(6) Facilitate distribution of grazing and browsing animals to improve forage-animal balance
(7) Improve and maintain habitat for soil organisms and enhance soil health

C. While any one purpose or objective may be used as a determining factor to utilize prescribed burning as a practice in the conservation planning process, generally, the nature of fire itself can accomplish more than one of the purposes or objectives. However, a single burn alone is rarely enough to complete a transformational process if that is the planned objective. Within the current ecological site descriptions (ESDs), lack of fire and prescribed burning are listed as drivers in maintaining the potential or (reference) plant communities and is as important as herbivory and rest in maintaining and enhancing many landscapes. Removal of fire from these communities will likely cause the community or phase to cross a threshold, often leading to development of a woody plant dominated community, which adversely affects livestock production and ultimately the loss of other ecosystem services (CEAP, 2011).

**Figure J-5**. Monitoring a prescribed burn.

D. One advantage to using prescribed fire is the lower cost of burning compared to other land management options. In comparison with mechanical or chemical treatments, prescribed burning is usually the most economical way to manage native landscapes (Bidwell et al. 2002). There are times when, due to years of mismanagement, prescribed fire alone is not the most effective management method. In this case, incorporating mechanical or chemical treatments with prescribed burning, to reclaim or restore certain areas may be needed. Combining treatment options with pre-burn planning allows prescribed fires to be more effective. Ultimately, the land manager chooses which treatments are best suited to their goals and objectives on a particular parcel of land (Weir, 2009).

E. Livestock Production

**Figure J-6.** Prescribed burning can be an important part of a livestock production plan.

(1) One of the main reasons many ranchers or land managers use prescribed fire is for the enhancement of livestock forage production. Improvement of forage production usually increases individual animal performance and possibly overall livestock carrying capacity. One of the main ways this is accomplished is through the control of woody plant species that are invading rangelands throughout the U.S. One, but not the only one, of the main woody plant problems that occurs throughout much of the Great Plains is the invasion of the eastern redcedar (*Juniperus virginiana*). This juniper species causes many problems in the areas where it grows, with the primary problem being a drastic decline in forage production.

Fine fuel loading and continuity are two the most important considerations of any burn. For pasture and rangelands, greater fine fuel loads will allow a more uniform ignition and burn pattern, thus enhancing ability to achieve burn objectives. Therefore, maintaining adequate fuel loads through proper stocking rates is the most important part of any prescribed fire and grazing program (Weir, 2009).

(2) Other brush species are also overtaking or invading the grasslands, shrublands, and forestlands of the U.S. However, most of these species will resprout after a fire. Some of the non-native brush species include multiflora rose (*Rosa multiflora*), Siberian elm (*Ulmus pumila*), and honey suckle (*Lonicera spp*.) or native species such as oaks (*Quercus spp*.), sumac (*Rhus spp*.), plum (*Prunus spp*.), dogwood (*Cornus spp*.), and other junipers (*Juniperus spp*.) aside from the eastern redcedar. These species tend to increase in height, density, and coverage area. Fire will reduce the height of these plants but increases the number of stems. Repeated fires will keep most of these plants suppressed or even remove certain species from the area all together (Weir 2009). Fire is as important as climate and soils to the structure, function, and maintenance of ecosystems. Altered fire regimes are the primary cause of ecological sites moving across thresholds (Twidwell et al. 2013).

(3) Another major benefit of using prescribed burning is the increase in weight gains of stocker cattle. Studies have shown that prescribed burning increases summer stocker cattle gains by 10 to 20 percent in the summer following the burn (Anderson et al. 1970; Smith and Owensby 1972; Wolfolk et al. 1975; Owensby and Smith 1979). Research on cow/calf operations that use fire to manage grazing land has shown that cows can usually increase their body condition score by one class over cows on unburned range, and calves have sometimes shown increased weaning weights (Weir 2009). Figure J-7 shows a burn being conducted on rangeland.

**Figure J-7.** A prescribed growing season burn on rangeland.

F. Wildlife Habitat

(1) Prescribed fire is a very important management tool for wildlife habitat improvement, reclamation, and maintenance. Implementing prescribed burns may increase flowering and seed set in many species. When using prescribed fire to manage for wildlife, be sure to consider the needs of all the species that utilize the habitat. Burning at different times of the year can increase the number of forbs or can cause different species of broad leaf plants to emerge. Forbs are an important component in many wildlife species diets. Keep in mind that burning during the same time of year over and over will promote certain forbs. By changing the time of year that you burn, you can encourage many other species to grow that normally would not occur or might not be there in large enough numbers to make a difference (Weir, 2009).

(2) Fire can be used with grazing to create a mosaic or heterogeneous landscape for wildlife (Fuhlendorf and Engle 2001). This mosaic landscape is important for many species. Some species require areas that are not grazed and not burned, while other species may require areas that are burned more frequently and grazed more heavily. Certain individual wildlife species require a broad range of habitats for survival. The lesser prairie chicken (*Typanuchus pallidicinctus*) is one such species. For nesting, the lesser prairie chicken requires areas that have not been burned or grazed for two years, while for brood rearing, it prefers areas that have large amounts of forbs. These weedy areas are created in the year following a fire and after heavy grazing has occurred. The lesser prairie chicken also requires areas that have very little vegetation present for their booming or leking. These booming grounds are found in areas that have been burned and grazed heavily. Finally, the lesser prairie chicken does not prefer vertical obstructions such as trees or tall shrubs anywhere on its range. These vertical obstructions can be removed and kept in check by frequent fires (Bidwell et al. 2003).

(3) Understanding the needs of the species living in your burn area is important, but there is no need to be overly concerned about trapping too many species within the prescribed burn. Most vertebrate animals escape the heat of fires by going underground just a few centimeters, finding water, rock outcrops, barren, or black areas, or just flying or running away. Infrequently, a single animal may have fire-induced mortality, but keep in mind what will eventually happen to the health of the habitat and wildlife population in total if you do not burn (Weir, 2009).

G. Forestry

(1) Fire has a large application in the forest industry throughout the U.S. Prescribed fires can be used to thin dense stands of trees, eliminate young trees, and maintain park or savanna-like openings (Wright and Bailey 1982). Prescribed burns can be used to thin stands and allow remaining trees to increase in diameter while eliminating thicket areas (Weaver 1967). Figure J-8 shows a burn being conducted in a forested area.

(2) Prescribed fires also help reduce the wildfire potential. In certain areas this protection can last for five to seven years following the burn (Truesdell 1969). Wildfires that start in areas that have been managed with prescribed fires are easier to control and cause less damage to the standing timber than do wildfires in unmanaged areas. In New Mexico and Arizona, prescribed burning significantly reduces the fire intensity and fire damage to trees following wildfires (Cram et al. 2003).

**Figure J-8.** A prescribed burn in a forested area.

(3) Although it depends upon the intensity and frequency of fires, prescribed burning is beneficial for forest regeneration because it encourages natural renewal. This is accomplished by seed bed preparation, as well as fire scarification of serotinous cones and other seeds. Prescribed fire can also be used for hardwood reduction in pine forests, which will reduce competition between pine seedlings and hardwoods. Prescribed fires will reduce competition for water, space, sunlight, and nutrients by thinning out the plant species, and will help recycle nutrients, making them available for the new growth (Weir, 2009).

**Figure J-9.** Prescribed burns can also control diseases and foster regeneration.

(4) Prescribed fires can be conducted to control many forest disease problems (Theis 1990; Wade and Lunsford 1989; Froelich et al. 1978). Many times, the fire destroys the infected tree or tree part, or the fire can change the micro-climate on the forest floor, which may destroy the disease. Fire can also be used to control many forest insect problems and has been shown to be more cost effective than chemical controls for certain insects (Mitchell 1990; Wade and Lunsford 1988; Miller 1978; Simmons et al. 1977).

## 645.1003 Training, Certification, and Authority

A. Successful prescribed fire requires training and experience, careful planning, and skilled execution. Clear and distinct knowledge of the physical, biological, and ecological effects of fire on specific ecosystems and the impact fire has on plants and plant communities are required (Wright and Bailey, 1982). The NRCS encourages its employees to participate in prescribed burn training activities and workshops. Training is required to address both the principles of planning and safely executing the prescribed burn, as well as the effects that the fire will have on the plant and animal species and communities within and outside of the burn area. Policy for prescribed burning is in the General Manual, Title 190, Part 413 – available online at NRCS eDirectives - Part 413 - Prescribed Burning (usda.gov).

B. Only trained and qualified personnel are authorized to assist in planning or implementing prescribed burns. The extent to which an NRCS employee may provide technical assistance is restricted by the job approval authority or certification level that has been attained. NRCS job approval authority criteria are required to be established in States where prescribed burning is practiced. Authority criteria are progressive in nature, allowing employees to participate in more complex burns only when they are qualified. Exhibit J-1 shows job approval authority criteria in the NRCS. In States where certification or licensing is required for prescribed burning authority, NRCS personnel must be certified or licensed, or both, by the designated agency to participate in prescribed burning activities.

C. Any NRCS employee who violates NRCS prescribed burning policy may have disciplinary actions taken or job approval authority (JAA) revoked as determined by the State conservationist.

D. Prescribed burn JAA may be granted to employees who have documented evidence of previous training or experience that equals or exceeds NRCS prescribed burning requirements. NRCS employees with extensive training, experience, and education in prescribed burning may provide supporting documentation to the State conservationist and directors of the Caribbean and Pacific Islands Areas to receive consideration for certification and JAA.

E. Employees without appropriate level of prescribed burn JAA are encouraged to participate, under the supervision of an employee with proper certification and prescribed burn JAA or others with appropriate authority (State certification, National Wildfire Coordinating Group certification, etc.), as a means of receiving training and experience.

**Figure J-10.** Training and JAA are required to conduct prescribed burning.

**Exhibit J-1.** Job Approval Authority (JAA) Criteria

To have ESJAA above Awareness Level, an employee must have completed an approved prescribed burning training course, including participation in a field training burn. Employees will develop plans and provide technical assistance on at least three burns at a class rating equivalent to the desired JAA level that has been approved by an employee with the appropriate JAA. Complexity ratings can be used and set by the state. Following are the requirements for the job approval authority for prescribed burning:

Class I – Awareness Level – Individual must complete 16 hours of awareness training to discuss prescribed burning as an alternative practice in a conservation planning process.

Class II – Individual must have properly planned and participated on at least three Class I burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class I burns.

- Size of area: <= 100 acres
  Vegetation: non-volatile fuels OR Low Complexity Rating
  Terrain: <= 15% slope

Class III – Individual must have Class II approval authority, must have properly planned and participated on at least three Class III burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class II burns.

- Size of area: >100 acres
  Vegetation: non-volatile & restricted volatile fuels OR Medium Complexity Rating
  Terrain: <= 25% slope

Class IV – Individual must have Class II approval authority, must have properly planned and participated on at least three Class IV burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class III burns.

- Size of area: > 100 acres
  Vegetation: volatile & non- volatile fuels OR High Complexity Rating
  Terrain: <= 25% slope

Class V – Individual must have Class II approval authority, must have properly planned and participated on at least three Class V burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class V burns.

- Size of Area: no restrictions
  Vegetation: no restrictions
  Terrain: no restrictions

F. At a minimum, 16 hours of awareness training must be accomplished by each employee to have the minimal requirements needed to utilize prescribed burning as an alternative practice for conservation planning. The 16 hours of training must include fire behavior, fire ecology, fire effects on resources, safety, smoke management, and NRCS policy on prescribed burning. While the 16 hours will allow prescribed burning to be included in a conservation plan, it does not provide enough training for prescribed burn planning. Participating on actual prescribed burns and understanding fire behavior in various fuel types, weather, and the fire effects is the only way to ensure good planning.

## 645.1004 Technical application assistance

A. Only NRCS personnel with the required training and certification are authorized to assist with the planning and application of prescribed burns. Extent of assistance is restricted by the individual's JAA, certification level, or both.

B. For purposes of providing technical assistance to landowners, managers, and NRCS employees, NRCS personnel with appropriate prescribed burn JAA may participate in the following activities

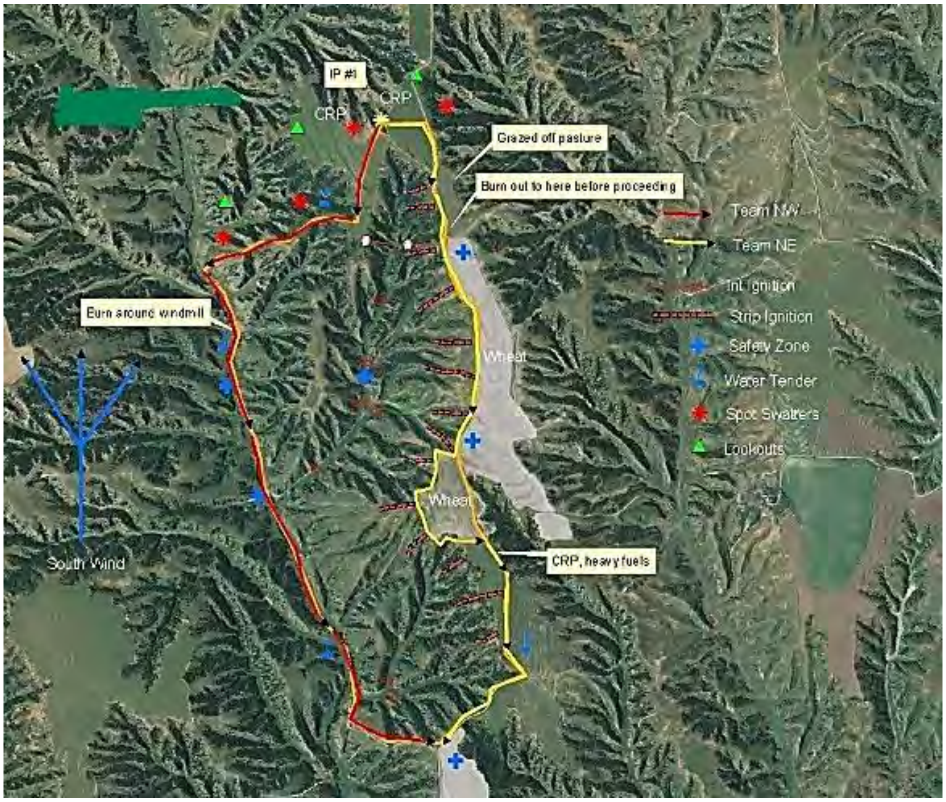
(1) Development and design of the prescribed burn plan
(2) Serve as an operations manager for the implementation and completion of the burn
(3) Serve as crew chief and make decisions, adjustments, and corrections necessary to ensure that the fire meets the planned objectives and that all participants are safe
(4) Assist with ignition of the fire
(5) Provide assistance with suppression activities
(6) Take weather measurements
(7) Serve as spotters or flagmen
(8) Serve as prescribed burn boss only on official designated NRCS training burn when seeking JAA for a higher-class burn. *This is not the client's designee.*

C. Safety must always be the first consideration in prescribed burning. The landowner or cooperator must be informed in writing that he or she may be liable for damages if the fire escapes or smoke damage occurs. *The landowner, manager, or other non-NRCS designee will be the fire boss or burn boss on all burns.* If unfavorable or unstable atmospheric, fuel, or logistical situations exist, the NRCS employee must advise the fire boss or landowner to postpone the burn. If the landowner or manager is unwilling to postpone the burn, NRCS personnel must document actions and leave the area. If an emergency situation develops after the burn has commenced under prescribed parameters, NRCS employees are to follow the direction of the designated fire boss and act responsibly to resolve the situation.

## 645.1005 Planning prescribed burns

A. Burns planned with NRCS assistance must adhere to all Federal, State, and local laws regarding outdoor burning, fire control, smoke management, and air quality. Adherence to the Clean Air Act (42 U.S.C. 7401 - 7671q) is required for all prescribed burns. In States where designated agencies have responsibility for burning activities, NRCS will work with them and through them to fully utilize their expertise, personnel, and equipment. Where no agency has this responsibility, prescribed burns will be planned cooperatively and cleared through such groups as rural fire departments, county commissioners, law enforcement offices, adjacent landowners, Tribes, U.S. Forest Service, Bureau of Land Management, and State forestry, wildlife, and natural resource agencies, as applicable.

**Figure J-11.** Example of a map of a proposed planned burn.




B. A written prescribed burn plan, which thoroughly addresses and meets the minimum prescribed burn conservation practice standard and specifications established by each State, is developed prior to implementation. When NRCS does not develop the prescribed burn plan, documentation must be provided prior to implementation showing the burn plan meets or exceeds NRCS standards.

C. Clients must be informed in writing of their potential liability. The client is responsible for obtaining all permits and clearances as required by law and regulation. NRCS employees should assist with obtaining necessary permits where applicable.

D. The national and State practice standards for prescribed burning are used to guide the overall development of the detailed plan. Prior to burning, a detailed plan for the prescribed burn must be prepared. See Appendix J-A for an example of a prescribed burn plan. Appendix J-B provides a fillable burn plan form.

Required items to be addressed include, but are not limited to:
(i) Location and description of the burn area
(ii) Pre-burn vegetative cover
(iii) Resource management objectives
(iv) Required weather conditions for prescribed burn
(v) Notification checklist
(vi) Pre-burn preparation
(vii) Equipment checklist, personnel assignments, and needs/safety requirements
(viii) Firing sequence
(ix) Ignition method
(x) Basic smoke management practices to minimize smoke impacts
(xi) Approval signatures

(xii) Postburn evaluation criteria

E. States have and can write supplemental guidance on the planning and application of prescribed burning that may exceed national guidance. Such guidance may include practice specifications, implementation requirements, statement of work, and technical notes that should be referenced in States that have developed this guidance.

## 645.1006 Smoke Management

A. Smoke management has become one of the most challenging aspects of prescribed burning. Effective smoke management mitigation is vital for the continued use of prescribed fire. Some States may require a smoke permit and other requirements before, during, and after a burn. See table J-1 for some basic smoke management practices.

B. Smoke releases airborne particulates into the atmosphere and affects visibility. However, burning under favorable dispersal conditions will minimize the visibility problem (Martin et al. 1977).

**Table J-1.** Basic smoke management practices.

| Basic Smoke Management Practice | Benefit achieved with the BSMP | When the BSMP is Applied – Before/During/After the Burn |
|---|---|---|
| Evaluate Smoke Dispersion Conditions | Minimize smoke impacts | Before, During, After |
| Monitor Effects on Air Quality | Be aware of where the smoke is going and degree it impacts air quality | Before, During, After |
| Record- Keeping: Maintain a Burn/Smoke Journal | Retain information about the weather, burn and smoke. If air quality problems occur, documentation helps analyze and address air regulatory issues | Before, During, After |
| Communication – Public Notification | Notify neighbors and those potentially impacted by smoke, especially sensitive receptors | Before, During |
| Consider Emission Reduction Techniques | Reducing emissions can reduce downwind impacts | Before, During |
| Share the Airshed – Coordination of Area Burning | Coordinate multiple burns in the area to manage exposure of the public to smoke | Before, During, After |

C. The 2011 USFS-NRCS guide to Basic Smoke Management Practices (BSMPs), Basic Smoke Management Practices, describes six basic practices. While not all-inclusive, they are good starting points for prescribed fire planning (O'Neill et al. 2011, Godwin, D., et.al., 2014). Figure J-12 illustrates smoke from a burn. Figure J-13 illustrates how smoke can have far reaching effects.

(1) Evaluate smoke dispersion conditions to minimize impacts
   (i) Before, Burning – Develop a smoke management plan for your burn, using online models such as the Simple Smoke Screening Tool (Florida Forest Service, fdacs.gov). Evaluate weather conditions that will be most appropriate for meeting your smoke management objectives. Analyze predicted weather conditions with regards to smoke movement and potential impacts on smoke sensitive areas (SSAs).
   (ii) During Burning – Actively monitor weather conditions and forecasts and compare them to the predicted and observed on-site weather conditions and smoke dispersion.
   (iii) After Burning – Continue to track weather conditions and forecasts to understand possible effects of lingering smoke from smoldering fuels.

(2) Monitor effects of fire on air quality.

**Figure J-12.** Smoke is a significant hazard that requires careful planning for burns.

**Figure J-13.** Smoke from prescribed burns can have large scale effects.

  - (i) Before Burning – Assess regional air quality conditions and forecasts using online resources such as the National Weather Service Fire Weather, local air quality monitoring sites, and EPA AirNow, AirNow.gov. If air quality is poor, consider postponing a burn until air quality conditions improve and realize that your State forestry, fire, or air quality agency may already conduct this assessment as part of their burn authorization process.
  - (ii) During/After Burning – Monitor smoke impacts on air quality, particularly near SSAs, towns, highways and schools using resources such as field reconnaissance and monitoring reports. Larger burns may access satellites, radar, and aircraft for additional information to track smoke movement and air quality impacts.
- (3) Record basic smoke management practices, fire activity, and effects.
  - (i) Before Burning – Track and document observed weather and air quality conditions as well as current forecasts.
  - (ii) During Burning – Record BSMPs used on the burn, ignition patterns, on-site weather, fire behavior, smoke dispersion and impacts, size of area burned, fuels burned, and time and date. These records can often be made on, or attached to, your prescribed burn plan.
  - (iii) After Burning – Suggest retaining records, observations and burn plans for five years after the fire in case of an inquiry or an adverse air quality impact.
- (4) Communicate and notify authorities and affected public.
  - (i) Before Burning – Notify appropriate authorities, air quality regulators, highway patrol, fire departments, neighbors, and citizens of affected SSAs of anticipated smoke and air quality impacts. Develop contingency plans for potential undesirable impacts and notify appropriate agencies of those plans.
  - (ii) During/After Burning – If travel corridors are, or might be, affected, provide signage noting that a prescribed burn is occurring, and provide appropriate timely smoke impact updates to authorities, highway patrol and fire departments during and after the burn. Pay close attention to smoke impacts from smoldering fuels.
- (5) Utilize emission reduction techniques whenever possible.
  - (i) Before Burning – Consider available emission reduction techniques (ERTs) when planning the burn. Possible ERTs include burning just prior to precipitation, limiting fuel consumption, limiting the burn area, and varying ignition techniques (e.g., backfires generally produce less smoke than head fires, but they also generate less plume rise). For more information on ERTs see the NWCG Smoke Management Guide listed in table J-2.
  - (ii) During/After Burning – Document use of ERTs employed and observed effects. Complete mop-up as quickly as possible and extinguish smoldering fuels if necessary, to address any adverse impacts.
- (6) Collaborate with nearby burners to manage smoke emissions.
  - (i) Before Burning – Many burn authorization agencies determine regional emission loads as part of their authorization process. However, individual landowners or burn managers should collaborate to help avoid local adverse smoke impacts (Godwin et al. 2014).

**Table J-2.** Resources for basic smoke management practices

| Resource | Source |
|---|---|
| USFS-NRCS guide to Basic Smoke Management Practices (BSMPs) | Basic Smoke Management Practices |
| USFS Online Smoke Screening Tool | Florida Forest Service (fdacs.gov) |
| NWS Fire Weather Forecasts | Fire Weather |
| NWS Fire and Smoke Mapping Resources | Office of Satellite and Product Operations - Hazard Mapping System (noaa.gov) |
| EPA AirNow! Air Quality Observations and Forecasts | AirNow.gov |
| USFS BlueSky Playground | BlueSky Playground (airfire.org) |
| NWCG Smoke Management Guide for Prescribed Fire and Wildland Fire | Smoke management guide for prescribed and wildland fire: 2001 edition. \| Treesearch (usda.gov) |
| USFS Intro to Prescribed Fire in Southern Ecosystems | Introduction to prescribed fires in Southern ecosystems \| Treesearch (usda.gov) |
| NWCG Smoke Committee (SmoC) | Air Quality and Fire Issues - Wildland Fire Lessons Learned Center (wildfirelessons.net) |

**Figure J-14.** Coordinated planned burn.

## 645.1007 Prescribed Burning Laws

A. Prescribed fire is a land management conservation practice utilized by landowners and managers in many parts of the United States. A primary concern for both the landowner, as well as NRCS planners, is the liability associated with prescribed fire activities. It is important to have an understanding of local and State laws that address liability related to prescribed burning on private lands. There is a misconception that all fires are perceived as the type most often portrayed in the media as “out of control” wildfires. Those who have experience with prescribed fire over time realize that not all fire is an extreme wildfire. Fire behavior is a product of location, timing, fuels, weather, and execution (Weir et.al. 2020).

B. Risk – Risk is defined as the likelihood of liability for or loss from exposure, to a potentially harmful action or event. Risk can be characterized in three ways:

(1) probability of a loss
(2) degree of exposure to the loss
(3) magnitude of the possible loss (Weir et.al. 2020)

C. Liability – Liability means the legal responsibility for one's acts or omissions. Failure of a person (e.g., landowner or burn boss) to meet those responsibilities leaves them vulnerable to the possibility of a lawsuit. This varies by State (Weir et.al. 2020).

D. State Laws – Each State has its own laws and requirements for prescribed burning. Liability also varies from State to State. Three types of laws cover prescribed burning liability for both smoke and from damages due to escaped fire. These are:

(1) Strict Liability – Places the burden of restitution for damages from the fire on the burner, regardless of any and all actions taken to avoid damages.
(2) Simple Negligence – Requires that the complainant seeking legal action must prove damages, and that proximate cause of the damages was negligence by the burner. This is the most common but has many variations in the language from State to State.
(3) Gross Negligence – Requires the complainant to show that the damage resulted from the burner have a conscious and voluntary disregard for the need to use even reasonable care. In most States where gross negligence applies, a burner must follow usually statutorily prescribed fire standards and certification requirements to receive the benefit of a lesser liability standard (Weir et.al. 2020).

## 645.1008 NRCS employee liability

A. Employees acting in accordance with all Federal, State, and local laws and within the scope of their work accept no greater or less liability than that associated with the performance of any other assigned duty. Any questions concerning liability should be referred to the appropriate State conservationist.

B. The USDA Office of the General Counsel (OGC) reviewed NRCS involvement in prescribed fire and provided this synopsis in January 2015:

> "All federal employees, including State Conservationists, are immune from legal actions brought under the theory of negligence as long as the federal employees at the time of the incident were acting within the scope of their employment. This applies to both supervisors and employees participating in the prescribed burn process as long as the employees are carrying out their official duties regardless of whether the employees were negligent in carrying out their duties. The U.S. government as a whole is liable for negligent acts or omissions of federal employees committed within the employees' scope of employment. Even if employees who were acting within the scope of their employment were negligent, the U.S. government may still be immune from liability through the doctrine of discretionary function. This defense is available if the employees did not violate any mandatory statues, regulations, or policies in carrying out their duties regardless of whether their conduct was ultimately negligent," (From report prepared by G. Johnson, with assistance from C. Stanley and S. Brantley, 2015).

C. State office responsibility

> The NRCS state office is responsible for providing adequate training and equipment for employees involved in prescribed burning activities. States will develop JAA criteria and ensure that employees act within their training and certification levels. States will ensure that only qualified NRCS employees are used for reviews and spot checks of prescribed burning activities, and that JAA criteria are reviewed and concurred in by an individual with the appropriate level of JAA. Figure J-15 shows a group undergoing training.

**Figure J-15.** A prescribed burn training exercise.

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## 645.1010 Appendices

# PRESCRIBED BURNING MANAGEMENT PLAN

| **Client Information** | | | |
|---|---|---|---|
| **Name:** A Nice Ranch | | **Phone:** 555-555-1111 | |
| **Ranch Name:** Example | | | |
| **Address:** 1 | | **County of burn location:** God's County | |
| **City:** Heaven | | **State:** Yep | **Zip:** 555555 |

| **Description of Area to be Burned** | | | |
|---|---|---|---|
| **Pasture Name and/or Number:** Field 15 | | | |
| **Vegetation Type:** (Grassland, timber, grass with scattered cedars, etc.) Native Range | | | **Acres:** ~160 acres |
| **Legal Description:** | **Section:** 12 | **Township:** 34 | **Range:** 56+ |
| **GPS Coordinates (if known):** 90.00.00 N 0.00.00 E | | | |

| **Written directions from nearest town:** (Be specific so that these directions can be read to emergency personnel if needed) | |
|---|---|
| Approximately 15 miles south and west of a town in the state of YEP | |
| **Projected Date of Burn:** 3/1/20 - 12/31/20 | **Date of Previous Burn:** 2004 |

**Objective(s) to be Accomplished with the Prescribed Burn**

- [x] Control undesirable vegetation
- [ ] Prepare sites for harvesting, planting, or seeding
- [ ] Control plant disease
- [x] Reduce fuel hazards that lead to wildfire
- [x] Improve wildlife habitat
- [x] Improve plant productivity, health, and vigor
- [ ] Remove slash and debris
- [ ] Enhance seed and seedling production
- [ ] Facilitate distribution of grazing and browsing animals
- [x] Restore and maintain ecological processes and ecological site integrity
- [ ] Protect air quality from wildfire smoke impacts

**Provide further comments and/or list other objectives that may be accomplished from the prescribed burn:**

Maintain ecological community phase and enhance or maintain soil health

**Notifications: (Responsibility of Client)**

| When burning within designated forest protection areas, contact your State Dept. of Forestry or Agriculture | Location | Phone Number |
|---|---|---|
| | | |

| Fire Departments | Phone Number | Date, Time, and Person Notified |
|---|---|---|
| Rural Fire | 555-555-9111 | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

| Adjoining Landowners | Phone Number | Date, Time, and Person Notified |
|---|---|---|
| Bill | 555-555-0123 | |
| George | 555-555-0124 | |
| Sue | 555-555-1235 | |
| | | |
| | | |
| | | |
| | | |

| Others, as needed (Sheriff, HP, DEQ, Utility Companies, Oil and Gas Leases) | Phone Number | Date, Time, and Person Notified |
|---|---|---|
| Sheriff | | |
| Big Oil Company | | |
| Wind Farmers | | |
| | | |
| | | |
| | | |
| | | |

**Pre-Burn Preparations – Describe management needed prior to burn in order to successfully accomplish burn and meet objectives.** (Deferred grazing to build fuel loads; prescribed grazing to reduce fuel loads; firebreak preparation; burning of bush piles; moving brush piles, etc.)

Defer grazing to allow for proper fuel load to carry fire and accomplish objectives. ~ 2000 lbs./ac. Cut fireguards with dozer ~ 12ft. wide along south fence line to road. County roads and ranch roads and creeks will be used where appropriate. See burn map for fireline details. Remove all cedar from fireguard and adjacent to fireguard. Cedars should be pushed 300 ft. from fire break.

| **Firebreak Types** (include locations on map) (Refer to NRCS CPS Firebreak (Code 394) Standards, Specifications, and Job Sheets for details) | **Dimensions** | **Preparation / Installation** | |
|---|---|---|---|
| | | **Dates** | **Equipment needed** |
| Bare mineral soil | 12ft | 1/20 | dozer or maintainer |
| Burned Firebreak | ~300ft | 3/20 | Drip torches |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Smoke Management Considerations – Refer to Basic Smoke Management Practices V5 (add link here) or your State Smoke Management references.**

| Sensitive Areas Identified | Direction from Burn Area | Distance to Area |
|---|---|---|
| House | South | 1/4 mile |
| County Road | North | 0.1 mile |
| | | |
| | | |
| | | |
| | | |

**Other Smoke Management Considerations**

Category day, hours of burning, local ordinances, dispersion conditions, and applying various smoke control strategies such as:
- Avoidance (burn when the wind is blowing away from all smoke-sensitive areas, avoid burning if temperature inversions are present, etc.);
- Dilution (reducing smoke concentrations by burning during good and rapid dispersion conditions, burning at slower rates, burning smaller areas, burning lighter fuel loads if the desired results can be achieved by doing so, burning mid-day rather than late afternoon or evening, etc.);
- Emission reduction (minimize smoke output per unit area by utilizing effective firing techniques such as backfires, by proper scheduling for periods when duff and larger fuels are too wet to burn, by removing larger materials from the area to reduce emissions from residual smoldering smoke, etc.);
- Burning under favorable moisture conditions.
- Mopping-up quickly to reduce residual smoldering smoke, etc.

| | | | | |
|---|---|---|---|---|
| **Category Day** | **Preferred Category Day** | III - Three or better | **Actual Category Day (day of burn)** | |
| **Dispersion Conditions** | **Preferred Dispersion Conditions** | Excellent | **Actual Dispersion Conditions (day of burn)** | Good |

| Pre-Burn Checklist - The following items should be addressed prior to implementing burn and appropriate action taken. Protection of facilities and/or special areas should be documented and included on map. | | | |
|---|---|---|---|
| | Present in burn unit | If Present - Action Needed / Recommended | ACCOMPLISHED (CLIENT CHECKS) |
| LIABILITY PROTECTION AND NOTIFICATIONS | | | ☐ |
| Pens/barns | ☑ | Corrals in burn area are not a problem | ☐ |
| Oil/gas/pipelines/ utility structures | ☑ | remove standing fuels around items if necessary | ☐ |
| Fences - with wood or plastic components | ☑ | Can burn through fences not a problem | ☐ |
| Homes/cabins | ☐ | | ☐ |
| Windmills | ☐ | | ☐ |
| Watering facilities | ☐ | | ☐ |
| Feeding facilities/hay storage | ☐ | | ☐ |
| Equipment/vehicles | ☐ | | ☐ |
| Wildlife habitat areas | ☐ | | ☐ |
| Critical eroding areas | ☐ | | ☐ |
| Remnant livestock | ☐ | | ☐ |
| Volatile fuels | ☑ | Cedar | ☐ |
| Other areas desired for protection | ☐ | | ☐ |
| Inspection of firebreaks (Check all firelines for "fuel bridging" before starting the burn. | ☐ | | ☐ |
| | ☐ | | ☐ |
| | ☐ | | ☐ |

**Fuel Conditions Needed to Accomplish the Burn and Achieve Objectives –** Planning should begin early enough to achieve adequate fuel conditions needed to accomplish the burn. Special management needed to achieve this should be addressed in pre-burn preparations.

| | Prescription | Actual (day of burn) |
|---|---|---|
| Estimated fine fuel amount (lbs/ac) [1] | 2000+ | |
| Continuity [1] | ■ Good ☐ Fair ☐ Poor | ☐ Good ☐ Fair ☐ Poor |
| 10 hour fuel moisture (% dry wt. basis) [2] | | |
| Estimated mulch load (lbs./ac) [2] | | |
| Mulch depth (inches) [2] | | |
| Estimated mulch moisture content (%) [2] | | |

*[1] – Required entry; [2] – As needed*

**Weather Conditions - Prescription**

| Prescription | Blackline Firebreaks or Backfires | | Prescribed Burn | |
|---|---|---|---|---|
| | Optimum | Maximum Range | Optimum | Maximum Range |
| Wind Speed | 4-10 | 4-15 | 4-15 | 4-20 |
| Wind Direction | SW | S-W | SW | |
| Relative Humidity | 40 - 60 | 30 - 80 | 40 | 15-60 |
| Air Temperature | <60 | 40-80 | <80 | 50-100 |

| | Blackline Firebreaks or Backfires | Prescribed Burn |
|---|---|---|
| Duff and Soil Surface | ☐ Dry ■ Damp ☐ Wet | ☐ Dry ■ Damp ☐ Wet |
| Soil Profile | ☐ Dry ■ Damp ☐ Wet | ☐ Dry ■ Damp ☐ Wet |
| Risk of Spotfires (Refer to Table 1 in General Specification) | ☐ High ☐ Med ■ Low | ☐ High ☐ Med ■ Low |

**Other Fuel or Weather Considerations** (Fine fuel moisture, days since last major rainfall event, any other special considerations)

***Weather Forecasts – (Responsibility of Client)*** *Timing of burning is dependent upon prescribed weather conditions. Both the 7-day and 24-hour forecasts should be checked and documented in order to plan burn according to prescription.*

| Forecasted Item | Seven (7) day Forecast | Twenty-Four (24) hour Forecast |
|---|---|---|
| Predicted wind shifts | | |
| Wind speeds | | |
| Wind direction | | |
| Temperatures | | |
| Relative humidity | | |
| Other as needed | | |
| Source of data | | |

**Possible Sources of Weather Data**

**Fire Danger Model:** **and/or**

**Forecasts:** **and/or**

**Equipment Needs and Crew Member Responsibilities Checklist –** Various types of equipment may be needed in order to have a safe and successful burn. The following checklist should be used to inventory available equipment and plan for needed equipment. All equipment should be tested prior to starting the fire. It is also a good idea to have back-up equipment on hand.

| | Equipment Items | Equipment Purpose(s) | Desired on burn | Amount On-Hand | Amount Needed | Comments / Other Considerations | Available Day Of Burn |
|---|---|---|---|---|---|---|---|
| *HAND TOOLS* | Drip torch(es) | For lighting the firelines. Air vent should be adjusted for fine fuel conditions and a walking pace. They should be held upright and extinguished when not in use. | ☑ | 6 | | | |
| | Flapper(s) | Place and hold over fire or use like a mop over an area to smother flames – Do Not Flap Or Swat! | ☑ | 2 | | | |
| | Shovel(s) | Clear small areas of firebreak; smother flames; place dirt over flames. | ☐ | | | | |
| | Rake(s) (McLeod rakes, garden rakes, etc.) | Clear areas or widen firebreaks, especially in wooded areas; spread fire by dragging fine fuel; prevent fire from spreading by dragging fine fuel & fire back on itself. | ☑ | 4 | | | |
| | Backpack pump(s) / sprayer(s) | Used for putting fire out especially in areas where larger sprayers or equipment may be hard to get in. | ☑ | 2 | | | |
| | Leaf blower(s) | May be used in timbered areas to blow a clean line to bare soil through leaf litter; also used to blow out backfires or small flank fires. | ☑ | 1 | | | |
| | Flags for flagmen | To regulate traffic on roads or highways when smoke reduces visibility. | ☑ | 2 | | | |
| | Chainsaw(s) / tree saw(s) / axe(s) | Helpful for cutting down snags and hollow trees near firebreaks before or after the burn. | ☐ | | | | |
| | | | ☐ | | | | |
| | | | ☐ | | | | |
| *LARGE EQUIPMENT* | Pumper truck(s) | Helpful should the fire escape; source of additional water. | ☑ | 1 | | | |
| | Tractor(s) / maintainer(s) | Helpful to contain an escape by blading or covering small fires to put them out. May be used to move or push out burning snags. | ☐ | | | | |
| | Large sprayer(s)/ (slip in or pull behind) | Helpful for putting out small escapes; can be used to lay down wetlines in areas where bare soil firebreaks can't be installed; source of extra water. | ☑ | 1 | | | |
| | ATV's, (4 wheelers) | Helpful for large areas or rough terrain; can mount ATV water sprayers on them or light firelines. | ☑ | 2 | | | |
| | | | ☐ | | | | |
| | | | ☐ | | | | |

| | Equipment Items | Equipment Purpose(s) | Desired on burn | Amount On-Hand | Amount Needed | Comments / Other Considerations | Available Day Of Burn |
|---|---|---|---|---|---|---|---|
| SUPPLIES | Diesel & gas mixture for torches | Fuel mixture is a 1:1 diesel:gas – on warmer days this can approach a 2:1 diesel:gas mixture. | ✓ | 30 | | | |
| | Matches or lighters | Used for lighting the torches; may be needed in emergencies to burn out a black area around yourself should one get trapped inside a burning area accidentally. | ✓ | 30 | Crew | | |
| | Fuel (mixed and not mixed) | Needed for motors on pumps, sprayers, ATV's, chainsaws, leaf blower, etc. | ✓ | | | | |
| | Drinking water | Needed to keep the fire crew hydrated and functioning. | ✓ | | | enough for crew | |
| | Toolkit / fencing pliers / other tools | Pliers may be needed to cut fences to allow vehicles to get to an escape; other tools for repairs on equipment. | ✓ | | | | |
| | | | ☐ | | | | |
| | | | ☐ | | | | |
| COMMUNICATIONS | Weather kit | Obtain onsite weather information & monitor weather parameters during the burn. | ✓ | 2 | | | |
| | Two-way radio(s) | Vital for communication between all crew members & the fire boss. | ✓ | 6 | | | |
| | NOAA Radio | Helpful to monitor weather especially if a front or wind shift is predicted. | ☐ | | | | |
| | Cellular phone | Fire boss should have a means of contacting emergency personnel if the need arises. | ✓ | | | | |
| | GPS | Coordinates can be useful for emergency personnel if site is in a remote area. | ☐ | | | | |
| | | | ☐ | | | | |
| | | | ☐ | | | | |
| SAFETY EQUIPMENT | Cotton / Nomex (fire retardant clothing) | Long sleeve shirts, pants - no cuffs, worn outside of boots; no rips, tears, or frays in clothing. | ✓ | | | All crew members | |
| | Cotton cap(s) / helmet(s) | Long hair inside. | ✓ | | | All crew members | |
| | Leather gloves and boots | Gloves – no large cuffs; Boots – lace-up preferred; No sneakers. | ✓ | | | All crew members | |
| | Dust masks / respirators<br>Goggles / face shields | Filtering ash & some smoke; Protect eyes from heat & smoke irritation or when using power tools (leaf blowers, chainsaws). | ✓ | | | All crew members | |
| | Face / neck protectors | Nomex fire resistant material for use on fireline to protect face and / or neck from heat. | ☐ | | | | |
| | | | ☐ | | | | |
| | | | ☐ | | | | |

| | | | |
|---|---|---|---|
| ***Crew Members and Responsibilities –*** *Do not burn until all precautions have been taken and all personnel on site are informed of the burn plan and their responsibilities during the burn. Have on hand sufficient equipment and manpower needed to control the fire at all times. Ensure that all personnel are able to operate their assigned equipment.* | | | |
| **FIRE BOSS ***** | Ranch owner or Operator -- NOT NRCS | **Total number of crew members needed:** | 8+ |
| *****The fire boss will be the sole leader and coordinator of all prescribed burning activities. If the fire boss is not satisfied with the firebreak preparation, fire prescription, personnel, weather conditions, or other aspects of safety, then the burn shall be postponed.** | | | |

| **Name** | **Responsibility** *(i.e. torch, suppression, spotters, flagmen, etc.)* | **Reviewed w/ Crew (Y/N)** |
|---|---|---|
| Bill | Torch | |
| Ted | Torch | |
| Ralph | Pumper | |
| Carrie | ATV sprayer | |
| Brandon | Back pack sprayer | |
| Catherine | ATV sprayer | |
| Donna anna | Flapper / Swatter | |
| ETC. | etc. | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

| **Application Of Burn** | .**Projected Date Of Burn** | **From:** | | **To:** | |
|---|---|---|---|---|---|
| **Ignition Plan –** Describe sequence of ignition for both burned firebreaks and main fire. Include details of ignition plan on burn plan map. | | | | | |
| With a southwest wind ignition will start in the northeast corner at point A (see attachment C). Crew will be divided into two groups, crew 1 (east) and crew 2 (west). Equipment will be divided between both groups with 1 UTV and the 200 gallon pumper going with Crew 1 since that firebreak is rough and harder to traverse. The 300 gallon pumper and other UTV will go along the north line. Ignition will consist of strip heaffires using a minimum of 2 torches starting at Point A with Crew 1 going south along the east line stopping at Point B and Crew 2 going west along the north line stopping at Point C. A blackened area of 300 ft wide minimum will need to be established before either Crew can proceed. The UTV's will patrol their respective lines, while the pumpers will be positioned in problem areas and moved as needed. Once adequate black is established one torch from each crew will begin igniting the headfire and meet at Point D. While the headfire is being ignited equipment and crew will continue to monitor the east and north lines. Equipment will be moved to the west and south lines as needed. Crew 2 should take extra caution along the west side due to traffic on CountyRoad. | | | | | |
| **Plan of action should the fire escape or wind changes directions** (See figure 1 for attacking spot fires). | | | | | |
| If fire escapes, ignition will stop immediately. Critical personnel will attack spot fire and extinguish promptly. Make sure that there are some of the crew continuing to observe prescribed burn area to prevent another escape. If fire becomes greatly out of control fireboss should call local fire departments to help assist in extinguishing the escaped fire. It is a good idea to have a local fire department send a truck to the burn as a standby if possible.<br>This usually requires a donation from the land owner but is well worth the extra dollars.<br><br>Do not begin ignition on the rest of the prescribed area until all escapes have been handled properly and there is still time in the day to finish the burn.<br><br>If wind changes directions, stop ignition, inform crew members of plan to go and get burned area backfired and blackened to help with control on downwind sides. | | | | | |

**Burn Plan Map** – (Include legend with north arrow, archaeological/cultural resource sites, roads, firebreaks, utilities, water sources, ingress/egress routes for emergency vehicles, ignition plan, areas not to be burned, facilities and other items as needed.)

Example only

**Smoke Trajectory Map –** (Include legend with north arrow, burn unit, wind direction, 30° angle on each side to account for the horizontal dispersion of the smoke, and then mark the critical distances downwind of 5 miles, 10 miles, etc.)

Example Only

| **Fire boss' Go / No-Go Checklist:** If the answer to any item below is "NO," ***DO NOT*** burn until corrected. | | | |
|---|---|---|---|
| **Fire plan prepared?** | Yes ☐ No ☐ | **Is all the necessary equipment onsite and operational?** | Yes ☐ No ☐ |
| **Firebreaks prepared?** | Yes ☐ No ☐ | **Adequate personnel available for burn?** | Yes ☐ No ☐ |
| **Have all notifications been made? (Neighbors, fire departments, etc.)** | Yes ☐ No ☐ | **Will smoke management be within prescription?** | Yes ☐ No ☐ |
| **Are all weather parameters within prescription?** | Yes ☐ No ☐ | **Have all personnel been briefed on the plan, objectives, assignments, tactics, hazards, and safety?** | Yes ☐ No ☐ |
| **Are current and projected weather forecasts favorable?** | Yes ☐ No ☐ | **Can the burn objectives be met?** | Yes ☐ No ☐ |
| **Have the necessary permits been obtained?** | Yes ☐ No ☐ | **In your opinion, can the burn be conducted safely according to the Prescribed Burn Plan?** | Yes ☐ No ☐ |
| **Provide additional notes or comments pertaining to any aspect of this prescribed burn:** | | | |
| | | | |

| This prescribed burn plan was designed / written by: | |
|---|---|
| | |
| Planner's Signature | Date |
| If planner above is certified higher than "Apprentice," show certification levels below. If planner above is "Apprentice" certified, this plan was reviewed and approved by: | |
| | |
| Signature of Certified Conservationist (Show certification levels below) | Date |

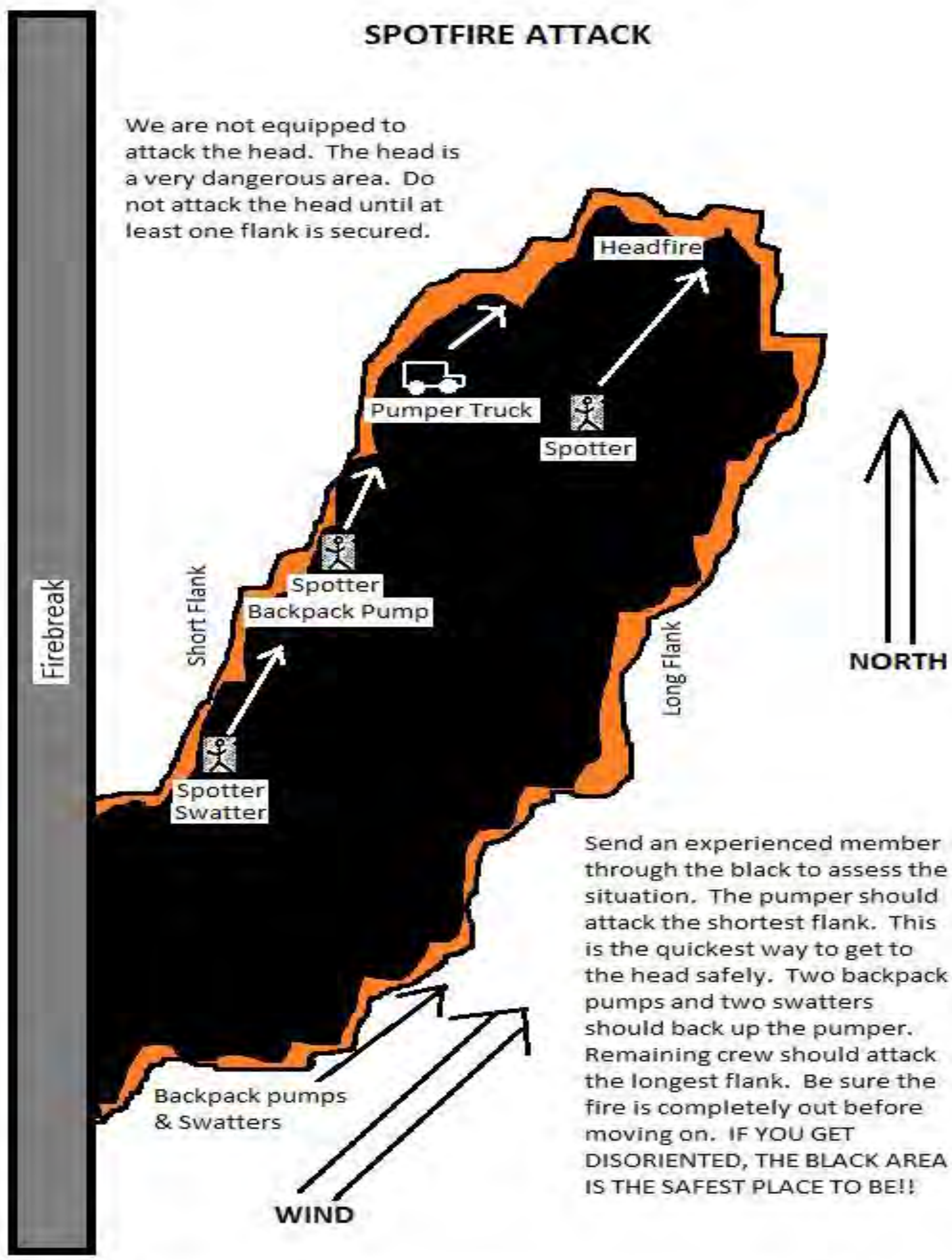
| NRCS Certification Information – (Refer to General Manual 190, Part 413, Subpart B for NRCS Policy and Job Approval Authority. Planners should review their individual job approval authority for certification levels) | | |
|---|---|---|
| Category | Select Appropriate Categories for Planned Burn | For each Category, select appropriate Certification Level of person planning burn |
| Fuel type | 1c. Volatile woodies larger than 6' | Fireboss |
| Fireguard type | Bare soil or green, growing crop | Qualified |
| Terrain type | 3a. < 12% slopes, burn completed in one day | Fireboss |

| *Items within the burn plan that are in red are responsibility of client. Planner may assist where needed. Some items will be documented day of burn.* | |
|---|---|
| Client Certification | |
| This is to certify that the Natural Resources Conservation Service has informed me that I could be liable for damages resulting from this prescribed burn and the cost of fire suppression should the fire escape from the designated area. Damages could be from the fire burning something and/or from the smoke produced by the fire. I also certify that it is my responsibility to be familiar with and comply with State burning laws. | |
| | |
| Client's Signature | Date |

**Separate prescribed burn plans must be developed for each prescribed burn. Prescribed burn plans are valid only for the location and time frame planned. If a client decides to change the location of the burn, or is unable to burn during the prescribed time frame and conditions, a new or revised prescribed burn plan must be prepared prior to conducting the burn.**

Reset Form

**Figure 1**


SPOTFIRE ATTACK
We are not equipped to attack the head. The head is a very dangerous area. Do not attack the head until at least one flank is secured.
Headfire
Pumper Truck
Spotter
Spotter
Backpack Pump
Short Flank
Firebreak
Long Flank
NORTH
Spotter
Swatter
Send an experienced member through the black to assess the situation. The pumper should attack the shortest flank. This is the quickest way to get to the head safely. Two backpack pumps and two swatters should back up the pumper. Remaining crew should attack the longest flank. Be sure the fire is completely out before moving on. IF YOU GET DISORIENTED, THE BLACK AREA IS THE SAFEST PLACE TO BE!!
Backpack pumps
& Swatters
WIND

# Part 645 – National Range and Pasture Handbook

## Subpart K – An Ecosystem View of Range and Pasture Soil Health

### 645.1101 Introduction: A Holistic View of Soil Health and Soil Quality on Range and Pasture

A. The purpose of this subpart is to provide information about

(1) The importance of ecosystem functions in determining overall health on range and pastureland;
(2) Concepts of soil quality and health and how they apply to rangeland and pasturelands;
(3) Discussions of carbon cycle and sequestration dynamics;
(4) Reviews of technologies and tools that can be used to assess overall range and pasture health;
(5) Identification of opportunities to provide information about the components of range and pasture health as an important part of grazing land management.

B. The terms rangeland and pastureland health are use in this document to encompass the full suite of ecosystem components, including soil health concepts.

C. A considerable amount of literature on the health of range, pasture, and soils has been published by the Soil Health Division (USDA-NRCS 2021a), other NRCS sources, university and government agency technical documents, books, journal articles, and the popular literature. A logical first step in becoming knowledgeable on the subject of health and the functionality of grazing lands is to understand that an environmental variable does not act alone. Grazingland plant communities are diverse and multivariate in nature, meaning that many variables (climate, geophysical factors, soils, plants, and biological components) all interact and act in concert within the ecosystem, which implies a holistic view to plant and soil health. Although soil health in particular is a key subject of importance in agriculture, addressing singular functions relative to soil, plants, and biotic components should be secondary.

D. In addition to climate, geophysical factors, soils, plants, and biological component interactions, the health of an ecosystem also includes ecological processes such as the hydrologic cycle, energy flow, the nutrient cycle, and the function of each within a natural range of variability. Since the complexity of environmental factors and ecological processes within grazing land systems are multivariate in nature, internal environmental processes are usually unique from one ecological site to another. The ecological site (ES) and its full range of dynamic attributes (see subpart B) is the foundation for NRCS conservationists in addressing range and soil health. The parameters of the ES are the key to addressing range and pastureland health. An ecological site is a conceptual classification of the landscape. It is a distinctive land unit based on a recurring landform with distinct soils (chemical, physical, and biological attributes), kinds and amounts of vegetation, hydrology, geology, climatic characteristics, inherent ecological resistance and resiliency, unique successional dynamics and pathways, natural disturbance regimes, geologic and evolutionary history including herbivore and other animal impacts, and response to management actions and natural disturbances. These discrete characteristics separate one ecological site from another. A range, pasture, and soil health assessment system must be based on a realistic baseline or standard as described in an Ecological Site Description (ESD) and requires a means of identifying current status and communicating the implications of departure from the standard. The ESD is the document that contains information about the individual ecological sites.

E. Direct quantitative measures of processes relating to biotic, soil dynamics, and hydrology are usually very time consuming, expensive, and may not be feasible for conservation planners and grazing land managers. It is important to point out that there are situations where detailed tests and analyses related to soil health are desirable and needed, especially in cropland settings (cash and specialty crops, etc.) (USDA-NRCS 2021a). For example, Cornell University has a comprehensive protocol: "Cornell Comprehensive Assessment of Soil Health (CASH)." Moebius-Clune (2016) provides a thorough examination of the physical, chemical, and biological indicators of soil health including soil organic matter, structural stability, microbial activity, diversity, and microbial and plant available nutrients. In addition to quantitative analyses of soil health, the In-Field Soil Health Assessment (Technical Note 450-06) is used to determine soil health using a mixture of quantitative and qualitative observations of biological and physical indicators. Observable biological and physical indicators can be used as indicators of the functional status of ecological processes (Printz et al. 2014; Brown and Herrick 2016; Pellant et al. 2020).

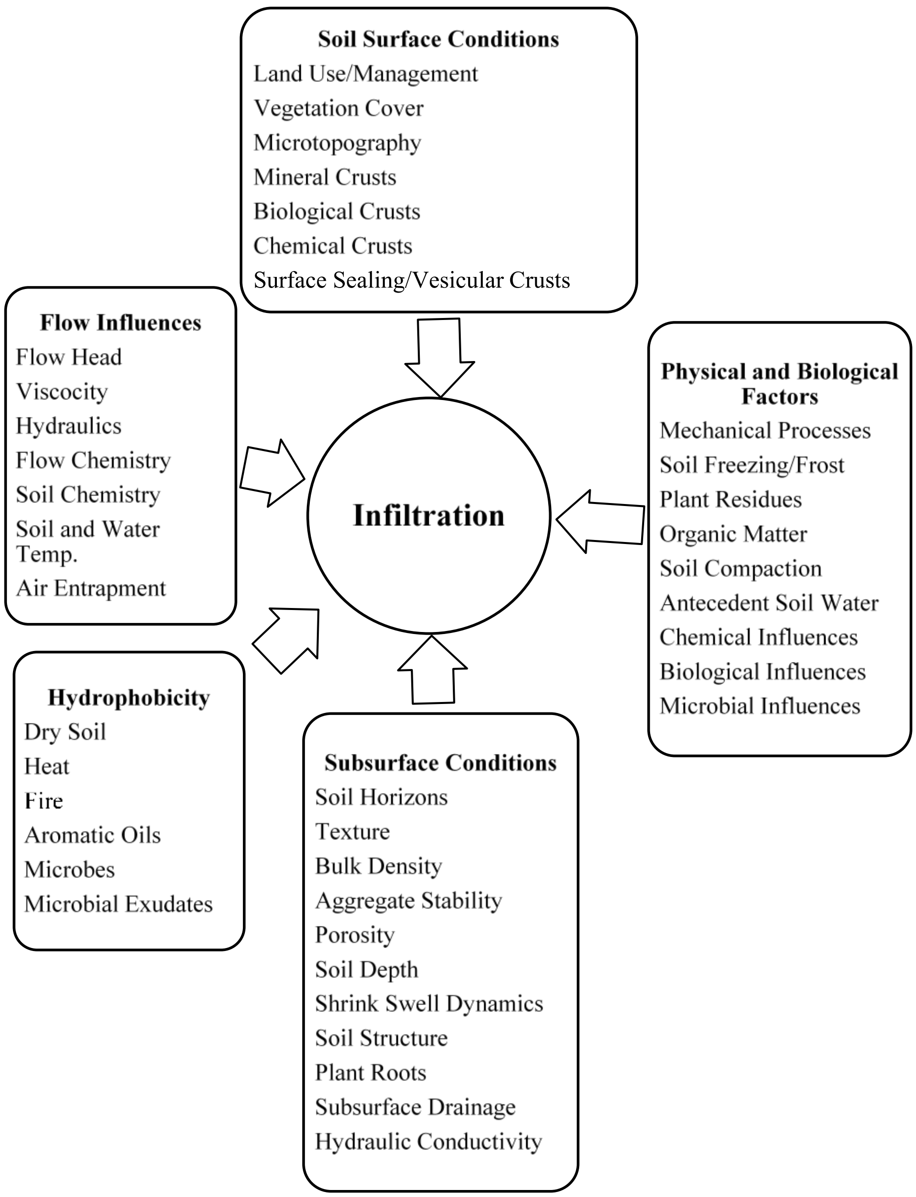
F. Some ecosystem processes or variables can be directly observed and measured, while other ecosystem processes or variables are inferred through other directly measured or observed characteristics. Statistically, variables that are not directly observed but are rather inferred (through a mathematical model) from other related variables are called latent or hidden variables. For example, a person's overall health is a latent variable – there isn't a single measurement of "health" that can be measured. Health is an abstract concept; however, measures of physical and chemical properties from our bodies, such as blood pressure, cholesterol level, weight, various measurements (waist, hips, chest), blood sugar, temperature, and a variety of other measurements are used holistically. The opposite of latent variables are manifest, observable, or indicator variables or factors that can be directly measured or observed. The same concept applies to rangeland and pastureland health. For example, measuring hydraulic properties such as infiltration capacity as a function of soil health in the field can be highly variable in space and time because there are many interacting factors (figure K-1). Infiltration capacity can be measured in the field with double ring infiltrometers, disc permeameter, Guelph Permeameter, and rainfall simulators. However, field infiltration measurements require specialized equipment, considerable time, and expense. Also, locating replicated samples, even within short distances on the same soil type, often results in high variability. Indicators such as level of compaction, amount of bare ground, plant cover, plant productivity, litter amount, lack of significant evidence of accelerated runoff and erosion, and nature of soil aggregates can be used to evaluate whether infiltration capacity is in sync within normal parameters for the site.

G. Measuring soil organic matter, chemical analyses, and macro and micro-nutrients can also be highly variable. Cornell University recommends sampling in about 10–15 locations throughout the garden or field, mixing the sub-samples, and obtaining a representative composite sample. In cases where erosion has occurred or significant changes in condition are apparent across the soil component or within the specific ecological site, stratification of the sample and sampling separate sites is warranted.

H. Evaluation of short-term grazing effects on range and pasture health may also not be readily detectable. Biomass, plant height, litter, plant cover, soil compaction, and keeping bare ground withing limits are correlated with short-term grazing effects and are also strong indicators of long-term grazing management. No single factor can assess grazing effects, although outcomes may be predictable and documented in state-and-transition models. Grazing impact has an immediate effect on the soil surface and plant growth and composition, which successively affects hydrology, energy and nutrient cycles, and erosion and sedimentation dynamics (figure K-2). Therefore, one measure cannot be used to evaluate grazing effects, thus the importance of a holistic approach to evaluating rangeland health.

I. Various range and pasture health protocols rely on specific indicators whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute such as soil or site stability, hydrologic function, and biotic integrity. It is important to acknowledge that a single indicator or attribute cannot represent health on rangeland, pastureland, or cropland. Interpreting Indicators of Rangeland Health (IIRH) (Pellant et al. 2020), Pasture Condition Score Sheet (PCSS), relies on a suite of key indicators for an overall numerical score assessment; whereas Determining Indicators of Pasture Health (DIPH) (Spaeth 2020, see subpart E) evaluates three separate attributes (soil or site stability, hydrologic function, and biotic integrity). The IIRH protocol is the preferred tool to evaluate rangeland health, and the user may choose PCSS or DIPH for determining pasture health. The PCSS is generally a quick assessment, whereas DIPH provides an evaluation of soil and surface stability, hydrologic function, and biotic integrity.

**Figure K-1.** Interrelated factors associated with infiltration.

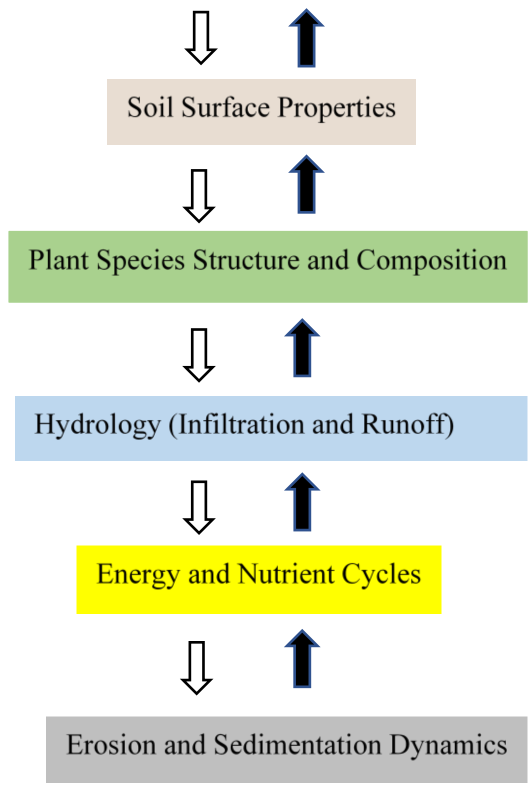



J. Interpreting Indicators of Rangeland Health lists appropriate applications and limitations (Pellant et al. 2020). For example, IIRH is determined with an appropriate reference sheet that is specific to the ecological site. If an ecological site has not been identified or written, then the procedure for Describing Indicators of Rangeland Health can be used (see Pellant et al. 2020). Interpreting Indicators of Rangeland Health is to be used by knowledgeable and experienced people with prior training (either a workshop or working closely with other users). The IIRH protocol is not to be used for identifying cause(s) of resource problems, and when used for monitoring or determining trends, quantitative data should also be used to support the indicator ratings (e.g., production, plant species ID and extent, invasive species ID and extent, and erosion and hydrology evaluations). The Rangeland Hydrology and Erosion Model can be used in conjunction with Soil and Surface Stability and Hydrologic Function (see subparts B and G). The DIPH tool can also be used with supporting information in the Ecological Site Description or be used as a stand-alone assessment with supporting documentation. The PCSS is designed to be used as a stand-alone tool.

**Figure K-2.** Model depicting influence of grazing practices on soil surface and subsequent results on plant communities, hydrology, energy and nutrient cycles, and erosion and sedimentation dynamics.

**Short and Long-Term Influence of Grazing Practices and**

**Potential for Modification of**




## 645.1102 Ecosystem Components of Range and Pastureland Health

A. Some of the major components related to range and pasture health are addressed in this section. Two terms, "ecosystem" and "plant community," are reviewed because they are integral components to range and pasture health.

(1) An ecosystem is a community of plants, animals, and soil organisms and their environment combined as a functional system of complementary relationships and transmission of energy and matter (Whittaker 1975).

(2) A plant community is an assemblage of populations of plants that interact in a specific environment, forming a distinctive living system with inherent composition, structure, environmental relationships, historic development, and function. The function of plants

within the concepts of IIRH (Pellant et al. 2020) and DIPH (Spaeth 2020) are addressed principally as biotic integrity (tables K-1, K-2). The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below ground. Pellant et al. (2020) define biotic integrity as the “the capacity of the biotic community to support ecological processes within the natural range of variability expected for the site (ecological site associated plant community), to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur.”

B. In all terrestrial plant communities, both soil and surface stability and hydrologic function are interconnected with biotic components. Each dynamic affects and reacts to each other. As mentioned in the introduction, “many variables (climate, geophysical factors, soils, plants, and biological components) all interact and act in concert within the ecosystem.” For example, in IIRH, certain indicators overlap for all three assessments (table K-1, e.g., soil surface resistance to erosion, soil surface loss and degradation, and compaction layer). Litter cover and depth span both hydrologic function and biotic integrity (table K-1). Rills, water flow patterns, pedestals and terracettes, bare ground, and gullies encompass both soil and site stability and hydrologic function. Pellant et al. (2020) define soil or site stability as “the capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water and to recover this capacity when a reduction does occur; and hydrologic function – the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.”

**Table K-1.** Three attributes of rangeland health and 17 associated indictors. Indicators are arranged under the respective attributes. Some indicators span more than one attribute. (Pellant et al. 2020.)

<table>
<tr><th>Soil/Site Stability</th><th>Hydrologic Function</th><th>Biotic Integrity</th></tr>
<tr><td colspan="2">1. Rills</td><td>12. Functional/Structural Groups</td></tr>
<tr><td colspan="2">2. Water Flow Patterns</td><td>13. Dead or Dying Plants or Plant Parts</td></tr>
<tr><td colspan="2">3. Pedestals and/or Terracettes</td><td>15. Annual Production</td></tr>
<tr><td colspan="2">4. Bare Ground</td><td>16. Invasive Plants</td></tr>
<tr><td colspan="2">5. Gullies</td><td></td></tr>
<tr><td>6. Wind-Scoured and/or Depositional Areas</td><td colspan="2">14. Litter Cover and Depth</td></tr>
<tr><td>7. Litter Movement</td><td>10. Effects of Plant Community Composition and Distribution on Infiltration</td><td>17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants</td></tr>
<tr><td colspan="3">8. Soil Surface Resistance to Erosion</td></tr>
<tr><td colspan="3">9. Soil Surface Loss and Degradation</td></tr>
<tr><td colspan="3">11. Compaction Layer</td></tr>
</table>

C. Table K-2 shows the commonality between IIRH and DIPH. There are common and unique indicators for DIPH because they represent specific characteristics of pasture environments. Unique indicators associated with DIPH include forage plant diversity, percent desirable forage plants, percent non-toxic legumes, based on adaptability with the ES and expected stand and longevity for the site, uniformity of use, and grazing and utilization. Seven livestock management factors are included in DIPH to focus on issues that are specific to livestock management. Although DIPH has over twice as many indicators as PCSS, certain indicators may not have issues, such as rill, wind, gully, and streambank erosion, and percent legumes; therefore, the field assessment process can proceed quickly. In field tests, comparison of time to complete PCSS and DIPH differ by not more than 10 minutes. The PCSS protocol derives a number score, where DIPH evaluates "preponderance of evidence" to determine the functional status of the three rangeland health attributes (see subpart E). The preponderance of evidence approach is used to select the appropriate departure category for each attribute and the overall decision for each of the three attributes. This assessment is based, in part, on where the majority of the indicators for each attribute fall under the five categories (none to slight, slight to moderate, moderate, moderate to extreme, and extreme to total).

**Table K-2.** Proposed Matrix for Determining Indicators of Pasture Health (DIPH). Comparison of indicators in rangeland health matrix and proposed matrix for Determining Indicators of Pasture Health. LMQF=Livestock Management Quality Factor.

| Interpreting Indicators of Rangeland Health V 5 | | Determining Indicators of Pastureland Health | Assessment |
|---|---|---|---|
| 1. Rills | SSS, HF | Erosion (Sheet and Rill) | SSS, HF |
| 2. Water-flow Patterns | SSS, HF | Water-flow Patterns | SSS, HF |
| 3. Pedestals and/or terracettes | SSS, HF | Pedestals and/or Terracettes | |
| 4. Bare ground | SSS, HF | Bare Ground % | SSS, HF |
| 5. Gullies | SSS, HF | Erosion (Gullies) | SSS, HF |
| 6. Wind-scoured, blowouts, and/or deposition areas | SSS | Erosion (Wind) | SSS |
| | | Erosion (Shoreline) if present | SSS, HF |
| 7. Litter movement | SSS | Litter Movement | SSS, HF |
| 8. Soil surface resistance to erosion | SSS, HF, BI | | |
| | | Live Plant Foliar Cover (hydrologic and erosion benefits) | SSS, HF |
| 9. Soil surface loss and degradation | SSS, HF, BI | Soil Surface Loss or Degradation | SSS, HF, BI |
| 10. Effects of plant community composition and distribution on infiltration and runoff | HF | Effects of Plant Community Composition and Distribution on Infiltration and Runoff | HF |
| 11. Compaction layer | SSS, HF, BI | Compaction Layer | SSS, HF, BI |
| 12. Functional/structural groups | BI | | |
| | | Forage Plant Diversity | BI, LMQF |
| | | Percent Desirable Forage Plants (for identified livestock class) | LMQF |
| 13. Dead or dying plants or plant parts | BI | Dead or Dying Plants or Plant Parts | BI |
| 14. Litter cover and depth | HF, BI | Litter Cover and Depth | HF, BI |
| 15. Annual production | BI | Annual Production | BI, LMQF |
| 16. Invasive plants | BI | Invasive Plants | BI |
| 17. Vigor with an emphasis on reproductive capability of perennial plants | BI | Plant Vigor with an emphasis on Reproductive Capability of Perennial Plants | BI |
| | | Percent non-toxic Legumes (based on adaptability with Ecol. Site and/or what is expected stand and longevity for the site) | BI, LMQF |
| | | Uniformity of Use | HF, BI, LMQF |
| | | Grazing and Utilization | BI, SSS, HF, LMQF |

D. If an ecological site does not exist or has not been completed, or the pasture state narrative in the ecological site description is not complete, the DIPH matrix can be used as a "stand-alone" document to determine indicator status. Likewise, if an ecological site is not available or does not exist, as is often the case on public lands, the protocol Describing Indicators of Rangeland Health can be used for rangeland health (see subpart E and Pellant et al. 2020). If repeated DIPH assessments are made on specific ecological sites, data can be collected to help develop the narrative for pasture groups and the ecological site description converted pasture state. In table K-1, several indicators can be evaluated with ecological aspects inherent to the ecological site. For example:

(1) Annual production capacity
(2) Percent non-toxic legumes (based on adaptability associated with ES or what is the expected stand for the site)
(3) Forage plant adaptability and projected diversity
(4) Litter amount and plant residue
(5) Erosion (sheet and rill)
(6) Erosion (gullies)
(7) Erosion (wind)
(8) Water flow patterns
(9) Percent bare ground
(10) Soil health attributes
(11) Dynamics of weeds and invasive plants

## 645.1103 Soil Health and Quality (selected excerpts included from Spaeth 2020)

A. Soil health and quality are not new ideas for sustainable agriculture; however, they have gained a resurgence among land users, especially on cropland. Many current popular publications and scientific studies published in peer-reviewed journals address new ideas and research on cover crops, applying manure and other soil amendments, practicing crop rotations, and using minimum tillage or no-till cropping systems. In 2013, the Food and Agriculture Organization of the United Nations (FAO) emphasized a greater focus on soil health (FAO-2013). FAO stated:

(1) "More attention to the health and management of the planet's soils will be needed to meet the challenge of feeding a growing world population . . . the importance of soil for food security should be obvious. From the origins of civilization in early farming communities up through today, we can see how societies have prospered thanks to healthy soils and declined when their lands became degraded or infertile . . ."
(2) "Healthy soil is not only the foundation of food production, but serves other functions . . . for example, soil is critical to the health of ground and surface waters and ecosystem health, and sequesters twice as much carbon as is found in the atmosphere . . . until recently, soils were the most overlooked and widely degraded natural resource. Today that state of affairs has at last begun to change, with World Soil Day poised to be recognized by the United Nations and a new, international Global Soil Partnership."

B. The resurgence of interest in soil health across all land uses is due to a variety of reasons:

(1) Exponential growth and interest in organic food products and farming ($43 B according to the Organic Trade Association's industry; Global sales of organic foods amounted to about 81.6 B U.S. dollars in 2015) (Statista 2018).
(2) The USDA reported 19,474 organic farms, ranches, and processing facilities in 2015, up more than five percent from the previous year and 250 percent from 2002, when record-keeping began. Throughout the world, there are more than 27,800 organic producers.
(3) Impetus from the FAO International Year of Soils (2015) by the United Nations Food and Agriculture Organization.
(4) Interest worldwide on landscape sustainability.
(5) Earth's population growth.

(6) Increasing recognition of degraded resources throughout the world.
(7) Interest in sustainable crop production systems that reduce tillage operations and wind and water erosion, use of no-till and reduced tillage to reduce soil disturbance.
(8) The correlation between soil health and human health.
(9) Greater affluence throughout the world and desire for higher protein diets.
(10) Desire to improve water quality.
(11) Maintaining productive farmland and rangelands for future generations.
(12) The economics of reducing fuel, soil amendments, and wear and tear on equipment.
(13) Improve and sustain crop yields and productivity.
(14) Maximize the local water budget, improve hydrologic function, and manage soil moisture.
(15) Enhancing wildlife habitat.
(16) New science and better information about the quantitative effects of soil health.

C. Conservationists and land managers should not lose sight of the functionality of the ecosystem in place. Soil health, plant health, soil and site stability, hydrologic function, biotic integrity, energy, and nutrient cycling, are all integral to the health of the plant community—one process does not exist or function without the other.

D. Soil functions in various capacities:

(1) Sustains biological components, their activity, diversity, and ultimately productivity
(2) Regulates and partitions water as a function of the hydrologic cycle
(3) Serves as an environmental filter by buffering and degrading organic and inorganic matter
(4) Stores and cycles nutrients and other elements in the environment
(5) Provides the foundation and support for the infrastructure of civilization

E. The concepts of soil health and quality are often intertwined and used synonymously; however, soil quality is associated with a soil's natural composition, while soil health is related to the capacity and functionality of the soil. Soil quality relates to quantifiable natural properties that are inherent for a particular soil type; e.g., soil physical and chemical characteristics and historical soil-forming factors, which are fixed by nature. The USDA-NRCS defines soil health as "the capacity of the soil to function as a vital living ecosystem to sustain plants, animals, and humans" (USDA-NRCS 2021b). Six key soil physical and biological processes must function in a healthy soil (USDA-NRCS 2019):

(1) Organic matter dynamics and carbon sequestration
(2) Soil structural stability
(3) General microbial activity
(4) Carbon food source
(5) Bioavailable nitrogen
(6) Microbial community diversity

F. The United Nations states: "Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production" (FAO 2008).

G. The overall goal of conservation management practices for soil health are:

(1) Minimize soil disturbance and maintain natural soil quality factors
(2) Maximize soil cover
(3) Maximize biodiversity
(4) Maximize and enhance living roots—microorganisms are most active in and around plant roots, increase in diversity of beneficial microbia, and enhance the nutrient cycle in soils

H. In order to accomplish goals of improving soil health, an integrated approach is needed. For example, on cropland, cover crops, residue, and tillage management, reduced and no-till, and conservation crop rotation are some of the principal conservation management practices used in sustainable cropping systems and maintaining or building soil health. Likewise, on grazing lands, integrated approaches commonly include managed grazing, and the periodic use of prescribed burning, brush management, and herbaceous weed treatment, according to ecosystem dynamics and need. The objective of these practices is to maintain or restore plant communities. On native rangelands with representative levels of native species, maintaining these species is critical to biodiversity and long-term health and sustainability.

I. Significant correlations exist between livestock management (stocking rate), vegetation change, and soil function (Briske et al. 2011). As a consequence, other factors such as shrub invasion and increased woody species densities (Archer et al. 2001; Archer et al. 2011) and exotic plant species invasion (Sheley et al. 2011) are associated with land degrading processes. Inappropriate grazing management such as overutilization, unsustainable stocking rates, and continuous use are usually directly or indirectly linked to the initial stages of undesirable change. Although managing most rangeland systems involve inherent complexity, many soil and vegetation degrading factors can be linked in some fashion to poor grazing management (Brown and Herrick 2016). Early warning indicators of changes in range, pasture, and soil health are commonly associated with some aspect of livestock grazing management, which is expressed in vegetation changes (species composition, diversity, and production) (Briske et al. 2011). Fortuitously, improved managed grazing is frequently the most cost-effective means of avoiding soil health degradation or reversing a downward trend in soil health on rangelands (Brown and Herrick 2016).

J. Soils develop and evolve over long periods of time in conjunction with climate, geology, parent materials, vegetation, and local microbial and animal floras (Jenny 1941; 1961). “Soils—in the pedological [science that deals with formation, biotic and abiotic components and classification] sense—are born, mature, and die. They are born when sediments are deposited. They mature after sedimentation stops and soil horizons develop. And they die when erosion strips away the soil horizons and exposes underlying parent material” (USDA-NRCS 2016). Early Russian pedologists developed a metaphor called “soil memory.” Soils have a past history and so-called memory dictated by climate, vegetation, and land use. These properties are discernable by the properties and stratigraphy of the soil (scientific study of rock strata or layers, especially the distribution, deposition, correlation, and age of sedimentary rocks). All intact non-cultivated soils have a natural level of soil quality and health, which are both unique to that particular soil in its ecosystem setting.

K. Where soil organic matter may be naturally low (e.g., semiarid and arid environments), this property of soil quality is representative of that soil type, which was influenced by the historic soil-forming factors and the soil’s evolution over time. Naturally occurring pH of soils developing with forest vegetation are typically acid; however, a soil with high carbonates and limestone-derived parent material are typically alkaline. Both of these conditions are representative inherent soil quality factors and cannot be altered easily without high agricultural inputs. Natural levels of organic matter, pH, carbonates, sodium, sand, silt, clay, and soil structure constitute “natural soil quality.” Some of these physical and chemical soil attributes may not be conducive to agricultural or construction pursuits (or to one’s objectives). They represent the particular qualities of that soil. Because a natural soil may not have abundant organic matter, or a pH level that is desirable for a particular crop, or may be relatively low in essential plant nutrients, does not imply that the soil is “bad” or “unhealthy.” It just means that that soil may not meet specific needs or agricultural objectives; but regardless, it is healthy from a soil quality or naturalized point of view. The critical point regarding soil quality or health is that a reference condition is required for each soil type so that comparisons of existing plant and soil conditions can be made. Without a reference for each particular soil, soil quality or health determinations are not possible. This is an extremely important point: the soil component characteristics associated with the ecological site as defined in the ecological site description are the reference standard, as well as state changes and site thresholds caused by perturbations to the system.

## 645.1104 Soil Health Management on Rangeland and Pastureland

A. The management of rangeland ecosystems and subsequent effects on soil physical and chemical properties are dynamically different from cropland and other agricultural land uses, such as pastureland, that have a history of cultivation. Rangelands are largely managed as naturalized systems with minimal cultural inputs with multiple use objectives that may or may not include livestock grazing (see subpart A). Rangeland plant communities vary considerably across the continuum of rangeland ecosystems in the United States with respect to climate, geomorphology, soils, plant species composition and physiological traits, physical and chemical soil properties, and hydrology.

B. Pastoral systems that have a prior history of cultivation are typically seeded to adaptable forage species (introduced and native). Over time, any cultivated soil has a history of soil erosion and ultimately soil carbon losses. The dynamics of soil health on pasturelands can be significantly different than uncultivated rangelands, and recognition of these differences is critical to current and future management. Franzluebbers and Stuedemann (2013) state:

> Historic loss of soil organic C (SOC) with cultivation of land for crops has been dramatic. Estimates in different regions of the world range from 20 to 60 percent SOC loss when compared with native conditions (Giddens 1957, Mann 1986, Davidson and Ackerman 1993, VandenBygaart et al. 2003, Liebig et al. 2005, Ogle et al. 2005, Luo et al. 2010). In the Appalachian Piedmont region of the southeastern USA, topsoil loss from historic cultivation of a variety of crops, but primarily cotton (*Gossypium hirsutum* L.) and tobacco (*Nicotiana tabacum* L.) without sufficient conservation measures, has been estimated to be 20 cm (Trimble 1974).

C. Erosion is a natural process. Approximatively 80 percent of the world's land surface is vulnerable to geologic erosion (Thurow 1991). An extreme example in the United States is the Badlands National Park. Geologic erosion there has been active for the last 500,000 years (Stetler et al. 2011), and current average soil loss in the park is estimated at ~2.5 cm $yr^{-1}$ (Stoffer 2003), approximately equivalent to 325 Mg $ha^{-1}$ $yr^{-1}$ (144.9 t $ac^{-1}$ $yr^{-1}$). See exhibit K-1 below for examples of geologic soil loss (see subpart G for additional information on soil erosion).

**Exhibit K-1.** 1 mm of Soil Loss?

Several publications have provided estimates of average soil loss:

- 0.1 mm $yr^{-1}$ for our most recent geologic epoch (Wilkinson and McElroy 2007)
- 0.021 mm $yr^{-1}$ the average erosion rate at 21 meters per million years (m/m.y.) (Summerfield and Hulton 1994)
- Loess and glacial till areas of Iowa, United States, ~0.8–1.9 Mg $ha^{-1}$ $yr^{-1}$ (Ruhe and Daniels 1965, Walker 1966)
- On cultivated US croplands, average estimated erosion rates are about 600 m/m.y. (0.6 mm $yr^{-1}$) (USDA-NRCS 2000)

**Equivalency of 1 mm of Soil Loss to Mg $ha^{-1}$ and t $ac^{-1}$?**

If 1 mm of soil erodes on a silt loam with a bulk density of 1.33 Mg $m^3$, what is the equivalent soil loss in Mg $ha^{-1}$ and US tons $ac^{-1}$?

- For 1 mm soil depth = (1 m) (1 m) (0.001 m) = 0.001 $m^3$
- Weight of soil 1 $m^2$ at 1 mm depth = (0.001 $m^3$) (Bulk density 1.33 Mg $m^3$) = 0.0013 Mg $m^3$
- Weight of soil for 1 hectare at 1 mm depth = (100 m) (100 m) (0.0013 Mg $m^3$) = 13 Mg $ha^{-1}$ (5.79 t $ac^{-1}$)

D. For example, Bakker et al. (2004) find that crop productivity decreases 4.3–10.9 percent per 10 cm of soil loss. Soil erodibility is multivariate in nature, and many factors are involved such as intensity, duration, and amount of precipitation; topography – land slope and shape (linear, convex, con- cave) – types and amounts of vegetation; organic matter content and associated aggregate stability; soil particle size (texture); and nature of parent material (Butzer 1974).

E. In many natural terrestrial plant communities, a relative balance exists between weathering and erosion:

$$E = W + S$$

where $E$ = erosion by runoff and mass movement, $W$ = rate of weathering and soil formation, and $S$ = soil wash and other incoming upslope colluvium (Bunting 1965). The soil building process continues where $E < W + S$; examples may be where convex slopes increase until an equilibrium is reached. Where ecological balance is disrupted, $E > W + S$. Erosion continues until a new equilibrium is reached or erosion continues to bare rock or other restrictive layer.

F. In the Great Plains of the United States, examples of organic matter depletion as a result of intense cultivation of native grasslands by pioneer farmers have reduced soil productivity by 71 percent over a 28-year period (Flach et al. 1997). The worst modern erosion event was the Dust Bowl of the Southern Great Plains of North America (western Kansas, southeastern Colorado, Oklahoma Panhandle, the northern two-thirds of the Texas Panhandle, and Northeastern New Mexico). Unfortunately, by the end of the Dust Bowl, many areas in the Midwestern Great Plains had cumulatively lost more than 75 percent of its topsoil from wind and water erosion (Hornbeck 2009). Many authors report that once cultivation begins by breaking up undisturbed native grassland and forest soils, about 20–50 percent of the original soil organic carbon is lost within 40–50 years (Campbell and Souster 1982; Mann 1986; Schimel 1995; Donigian et al. 1994; Rasmussen and Parton 1994; Houghton 1995) (figures K-3, K-4). After the decline of soil organic carbon, further changes are largely a function of active erosion and subsequent soil management (Rasmussen and Collins 1991).

**Figure K-3.** **(a)** Decline of SOM after cultivation in native tallgrass prairie with high historic organic matter content (7.5 percent). Graph shows progressive loss of organic matter in the upper 25.4 cm (10 in) after cultivation. If a field is seeded back to native grasses after 100 years, organic matter would slowly increase. **(b)** Development of organic matter over time, rate of accumulation is progressive until a constant level is reached—in equilibrium with climate, soil properties, plant community, and decomposition processes. (Spaeth 2020.)

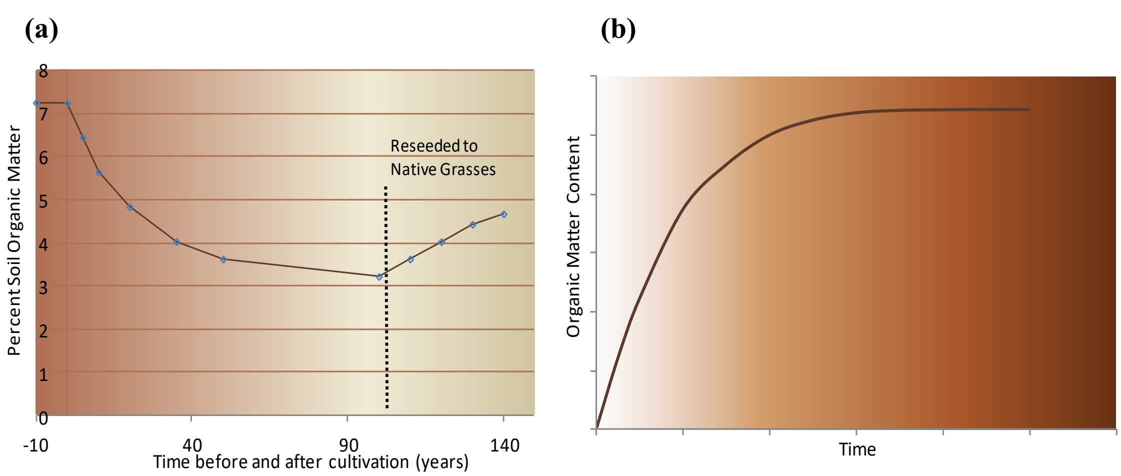


**Figure K-4.** Simulation of soil carbon changes from 1907 to 1990 for corn belt in central U.S. (Spaeth 2020, adapted from Donigian et al. 1994.)

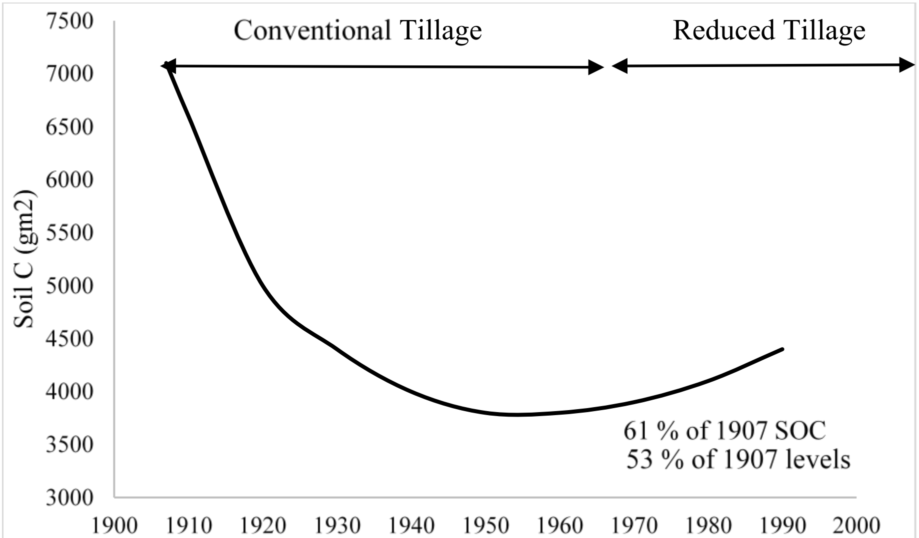



**Exhibit K-2.** (Spaeth 2020).

Ten Differences Between Rangeland and Cropland Factors that Influence Soil Health

Note: existing rangelands are typically not suitable to cultivation or have been re-established because of high erosivity and low crop potential.

- In contrast to croplands, which on the average either receive adequate rainfed precipitation or are irrigated, many arid and semiarid rangelands are characteristic of high inter- and intra-annual variability in timing and amount of precipitation, which is the key factor that drives ecological dynamics including hydrologic function, soil and site stability, biotic integrity, and response to management. Microbial populations that are active with carbon cycle "wax and wane" with available soil moisture content; therefore, many cropland soil health indicators are not applicable to rangeland. Rangeland and cropland are unique in their capacities, and evaluations of soil health should be based on their particular potentials and dynamics.
- Existing undisturbed rangeland soils are highly variable, ranging from shallow to very deep. Many highly productive croplands were highly productive rangelands (grasslands) with lower tolerable soil loss rates than cropland, especially on fragile arid and semi-arid rangelands. Much of the remaining uncultivated Great Plains prairies occur on soils with soil properties (shallow, steep, droughty, gravely and rocky, wet, saline, and high pH) that are unsuitable for crop production.
- Many rangeland soils in the southwest and western rangelands have lower soil organic matter content; however, the true prairie soils of the Great Plains with higher organic matter have greater soil organic carbon percentages for maintenance of sequestered carbon. Prairie grassland soils that were suitable for cultivation are now some of the most productive cropland soils.
- Soil organic carbon sequestration in arid and semiarid rangeland environments can be substantial because of carbon stocks from perennial root systems and large biomass turnover of above-ground plant litter. Rangeland ecosites with perennial shrubs and trees have substantial carbon storage above and below ground. Forests (1.2–1.4 Pg C $yr^{-1}$) and cropland (0.4–1.2 Pg C $yr^{-1}$) have the largest potentials for sequestering carbon, although grazing lands (range and pasturelands) can contribute up to 10 percent of the carbon sink capacity. On a global perspective, rangelands occupy about half of the world's land area, 10 percent of the terrestrial biomass, and 10–-30 percent of the

soil organic carbon (Schlesinger 1997). An average estimate of globally sequestered soil carbon on rangelands is 0.5 Pg C $yr^{-1}$ (Schlesinger 1997; Scurlock and Hall 1998).

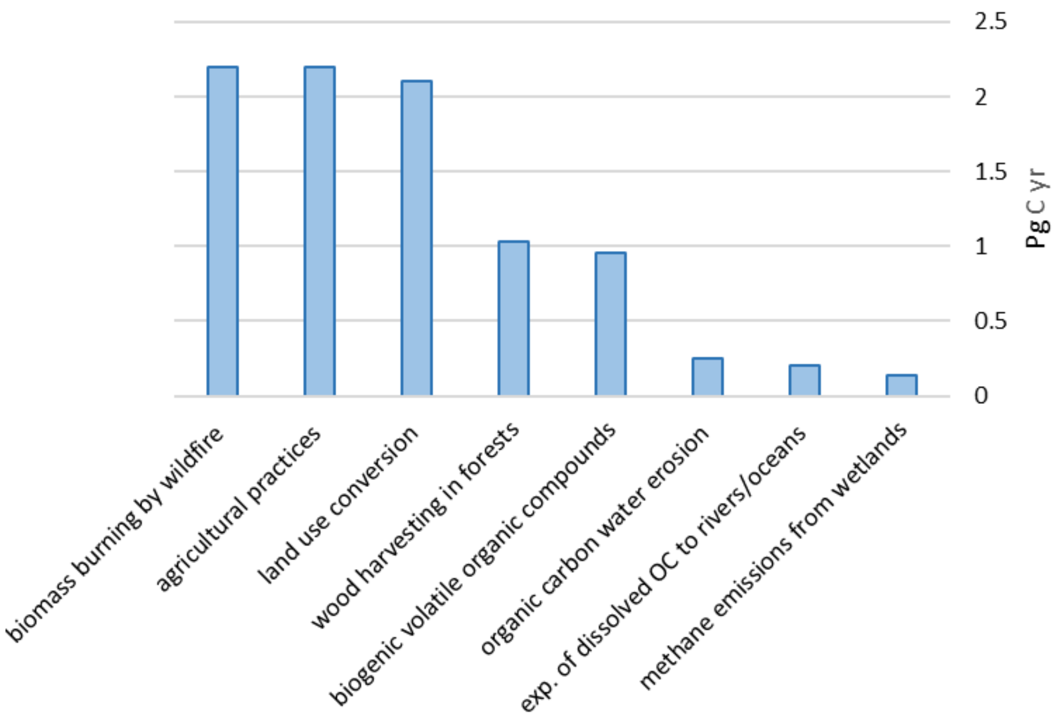
- Rangelands include many different types of vegetation life forms (trees, shrubs, forbs, grasses, and biotic crusts) and growth forms (bunch, sod, vine, stoloniferous, rhizomatous, tap and fibrous root systems) compared to monocultures or limited plant diversity in cropland settings. Carbon cycles, turnover, and sequestration comparisons between perennial rangeland vegetation and cropland are significantly different due to rooting depth dynamics and soil surface cultivation.
- Perennial vegetation on rangelands is typically associated with less soil disturbance than cultivated croplands (exceptions are no-till and reduced tillage). In heavier-textured rangeland soils, soil aggregates are maintained with more stable soil organic matter pools and microbial populations. Rangeland soil structure is typically not altered to the extent that may exist in recurring tillage operations with cropland agriculture. Also, cropland soils often have a plow layer or plowpan layer that persists after cultivation and may inhibit infiltration capacity and root development of plants.
- Soil heterogeneity is often more prevalent on existing rangeland because of geomorphic topographic influences that inhibit cultivation. This heterogeneity promotes plant species diversity and associated microbial mycorrhizal associations.
- Erosion control on rangeland is highly dependent on maintaining living plant foliar cover (> 60 percent cover), litter, and health root systems; whereas, on cropland, plant cover usually consists of annual plants that are harvested with various levels of remaining litter. On crop fields, residue management, crop and tillage management (reduced tillage and no-till, cover crops, strip cropping) and structural practices (terraces, waterways, diversions) are commonly used to manage runoff and erosion.
- Natural biological soil crusts can be prevalent in rangeland plant communities, especially in semiarid and arid shrub ecosites with plant interspaces. They provide soil surface stability against wind and water erosion and are active in nutrient cycling.
- Arid and semiarid rangelands have slower decomposition and carbon turnover rates because of more erratic climate and precipitation compared to temperate grasslands, savannahs, and shrublands. Cropland environments (rainfed and irrigated) supply more consistent moisture that is necessary to maintain microbial populations associated with nutrient cycling, decomposition, and organic matter turnover. Management associated with soil health and soil organic matter restoration may not be possible in many arid and semiarid rangeland plant communities due to inherent climate restrictions, original soil carbon dynamics, wind and water erosion, and changes from perennial to annual plant dominance. Rangelands dominated by annual exotic grasses and forbs are prone to increased wildfire and subsequent wind and water erosion, which creates an unstable environment to maintaining soil organic carbon levels. If major depreciating vegetative state changes have crossed critical thresholds, they may be permanent and irreversible. On croplands that still have good production potential (with adequate rainfall and/or irrigation), enhancement of soil organic matter and microbial mycorrhizae interactions are significantly more probable with the use of reduced and no-till practices and cover crops.

## 645.1105 Carbon Budgets and Balance in Terrestrial Ecosystems

A. Carbon is an essential element of all Earth’s systems and the building block of all living organisms, a key foundational element of soil health. Carbon is fundamental for life because of its ability to combine with other important elements, such as oxygen, nitrogen, and phosphorus, and hydrogen to form organic molecules that are essential for cellular metabolism and reproduction (Bruhwiler et al. 2018). The carbon cycle is central to plant-soil interactions and ultimately soil health. On a weight basis, carbon ranks 19$^{th}$ in order of elemental abundance in Earth’s crust (about 0.025 percent of the Earth’s crust); however, carbon is a component of more compounds than all the other elements combined. Carbon is found throughout nature in vastly different forms: graphite is very soft, while diamond is one of the hardest substances found in nature. Chemically, carbon is a nonmetal and is a component of over 10 million different compounds, thousands of which are vital to life processes. When carbon combines with oxygen in differing amounts, hydrocarbons are formed (coal, petroleum, and natural gas). All organically derived substances contain the element carbon, and in soils, organic matter is about 58 percent carbon.

B. Atmospheric carbon represented as carbon dioxide ($CO_2$) and methane ($CH_4$) helps regulate the Earth's climate by trapping heat in the atmosphere (the greenhouse effect), and these and other greenhouse gases such as water vapor and nitrous oxide ($N_2O$) help maintain a habitable equilibrium (Ito 2019). The global carbon budget of terrestrial ecosystems is determined mainly by major flows of carbon dioxide ($CO_2$) from photosynthesis and respiration; however, various minor flows also influence global carbon stocks and their turnover (Ito 2019) (figures K-5, K-6). The carbon cycle and temporal fluxes (natural and anthropogenic) are the foundation to understanding the dynamics of how carbon is processed and compartmentalized into various pools and reservoirs. The carbon cycle involves four basic carbon reservoirs: the atmosphere, oceans, terrestrial biosphere, and fossil carbon. As seen in figure K-6, natural pools and rates from heterotrophs are much greater than anthropogenic-derived carbon from burning fossil fuels and other activities, and rising $CO_2$ in the atmosphere is due to an imbalance between anthropogenic production and $CO_2$ consumption (Kirchman 2010). The global estimate of burning of fossil fuels is 4–10 Pg $yr^{-1}$, and open burning produces 2–3 Pg C $yr^{-1}$. (Wiedinmyer and Neff 2007); however, soil organic carbon losses from erosion are estimated at 5.7 Pg C $yr^{-1}$, of which about 4 Pg C $yr^{-1}$ is redistributed elsewhere on the landscape, 1.14 Pg C $yr^{-1}$ is emitted to the atmosphere, and 0.57 Pg C $yr^{-1}$ is transferred to the oceans (Lal 2003, 2008, 2010, 2018).

**Figure K-5.** Ranking of minor carbon flows associated with land use change (data from Ito 2019).




C. Ito (2019) identified eight minor carbon flows associated with land-use change (figure K-5):

(1) Biomass burning by wildfire
(2) Emission of biogenic volatile organic compounds from plants
(3) Methane emissions from wetlands
(4) Methane oxidation in uplands

(5) Agricultural practices from cropping to harvesting
(6) Wood harvesting in forests
(7) Export of dissolved organic carbon by rivers to oceans
(8) Displacement and transport of soil particulate organic carbon water erosion

**Figure K-6.** The global carbon cycle with representative carbon pools and reservoirs that interact with Earth's atmosphere (units next to reservoir names are Pg C. Note: Pg = $10^{15}$ g; $10^{6}$ g Mg megagram (ton); $10^{12}$ g Tg teragram; $10^{15}$ g Pg petagram). The soil reservoir contains about as much of the carbon reservoir as plants and the atmosphere combined. Carbon imbalance exists from the flow of burning fossil fuels, open burning (fire); and more carbon is emitted from the soil (62 Pg) than entering the soil (59–60 Pg) due to erosion and loss of organic matter. Land use changes have been estimated to produce 1.6–2 Pg C $yr^{-1}$, and the largest carbon reserve is in carbonate rocks (75 million Pg). Estimates are slightly different among authors (adaptations and data from Berner 1990; Schimel 1995; Batjes 1996; Falkowski et al. 2000; Pacala and Socolow 2004; Houghton 2007; Solomon 2007; Battin et al. 2009; Haddix et al. 2011; Pan et al. 2011; Lal 2018) (adapted from Spaeth 2020).

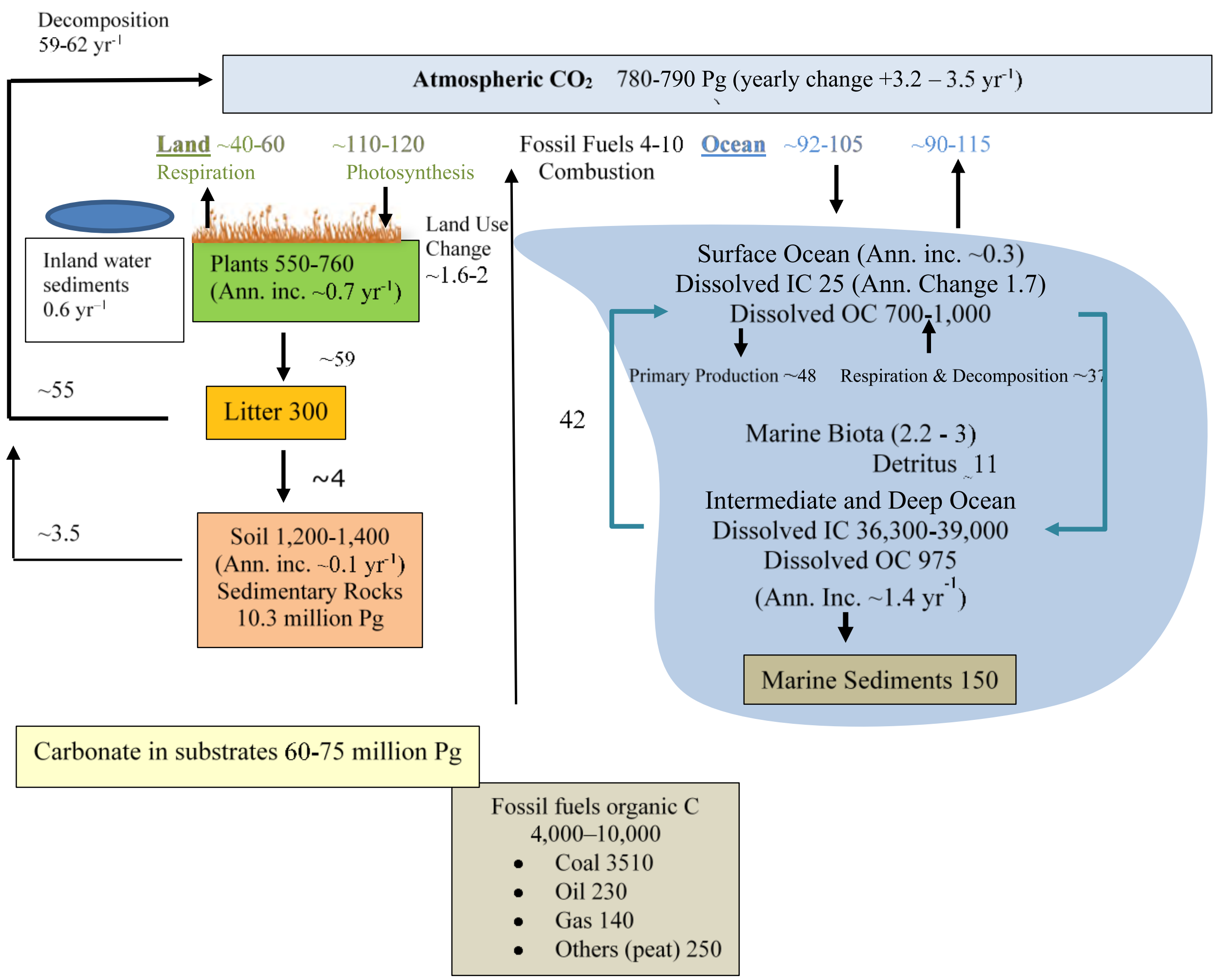
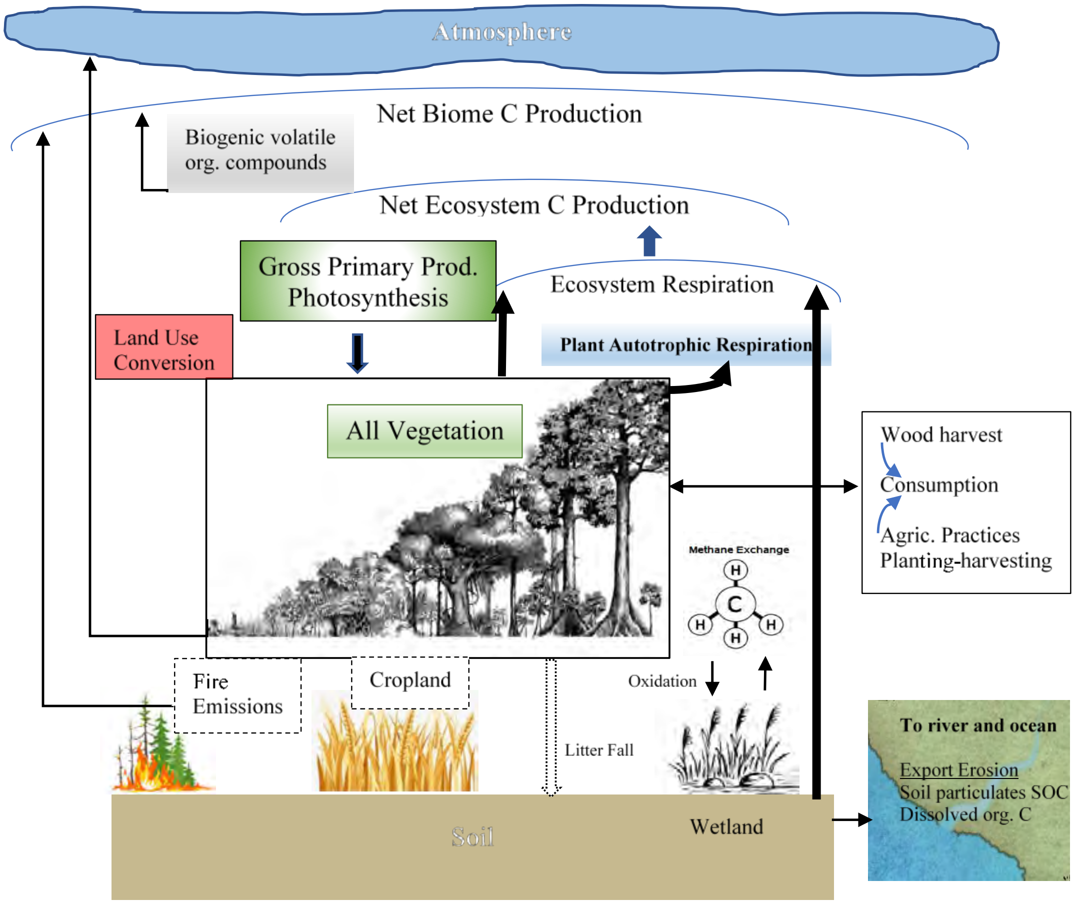


**Figure K-7.** Carbon budget with major and minor carbon flows. Thick lines=major C flows, thin lines=minor carbon flows.




## 645.1106 Soil Organic Matter

A. Unfortunately, there are many exaggerated and false narratives in the popular literature regarding organic matter (Spaeth 2020). Here we review some basic information with quotes relevant to soil organic matter. The major components of the soil environment are comprised of minerals, air, water, and living and dead organic matter (figure K-8). The amounts of each varies with soil type and management, but in general minerals comprise 45 percent, air and water 25 percent, and 1–5 percent is living or dead organic matter. Air and water change with soil moisture levels, while organic matter varies with soil type, climate, plant community, and management practices. Intrinsic physical, chemical, and biological properties in soils provide a basis for soil quality, while management affects plant growth, productivity, and soil carbon dynamics (figures K-7, K-9).

B. Soil organic matter represents the smallest fraction in soil but is one of the most important constituents as it is directly related to agricultural production. Organic matter is ~58 percent carbon and is derived from contributions of decomposed plant residues from leaf litter, crop residues, plant roots, root exudates, animals and feces, and decomposing remains of soil fauna and microbes. Carbon fixation from the atmosphere occurs through photosynthesis, and carbon content in the soil is dependent upon inputs from plants and microbes[1].

**Figure K-8.** Components of organic matter.

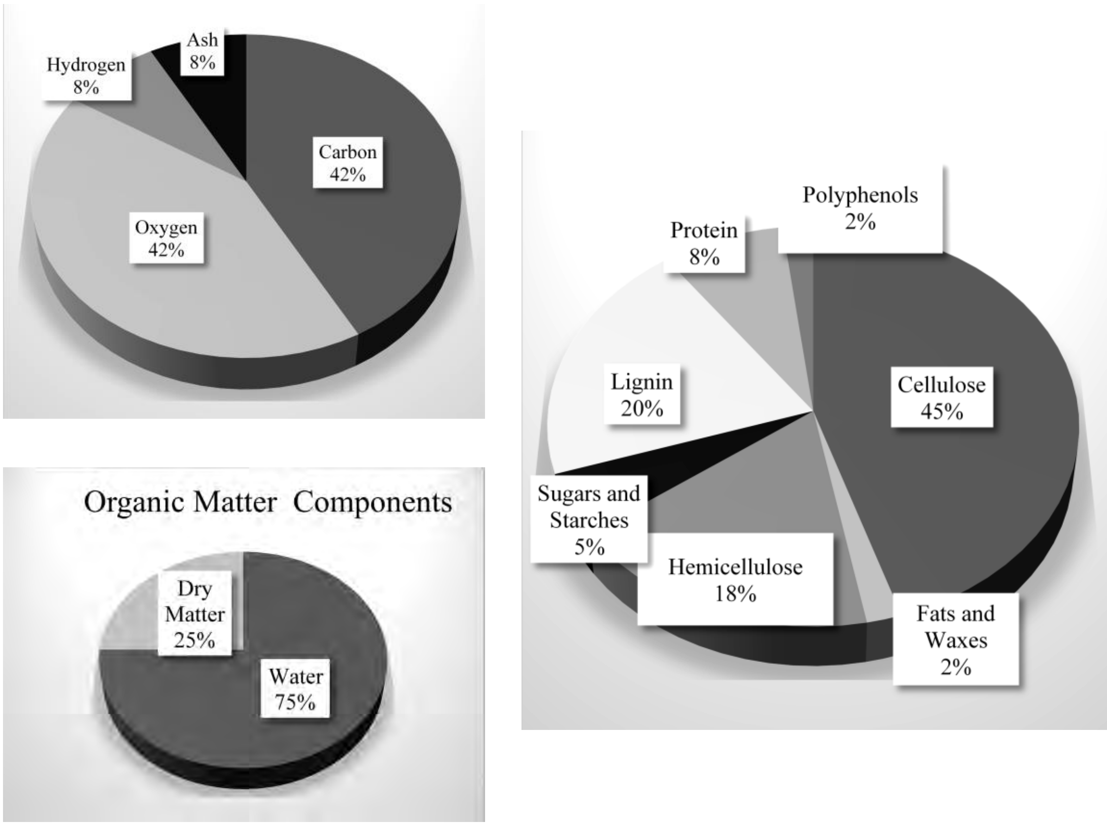



**Figure K-9.** Physical, chemical, and biologic properties associated with overall health of a plant community (adapted from Stirling et al. 2016).

| Inherent Components of Soil | | Plant and Management Practices | | Soil and Plant Community Properties | | |
|---|---|---|---|---|---|---|
| Minerals<br>Soil Organisms<br>Organic Matter<br>Water<br>Air | → | Tillage<br>Fertilizer Inputs<br>Soil Amendments<br>Pesticides<br>Residue Management<br>Grazing<br>Trafficking | → | Water Availability<br>Acidity/Alkalinity<br>Nutrient Availability<br>Aeration<br>Soil Borne Pathogens<br>Weed Competition<br>Compaction/Crusting<br>Biodiversity | → | **Plant Growth and Productivity** |

[1] Carbon dioxide ($CO_2$), the most common oxide of carbon, is a trace gas [also classified as a greenhouse gas; 0.04 percent (410 ppm and increasing by 0.5 percent per year) by volume compared to 280 ppm before the onset of the industrial revolution].

**Exhibit K-3.** Importance of Soil Organic Matter: Quotes (Spaeth 2020)

- "Soil organic matter is the main reservoir of SOC and soil organic nitrogen in rangelands and determines soil fertility, water retention, and soil structure" (Pineiro 2010).
- "Humus plays a leading part in the storage of energy of solar origin on the surface of the earth" (Waksman 1936).
- "Soil plays an essential role in the global carbon (C) cycle acting as both a source and sink of organic C . . . Soil contains three times more organic C than is contained in plants and the atmosphere, and while soil is classically viewed as a C sink on a global scale there is concern that climate and land use change will turn it into a C source" (Caruso et al. 2018).
- "When grassland or forest ecosystems are first converted to agriculture, multiple mechanisms result in SOM declines of between 20 percent and 70 percent. Two of the most important mechanisms are the reduction in organic matter inputs from roots following the replacement of perennial vegetation with annual crop species, and increases in microbial respiration when tillage breaks open soil aggregates exposing previously protected organic matter . . . Two of the overarching reasons why native terrestrial ecosystems have achieved greater soil organic matter levels than human agroecosystems are because they direct a greater percentage of productivity belowground in perennial roots, and they do not require frequent soil disturbance. A growing body of research including that presented in this review suggests that developing perennial grain agroecosystems may hold the greatest promise for agriculture to approach the SOM levels that accumulate in native ecosystems" (Crews and Rumsey 2017).
- "Carbon accumulation in temperate grasslands occurs mostly below ground. Past and current land use changes (e.g., conversion of arable land to grassland) as well as the agricultural management of grasslands affect the below-ground carbon stocks" (Soussana et al. 2004).
- "The amount of organic matter in soil depends on the input of organic material, its rate of decomposition, the rate at which existing soil organic matter is mineralized, soil texture, and climate. All four factors interact so that the amount of soil organic matter changes, often slowly, toward an equilibrium value specific to the soil type and farming system. For any one cropping system, the equilibrium level of soil organic matter in a clay soil will be larger than that in a sandy soil, and for any one soil type the value will be larger with permanent grass than with continuous arable cropping" (Johnston et al. 2009).
- "In rangeland ecosystems, above ground biomass provides carbon inputs to the soil over long periods of time. Rhizodeposition of below-ground carbon is important for carbon sequestration as carbon residence times are longer than above-ground biomass" (Cougnon et al. 2017; Sainju et al. 2017).
- "Grassland plant species allocate more below-ground carbon than cereal crops" (Pausch and Kuzyakov 2018).
- "Centuries before there was any science that acquainted people with the intricacies of plant nutrition, decaying organic matter, as in manure or other forms, was recognized as an effective agent in the nourishment of plants . . . Soil organic matter is one of our most important national resources: its unwise exploitation has been devastating, and it must be given its proper rank in any conservation policy as one of the major factors affecting the levels of crop production in the future" (Albrecht 1938).
- "Soil organic matter is a natural product resulting from microbial activity in the inorganic and/or organic soil environment. The amount and accumulation of soil organic matter are controlled by the composition and amounts of the plant residues, by climatic conditions, and soil texture. Other important factors are microbial activity, soil redox conditions, and other soil chemical and physical properties" (Haider and Guggenberger 2005).
- "In most soils, the percentage of soil organic matter is small, but its effects on soil function are profound. This ever-changing soil component exerts a dominant influence on many soil physical, chemical, and biological properties and ecosystem functions of soil" (Weil and Brady 2017).

- “Grassland soils can sequester more than 100 Mg $ha^{-1}$ (40.5 t acre) of soil organic carbon and 10 MG $ha^{-1}$ (4.05 t acre) of soil organic nitrogen in a surface meter of soil” (Milchunas and Lauenroth 1993; Derner et al. 2006; Pineiro et al. 2009).
- “The value of soil organic matter is more than just its ability to hold water and nutrients for plant growth. Its hidden value lies in its ability to regulate the environment, especially to mitigate the greenhouse effect” (Lal et al. 1998).
- “A fertile and healthy soil is the basis for healthy plants, animals, and humans. And SOM is the very foundation for healthy and productive soils. Understanding the role of organic matter in maintaining a healthy soil is essential for developing ecologically sound agricultural practices” (SARE 2012).
- “The value of SOM has long been recognized. From earliest times, its level in the soil was used as a general indicator of soil productivity . . . A major factor contributing to the level of SOM is annual input of plant residues . . . Under cultivated agriculture, crop residues serve as carbon inputs and thus influence both the level and the dynamics of organic matter in the soil” (Buyanovsky and Wagner 1997).
- “Soil organic matter is where soil carbon is stored and is directly derived from biomass of microbial communities in the soil (bacterial, fungal, and protozoan), as well as from plant roots and detritus, and biomass-containing amendments like manure, green manures, mulches, composts, and crop residues . . . OM in its various forms greatly impacts the physical, biological, and chemical properties of the soil. OM acts as a long-term sink, and as a slow-release pool for nutrients. It contributes to ion exchange capacity (nutrient storage), nutrient cycling, soil aggregation, and water holding capacity, and it provides nutrients and energy to the plant and soil microbial communities” (Moebius-Clune et al. 2016).
- “The weathering of minerals is an essential function in the development of soils. The second process of great significance to soil formation is the accumulation of organic matter, which tends toward an equilibrium level in well-developed soils. The level to which organic matter accumulates in the soil depends on the nature of the soil forming environment as it affects two opposing processes, namely: the addition of residues, principally from plants, and the decay of these residues by microbes and other soil-inhabiting organisms” (Hausenbuiller 1978).
- “Soil organic carbon is a complex of organic carbon compounds in the form of SOM. Soil organic matter includes everything in or on the soil that is of biological origin, irrespective of origin or state of decomposition (Baldock and Skjemstad 1999). It includes plant and animal remains in various states of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. The ultimate product of the decomposition process is humus, an amorphous array of compounds highly resistant to further decomposition. Many organic compounds in the soil are intimately associated with inorganic soil particles. In agricultural soils, soil organic carbon content is usually less than 5 percent and decreases with soil depth (Baldock and Skjemstad 1999)” (citation from Xiao 2017).
- “Plant residues are the major source of carbon inputs in all terrestrial ecosystems” (Paustian et al. 1997).
- “Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides, and herbicides” (Bot and Benites 2005).
- “Organic residues are carbon-containing compounds of biological origin. Decomposition is the breakdown of these complex organic materials into simpler components” (Franzluebbers 2005).

## 645.1107 Organic Matter Losses with the Advent of Agriculture and Land Use Practices

A. The terrestrial biosphere stores about two-thirds of the global carbon in the surface meter of the soil. There are five global carbon pools (Pg is a unit of mass equal to 1,000,000,000,000,000 ($10^{15}$) grams; 1Pg= 1,000,000,000 metric tons) (Berner 1990; Schimel 1995; Batjes 1996; Falkowski et al. 2000; Pacala and Socolow 2004; Houghton 2007; Canadell et al. 2007a, b; IPCC 2007; Battin et al. 2009; Haddix et al. 2011; Pan et al. 2011; Lal 2018):

(1) Oceanic 36,000–39,000 Pg, increasing at 2.3 Pg C yr-$^{1}$
(2) Fossil fuels 4,000–10,000 Pg, mined and combusted 8 Pg C $yr^{-1}$
(3) Pedologic 2,500 Pg @ 1 m soil depth
    (i) 1,500–1,550 Pg Soil organic carbon
    (ii) 950 Pg Soil inorganic carbon
(4) Atmospheric 780–790 Pg, increasing at 3.2–4 Pg C $yr^{-1}$
(5) Biotic pool 550–760 Pg live biomass
    (i) 60 Pg detritus material
    (ii) 300 Pg litter

B. Historical Record of Soil Carbon Loss

(1) Assuming that organized agriculture began about 10,000 years ago (Ruddiman 2003), more than 320 Pg carbon has been depleted by anthropogenic activities such as deforestation, biomass burning, cultivation, and drainage of peatlands. Of this amount, about 78±12 Pg of carbon has been lost from the soil (Lal 2010). Global conversion of 1.136 billion hectares (Bha) of forest and woodlands and 0.669 Bha of savannah and grasslands have occurred between 1700 and 1990 (Foley 2005). Since the 1850s, estimates between 124 and 158 Pg of soil carbon have been depleted by various land-use conversions (Canadell et al. 2007b). Lewis (2005) estimates that between the years 1750–2000, about 180 Pg carbon have been released to the atmosphere, 60 percent originating from the tropics.

(2) On a global scale, intensive cultivation has resulted in a soil carbon loss of about 55 Pg carbon – 25 percent of the original historic soil organic carbon levels (Cole et al. 1997; Lal et al. 1998; Six et al. 2006). The cumulative loss of soil carbon from cultivated soils (55 Pg) accounts for about seven percent of the current carbon in the atmosphere (Lal et al. 1998).

(3) Plant communities containing specific plant life and growth forms display inherent productivity levels, both above and below- ground, and therefore have different capabilities concerning inherent and potential sequestration of soil organic carbon. Plant productivity and subsequent carbon balance in plant communities are dependent upon temperature, timing, and amount of precipitation, both of which enhance or constrain the microbial process of decomposition. In arid plant communities, productivity and decomposition of organic matter are constrained and tenuous because of low annual precipitation, higher summer temperatures, and high occurrence of drought, wherein subhumid ecosystems, plant growth, and decomposition are more constant. Soil texture also plays an integral role in baseline carbon contents. Jobbagy et al. (2000) found that precipitation and climate were the best predictors of soil organic carbon in the upper 20 cm soil layer; however, clay content was the best predictor in deeper soil layers. Higher clay content may be responsible for slower soil organic carbon cycling due to clay particles and noncrystalline minerals that act to stabilize organic matter (Trumbore 2000). The soil orders Histosols, Mollisols, and Vertisols contain the highest soil organic carbon contents on rangelands (figure K-10); however, from a global perspective they do not comprise the highest global carbon percentages in the upper 1 m of soil (table K-3).

**Figure K-10.** Average SOM content for selected soil orders on rangeland (USDA-NRCS soil data).

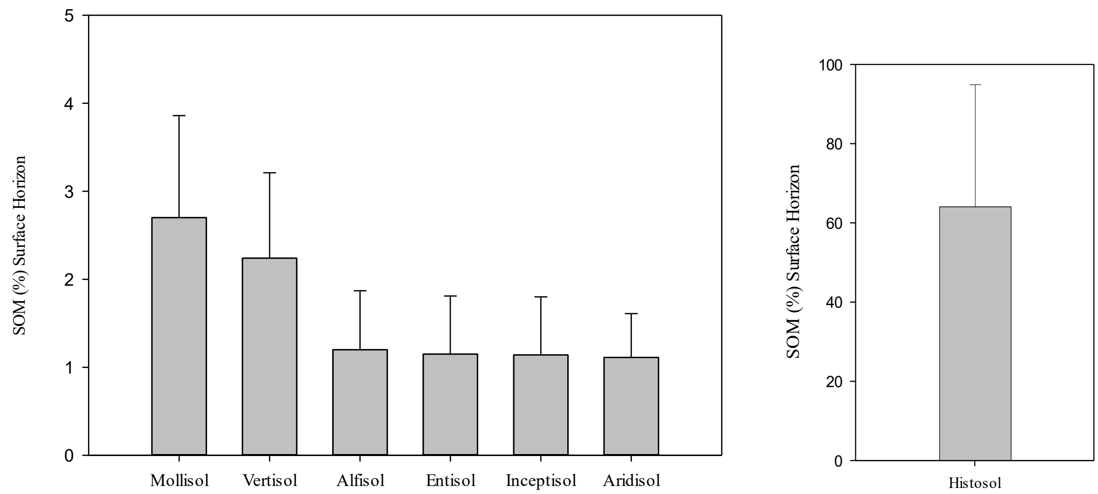



**Table K-3.** Organic and inorganic carbon mass in upper one meter of global soils. Note: inorganic matter is largely calcium carbonate in soils of arid regions. About 60–90 percent of carbon is in the upper one meter of the soil profile, although stored carbon is also significant below one meter in Histosols and Gelisols. (Data from Eswaran et al. 2000; Weil and Brady 2017.)

| Soil Order | Global Area $10^3$ $km^2$ | Global carbon in upper 1 m (Pg) | | | Total C % of global soil |
|---|---|---|---|---|---|
| | | Organic | Inorganic | Total | |
| Aridisols | 15,699 | 59 | 456 | 515 | 20.6 |
| Entisols | 21,137 | 90 | 263 | 353 | 14.2 |
| Gelisols | 11,260 | 316 | 7 | 323 | 12.9 |
| Mollisols | 9,005 | 121 | 116 | 237 | 9.5 |
| Inceptisols | 12,863 | 190 | 34 | 224 | 9.0 |
| Alfisols | 12,620 | 158 | 43 | 201 | 8.0 |
| Histosols | 1,526 | 179 | 0 | 180 | 7.2 |
| Ultisols | 11,052 | 137 | 0 | 137 | 5.5 |

## 645.1108 Carbon Geochemical Cycle

A. Terrestrial ecosystems are a complex of biotic and abiotic components with various cycles that are active in all environments. Cropland settings, forest, rangeland, pastureland, and gardens all have particular features concerning biomass production, plant decay rates, soil-microorganism dynamics, and climatic effects (water and temperature are principal drivers of productivity in all plant communities). Organic matter gains and losses in the soil are dependent upon gains and losses of carbon. There are five biogeochemical cycles: carbon cycle, nitrogen cycle, oxygen cycle, phosphorus cycle, and the water cycle (see subpart G) that represent the flow of chemical elements between living organisms and the environment. Here we focus on the carbon cycle as it is an integral link to plant productivity on all land uses. The carbon cycle is of primary importance to soil health and is closely tied to energy flow and all the other cycles via living organisms. The carbon cycle involves the assimilation of $CO_2$ by plants and animals and microbial tissues, all of which release $O_2$ by respiration.

B. Essentially, soil organic carbon originates from atmospheric $CO_2$, processed by plants during photosynthesis. Herbivores and secondary animal predators process this carbon in the food cycle, which in part is ultimately returned to the soil via microbial decomposition. The amount of soil carbon that soil can eventually accumulate is a balance of carbon inputs and carbon of organic material. Soil organic matter content is dependent upon climate and climatic conditions, soil type, parent materials, physiographic influences, and how the land is used (wildlands or domestically grazed). Decomposition involves both abiotic and biotic processes. Abiotic processes include weathering, freeze/thaw cycles, alternating drying and wetting, and UV photooxidation. Microorganisms decompose soil organic matter by cellular metabolism and extracellular excretions of exoenzymes. Although microbial biomass represents a small fraction (1–5 percent) of the total carbon, nitrogen, phosphorus, and sulfur pools, microorganisms are necessary for the decomposition process to proceed (Balota et al. 2003). Bacteria and fungi provide more than 95 percent of the biotic contribution to organic matter decomposition (Persson et al. 1980). Since microorganisms are living components and have high surface-to-volume ratios, they respond more quickly to changes in the soil environment than chemical alteration of soil organic matter and other soil physical and chemical properties. Microbial function and action is a key factor in diagnosing and monitoring soil health.

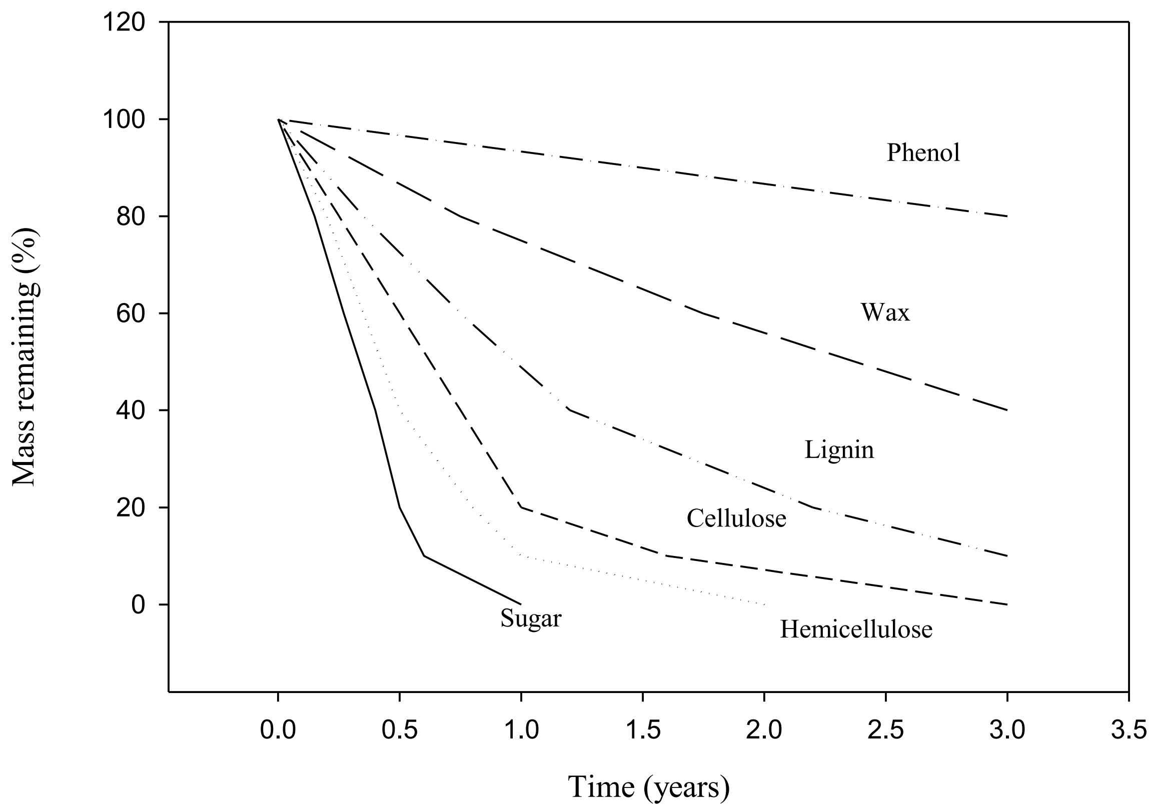
C. Decomposition via microbial action begins on standing live vegetation as different fungal species colonize different parts of plants. When moisture is adequate, fungi can colonize the culms of grasses. Some fungal species inhabit various internode and culm distances from the ground (microenvironments are more humid near the ground). Nutritional differences of the upper and lower internodes may also influence fungal flora (Hudson and Webster 1958). Fungi also can infect above-ground pine needles five to six months before needle fall (Burges 1963). In deciduous trees, leaf miners can damage the palisade layers of leaves, which instigates microbial attack of attached leaves. Most of the decomposition phase occurs when organic material is in contact with the soil.

D. A myriad of organisms (insects, earthworms, mites, millipedes, centipedes – detritivores and saprophages, etc.) fragment the debris, open plant cuticles, exposing parenchyma cells to microbial invasion, and consume raw material, which through excreta, is again acted upon by microorganisms. The physical action of these macro feeders can expose leaf area 15 times the original leaf size (Ghilarov 1970). This initial stage of decomposition by the macro feeders assimilates about 10 percent of the plant debris (mostly easily digested proteins and carbohydrates), thus allowing most of the material to pass through the gut. Plant debris, once in contact with the soil, is acted upon by bacteria, fungi, yeasts, and actinomycetes that feed on the material at rates determined by temperature and moisture. Decomposition is accelerated at high temperatures (35°C; 95°F), provided that sufficient moisture and oxygen are available for decomposition. Loceya and Lennona (2016) report that the Earth could contain nearly one trillion microbial species, only one-thousandth of one percent which are now identified. Oxygen can be a limiting factor in decomposition, as it is limited in oxygen-poor environments (Sierra et al. 2017). Figure K-8 shows some of the basic components of organic matter: dry matter-water content, elemental composition, and biologically derived components. These components in organic matter break down at different rates. Fungal mycelium and non-spore-forming bacteria quickly utilize carbohydrates (sugars) and simple proteins in the organic material. The composition and breakdown of organic compounds vary, from rapid to slow rates (figure K-11):

(1) Sugars, and simple proteins
(2) More complex proteins
(3) Hemicellulose
(4) cellulose
(5) Lignin and fats

E. The portion of organic matter that is not mineralized is humus, the stable fraction of organic matter. There are four basic pools of soil organic matter, each with variable turnover times: plant residues, particulate organic carbon, humus carbon, and recalcitrant organic carbon (figure K-13). These organic matter pools vary in chemical composition, decomposition rates, and carbon and nutrient cycles. The response of these carbon pools to management is critical to soil function and health. The labile pool which turns over relatively rapidly (weeks to < 5 years), results from the addition of fresh residues such as plant roots and living organisms, while resistant residues, which are physically or chemically protected, are slower to turn over (20–40 years). The protected humus and charcoal components make up the stable soil organic pool, which can take hundreds to thousands of years to turn over.

**Figure K-11.** Theoretical rates of decomposition for individual components of plant cells (Spaeth 2020 – source adapted from Minderman 1968, Franzluebbers 2005).




F. Bacteria and fungi provide more than 95 percent of the biotic contribution to organic matter decomposition (Persson et al. 1980). Bacteria and fungi are short lived and are consumed by other microbial organisms as they expire. As this process continues, nutrients are immobilized in microbial tissue, and upon death, nutrients are released, or mineralized-nutrients (nitrogen, phosphorous, sulfur, etc.) are again available for use by microbes and primary producers[2]. As bacteria decompose plant residues, they use low-molecular-weight compounds from plant biomass (nucleic acids, lipids, proteins, and carbohydrates) to develop their own biomass (Miltner and Bombach 2012). Enzymatic biochemical processes of soil microorganisms reduce decomposed organic matter into mineral compounds that may be utilized by plant roots. One important point that is often not recognized is that, as plant residues are being decomposed by microorganisms in a yearly cycle and become part of

[2] Primary producers in the ecosystem are organisms that produce biomass from inorganic compounds (autotrophs). Autotrophs are photosynthetically active organisms (plants, certain algae, and photosynthetic bacteria, cyanobacteria, and other unicellular organisms).

the soil, a considerable amount of the original carbon (65–85 percent of what was part of plant litter and animal detritus) is released back into the atmosphere as $CO_2$ via respiration (figure K-12). Only about 15–35 percent of this remaining carbon may remain in the soil as either live biomass (~2–5 percent), non-living labile carbon compounds (~3–10 percent), and stabilized humus (~10–30 percent) (Weil and Brady 2017).

**Figure K-12.** Carbon dioxide respiration as a consequence of the breakdown of carbon-based organic residues. Example of an annual cycle where organic matter is incorporated into the soil and 65–85 percent of the biomass is released as $CO_2$. Less than one-third of the original carbon remains in the soil as microbial biomass, non-living labile carbon, and humus (Spaeth 2020 – adapted from Weil and Brady 2017).

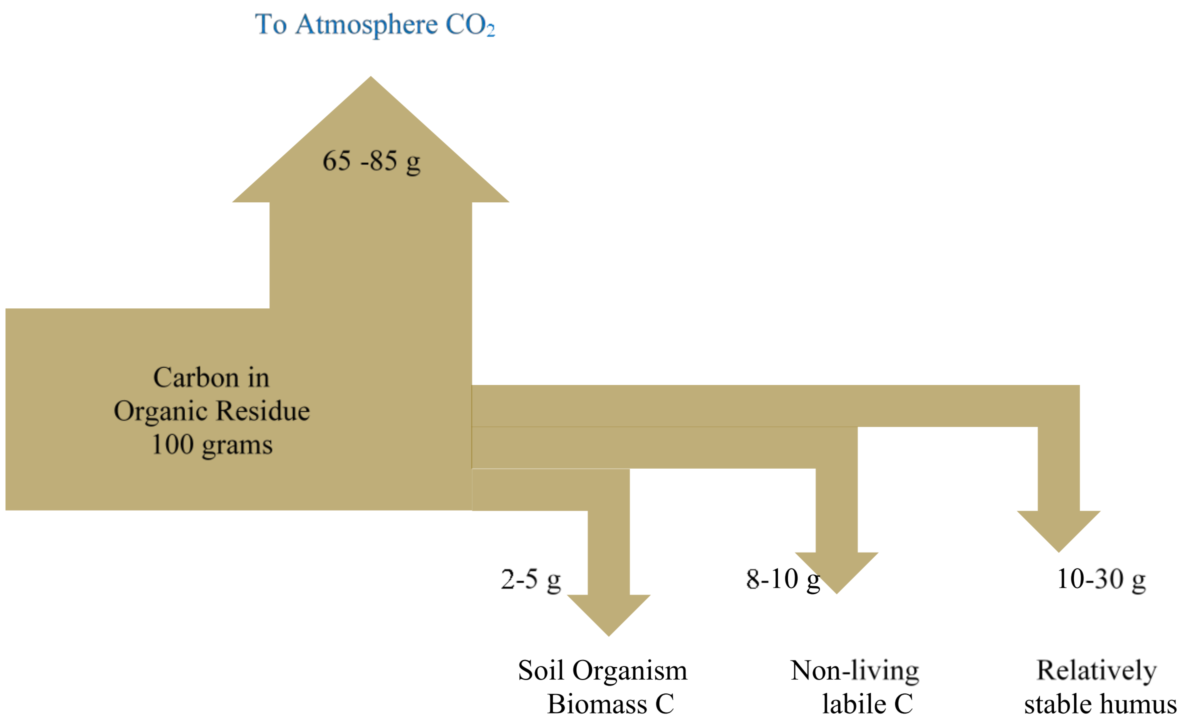



**Figure K-13.** Decomposition or turnover rates of four organic carbon pools (Spaeth 2020).

| Crop Residues | Particulate Organic Carbon | Carbon-Humus | Recalcitrant Organic Carbon |
|---|---|---|---|
| labile | labile | resistant | inert |
| weeks to years | years to decades | decades to centuries | centuries to millennia |

G. Soil respiration is an important indicator of microbial activity, soil organic matter cycling, and decomposition dynamics. Temperature, moisture levels, pH, salinity, porosity, and soil physical factors such as soil texture, bulk density, and aggregate stability can impact soil respiration. For example, low porosity relates to lower soil respiration rates. For every 10°C (18°F) increase in soil temperatures, microbial respiration more than doubles to a maximum of 35 to 40°C (95 to 104°F) (USDA-NRCS 2014). As $CO_2$ is released from the soil via microbial decomposition of soil organic matter, the rates of respiration can be an indicator of soil health trends. For example, high respiration rates in cropland settings may be an indicator of excessive tillage or other factors that degrade soil health (USDA-NRCS 2014). Soil respiration can also be an indicator of organic matter nutrients being converted to usable forms, such as phosphate as $PO_4$, nitrate-nitrogen as $NO_3$, and sulfate as

$SO_4$. Climate plays an important part in soil respiration on rangelands; compaction from livestock (increasing bulk density and lowering porosity) most commonly affects soil respiration.

H. Stabilization and the accumulation of organic matter in the soil are regulated by the soil environment and microbial activity. In almost every aspect of our terrestrial ecosystem, especially the soil environment, organic matter is involved in the chemical and physical aspects in one way or another. The ramifications are complex and beyond the scope of this discussion. One important soil physical factor, soil aggregate stability, is especially affected by particulate organic matter (plant tissues and cell wall materials) that were inaccessible to microbial action, where microaggregates form around them, together with microbial exudates. These hydrophobic (water repellent) biomolecules of either plant origin or byproducts of microbial synthesis (bacterial polysaccharides, fungal glycoproteins (glomalin)) are important constituents in stabilizing soil aggregates, which are an important aspect of hydrologic function and indicator of soil health. Polarity zones formed by microbial oxidation of these biomolecules allow the carbon to be stabilized and bonded to soil mineral surfaces, forming stabilized aggregates. Many other compounds are associated with soil aggregate stability: waxes, humic acids, aliphatic carbon, hydrophobins (fungal proteins), fatty acids, fulvic acids, and many other extracellular enzymes and polysaccharides. Cultivation, grazing hoof impact, foot traffic, intense fire effects, and erosion can cause degradation of soil aggregates. On grazing lands, managed grazing can be used to mitigate the effects of soil aggregate disturbance and breakdown. Stocking rates and timing of grazing with consideration to soil texture and soil stability dynamics are important variables to consider. For example, heavy stocking on heavier textured soils in early spring during wet periods will result in compaction and have a significant effect on soil aggregates, which will have an effect on infiltration and subsequent runoff and erosion risks.

I. Conceptual Flow of Soil Organic Matter and Associated Nutrients

(1) Several iterations of the organic matter cycle are presented because many examples are available in the literature. Although basic patterns are similar, each includes different details (figures K-14, K-15, K-16, K-17). In figure K-14, a simple representation of the organic matter cycle is given. Figure K-15 shows plant litter carbon dynamics in a grassland soil (Mollisol). Figure K-16 provides an example of microbial metabolic processes associated with carbon cycling. Figure K-17 shows content and turnover of organic dry matter in the tallgrass prairie with calculations of soil organic matter turnover. Figures K-18, K-19, and K-20 provide estimates for soil organic carbon sequestration after long-term grass establishment on farmed soils in central Texas. Figure K-21 shows soil C dynamics for long-term studies in the United Kingdom for permanent grass, seeded grass, long-term arable, and plowed grassland. Figures K-24 and K-25 show soil organic carbon dynamics in rangeland plant communities with disturbances (including grazing).

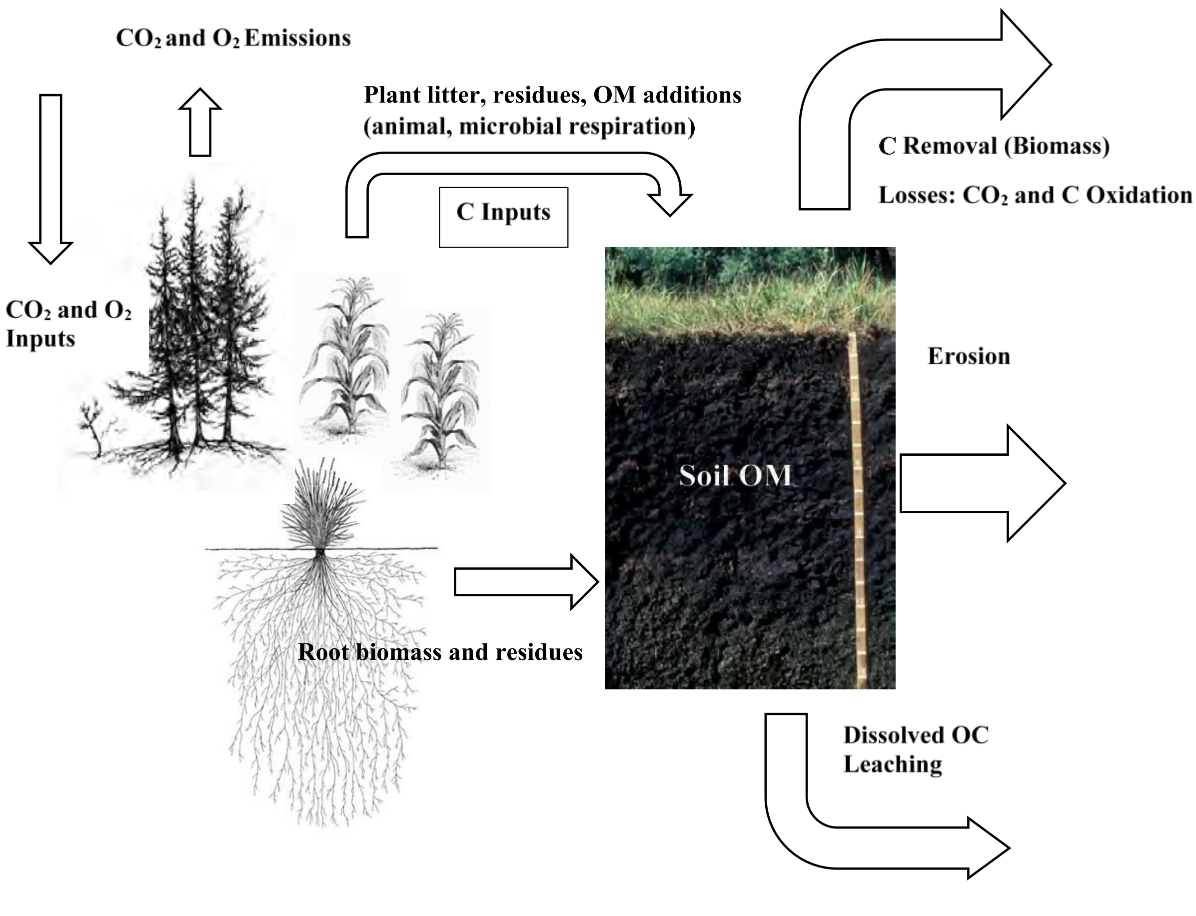
(2) Two figures are included showing carbon balance in cropland. These examples are included to show the progression and reality of increasing or enhancing soil organic matter in short time periods (see figures K-22, K-23).

(3) One important point regarding soil organic matter on stable rangelands: The annual increase in organic matter fluctuates between positive and negative values, but the long-term average is approximately a zero gain (Larcher 1983). Many studies document that organic matter contents of undisturbed soils (under natural vegetation) are in equilibrium with biological and biochemical properties (Dzurec et al. 1985; Trasar-Cepeda et al. 1998; Potter et al. 1999; McLauchlan et al. 2006; Zhang et al. 2007; Guilherme et al. 2009; Johnston et al. 2009; Johnston 2011; Crews and Rumsey 2014). There is a biochemical balance in undisturbed soils, and when soils are disturbed or subject to stress conditions, this balance is disrupted (Guilherme et al. 2009). Crews and Rumsey (2014) state: “Grassland restorations have been shown to sequester soil organic carbon (SOC) at rates of ~0.5 Mg C $Ha^{-1}$ $yr^{-1}$ averaged over several decades (Potter et al. 1999 – a century) through increased below-ground primary

productivity and stabilization of soil organic matter (Burke et al. 1995, Potter et al. 1999, Conant et al. 2001, McLauchlan et al. 2006, Kucharik 2007, Matamala et al. 2008)."

(i) In central Texas tall grass prairie, Potter et al. (1999) showed that agricultural practices reduced soil organic carbon 30 to 43 percent in the surface 60 cm of heavy clay soils. Restoring previously tilled (six to 60 yrs.) soils to tall grasses resulted in an increase in soil organic carbon in the surface 60 cm at a mean rate of 0.447 Mg C $ha^{-1}$ $yr^{-1}$ (0.199 t $ac^{-1}$ $yr^{-1}$) (figs. K-18, K-19, and K-20). Using the bulk density values in the study (Clay, bulk density=1.250 Mg $m^3$), the equivalent percent soil organic carbon increase at 0.447 Mg C $ha^{-1}$ $yr^{-1}$ equals about 0.006 percent increase per year (figure K-18). Thus, the estimated time to restore soil organic carbon to comparative levels of native prairie from cropped lands seeded to grass ranged from 100 to 175 years. On farmed soils (> 20 yrs.) in Minnesota, soil organic carbon on restored 40-year grass stands (mixtures of C3 and C4 species) in the top 10 cm of soil accumulated at a constant rate of 0.62 Mg $ha^{-1}$ $yr^{-1}$, regardless of whether the vegetation type was dominated by C3 or C4 grasses (Mclauchlan et al. 2006). They estimated that 55–75 years would be required to achieve soil organic carbon equivalents with unplowed native prairie sites.

**Figure K-14.** Input and output of soil organic matter. Balance can be sustainable or unsustainable, depending on disturbances (natural and anthropogenic), and land use and management. Management in terrestrial plant communities, especially those concerned with soil health, should focus on inputs and minimize outputs. (Spaeth 2020 – adapted from Weil and Brady 2017.)



(ii) Johnston et al. (2009) point out that it is "not always appreciated that soil organic matter changes toward an equilibrium level in any farming system, and the level will vary with a number of factors . . . Existing evidence shows that the amount of organic matter in soils depends on: 1) the input of organic material and its rate of oxidation, 2) the rate at which existing soil organic matter decomposes, 3) soil texture; and 4) climate conditions. . . For any single cropping system, the equilibrium level of soil organic matter in a clay soil will be larger than in a sandy soil, and for any single soil type the equilibrium level will be larger under permanent grassland than under continuous arable cropping."

(4) In Liang et al. (2017) (figure 13) a "conceptual scheme" shows related pathways and effects of fungi and bacteria growth, metabolism, and death in a terrestrial carbon cycle. The primary inputs of carbon are achieved via two pathways: *in vivo* turnover (inside the living organism) and *ex vivo* (outside the organism) modification driven by microbial catabolism (the breakdown of complex molecules and compounds to form simpler ones, together with the release of energy), and/or anabolism (creation of other molecules that catabolism breaks down). The authors use the microbial carbon pump concept as a sequestration system during *in vivo* turnover, resulting in anabolism-induced necromass, the persistent carbon pool. The authors stress that much more work is needed to understand microbial contribution to the terrestrial carbon cycle.

**Figure K-15.** Plant Litter Carbon Dynamics in a Grassland Soil (Mollisol) (20 cm soil depth). Units for carbon pools expressed as (kg C $m^{-2}$) and annual allocations (kg C $m^{-2}$ $yr^{-1}$). At 20 cm soil depth, total carbon content is 10.4 kg C $m^{-2}$ (104 Mg $ha^{-1}$; 46.4 t $ac^{-1}$); 84 percent of carbon respired (Spaeth 2020 – adapted from Schlesinger 1977).

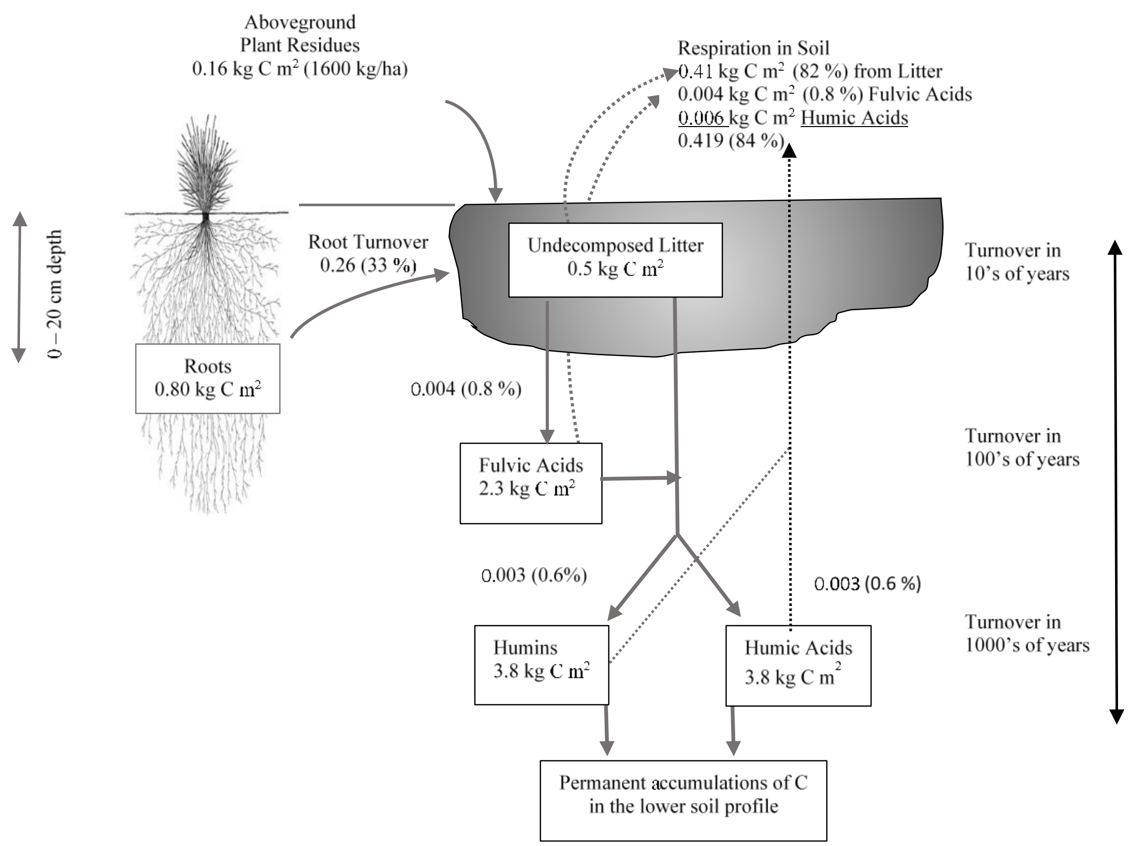


**Figure K-16.** Microbial metabolic processes associated with carbon cycling (Spaeth 2020 – adapted from Liang et al. 2014).

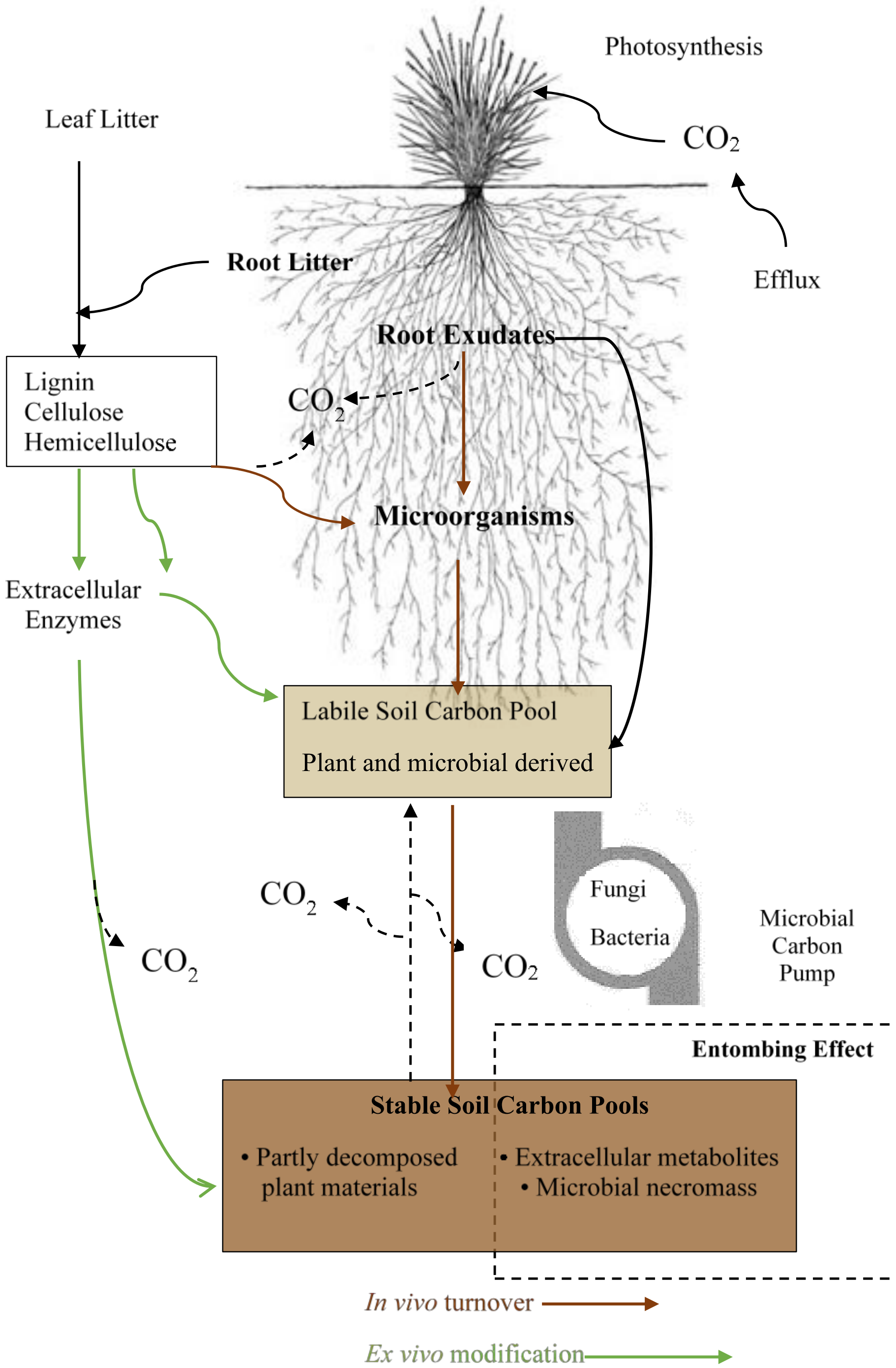
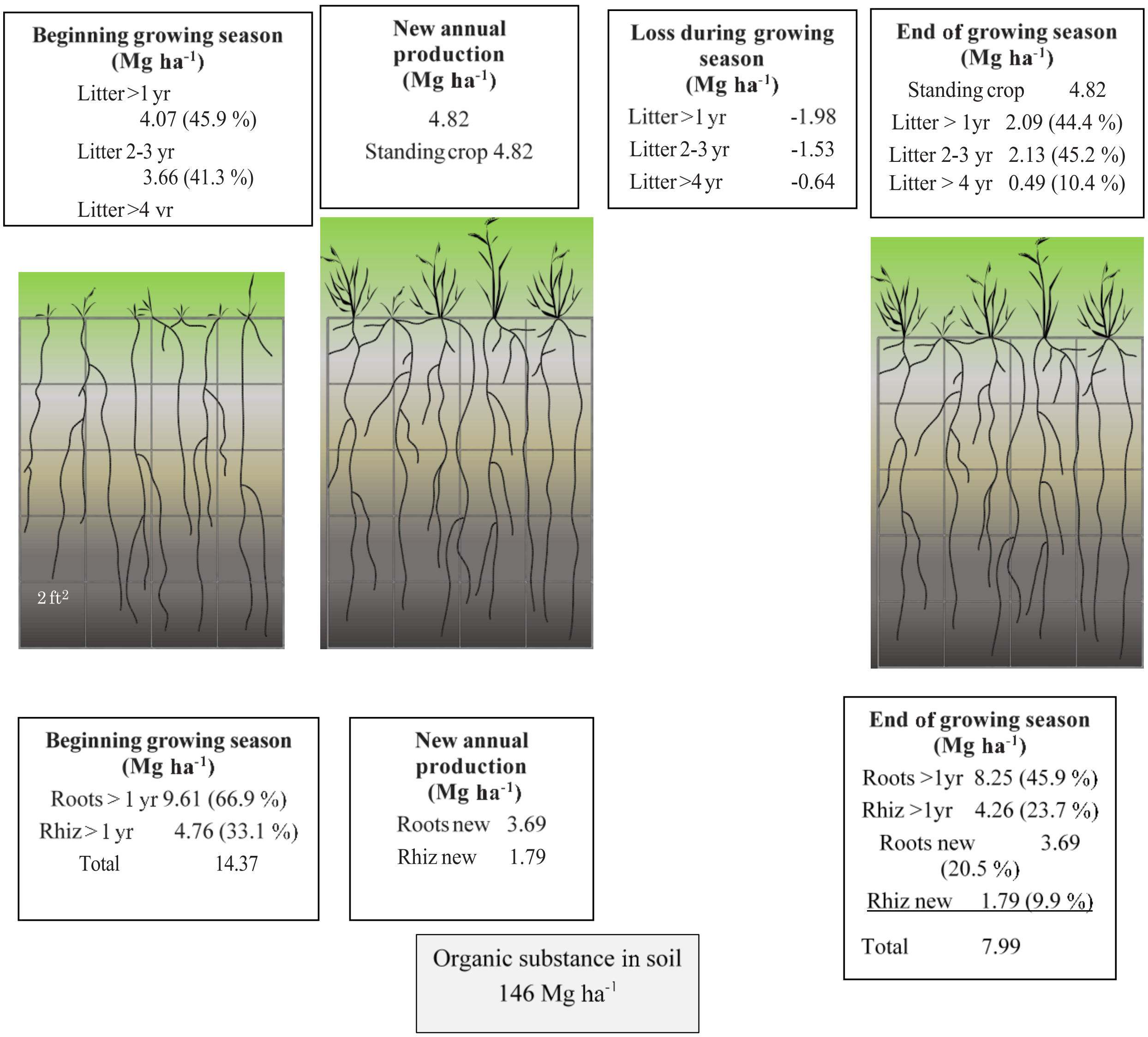


**Figure K-17.** Content and turnover of organic dry matter in the tallgrass prairie. Site Data: No grazing of large herbivores, only from insects and rodents. During the growing season, the vegetation grows rapidly and at the same time, parts of the shoots and roots die off or are eaten. The annual increase in organic matter fluctuates between positive and negative values, but the long-term average is approximately a zero gain (Larcher 1983 – adapted from Spaeth 2020; data from Kucera et al. 1967; Larcher 1983).




**Carbon Balance in Tall Grass Prairie (1 year)**

Weight of soil kg ha @ 0.15 m soil depth
(100m) (100m) (0.15m) = 1500 m$^3$ ha$^{-1}$
Weight of soil = (1,500 m$^3$ ha$^{-1}$) (Bulk density 1.5 Mg m$^3$) = 2,250 Mg ha$^{-1}$ = 2,250,000 kg ha$^{-1}$
SOC = 1.75% therefore total wt. of SOC per ha = (2,250,000 kg ha$^{-1}$) (0.0175 % SOC) = 39,375 kg C ha$^{-1}$
SOC Carbon to nitrogen ratio = 12:1; 39,375/12 = 3,281.3 kg N ha$^{-1}$
SOC Carbon to phosphorous ratio = 50:1; 39,375/50 = 787.5 kg P ha$^{-1}$
End of year above ground production 4.82 Mg ha$^{-1}$ or 2.15 t ac$^{-1}$ (Kucera et al. 1967)
Root mass (8.25 Mg ha$^{-1}$) and rhizomes (4.25 Mg ha$^{-1}$) end of year = 12.51 Mg ha$^{-1}$ (Kucera et al. 1967)
Root decomposition for Big Bluestem (Weaver and Darland 1947)

| Root Size | Pct Decomposition 1 yr |
|---|---|
| Coarse 87% | 55.7% |
| Medium 10% | 33.2% |
| Fine Roots 3% | 11.1% |
| Weighted average = 52.1% | |

Root Biomass remaining after decomposition (12.51 Mg $ha^{-1}$) (0.521%) = 6.52 Mg $ha^{-1}$
Above Ground Biomass 4.82 Mg $ha^{-1}$
Litter Mg $ha^{-1}$ = 2.09 Mg $ha^{-1}$ (Kucera et al. 1967)
Total Biomass Current Yrs. Growth, Litter, Roots = 13.43 Mg $ha^{-1}$

C content biomass ~ 40% (13.43 Mg $ha^{-1}$) (0.4) = 5.37 Mg $ha^{-1}$ = 5,371.68 kg $ha^{-1}$
Wt. of SOC and Total Prairie Site Veg OC = 39,375 kg $ha^{-1}$ + 5,371.68 kg $ha^{-1}$ = 44,746.68 kg $ha^{-1}$
Percent C retained in decomposed residue considered as humus (10-25%) used 20% = (5,371.68) (0.20) = 1,074.34 kg $ha^{-1}$
SOC + vegetation and roots 44,746.68 + 1,074.34 = 45,821.02 kg $ha^{-1}$
Increase of SOC from original soil carbon (1.75% SOC)
(45,821.02 kg $ha^{-1}$) (1.75%) / 39,375 kg C $ha^{-1}$ = 2.04%, a gain of 0.29% in 1 yr.
Equivalent Soil Organic Matter start (1.75%) (1.72) = 3.01%, End of year SOM = (2.04%) (1.72) = 3.5%

Summary: This example represents a stable undisturbed tall grass prairie site. The annual increase in organic matter fluctuates between large positive and negative values, but the long-term average is approximately a zero gain (Larcher 1983). Removing corn stover not only reduces carbon return to soil but also nitrogen.

J. Three locations in central Texas (Temple, Burleson, and Riesel) were evaluated for soil organic carbon sequestration after long-term grass establishment on farmed soils (adapted from Potter et al. 1999). A cropland example is given to show lag in litter breakdown and amount of $CO_2$ released. Treatments were long-term farmed cropland (> 100 yrs.), pristine never-tilled native prairie, and sites seeded to grass (Temple seeded site established six yrs.; Burleson est. 26 yrs.; and Reisel est. 60 yrs). Soil organic carbon sequestration rate was determined to be 0.447 Mg $ha^{-1}$ $yr^{-1}$ (approx. 0.006 percent yr.) (see calculation below). Soils at all three sites were Vertisols.

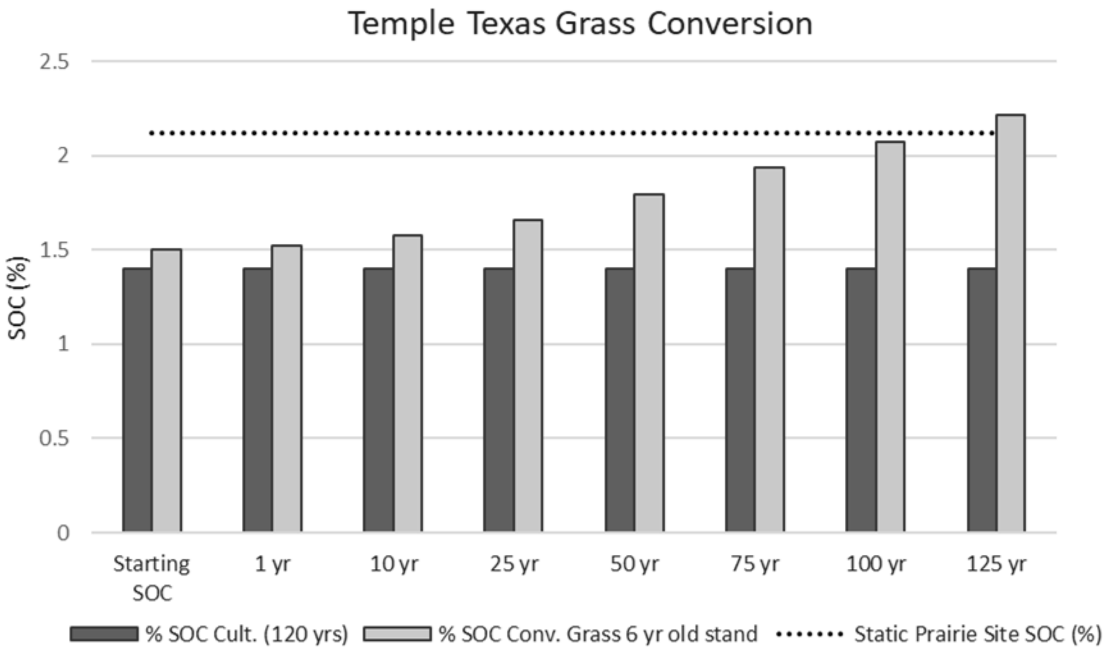
(1) Temple site:

(i) Site conditions

- Farmed 120 yrs., Clay, bulk density=1.250 Mg $m^3$ @ 0.6 meters soil depth
- (100 m) (100m) (0.6 m) = 6,000 $m^3$
- (6,000 $m^3$) (bulk density 1.250 Mg $m^3$) = 7,500 Mg $ha^{-1}$ (soil wt.)
- (sequestration rate 0.447 Mg $ha^{-1}$ $yr^{-1}$) (100) / 7,500 Mg $ha^{-1}$ = 0.006 percent SOC $yr^{-1}$
- wt. of soil 7,500 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.4 percent.
- Native prairie was indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), and Johnsongrass (*Sorghum halepense*), with some giant ragweed (*Ambrosia trifida*). Clay, bulk density = 1.178 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 7,068 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 2.12 percent.
- Seeded grass was switchgrass (*Panicum virgatum*) 6 yr. stand, bulk density = 1.34 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 8,064 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.50 percent.

(ii) Figure K-18 shows step increases of soil organic carbon sequestration in a converted six-yr-old stand of switchgrass at Temple, TX (1.50 percent soil organic matter). The farmed site static level for soil organic carbon = 1.4 percent, and the native prairie static soil organic carbon level was 2.12 percent. Soil organic carbon was reduced 66 percent by agricultural cropping practices in the surface 60 cm of heavy clay soils. Returning the previously tilled soils to seeded grass resulted in an increase in soil organic carbon in the surface 60 cm at a mean rate of 0.447 Mg C $ha^{-1}$ $yr^{-1}$. The length of time to reach static soil organic carbon levels to that of the native prairie would require 100 to 125 yrs.

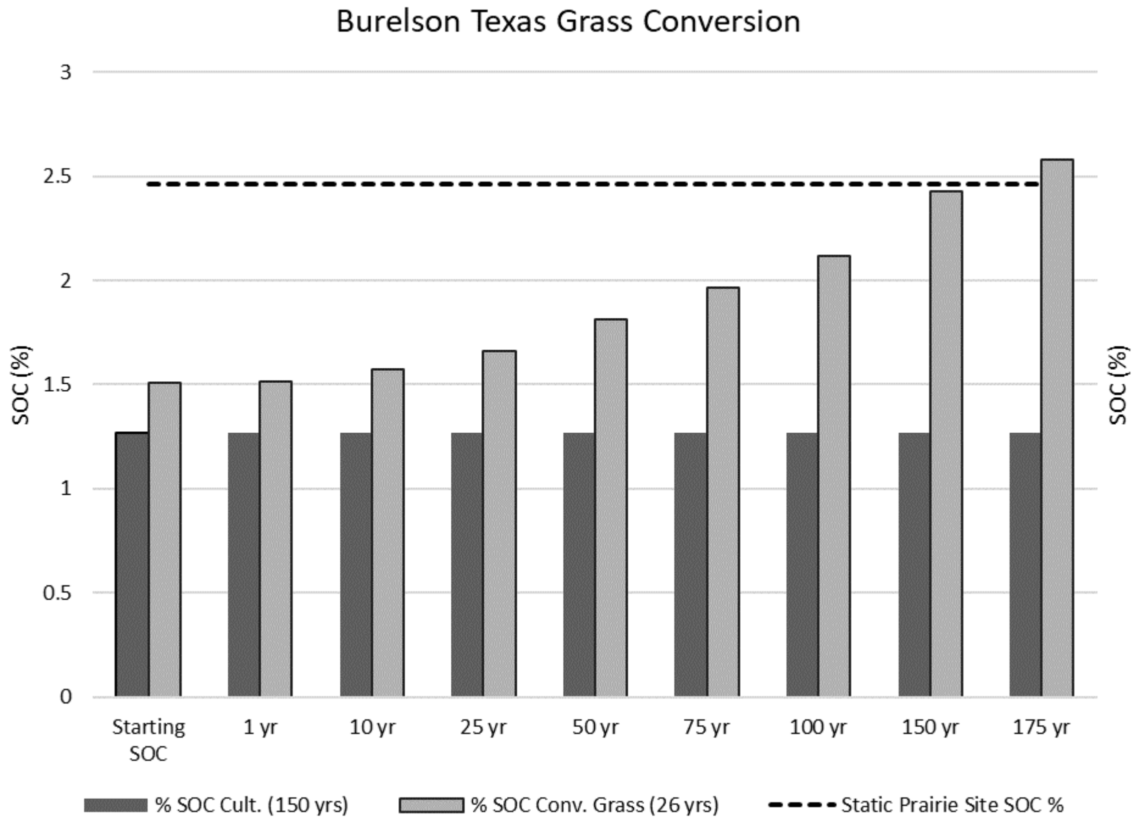
**Figure K-18.** Change in Soil Organic Carbon over time on a Temple, Texas, site.




(2) Burleson site:
   (i) Site conditions
   - Farmed 120 yrs., clay, bulk density=1.317 Mg $m^3$ @ 0.6 meters soil depth, wt. of soil 7,902 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.27 percent.
   - Native prairie was indiangrass and little bluestem (*Schizachyrium scoparium*), which may have been overgrazed in the past. Clay, bulk density = 1.278 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 7,668 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 2.464 percent.
   - Seeded grass was indiangrass, little bluestem, switchgrass, big bluestem (*Andropogon gerardii*), and sideoats grama *(Bouteloua curtipendula*) 26 yr. stand, bulk density = 1.22 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 7,320 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.51 percent.

   (ii) Figure K-19 shows step increases of soil organic carbon sequestration in a converted 26-yr-old stand of native grasses at Burleson, TX (1.51 percent soil organic matter). The farmed site static level for soil organic carbon = 1.27 percent, and the native prairie static soil organic carbon level was 2.464 percent. Soil organic carbon was reduced 51.5 percent by agricultural cropping practices in the surface 60 cm of heavy clay soils. Returning the previously tilled soils to seeded grass resulted in an increase in soil organic carbon in the surface 60 cm at a mean rate of 0.447 Mg C $ha^{-1}$ $yr^{-1}$. The length of time to reach static soil organic carbon levels to that of the native prairie would require 150 to 175 yrs.

**Figure K-19.** Change in Soil Organic Carbon over time on a Burleson, Texas, site.



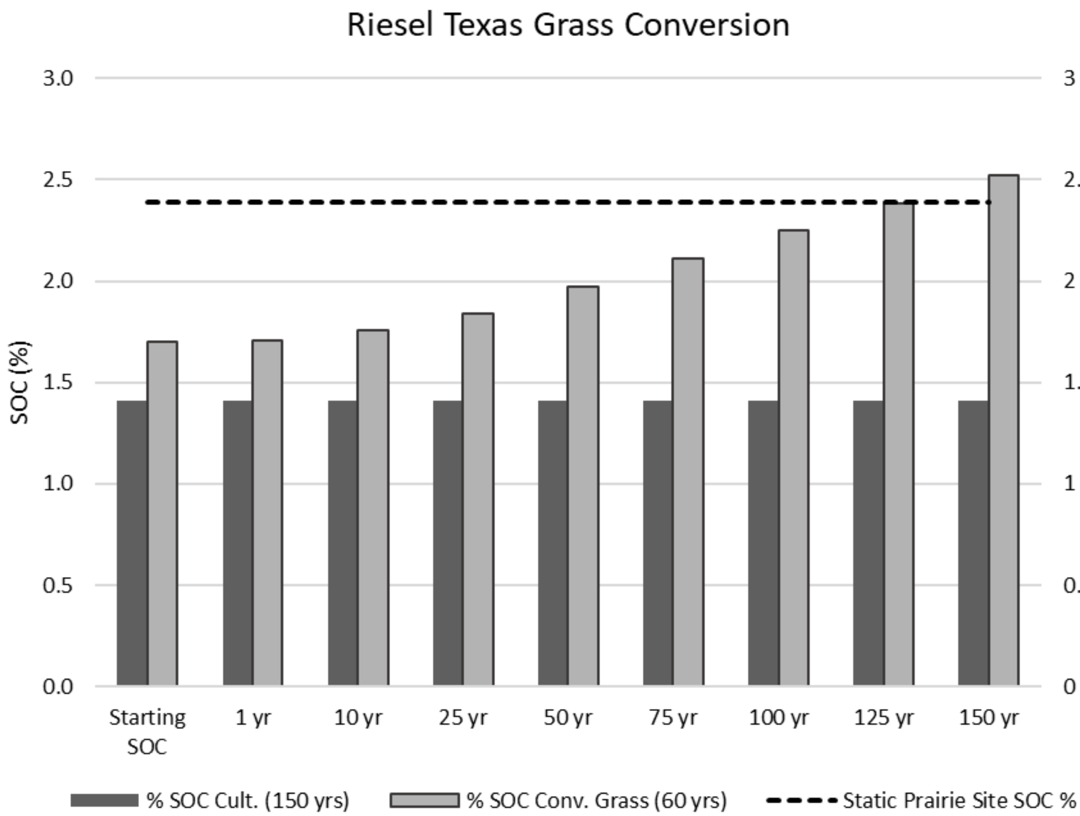

(3) Riesel site:

(i) Site conditions

- Farmed 120 yrs., clay, bulk density= 1.457 Mg $m^3$ @ 0.6 meters soil depth, wt. of soil 8,742 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.4 percent.
- Native prairie was King Ranch bluestem (*Bothriochloa ischaemum*) and little bluestem (*Schizachyrium scoparium*), with a strong influence of giant ragweed (*Ambrosia trifida*). Clay, bulk density = 1.22 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 7,320 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 2.39 percent.
- Seeded grass was King Ranch bluestem *(Bothriochloa ischaemum*), little bluestem, indiangrass (*Sorghastrum nutans*), and switch grass (*Panicum virgatum*) 60 yr. stand, bulk density = 1.37 Mg $m^3$ @ 0.6 m soil depth, wt. of soil 8,220 Mg $ha^{-1}$ @ 0.6 m, percentage SOC @ 0.6 m = 1.7 percent.

(ii) Figure K-20 shows step increases of soil organic carbon sequestration in a converted 60-yr-old stand of native grasses at Riesel, TX (1.7 percent soil organic matter). The farmed site static level for soil organic carbon = 1.4 percent, the native prairie static soil organic carbon level was 2.39 percent. Soil organic carbon was reduced 58.6 percent by agricultural cropping practices in the surface 60 cm of heavy clay soils. Returning the previously tilled soils to seeded grass resulted in an increase in soil organic carbon in the surface 60 cm at a mean rate of 0.447 Mg C $ha^{-1}$ $yr^{-1}$. The length of time to reach static soil organic carbon levels to that of the native prairie would require 125–150 yrs.

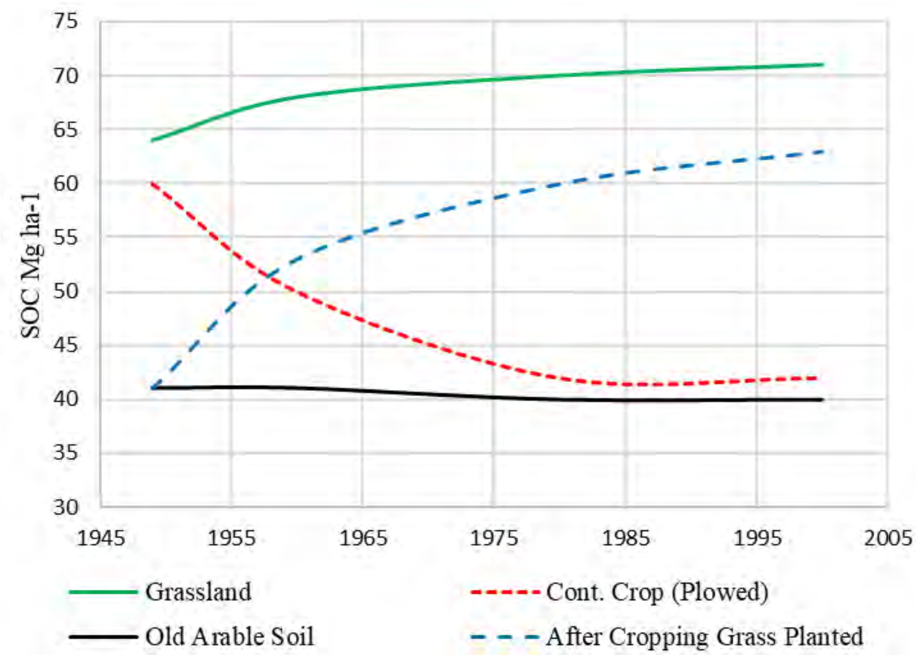
**Figure K-20.** Change in Soil Organic Carbon over time on a Riesel, Texas, site.




(4) In conclusion, in central Texas, agricultural practices reduced soil organic carbon 30 to 43 percent in the surface 60 cm of heavy clay soils (Potter et al. 1999). Restoring previously tilled (six to 60 yrs.) soils to grass resulted in an increase in SOC in the surface 60 cm at a mean rate of 0.447 Mg C $ha^{-1}$ $yr^{-1}$ (0.199 t $ac^{-1}$ $yr^{1}$). In three tall grass locations in Texas, estimated time to restore soil organic carbon of cropped lands seeded to grass ranged from 100 to 175 years.

K. Figure K-21 shows the changes in organic C $ha^{-1}$ for permanent grass, old arable field, continuous plowed crop, and reseeded grass for a period of about 50 years (Johnston et al. 2009). On the field with old arable cropping, organic C remained essentially constant but declined steadily where the old grassland soil was plowed. On the undisturbed permanent grass field, organic C slowly increased toward a new equilibrium level as a result of more intensive management and increased N applications that increased above-ground yields, resulting in greater root growth and decomposition that increased organic matter inputs. On the old arable soil sown to grass, the amount of C increased slowly; but after about 50 years it was still lower than the permanent grass field.

**Figure K-21.** Changes in SOC (Mg ha[-1]) in surface 23 cm silty clay loam (Rothamsted United Kingdom 1949–2002). Four treatments represent old grassland, plowed and cropped, old arable crop field, and field sown to grass (adapted from Johnston et al. 2009).




L. Corn stover harvest removes carbon that potentially could be recycled and incorporated into soil organic carbon pools. However, decomposition of crop residue by soil microbes with associated large carbon loss as $CO_2$ is not commonly recognized. Figure K-22 shows decomposition rates and cumulative $CO_2$ loss to the atmosphere at one to eight years. In the long term, 85 percent of the original corn stover biomass is lost as atmospheric $CO_2$. Removing corn stover not only reduces carbon return to soil but also nitrogen.

**Figure K-22.** Effect on Soil Carbon with Corn Stover Removal Over Time. What is the Effect on Soil Carbon with Stover Removal? (Spaeth 2020 – adapted from Sawyer and Mallarino 2007).

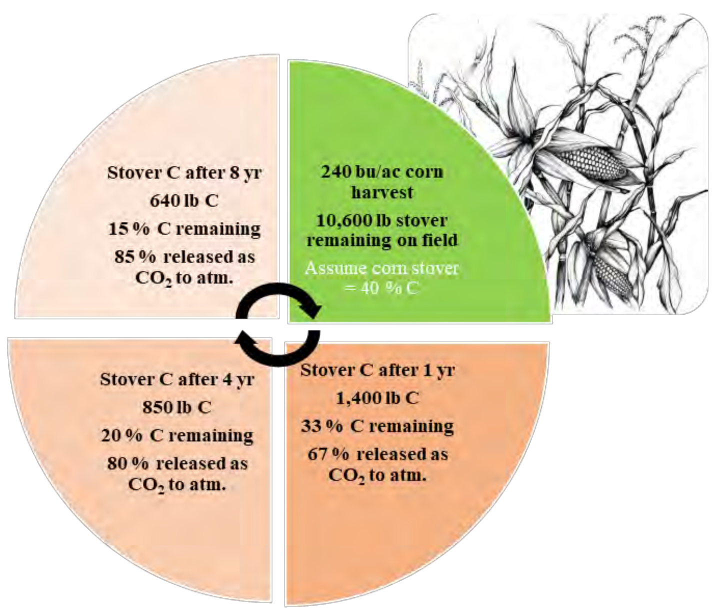


**Figure K-23.** Example of annual carbon balance in Iowa corn field. Units in parentheses are kg ha-1 (Spaeth 2020).

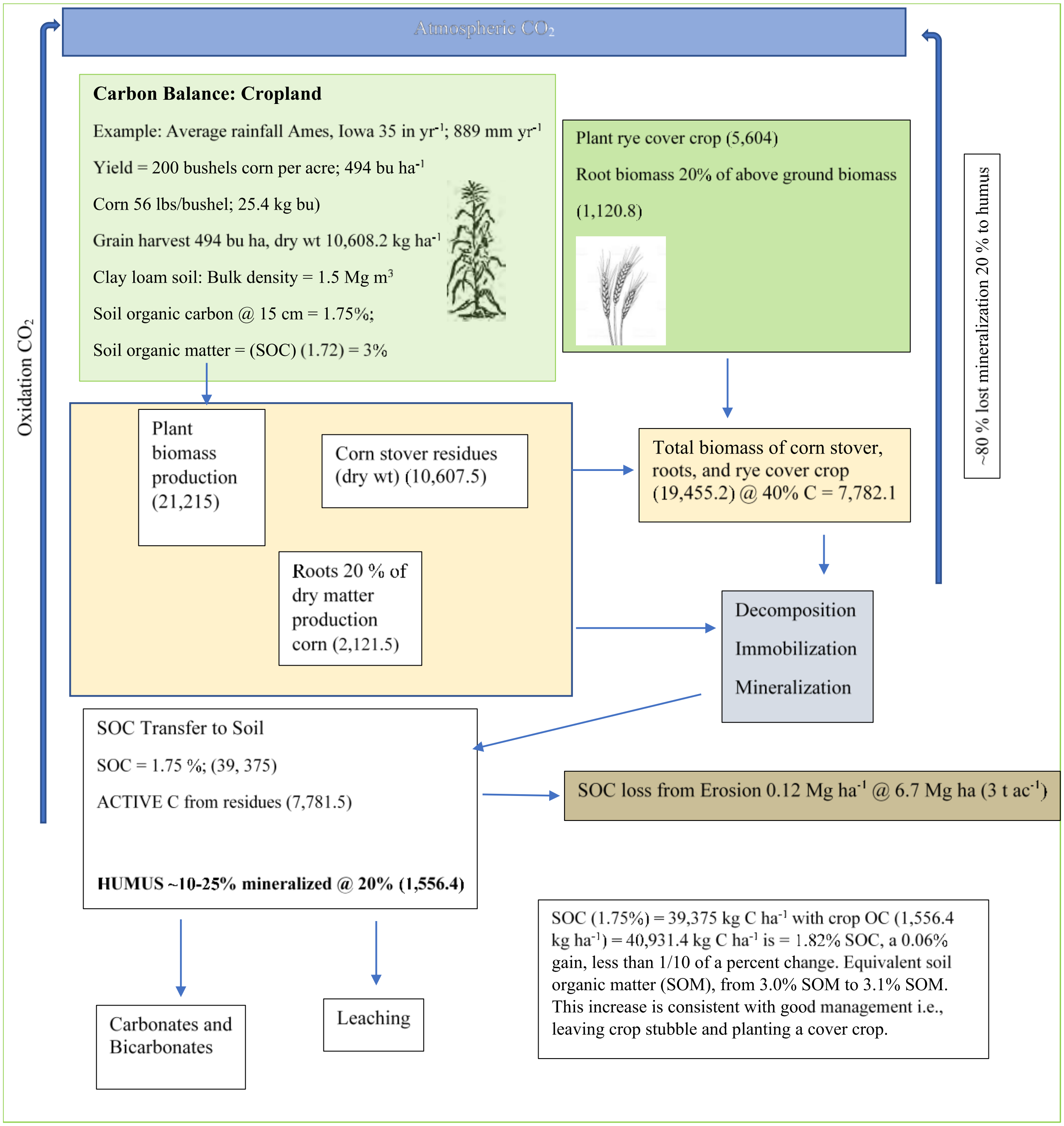
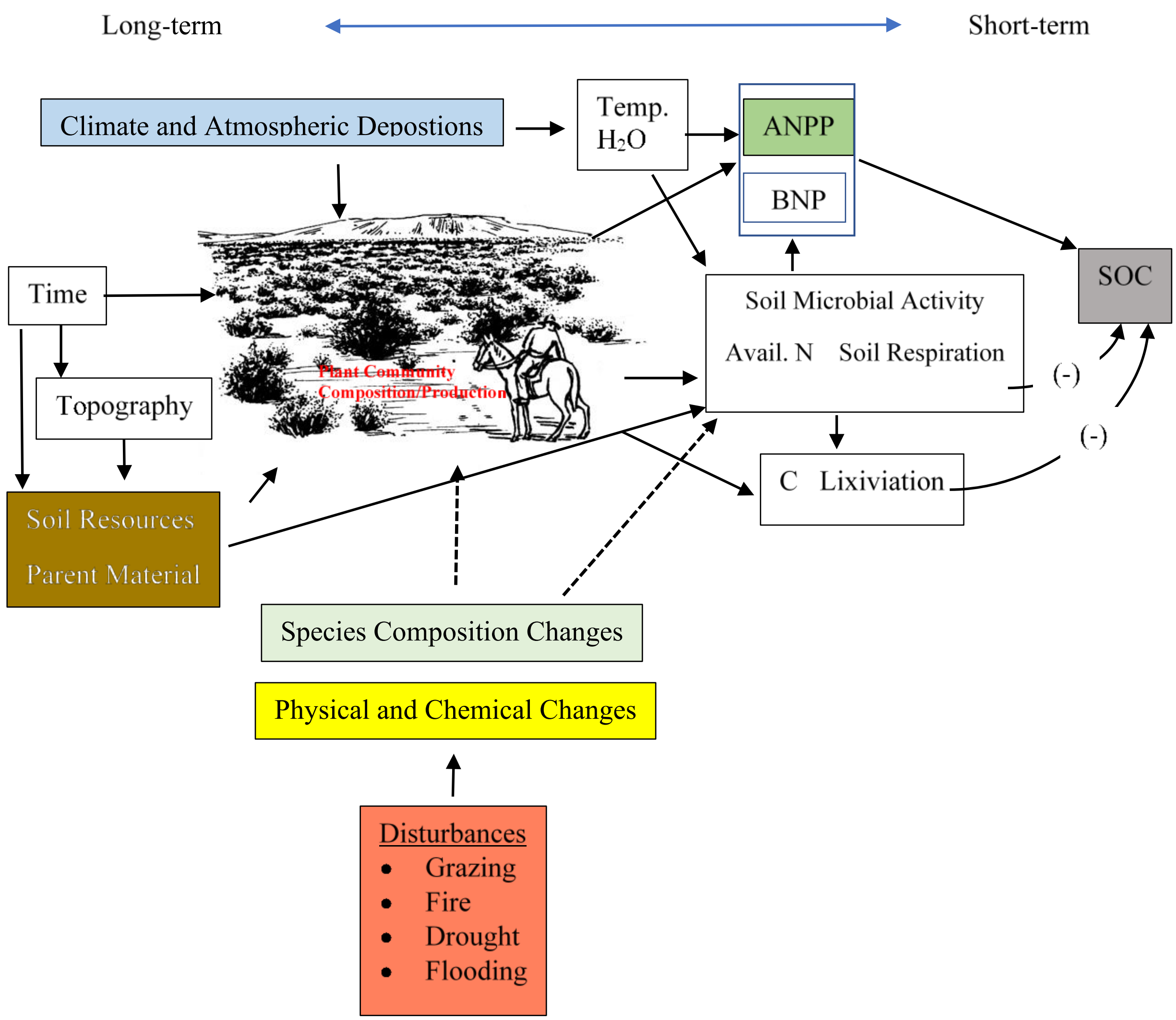


**Figure K-24.** Soil organic carbon (SOC) dynamics in rangeland plant communities with disturbance interactions. Dashed line shows effects of disturbances (including grazing), ANPP = above ground net primary productivity, BNPP = below ground net primary productivity. Lixiviation is the process of separating soluble from insoluble substances by dissolving the former in water (adapted from Pineiro et al. 2010).

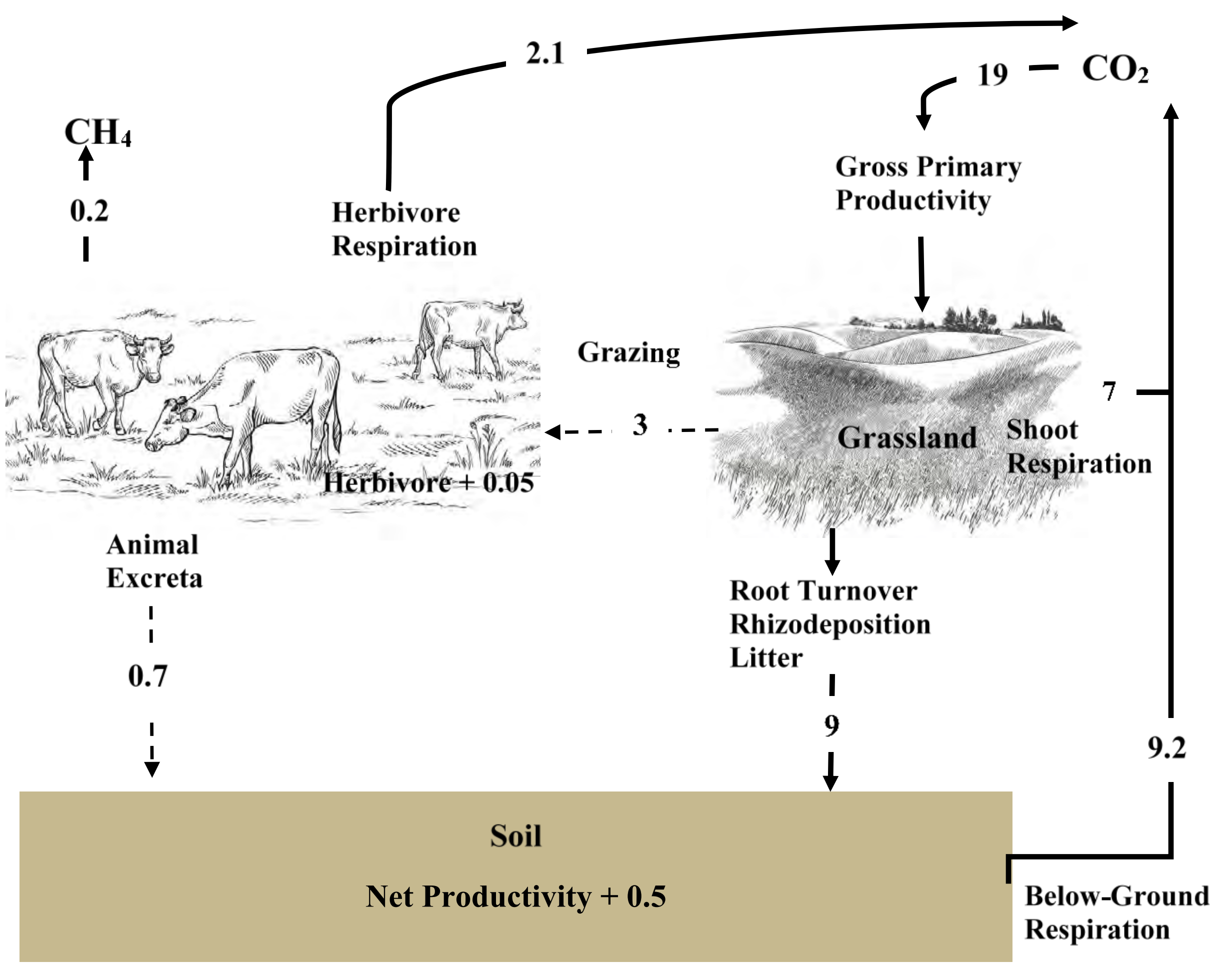



## 645.1109 Grazing Effects on Soil Organic Carbon

A. Rangeland plant communities are diverse and include grasses (bunch- and/or sod-forming spp.), forbs, shrubs, and trees; plants with different root morphologies; and mixtures of C3 (cool season spp.), C4 (warm season spp.), and CAM (succulents) plants. Included in the mix of complex environmental interactions are perturbations such as fire, herbivory, and a propensity to drought. All of these factors influence the soil organic carbon cycle. Soil organic matter is the main reservoir of soil organic carbon and soil organic nitrogen in rangeland ecosystems and plant communities and affects the three rangeland health attributes (soil and surface stability, hydrologic function, and biotic integrity). Range and pasturelands make up about 10–30 percent of the Earth's terrestrial capacity (Shuman and Derner 2004), and management practices such as grazing affect soil organic carbon because plant community production and composition are dynamic throughout the season and from year-to-year. On rangelands, carbon cycling and sequestration dynamics are quite complex, and estimation of rates and amounts are systematically more difficult than for cultivated croplands (Schuman et al. 2002) because of more heterogeneous edaphic characteristics, wide daily temperature fluctuations, intermittent precipitation, diverse vegetation life and growth forms, plant composition, productivity, root-shoot ratios, different rooting depths, herbivore use, and imposed disturbance and management practices.

B. Figure K-25 depicts a carbon cycle scenario of intensive continuous grazing (60 percent) utilization on grassland (Soussana et al. 2004). Frequency and intensity of grazing affects carbon balance. In this example, Sousanna et al. (2004) state that "The largest part of the ingested carbon is digestible (up to 75 percent for highly digestible forages) and, hence, is respired shortly after intake. Only a small fraction of the ingested carbon is accumulated in the body of domestic herbivores or is exported as milk. Large herbivores, such as cows, respire approximately one tonne of carbon per year. Additional carbon losses (0.5 percent of the digestible carbon) occur through methane emissions from the enteric fermentation. The non-digestible carbon (25±40 percent of the intake according to the digestibility of the grazed herbage) is returned to the pasture in excreta (mainly as faeces)."

**Figure K-25.** Carbon cycling in grazed grassland. Numerical carbon fluxes (Mg C $ha^{-1}$ $yr^{-1}$). Example represents continuously intensive grazing (adapted from Soussana et al. 2004).



C. The structural components of organic matter are soil organic carbon and nitrogen, characterized as carbon:nitrogen (C:N) ratios. Soil organic matter is also the primary source of nitrogen (12:1), phosphorus (50:1), and sulfur (70:1). The C:N ratio of the organic material is critical to the amount of nitrogen required by microbes for decomposition. If the C:N ratio is above 25:1, soil microbes will mine soluble nitrogen from the soil (Spaeth 2020). Mineralization and immobilization are important concepts related to C:N relationships and organic matter. Mineralization is a biological process where organic substances are converted to inorganic substances by soil microorganisms, with end products that include $CO_2$, $H_2O$, and nutrients. Carbon-nitrogen ratios less than 25:1 (25 parts carbon to 1 part nitrogen) have sufficient nitrogen for the microorganisms involved in decomposition (mineralization), as well as providing some excess inorganic nitrogen to plants. Immobilization is the reverse of mineralization and involves the incorporation of mineralized inorganic compounds into organic molecules within living cells of organisms. All living things require nitrogen; therefore, microorganisms in the soil compete with plants for nitrogen. During immobilization, nitrate and ammonium are taken up by soil organisms and therefore become unavailable to plants (Johnson et al. 2005).

D. Soil organic matter C:N ratios can shift with grazing or other disturbances. Soil organic nitrogen dynamics frequently constrain carbon dynamics and soil organic carbon accumulation in soils (Wedin 1995; Pineiro et al. 2006, 2009; Harpole et al. 2007). For example, the C:N ratios of plant materials and their respective litter dynamics are quite varied [fertilized Kentucky bluegrass (*Poa pratensis*) 20:1; Bermuda grass (*Cynodon dactylon*) hay 49:1; timothy grass (*Phleum pratense*) hay 58:1; blue grama (*Bouteloua gracilis*) 20:1 rangeland; rye cover crop 65:1; corn stover 60:1; wheat straw 80:1]. Soil organic nitrogen is not the only constraint to soil organic matter accumulation, as water availability, soil moisture, and carbon uptake (via photosynthesis and net primary production) can be limiting factors for soil organic matter accumulation and sequestration, especially in arid sites (Burke et al. 1998).

E. Grazing frequency and intensity affects soils, hydrology, plant composition, and productivity of grazing lands (McNaughton 1985; Sala 1988; Thurow 1991; Milchunas and Lauenroth 1993; Altesor et al. 1998; Schuman et al. 1999; Spaeth 2020). Effects can be assessed in three attributes: soil and surface stability, hydrology, and biotic components (Pellant et al. 2020). Understanding and communicating the effects of grazing on specific rangeland plant communities is important during conservation planning and implementation. For example, how does grazing affect soils (bulk density, soil organic carbon balance and cycling, aggregate stability, nutrient cycles), hydrologic implications associated with runoff and erosion, and the plant community (composition and trajectories of states and phases, and inherent thresholds at the ecological site level)? Ecological Site Descriptions, Rangeland Health worksheets, and State-and-transition models are all helpful in providing information and assisting rangeland users. However, some uncertainties are not predictable – climatic effects can change and alter what was once a predictable outcome to uncertain shifts in plant composition (both in the short and long term). For conservation planners, this is an important point that needs to be emphasized with land-users and land managers.

F. It is difficult to synthesize generalizations about the effects of grazing on soil organic carbon on grazing lands (Milchunas and Lauenroth 1993; Schuman et al. 2005; Derner and Schuman 2007; Pineiro et al. 2010). Managed grazing can avoid or alleviate serious soil disturbance factors. However, changes in vegetation composition in response to grazing can alter soil carbon (Pineiro et al. 2010; Hewins et al. 2018). In addition, soil microbial shifts also occur during drought, which can result in losses of soil carbon (Ingram et al. 2004). Pineiro et al. (2010) reviewed 20 articles with 67 comparisons of grazed and ungrazed sites. They found that soil organic carbon decreased or remained unchanged with contrasting grazing conditions with varied grassland temperature and precipitation gradients. Their conclusions were that grazing effects are complex in their effects on soil organic carbon. There is inconclusive evidence about how grazing affects the distribution and maintenance of soil carbon in different rangeland ecosystems. Since rangelands are so diverse with respect to vegetation composition, climate, and soils, deriving a general conclusion about grazing effects and systems on soil organic carbon cycles and carbon sequestration is unrealistic and unlikely. The dynamics of carbon balance and cycling can be documented at the ecological site level; however, the effects of grazing in the short-term cannot be reliably determined. In addition, Schuman et al. (2005) point out that the combination of severe drought and heavy grazing can result in significant losses of soil organic carbon that was previously stored under normal production levels. Rangelands then shift from sequestering carbon to releasing $CO_2$ to the atmosphere (Balogh et al. 2005a, b).

G. Numerous studies show varying effects of grazing on carbon balance:

(1) Grassland soils can store more than 100 and 10 tons per hectare of SOC and SON, respectively, in the surface meter (Jobbagy and Jackson 2000), and grazing can increase, decrease, or maintain unaltered the size of both pools (Milchunas and Lauenroth 1993; Derner et al. 2006; Pineiro et al. 2009, 2010).

(2) Soil organic content was reduced on grazed native grasslands compared to ungrazed grasslands (Bauer et al. 1987).

(3) In central Texas tall grass prairie, soil organic carbon in long term cropped fields in the surface 120 cm was 25 to 43 percent of the original prairie. In fields seeded to grasses (6 to 60 yrs. establishment), the estimated carbon sequestration rate was 0.447 Mg C $ha^{-1}$ $yr^{-1}$. Based on this rate, it would take 100 to 185 years for the carbon pool to be equivalent to that of the undisturbed prairie (Potter et al. 1999).

(4) Pineiro et al. (2010) reviewed 20 articles with 67 comparisons of grazed and ungrazed sites and summarized some general patterns:

(i) Root biomass (a primary control of SOC formation) was lower at sites with intermediate precipitation (400 mm to 850 mm), but higher in grazed compared to ungrazed counterparts at the driest and wettest sites

(ii) Soil organic matter C:N ratios frequently increased under grazed conditions, suggesting potential N limitations for soil organic matter formation with grazing

(iii) Soil organic carbon decreased or remained unchanged with contrasting grazing conditions with varied grassland temperature and precipitation gradients

(iv) Soil bulk density either increased or did not change in grazed sites.

(5) Heavily grazed fescue grasslands in Alberta, Canada [0.2 ha per animal unit month ($AUM^{-1}$)], had less soil organic matter compared to grazing at 0.8 ha per $AUM^{-1}$ (Johnston et al. 1971).

(6) Sheep grazing on native *Stipa-Bouteloua* prairie at 2.5 ha $AUM^{-1}$ showed increased soil carbon compared to grazing at 1.7 ha $AUM^{-1}$ (Smoliak 1986).

(7) In northern mixed-grass prairie, North Dakota, moderate grazed treatments contained 17 percent less soil carbon compared to ungrazed exclosures. Heavily grazed treatments did not result in less soil carbon compared to the exclosure. The authors surmised that an increase in blue grama (*Bouteloua gracilis*), a grass species with a heavy dense root system, may be responsible for maintaining soil carbon levels equal to the exclosure (Frank et al. 1995).

(8) In meadow bromegrass (*Bromus riparius*) pastures in Alberta, Canada, "heavy and medium grazing intensities produced 83 and 90 percent as much above-ground dry matter and 87 and 90 percent above-ground carbon as the light intensity . . . heavy grazing reduced the contribution of vegetative dry matter in vitro digestible organic matter, carbon and nitrogen to the residual 41, 50, 36, and 52 percent of that for light grazing . . . estimated fecal carbon inputs were 68, 51, and 42 percent of all carbon inputs for heavy, medium, and light grazing, respectively" (Baron et al. 2002).

(9) Derner and Schuman (2007) stated: "although there was no statistical relationship between change in soil carbon with longevity of the grazing management practice in native rangelands

of the North American Great Plains, the general trend seems to suggest a decrease in carbon sequestration with longevity of the grazing management practice across stocking rates."

(10) In northern mixed-grass prairie, Schuman et al. (1999) found that light or heavy grazing resulted in higher carbon sequestration compared to nongrazed exclosures.

(11) Eighty-one years of moderate and heavy grazing in northern mixed-grass prairie showed increases of 19 and 34 percent of soil carbon at 0–5 cm and 5–15 cm soil depth (Wienhold et al. 2001).

(12) Manley et al. (1995) found that short-duration rotational grazing, rotationally deferred grazing, and continuous season-long grazing at heavy stocking rates did not affect carbon sequestration rates.

(13) In shortgrass steppe in northeastern Colorado, Derner et al. (1997) found increased soil carbon storage in grazed (1983 g $m^2$; 0.41 lb $ft^2$) compared to ungrazed areas (1321 g $m^2$; 0.27 lb $ft^2$) at 0–15 cm (0–5.9 in) soil depth, while no differences were found at the 15–30 cm (5.9–11.8 in) soil depth.

(14) During a 12-year period in "coastal" Bermuda grass (*Cynodon dactylon*)/tall fescue (*Lolium arundinaceum*) paddocks, annual soil organic carbon change at 0–90 cm soil depth was as follows: low grazing pressure (1.17 Mg C $ha^{-1}$ $year^{-1}$; 0.52 t C $ac^{-1}$ $yr^{-1}$) was greater than unharvested grass (0.64 Mg C $ha^{-1}$ $year^{-1}$; 0.29 t C $ac^{-1}$ $yr^{-1}$) but nearly equal to high grazing pressure (0.51 Mg C $ha^{-1}$ $year^{-1}$; 0.23 t C $ac^{-1}$ $yr^{-1}$). Hayed paddocks showed the lowest annual rate of soil organic carbon change (0.22 Mg C $ha^{-1}$ $year^{-1}$; 0.1 t C $ac^{-1}$ $yr^{-1}$) (Franzluebbers and Stuedemann 2009).

(15) During a five-year evaluation of soil organic carbon sequestration in Bermuda grass (*Cynodon dactylon*) pasture, sequestration in the surface 6 cm was 1.4 Mg C $ha^{-1}$ $year^{-1}$ (0.62 t C $ac^{-1}$ $yr^{-1}$) when grazed in summer by cattle, 0.65 Mg C $ha^{-1}$ year−1 (0.29 t C $ac^{-1}$ $yr^{-1}$) when ungrazed, and 0.29 Mg C $ha^{-1}$ $year^{-1}$ (0.13 t C $ac^{-1}$ $yr^{-1}$) when hayed (Franzluebbers et al. 2001).

(16) Hewins et al. (2018) evaluated 108 pairs of long-term grazed and ungrazed study sites in dry mixed-grass prairie, central parkland, foothills fescue, and montane and upper foothills representing six distinct climate subregions across 5.7 M $ha^{-1}$ (14 M $ac^{-1}$) of Alberta, Canada. Their findings found that moderate grazing increased soil organic carbon by 12 percent in the upper 15 cm (5.9 in) of soil, and soil organic carbon concentrations in deeper mineral soil layers were associated more with regional climate and increase from dry to mesic subregions. They concluded that "longterm livestock grazing may enhance soil organic carbon concentrations in shallow mineral soil and affirm that climate rather than grazing is the key modulator of soil carbon storage across northern grasslands."

(17) Mountain meadows grazed for 1–3 months by sheep and cattle in the Medicine Bow National Forest in Wyoming showed higher soil organic carbon in grazed compared to ungrazed treatments at 0–7.5 cm (0–3 in) soil depth (Povirk 1999).

(18) "Proper grazing management has been estimated to increase soil carbon storage on US rangelands from 0.1 to 0.3 Mg C $ha^{-1}$year-1 (0.044 – 0.133 t C $ac^{-1}$ $yr^{-1}$) and new grasslands have been shown to store as much as 0.6 Mg C $ha^{-1}$$year^{-1}$ (0.26 t C $ac^{-1}$ $yr^{-1}$)" (Schuman et al. 2002).

## 645.1110 Conclusions

A. The objective of this chapter is to present basic information and facts about soil organic carbon and matter dynamics on grazing lands. Soil organic matter is a key concept to overall ecosystem function and health and integral to soil health. Understanding basic information about the carbon cycle is necessary to have accurate and meaningful discussions on range, pasture, and soil health with NRCS customers. Since individual range and pasture sites (fields) are representative of particular plant communities and on a larger scale, an ecosystem, it is necessary to focus on all the attributes that are connected to “overall health.” During the past three decades, the rangeland health assessment tool (Pellant et al. 2020) has a well-documented history and has continually been refined. Soil health is a major theme of IIRH and DIPH and is assessed by indicator variables (see subpart E for examples of assessments). More recently, the concepts of IIRH (Pellant et al. 2020) have been applied to pastureland (DIPH; Spaeth 2020). Both assessment tools have been sufficiently tested to provide a basis for assessing three overall attributes (biotic integrity, soil and site stability, and hydrologic function) of the plant community and ecological sites. The Pasture Condition Scoresheet is useful for a quick overall assessment of overall pasture health but does not provide a specific breakdown of the three attributes associated with IIRH and DIPH.

B. In conclusion, in determining range and pasture health with supporting soil health principles, three protocols are available: IIRH, PCSS, and DIPH. For IIRH, PCSS, and DIPH, quantitative data can be used in determining indicators (see discussion in this document and subparts B and E).

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# Part 645 – National Range and Pastureland Handbook

## Subpart L – Grazing Land Economics

### 645.1201 General

A. Grazing land managers make choices from a range of alternatives for the survival and prosperity of their farm or ranch enterprise. The conservationist's duty is to present ecologically and economically sound resource management system alternatives to the land managers to assist them in making informed decisions. Economic analysis tools are available to help clients evaluate and select the best alternative(s) for them.

B. Economic evaluation of conservation practices and systems can be a sensitive subject because it may involve personal information about costs, returns, and production. The conservationist's objective is not to determine whether an alternative is the correct economic choice for the land manager, but rather to offer the manager assistance in evaluating the economic feasibility of the alternative land uses, conservation practices, and systems.

C. Economic evaluation of a conservation practice or resource management system (RMS) can be estimated through ***partial budgeting***. Partial budgeting examines only the change in costs, returns, and benefits resulting from the practice or RMS. Using the partial budget technique greatly reduces the amount of information that is needed to adequately evaluate the alternative conservation activities. This technique is one that planners should become familiar with!

D. Knowledge of the science and application of conservation technologies provides the conservationist and decisionmaker with a range of alternative practices that can address resource problems or opportunities. Knowledge of economic analysis techniques provides the tools to determine which alternatives are economically feasible.

E. Failure to meet economic feasibility criteria does not mean that the practice or RMS should not be chosen. Economic feasibility is only one criterion to use in decision making. A landowner may choose to forego one economically feasible practice and implement another that is not economically feasible because of other extenuating circumstances, personal desires, or other resource concerns.

F. Conservation economic information reflects variable planning periods. These are dependent upon physical or economic life of the practice or system, funding sources, variable managerial ability, and risk factors. The starting point is the present condition. Future conditions reflect costs incurred and anticipated returns based on the land use and conservation practices or resource management systems being applied. Where resources are declining or improving under current management, future conditions without conservation applications should also be included in the analysis (future without condition).

### 645.1202 Application

A. The Natural Resources Conservation Service and the Society for Range Management have co-developed an online training course, utilizing live in-person interviews as a part of the training. It provides an excellent overview of the principles and considerations outlined in this Chapter. This can help teach and refine the skills in applying economic analysis to the field situations you may address.

The Economics of (Prescribed) Grazing is the study of the economic implications of alternative investments and management decisions that change the following:

(i) Grazing system structure
(ii) Grazing animal behavior

(iii) Grazing system performance
(iv) Combinations of these

B. Grazing land economics focus on efficiency, as measured in costs and returns, for informed decision making. These economic concepts can be applied to large and small grazing areas. The planner is trying to better utilize a resource and make it more efficient (and profitable). Scale (size) does not change these concepts.

Benefits and Costs Analysis

(i) Comparing benefits and costs is the basis for grazing land economics. Being able to evaluate the economics of a conservation system is an important evaluation measure. If benefits are greater than costs, it is deemed a good investment.

(ii) In order to make this economic evaluation, four steps are required:

- Estimate costs
- Estimate benefits
- Convert to like terms
- Compare costs and benefits

C. The most difficult part of this analysis is getting to ***Like Terms***. Some costs may be evaluated on a per-acre basis, others in costs per head, and some others in cost per ton, etc. Typically, the measure for comparison is in dollars per acre per year ($/ac/yr). In order to evaluate alternatives, all measures must be converted to the same denominator. If measures are not in like terms, they are difficult to compare and evaluate (think comparing apples and oranges).

Converting to Like Terms

(i) Costs of today ($/ac) are converted to future benefits ($/ac/yr) by using the concept known as the ***Time Value of Money***. To be able to make this evaluation, five variables are considered:

- Time period (years)
- Discount/interest rate (percent)
- Present value ($, installation costs)
- Future value ($, worth or return in future)
- Payment ($, annual benefit or cost)

(ii) Knowing three of the variables allows the 4$^{th}$ to be solved for. The most common calculation is for annual payments.

D. The basic formula, subject to manipulation, depending upon the variable to be solved for, is:

Payment = Present Value x "Time Period and Interest Rate"

(i) For example, consider installation of a fence in your grazing plan. The fence is expected to last for 15 years. The cost to borrow money is 6 percent interest, and it will cost $20,000 to install. What would the payment be?

- Time Period = 15 yrs.; Interest Rate = 6 percent; Present Value = $20,000.
- Expressing this in an equation yields: Payment = Present Value x (Years, percent).
- The next part requires an amortization table to find the numeric variable, a lookup function. For this example, 15 years at 6 percent is a 0.103 factor.
- $20,000 x 0.103 = $2,060. The payment would be $2,060 each year for 15 years.

(ii) Next step is to identify the acreage involved and convert to $/ac/yr. For this example, we will assume the benefit is for 240 Acres: $2,060/240 = $8.58/ac/yr in costs.

(iii) Do benefits of at least $8.58/ac/yr exist to determine if this is a good investment?

**Table L-1.** Amortization Table

| LIFE | % INTEREST RATE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEARS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | 0.508 | 0.515 | 0.523 | 0.530 | 0.538 | 0.545 | 0.553 | 0.561 | 0.568 | 0.576 | 0.584 | 0.592 |
| 3 | 0.340 | 0.347 | 0.354 | 0.360 | 0.367 | 0.374 | 0.381 | 0.388 | 0.395 | 0.402 | 0.409 | 0.416 |
| 4 | 0.256 | 0.263 | 0.269 | 0.275 | 0.282 | 0.289 | 0.295 | 0.302 | 0.309 | 0.315 | 0.322 | 0.329 |
| 5 | 0.206 | 0.212 | 0.218 | 0.225 | 0.231 | 0.237 | 0.244 | 0.250 | 0.257 | 0.264 | 0.271 | 0.277 |
| 6 | 0.173 | 0.179 | 0.185 | 0.191 | 0.197 | 0.203 | 0.210 | 0.216 | 0.223 | 0.230 | 0.236 | 0.243 |
| 7 | 0.149 | 0.155 | 0.161 | 0.167 | 0.173 | 0.179 | 0.186 | 0.192 | 0.199 | 0.205 | 0.212 | 0.219 |
| 8 | 0.131 | 0.137 | 0.142 | 0.149 | 0.155 | 0.161 | 0.167 | 0.174 | 0.181 | 0.187 | 0.194 | 0.201 |
| 9 | 0.117 | 0.123 | 0.128 | 0.134 | 0.141 | 0.147 | 0.153 | 0.160 | 0.167 | 0.174 | 0.181 | 0.188 |
| 10 | 0.106 | 0.111 | 0.117 | 0.123 | 0.130 | 0.136 | 0.142 | 0.149 | 0.156 | 0.163 | 0.170 | 0.177 |
| 11 | 0.096 | 0.102 | 0.108 | 0.114 | 0.120 | 0.127 | 0.133 | 0.140 | 0.147 | 0.154 | 0.161 | 0.168 |
| 12 | 0.089 | 0.095 | 0.100 | 0.107 | 0.113 | 0.119 | 0.126 | 0.133 | 0.140 | 0.147 | 0.154 | 0.161 |
| 13 | 0.082 | 0.088 | 0.094 | 0.100 | 0.106 | 0.113 | 0.120 | 0.127 | 0.134 | 0.141 | 0.148 | 0.156 |
| 14 | 0.077 | 0.083 | 0.089 | 0.095 | 0.101 | 0.108 | 0.114 | 0.121 | 0.128 | 0.136 | 0.143 | 0.151 |
| 15 | 0.072 | 0.078 | 0.084 | 0.090 | 0.096 | 0.103 | 0.110 | 0.117 | 0.124 | 0.131 | 0.139 | 0.147 |
| 16 | 0.068 | 0.074 | 0.080 | 0.086 | 0.092 | 0.099 | 0.106 | 0.113 | 0.120 | 0.128 | 0.136 | 0.143 |

E. Partial Budgeting. As mentioned above, partial budgeting is a critical tool. Partial budget analysis looks at “what changes” with a change in the operation.

This method does not require extensive economic training or background and does not require knowledge of and access to full enterprise budgets. The method evaluates changes in variables and their direction of change if adopted or rejected.

(i) Partial budgeting is a relatively simple and effective measure. Only the things that change are considered. This simplifies data collection and has numerous applications, from budget outlines to T-Chart formats.

T-charts, named for the T-shaped presentation format, systematically identify only the benefits and costs of a conservation alternative. This technique simplifies data collection and analysis. The T-chart also describes the resource setting, resource concerns and the conservation system. The best information used in the T-chart comes from your client; followed by a discipline specialist’s recommendations, and then, technical references. T-Charts are defined by their level and type of information.

- Level I T Chart: Includes only qualitative statements
- Level II T Chart: Qualitative statement plus units of measurement and dollars
- Level III T Chart: Complete economic or financial analysis

(ii) Some clients will only need the discussion and the narrative of the costs and benefits. These are well expressed in a Level I T-Chart format, as shown in the example in table L-2. Level I T-Charts for the majority of our conservation practices can be found here: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/data/?cid=nrcseprd1298864.

(iii) Planners should realize that the concepts being discussed in this chapter extend to all areas, and not just rangeland or pastureland. These concepts apply to cropland, forest land, and other resource areas. This is reflected in the following examples tables L-2. and L-3.

**Table L-2.** Example of a Level I T-Chart, showing effects of a conservation practice.

**Prescribed Grazing (Ac) 528**

**Definition:** Managing the harvest of vegetation with grazing or browsing animals.
**Major Resource Concerns Addressed:** Low plant and animal productivity and health.
**Benchmark Condition:** Native rangeland, poor livestock distribution, low forage yields.

**Date:** October, 2015. Developer/Location: Hal Gordon, OR

| Positive Effects | Negative Effects |
|---|---|
| **Soil**<br>• Sheet, rill, wind, and gully erosion reduced by improving the health and vigor of plant communities with increased vegetative cover and water infiltration.<br>• Streambanks protected with an increase in riparian vegetation.<br>• Increase in vegetative cover, deeper root systems, increased soil organic material and biological activity, and improved nutrient cycling.<br>• Reduced soil compaction.<br>• Increased cover reduces evaporative salt accumulation.<br>**Water**<br>• Spring and seep flows improved.<br>• Runoff, flooding, or ponding are reduced, and infiltration increased with improved vegetative cover.<br>• Soil moisture improved, less irrigation.<br>• Reduced pesticides and fertilizer use with better plant health and vigor, improved surface and ground water.<br>• Reduced risk of movement of pathogens in surface waters with increase in soil microbial activity.<br>• Reduced sediment delivery to surface water.<br>**Air**<br>• Improved vegetative cover reduces the generation of particulates and removes $CO_2$ from the air and stores it as carbon in plants and soil.<br>• Objectionable manure odor reduced.<br>**Plants**<br>• Improved plant and animal management enhances growing conditions of the desired plant community and reduces noxious and invasive plants.<br>• Improved forage yields and access.<br>• Reduced fuel loads and wildfire hazard.<br>**Animals**<br>• Improved fish and wildlife habitat, cover, shelter, water, habitat continuity and space. | **Land**<br>• Slight increase in land in production with improved livestock distribution.<br>• Protect buried cultural resources.<br>**Capital**<br>• Slight increase in equipment costs, some monitoring equipment may be required (camera, stakes, hoops, clippers, etc.)<br>• Minor increase in annual operation and maintenance costs for herding and forage monitoring.<br>**Labor**<br>• Additional labor herding livestock between pastures.<br>**Management**<br>• Increase in field scouting to determine when to move livestock and manage forage, minerals, and water.<br>• Increase record keeping.<br>**Risk**<br>• Possible foregone income from forage deferment during implementation. |

<table>
<tr><th>Positive Effects</th><th>Negative Effects</th></tr>
<tr><td><ul><li>Livestock numbers are in balance with feed and forage that meets livestock nutritional and productive needs.</li><li>Grazing management considers animal shelter throughout the year.</li></ul>Energy<ul><li>Opportunity to reduce herding requirements and fuel use.</li></ul>Human<ul><li>Improved livestock distribution and management options.</li><li>Increased profitability in the long run.</li></ul></td><td></td></tr>
<tr><td colspan="2">Net Effect: improved forage productivity and water quality, reduced erosion at a minor cost.</td></tr>
</table>

**Table L-3.** Level II T-Chart Partial budget analysis of costs and effects for a conservation treatment.

<table>
<tr><td colspan="2">Name: Dr. Joel Gruver and Andy Clayton<br>Location: Western Illinois University, Macomb, Illinois<br>Site: Allison Farm, Southwest Warren County. (18 miles Northwest of Macomb, IL.)</td><td colspan="2">Resource Concerns/Benchmark:<br>77-acre certified organic and research demonstration farm. Principal method of controlling weeds and competing vegetation is done via tillage and hand rogueing. By agricultural measures, it would be considered tillage intensive farming.</td></tr>
<tr><td colspan="4">Conservation Treatment:<br>The establishment of organic no-till soybeans. This is accomplished by planting a cover crop of cereal rye or triticale preceding soybeans planted without tillage. The cover crop reduces weed germination and growth and buffers soil temperature and moisture fluctuations. In addition, the cover crop reduces labor and time expended for weed control and reduces the number of passes across the field with a tractor and tillage tool. All of these factors combined provide improved timeliness of operations and increases the weather resilience of the soybean crop.</td></tr>
<tr><td colspan="2">Positive Effects<br>• Reduced weed pressure significantly in subsequent years.<br>• Improved soil structure and crop resilience.<br>• Increased timeliness.</td><td colspan="2">Negative Effects<br>• Soil moisture depletion by the cover crop can be a concern in dry springs.<br>• Inconsistent cover crop establishment[3]</td></tr>
<tr><td colspan="2">Increased Revenue (per acre)[1]</td><td colspan="2">Increased Cost (per acre)[4]</td></tr>
<tr><td>2.5 bu/ac x $22.61/bu[2]</td><td>$56.52</td><td>Cover crop seed mix</td><td>$26.70</td></tr>
<tr><td>Reduced hand rogueing by1.5 hours per acre</td><td>$22.50</td><td>Cover crop seeding</td><td>$13.10</td></tr>
<tr><td>Reduced rotary hoeing by 2 passes</td><td>$11.00</td><td>Roller-crimper</td><td>$12.10</td></tr>
<tr><td>Reduced row cultivating by 2 passes</td><td>$21.20</td><td>Planting, no-till drill (additional above planter cost)<br>Increased seeding rate</td><td>$ 5.70<br>$15.00</td></tr>
<tr><td>Total direct dollar benefits</td><td>$111.22/ac</td><td>Total direct dollar costs</td><td>$72.60/ac</td></tr>
<tr><td colspan="4">Net Direct Dollar Benefits = $111.22 - $72.60 = $38.62/ac</td></tr>
<tr><td colspan="4">Analysis of these costs and benefits shows that this conservation management strategy had a strong net return to the landowner, increased the conservation effects, and increased soil health; while still leaving a significant allowance for negative risk factors.</td></tr>
<tr><td colspan="4">Indirect Benefits—A number of indirect benefits and costs are recognized but are not quantified or monetized. These factors are important, but due to a lack of values and standards for measurement, are only recognized in the Case Study, and are not a part of the direct costs and benefits. These may be considered as risk factors, which can be positive or negative for the operation.</td></tr>
</table>

Notes:

1 Averages were calculated using data provided by Western Illinois University; comparing organic tillage and no-till plots. No-tillage out yielded conventional 4 out of 6 years in comparison. (only 1 year significantly less).

2 Reported price per bushel of organic soybeans. This is a four-year average of prices received by WIU. Actual positive effect may have been higher if 2012 drought had not had such a negative effect on the no-tillage soybeans (due to moisture depletion by cover crop).

3 comparisons were not done in 2013 and 2014 due to a poor stand of cereal rye.

4 Actual costs reported by Joel Gruver and Andy Clayton for organic cereal rye seed, drill cost and other fieldwork costs based on prices at the University of Illinois FarmDoc.

This document is a companion to “No-Till Organic,” released May, 2017 by USDA/NRCS, Illinois.

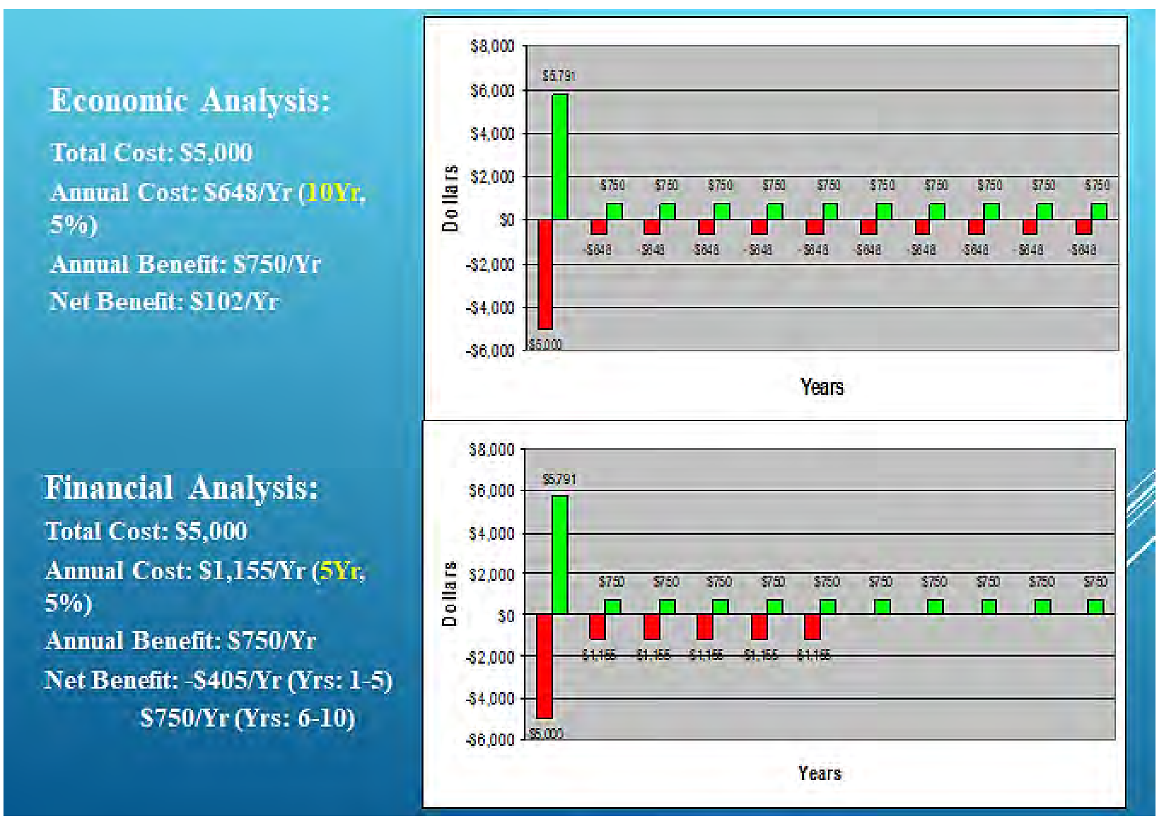
G. A key concern is whether or not the proposed management change will be profitable. These questions compare economic and financial analysis. They are not the same but use the same variables in the analysis. The difference in the analysis is the timeframe.

(1) Do the benefits of the change exceed the costs of the change over the given lifespan of the change?
(2) Is the proposed change affordable?
(3) Do the benefits of the change exceed the costs of the change over a given term of a loan or other payment period? If not, does the client have the cash flow or access to other capital that will support the investment?

H. Example

(1) A pasture fertilization and overseeding project that has a cost of $5,000, an expected life of 10 years, a 5 percent interest rate, and an annual benefit of $750 is being contemplated by the producer. The difference in the economic vs. financial analysis is shown in figure L-1.
(2) From an economic analysis, which considers the change over the entire 10 years, there is an annual net benefit of $102/yr. – a good investment.
(3) However, the financial analysis looks at the costs over the life of the 5-year loan that the client was able to get to finance the improvement. Over the first 5 years, the benefit is $405/yr. This means that the client must have access to the capital to cover the shortfall, or they cannot afford the improvement.

**Figure L-1.** Example of the difference between economic analysis and financial analysis of a conservation practice.



## 645.1203 Economic Analysis Tools

A. Other economic tools and analyses are available. NRCS Economists have developed multiple tools to evaluate various alternative practices from an economic and financial perspective. The tools can be found on the NRCS Economics Tools website at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/tools/?cid=nrcs143_009747.

B. A number of economic technical measures are available to a planner to utilize in evaluating alternatives. Some of them are detailed and complex. We acknowledge them here but reference the reader to specific other handbooks for further discussion of those techniques. Many of these techniques are spelled out in manuals and references found on the USDA/NRCS Economics Web Page, https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/econ/. You may also wish to reach out to economic technical specialists within your area for additional assistance or more in-depth explanation of these tools and concepts.

## 645.1204 References and Technical Terms and Definitions

A. More detail on how to conduct various economic analyses for conservation decision-making can be found in the NRCS National Resource Economics Handbook, H_200_NREH_610: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1257407&ext=pdf.

B. Some Important Definitions

(1) **Amortization–**Amortization is also called partial payment or the capital recovery factor. It is the "paying off" of a financial obligation in equal installments over time. The amortization factor determines the payment to pay off the principal and interest over a given time period. The time period can be months or years (average annual cost). Also, it is an investment that yields fixed payments over a stated period.

(2) **Break Even–**An improvement practice breaks even when added returns equal added costs at an acceptable rate of return. In other words, the improvement practice will pay for itself.

(3) **Compound Interest–**Compound interest is computed for one period and immediately added to the principal, thus resulting in a larger principal on which interest is computed for the following period.

(4) **Discount Rate–**Discount rate is the interest rate for the opportunity cost of money. The discount rate is determined by summing the time value of money (the rate someone is willing to pay to use someone else's money, or the rate that someone is willing to take to allow someone else to use their money for one year), the rate of inflation, and the rate of risk. The real discount rate consists of the time value of money and does not include risk and the rate of inflation.

(5) **Interest–**Interest is the earning power of money; what someone will pay for the use of money. Interest is usually expressed as an annual percentage rate (APR) and is most often compounded. Simple interest is not commonly used. Money can be invested and used to earn more money through accumulation of interest over time.

(6) **Internal Rate of Return–**the compounded interest rate that the practice will return based upon the inputs provided.

(7) **Time Value of Money–**Money has value today and in the future. Thus, the value of money is measured for some number of periods in the future. These periods may be years, months, weeks, or days.

(8) **Net Present Value–**The net present value is the difference between returns and costs when compared in present dollars. Value of today's dollar = Present value.

(9) **Opportunity Cost–**When money is used for a particular purpose, the opportunity to use it or invest it in some other way is foregone. The expected return from the lost opportunity from

another investment (i.e., savings account, certificate of deposit, IRA) is the opportunity cost of using it in the manner chosen.

(10) **Simple Interest–**Simple interest is money paid or received for the use of money, generally calculated over a base period of one year at a set interest rate.

(11) **Real versus Nominal Terms–**In economics one often hears the terms real and nominal. Real terms do not include inflation, whereas nominal terms include inflation. A price quoted today that is also used for the future price of the same input or output is said to be a real price. If the future price is estimated at a level different from today's price because of expected inflation, then the future price is said to be a projected nominal price. The rate of interest quoted by a lending institution is a nominal rate because it includes the time value of money, inflation, and risk.

(12) **Risk–**Risk refers to the variability of outcomes. In evaluating the economics of a conservation practice or RMS, risk is the probability that a conservation practice or RMS will be unsuccessful. If a particular practice has failed once in 25 times in the past, then the risk is calculated to be 4 percent.

# Part 645 – National Range and Pasture Handbook

## Subpart M – Pollinator Habitat Considerations for Range and Pasturelands

### 645.1301 General

A. Definition: Pollination is the transfer of pollen grains from a plant's anther (the pollen-producing part of the flower) to a stigma (the pollen-receiving part of a flower). In most plant species, pollination is required to produce fruit and seeds, and cross-pollination (pollination between two genetically different individuals) helps to enhance fruit and seed production. The three major types of pollination are:

(1) Self-pollination – Self-pollination occurs in some species of plants with perfect flowers, where there is proximity of the anther and stigma in the flower's morphology and when the plant is self-fertile (does not require cross-pollination). Cotton, soybeans, and tomatoes are examples of self-pollinating plants.

(2) Wind-pollination – Wind-pollinated plants produce pollen grains that are carried by the wind; they produce huge amounts of pollen to assure that some pollen grains, by random chance, to reach the stigmas of flowers growing on other individuals of their species. Most grasses (including rice, corn, and wheat) are wind-pollinated as are many nut trees (including pecans and walnuts) and conifers (pines, firs, cedars, etc.).

(3) Animal-pollination – For many species of plants, pollination is facilitated by animals transporting pollen from the anthers to the stigma. This reproductive strategy allows for less pollen production than wind-pollination. Approximately 85 percent of plant species (including almonds, blueberries, and apples) depend on animals for pollination. Pollinators are animals that transfer pollen from the anther to the stigma, usually while visiting flowers to consume nectar and/or pollen. Pollinators are essential for pollination of plants that do not self-pollinate or utilize wind-pollination. Some self-pollinating plants (e.g. cotton, soybeans, and tomatoes) are used as a nectar and/or pollen source by pollinators, allowing for cross-pollination of some of the seed. For those plants, pollinators provide value by increasing pollination rate (thus enhancing fruit and seed production) and by assuring increased genetic diversity of the offspring (seeds) – a critical characteristic for ecological adaptation.

B. Among the vertebrate animals, there are multiple hummingbird species that serve as pollinators, and some other vertebrate groups (e.g., bats, lizards) have at least a few species that are pollinators. However, insects including bees, butterflies, moths, flies, wasps, and beetles, make up the great majority of pollinator species. Insect pollinators such as managed honeybees and wild native bees not only play a critical role in our food production system, but also in the pollination of thousands of plant species in native and managed ecosystems. For the remainder of this chapter, the term "pollinator" and "pollinators" refers to insect pollinators, not vertebrate pollinators.

C. Federal Policies and Directives

(1) Over the past two decades, a significant decline in pollinators has been noted. In response, the federal government has made efforts to promote pollinator health and habitat. These efforts include a Presidential Memorandum (2014) and Federal Strategies (2015) to promote the health of honey bees and other pollinators as well as Farm Bill programs (particularly 2008, 2014, and 2018) that provide federal resources for creating and enhancing pollinator habitat on private lands. In support of the value of pollinators, NRCS provided specific policy regarding pollinators (Title 190, General Manual, Part 416, "Pollinators") that focuses on "preventing unnecessary harm to pollinators and their habitats and to enhance, whenever practical, the nesting and foraging habitats for pollinators."

(2) Some pollinator species, such as the rusty patched bumble bee (*Bombus affinis*), have decreased in abundance and extent and have been listed as threatened or endangered by the U.S. Fish and Wildlife Service. When threatened and endangered (T&E) species are of concern, NRCS will follow agency policies to assure that NRCS technical or financial assistance meets the mandates of the Endangered Species Act, 1973.

## 645.1302 Insect Pollinators on Range and Pasturelands

A. Value to Agriculture

Insect pollinators play a critical role in supporting agricultural production. Over 100 crops in the U.S. depend on pollinators to produce seeds, fruits, nuts, vegetables, and fiber, resulting in an estimated value of $30 billion annually (Jordan et al. 2021). These crops are often adjacent to rangelands and pasture. Pollinators and agriculture go hand-in-hand. Farmers and ranchers rely on pollinators to pollinate many of their crops, enhance on-farm biodiversity and support wildlife habitat, while pollinators rely on agricultural conservation practices and well-managed range and pasturelands for habitat and forage. Thriving populations of bees and other pollinators on rangelands and pasture pollinate native wildflowers (which often serve as nutritious forage to livestock) and exotic forage legumes. In doing so, they ensure that these plants remain present and abundant while also providing pollination services on other nearby crops.

B. Ecological Value and Linkage to Ecosystem Services

The benefits pollinators provide for ecosystems are wide-ranging and substantial. Pollinators play a critical role in range and pastureland ecosystem processes by increasing biodiversity and abundance of forbs, legumes, and flowering woody plants. They increase capacity of range and pasturelands for provisioning (animal feed, food, and fiber), regulating (carbon cycling), supporting (biodiversity and water and nutrient cycling), and providing cultural (recreational, spiritual, and aesthetic) services (Gibson 2006).

## 645.1303 Range and Pasturelands as Pollinator Habitat

A. North American rangelands, particularly those with a high diversity of native forbs, legumes, shrubs, grasses and grass-like species (graminoids) (figure M-1), are excellent habitat for thousands of species of insect pollinators. Rich and diverse native plant communities tend to increase ecosystem function and stability resulting in greater resilience and resistance to maintain ecosystem states and facilitating recovery from disturbances such as drought, grazing, and fire (Anderson 2006; Standish et al. 2014; Zuppinger-Dingley et al. 2016). On pasturelands, common seed mixes are often used and typically have only a few species of grasses and legumes (figure M-2); pasturelands with low plant species richness have been shown to have lower pollinator species richness (Orford et al. 2016). However, it is possible to create pasturelands with high plant diversity, by planting a diverse mix of native and non-native grasses, forbs, and legumes (figure M-3). If pasturelands are managed for high floral resource availability, they can support large populations of multiple pollinator species.

B. To meet the landowner's pollinator habitat objectives, the conservation planner should assist the client with setting realistic expectations. The establishment of rich and diverse plant communities requires different time, care, consideration, and maintenance, when compared to the management of grass-only communities (Gibson 2006, Symstad and Jonas 2011). For many grazing operations, particularly with improved pasture (e.g., Bermuda grass, bahia grass, fescue spp., timothy, orchard grass, and smooth brome), the establishment of a dedicated pollinator habitat area may be an additional alternative for the client.

**Figure M-1.** Rangeland grazed by cattle in Osage County, Oklahoma (Photo by Ray Moranz, Xerces Society and USDA-NRCS).

An example of the conservation practice standards (CPS) which may be utilized to promote dedicated pollinator habitat include Hedgerow Planting CPS 422A, Field Border CPS 386, Filter Strip CPS 393, Wildlife Habitat Planting CPS 420 or other conservation practice standards allowing for emphasis on pollinators (see Using 2018 Farm Bill Programs for Pollinator Conservation). Adding a mixture of clovers or diversifying with native species, particularly native legumes, are additional options for pasture overseeding and renovation. Herbicide options to control noxious or invasive plants may require the use of spot chemical treatments or mechanical removal. Planning and implementation of prescribed fire on rangeland may require additional considerations with regards to fire return interval and timing, if the objective is to maintain or increase the forb component. Additional monitoring and management may be required in managed grazing systems, as livestock often select preferred pollinator plants. Forage harvest management may require altering the timing and amount of harvest activities.

**Figure M-2.** Pastureland with cattle grazing in Maryland. Photo by Preston Keres, USDA.

**Figure M-3.** Legume-rich, diverse pastureland with cattle grazing in southeastern Iowa. Photo by Francis Thicke (Radiance Dairy).

## 645.1304 Major Pollinator Groups and their Biology

A. Overview

Among insects, the main groups that pollinate are the bees, butterflies, moths, flies, wasps, and beetles. Bees are considered to be the main pollinators. In addition to the European honey bee, there are close to 4,000 native bee species in the United States (Ascher and Pickering 2020; Moissett and Buchanan 2010), and they are efficient pollinators of flowers, including crops. All insect pollinators have multiple life stages (egg, larva, pupa, adult). To thrive, the needs of each life stage must be met. Biologists have identified four key habitat resources necessary to support diverse pollinator communities.

(i) Host plants – Provide vegetative forage needed for larval development of most butterfly and moth species, as well as for some flies and beetles. Insect species differ greatly in the host plants they require. Some pollinator species are host plant generalists (their larvae eat plant species from multiple plant families), but even these generalist species use only a small subset of the entire plant community. Other pollinators are host plant specialists, with their larvae eating plants from only one or two families. For instance, the monarch butterfly is a host plant specialist. In natural settings, its larvae feed only on milkweed plants (Family *Apocynaceae*). Rarely do two insect species have precisely the same host plant requirements. Therefore, having a diversity of plants is critical to provide for the larval needs of a diverse community of butterflies and moths. Many forb species serve as larval hosts, but so do many legumes, graminoids (grasses and grass-like plants such as sedges and rushes), and woody plants.

(ii) Nesting sites – Nesting sites are essential for bees and wasps to support their development from egg to larva to pupa to adult. Approximately 70 percent of native bee species nest underground. Bare areas between plants with crumbly textured, uncompacted (friable) soils are essential. Almost 30 percent of bee species nest in cavities in herbaceous or woody stems. Dead but standing stems from prior years are highly suitable for these cavity nesters. The 47 species of bumble bees in the U.S. nest in cavities such as abandoned rodent burrows or at the base of bunch-forming grasses (Michener 2007).

(iii) Overwintering sites – The great majority of insect pollinators do not migrate and are full-year residents. In most U.S. states, cold winter temperatures restrict insect activity, and those insects need somewhere to safely survive the winter while immobile. Some insect pollinators spend the winter underground, while others overwinter within leaf litter or within stems of forbs, legumes, graminoids and woody plants.

(iv) Floral resources – Flowers producing nectar and pollen, which serve as food for adult bees and butterflies, and some flies, beetles, wasps, and moths. Most pollinators feed on nectar from a diverse array of plant species, although many pollinators exhibit a strong preference for a few species. Pollen is consumed by bee larvae and adults, as well as some adult flies and beetles. Adult bees collect pollen to feed to their larvae, and many bee species are pollen generalists collecting pollen from plants from multiple plant families (polylactic). However, others specialize in pollen from a few plant species (oligolectic), and a handful of bee species specialize on pollen from a single species. A large percentage of forb, legume, and woody plant species produce nectar and edible pollen. Most graminoid species have wind-pollinated flowers that produce no nectar and produce pollen with limited nutritional value to most pollinators. Graminoid pollen may have incidental use particularly where forb pollen is lacking (Saunders 2018). More importantly, as mentioned above, graminoids can serve as host plants, nesting sites, and overwintering sites, and thus are important components of pollinator habitat.

## 645.1305 Characteristics of Suitable Pollinator Habitat

A. Suitable pollinator habitat usually has all four key resources in proximity (host plants, nesting sites, overwintering sites, and floral resources). Additionally, disturbance regimes (such as prescribed fire or grazing) are implemented so that they maintain habitat quality without causing excessive mortality to pollinator populations. If pesticides are used, their potential negative impacts on pollinators can be mitigated using Pest Management Conservation System (Conservation Practice 595) and other conservation practices.

B. In North American rangelands and pasturelands, maintaining or enhancing plant diversity is one of the central tasks of pollinator and grassland conservation (Gibson 2006; Zuppinger-Dingley et al. 2016). Diverse plant communities help to ensure that the key resources mentioned above are available, particularly host plants for a wide variety of butterflies and moths. Given that plant species flower at different times, high plant diversity also helps to ensure floral resources throughout the growing season. This is of great importance to pollinators, as numerous species are unlikely to persist if there are long periods with no nectar or pollen available.

C. Although there are exceptions (see Mack and Thompson 1982), a large number of North American grassland plant species are highly tolerant of grazing and can persist with moderate or high utilization rates. However, sometimes persistence of a diverse plant community is not enough. In some diverse grasslands, many of the forbs preferred by pollinators for their floral resources are grazed so low that they are unable to bloom or produce few flowers (Moranz et al. 2014). This is problematic because plants need to bloom to provide nectar and pollen to pollinators.

## 645.1306 Pollinator Habitat Management – Overview`

Ecologically diverse and well managed range and pasturelands provide many environmental benefits, including important habitat for pollinators. Managed grazing, prescribed burning, forage harvest management, and pest management conservation systems, either in combination or individually, can be important tools to increase plant and pollinator diversity on range and pasturelands (Jonas et al. 2015). Planners will need to consider how the timing, technique and scale of these practices may affect pollinators.

## 645.1307 Pollinator Habitat Management – Grazing

A. Grazing Effects on Pollinators

Few studies have been performed to assess the impacts of grazing on North American pollinators, and most studies performed to date have studied only a small subset of the pollinator community. Studies here and abroad show two main types of responses: (1) pollinators benefit from grazing when livestock forage selectively on grasses, allowing for an increase in forb abundance and diversity; and (2) pollinators are harmed by grazing when livestock feed heavily on forbs for a long duration (Hopwood et al. 2015). Below, we discuss variables to consider when the goals are to increase abundance and diversity of forbs and pollinators.

(i) Grazing Animal

Plants and pollinators in some North American grassland ecoregions, particularly tallgrass, mixedgrass, shortgrass prairies, evolved in with the presence of grazing by large ungulates such as bison and elk (Mack and Thompson 1982; Anderson 2006). Today, most rangelands and pasturelands are grazed by domesticated grazing animals from the old world (especially cattle, horses, sheep, and goats). In general, these livestock species differ from one another and from native grazers in their forage preferences and grazing behaviors. Additionally, different breeds, sexes, and age classes of grazers forage differently. When developing prescribed grazing or forage harvesting plans for landowners interested in pollinator conservation, NRCS planners should learn the feeding preferences and behaviors of the livestock on the ranch or farm, and if possible, should assess the effects of recent or current grazing by those animals on key resources for pollinators, particularly important floral resources and host plants.

(ii) Stocking Density

Stocking density impacts forage utilization, which in turn impacts pollinator habitat. High stocking rates can result in short-term and even long-term decrease in floral resources. On the other hand, if the grazing animals in question strongly prefer grasses over forbs, moderate and perhaps even high stocking rates can result in forb-dominant communities by releasing forbs from competition with grasses on native rangelands. Stocking density also can influence direct mortality of pollinators. Heavy stocking is likely to cause greater mortality of immobile eggs, pupae, and slow-moving larvae by trampling or incidental consumption. Regardless, the duration and timing of grazing events and rest and recovery periods are critical components of managed grazing that must be considered.

(iii) Duration, Timing and Rest Period

Regarding its effects on pollinator habitat, stocking density appears to interact strongly with the duration and timing of grazing. On most range and pasturelands, high stocking density for numerous consecutive months is likely to result in long-term depletion of floral resources and host plants, as well as greatly reduced grass biomass (Moranz et al 2014; DeBano 2016). High stocking density for a short period of time can cause short-term losses of pollinator resources; but if enough rest is provided to the grazing unit, these pollinator resources often send up new shoots that flower (from the ground or from leaf axils). In some regions of the U.S., moderate to high stocking density improves pollinator habitat by reducing the dominance of one or more exotic grasses (e.g., exotic Kentucky bluegrass in the Northern Plains). Regardless of grazing animal and stocking density, it is essential to plan for a rest period when plants can recover after a grazing event, so that the plant can regrow, replenish food reserves, and bloom.

B. Considerations for Managed Grazing (528)

NRCS field staff should consider the following when developing managed grazing plans for producers seeking to conserve pollinator populations.

(i) Determine if the site has any threatened and endangered (T&E) species or species of special interest to the producer, or if the producer's pollinator habitat goal involves pollinators in general.

(ii) Identify the plant species that meet the needs of target pollinators.

(iii) Although grazing management that increases plant diversity and floral resource availability often benefits pollinators, it is important to remember that high plant diversity does not guarantee floral resource availability. When pollinator habitat is an objective, a managed grazing plan should aim to minimize impacts to flowering stems.

(iv) The grazing plan should consider the objective of assuring that target forbs be allowed to flower and set seed. This may require season-long deferment of some pastures. The length of rest period varies by region. Refer to State guidance for specific recommendations.

(v) If conservation of native bees is an objective, aim to minimize livestock concentrations causing excessive soil compaction and trampling of ground-nesting sites. This may require deferment of some pastures for weeks or months.

(vi) Riparian areas can support high diversity and abundance of native forbs and pollinators (DeBano et al. 2016). NRCS conservation practices such as Fence (382) and Watering Facility (614) can be used to divert livestock away from riparian areas, thus reducing harm to forbs. This is particularly important for riparian areas in the arid West.

## 645.1308 Pollinator Habitat Management – Prescribed Fire

A. Fire Effects

Overall, insect pollinator diversity and abundance are enhanced by restoration of ecological processes associated with reference conditions or other states in the ecological site description and state-and-transition models for an area (Standish et al. 2014; York et al. 2017). This includes restoration of prehistoric fire regimes through the implementation of prescribed fire. Fire frequency is dependent upon ecosystem characteristics, where range and pasture with higher moisture regimes generally exhibiting higher fire frequencies (and shorter fire return intervals) than more arid systems (Symstad and Jonas 2011). Restoring prehistoric fire regimes through the implementation of prescribed burning can accomplish this in the following ways:

(i) Fire can slow or reverse woody plant encroachment, creating improved microclimates (more sunlight, warmth) for most insect pollinators, while also improving habitat conditions that increase forb and legume diversity.

(ii) Fire can reinvigorate plant communities by burning up litter and standing dead vegetation. This results in improved nutrient cycling, greater light penetration, and increases in soil temperature, which in turn stimulates seed germination, production, and plant growth.

(iii) Fire stimulates increased flowering in many plant species, some of which are preferred sources of nectar and pollen.

B. NRCS planners should note that many insect pollinators are vulnerable to fire (Black et al. 2011)., This is particularly true of the immobile eggs and pupae, as well as the slow-moving larvae. All three of these life stages are likely to be incinerated if they are above ground during the prescribed burn. Fire can have negative indirect effects as well, by top-killing host plants and floral resources, and by destroying the pithy stems used by stem-nesting bees.

C. Different timing, frequency, and intensity of fire provides different outcomes. Fire can be used to benefit grass to the detriment of forbs. If pollinator habitat is an objective, prescribed burns require the consideration of the forb community.

D. In figure M-4a, pasture to the right of the burn boundary was burned with higher windspeed and lower relative humidity, whereas pasture to the left of the burn boundary (burned one day after the burn on the right) was burned with lower windspeed and higher relative humidity. Figure M-4b shows natural skips associated with higher frequency burns. Ecosystem response to fire must be carefully considered in conservation planning. Follow NRCS planning policy, standards, State specific protocols, and refer to Subpart J – Prescribed Burning in this handbook for additional information. The following parameters should be considered to address pollinator needs when implementing prescribed burns. These parameters promote a lighter and patchier spatial distribution of prescribed fire resulting in a natural mosaic structure and refugia for pollinators, as exemplified in figures M-5a and M-5b.

(1) Higher relative humidity results in a slower fire with a greater number of natural skips.

(2) Shorter fire return intervals reduce fuel load build up, creating less intense fires with greater number of natural skips, particularly in mesic systems.

(3) Burning during periods of lower wind speed can lead to lower intensity fires with a patchy spatial distribution, which can reduce direct mortality to pollinators.

(4) Consider varying the timing of prescribed burns to benefit a broader diversity of plant and pollinator species.

**Figure M-4.** Prescribed fire implemented in mesic pastureland in eastern Iowa. Photos by Christine Taliga, (USDA-NRCS).

**(a)**

**(b)**

**Figure M-5.** Prairie pasture showing refugia after prescribed fire implementation in eastern Iowa **(a)** and the following summer **(b)**. Photos by Christine Taliga (USDA-NRCS).

**(a)**

**(b)**

E. Considerations for Prescribed Burning (338)

Prescribed burn implementation may offer an important tool for landowners interested in improving pollinator habitat, plant diversity, and productivity, and reducing pest pressure. NRCS planners should consider the following during the prescribed burn planning process:

(i) Determine if the site has any T&E species or species of special interest to the producer, or if the producer's pollinator habitat goal involves pollinators in general.

(ii) Identify the plant species that meet the needs of target pollinators.

(iii) The burn plan should be designed to benefit the target plant community. However, the needs of the plant community need to be balanced with the need to mitigate mortality to pollinators. One way to achieve this balance might be to burn only a portion of the farm or ranch each year. This would reduce the likelihood of extirpating local pollinator populations that can occur when their entire habitat is burned at the same time. For example, in tallgrass prairie rangeland, some pollinator ecologists recommend burning no more than one third of the habitat per year.

(iv) Allow unburned skips to remain. Don't go back after the main fire to try to burn every square foot of the burn unit.

(v) If the producer is concerned about one or more imperiled pollinator species on their land, incorporate information about this pollinator's life cycle to modify the planned season of burn to minimize likelihood of causing significant species harm.

(vi) Burn at different times of year, rather than at the same time each year. Burning during the same season over time may shift community dynamics, favoring some plant species and pollinator species at the expense of others.

## 645.1309 Pollinator Habitat Management – Mowing and Haying

A. Mowing and Haying Effects

Although livestock grazing is the main land use of rangeland in the U.S., significant acreages of rangeland are hayed, particularly in the tallgrass prairie region of the central U.S. The effects of haying on rangeland pollinators have seldom been studied in the U.S. However, like other management activities, haying can have positive and negative effects. On the positive side, haying can help to maintain plant richness and abundance in native range (Kansas Natural Heritage Inventory 2010). This removal of above ground biomass increases light availability to seedlings and crowns of forbs, legumes, and grasses. Unfortunately, as with prescribed fire, haying can kill pollinators, particularly the immobile or nearly immobile immature forms. Haying also temporarily reduces availability of host plants, stems for stem-nesting bees, and floral resources used by most pollinator species.

B. Considerations for Forage Harvest Management (511)

Forage and harvest management may be utilized to enhance desirable species, reduce pest pressure, and increase wildlife habitat, while also benefitting pollinators. NRCS planners should consider the following techniques when the landowner's objectives include pollinator protection:

(i) Determine if the site has any T&E species or species of special interest to the producer, or if the producer's pollinator habitat goal involves pollinators in general.

(ii) Identify the plant species that meet the needs of target pollinators.

(iii) Consider two cuttings or fewer per growing season from each site. Multiple cuttings per year is suspected of causing greater direct mortality to pollinators and of limiting the availability of floral resources (McKnight 2018).

(iv) Consider adjusting the timing of haying to avoid impacts to pollinators. Stagger cutting and harvest to accommodate bloom time and allow for re-bloom, if practical, considering hay quality.

(v) If harvesting an entire field, harvest from one end of the field to another (or from the middle going outward) to allow insects an escape route, rather than harvesting from the perimeter inward.

(vi) Use a flushing bar on the mower and reduce mowing speeds to allow pollinators to escape.

(vii) Leave some unharvested areas each growing season for pollinator habitat.

## 645.1310 Pollinator Habitat Management – Herbaceous Weed Treatment (315)

Removal of herbaceous weeds including noxious, prohibited, and undesirable plant species not only enhances the quality of the forage for grazers, but also releases native or desired plant communities essential for pollinator habitat.

NRCS planners should consider the impacts to pollinator food supplies and habitat when planning the method and amount of herbaceous weed treatment when the landowner's objectives include pollinator protection along with the following:

(i) Determine if the site has any T&E species or species of special interest to the producer, or if the producer's pollinator habitat goal involves pollinators in general.

(ii) Identify the plant species that meet the needs of target pollinators.

(iii) Adjust the timing of treatments to periods of the year that accommodate reproduction and other life cycle requirements of target pollinator species.

(iv) Apply herbaceous weed treatments that protect the health and vigor of native or desired plant species to preserve and enhance habitat for pollinator insects.

(v) Select treatments that maintain or enhance plant community composition and structure to meet the requirements of target pollinator species.

(vi) When the herbaceous weed treatment of undesirable species results in the need to reestablish desired herbaceous species, follow details in the appropriate NRCS vegetation establishment practices and use native vegetation to preserve and enhance pollinator habitat.

(vii) Consider selective herbicides with minimal impacts to desired plant species supporting pollinators.

## 645.1311 Pollinator Habitat Management – Pest Management Conservation System (595)

Pests, including noxious and invasive plant species, are of considerable concern in the maintenance of healthy range and pasturelands. By protecting pollinators during pest management activities, other beneficial insects and other wildlife may also benefit. In rare situations, the use of Pest Management Conservation System (Code 595) may be warranted on grasslands. In such situations, conservation planners can help producers prevent or mitigate pest management risks to pollinators by utilizing the principals of PAMS (prevent, avoid, monitor, suppress) in their integrated pest management (IPM) approach.

(1) Use the following techniques to reduce impacts to pollinators:

(i) Determine if the site has any T&E species or species of special interest to the producer, or if the producer's pollinator habitat goal involves pollinators in general.

(ii) Assess potential impacts to target pollinators from pest management activities.

(iii) Prevent pest populations from infesting a field or site by reducing conditions favoring pest populations. This may be achieved by conducting regular soil analysis to prevent overapplication of nutrients and increasing species diversity (Zuppinger-Dingley et al. 2016). Clean equipment thoroughly and implement sanitation procedures to prevent introducing plant pests and pathogens.

(iv) Avoid pest populations by choosing pest-resistant cultivars and native species.

(v) Monitor for pests regularly by implementing a scouting program and keeping records of pest location and distribution. Also monitor pollinator types and species in the area to avoid potential impacts.

(vi) Suppress pests with the most targeted and least damaging methods available to pollinators when economic thresholds are determined. Choose alternative active ingredients, formulations, or applications methods that offer less risk to pollinators. Adjust the timing of pesticide applications (an hour after sunset) to avoid periods when pollinators are more likely to be present and active.

(2) Refer to the following USDA resource when considering the impacts of pesticides on pollinators:

Agronomy Technical Note 9 (Title 190), "Preventing or Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Other Conservation Practice."

## 645.1312 Pollinator Habitat Management – Brush Management (314)

A. Livestock and many pollinator species benefit from brush management because high woody plant cover can reduce the abundance and diversity of herbaceous plants used by livestock and pollinators alike (Archer et al. 2017). Practices that reduce woody plant cover will usually have a net long-term benefit to grassland pollinator communities if the negative effects of the woody plant reduction are short-lived and do not eliminate a local population of a pollinator species. Determine the pollinators the producer aims to conserve and assess potential impact of brush management to those pollinators. Schedule implementation of brush management so that it is effective but also reduces impact to pollinators.

B. When implementing chemical treatments for woody management follow the Pest Management Conservation System standards (595) above.

## 645.1313 Pollinator Habitat Management: Planting and Stand Rejuvenation - Range Planting (550), and Pasture and Hay Planting (512)

A. Conservation Practice 550 (Range Planting) and Conservation Practice 512 (Pasture and Hay Planting) can involve seeding onto a clean soil bed or sowing seeds in already established range or pasture via the methods of overseeding, interseeding, or spot replanting. Regardless of the method, producers can improve pollinator habitat by including a diverse array of forb and legume species in their seed mix.

(1) Utilize the considerations below to enhance pollinator habitat.
- (i) Determine the pollinators that currently utilize the site.
- (ii) Determine the flowering resources currently available at the site.
- (iii) For native range, the site should have a diversity of native forbs, legumes, and shrubs blooming each month of the growing season so that they provide nectar, nesting sites, shelter, and larval host plants throughout the growing season.
- (iv) For pasture, increase the diversity of flowering legume and forbs species. Utilize a flowering cover crop when implementing long-term crop rotations that include rotation of pasture and hayland planting. Schedule cultural practices (mowing, fertilization, irrigation) to avoid or minimize prime foraging times for bees and breeding, egg, and larval stages for key butterflies. Implement Field Borders (386), Contour Buffer Strips (330), and Filter Strips (393), with abundant floral resources to provide additional plant diversity.
- (v) If the client is interested in pollinator habitat but also interested in maintaining "improved" pasture (e.g., Bermuda grass, bahia grass, fescue, etc.), consider informing the client of the alternative of establishing a dedicated pollinator habitat area that is excluded from grazing.

(2) If interseeding to improve pollinator habitat, consider the following:
- (i) Remove built-up thatch by conducting a Prescribed Burn (338) during the dormant season, followed by interseeding forbs, shrubs and subshrubs, and legumes with the use of a no-till drill or broadcast method. Ensure seed-to-soil contact and seeding depth is specific to seed type. Use native species whenever possible. Fall or dormant seeding of forb-rich seed mixes allows for natural winter stratification, necessary for the germination of many forb species.

(ii) Strategic livestock use or mowing may aid in the establishment of newly seeded vegetation. Implement the timing of these activities to allow for blooming of the newly seeded species if applicable.
(iii) Commence site preparation activities during the dormant season to minimize impacts to pollinators. Implement seeding with the use of a no-till drill to minimize ground nesting habitat, erosion, and weed growth. For bare seed beds, consider the use of mulch or cover crops to prevent erosion and protect ground nesting sites, while allowing for some bare ground where sites are least subject to erosion. If utilizing a blooming cover crop (340) allow for bloom completion before termination.
(iv) When selecting species for range and pasture planting, use adapted species and cultivars specific to the area. Use those species of high pollinator value (NRCS Plant Materials Pollinator Conservation Plants) and ensure high seed viability with current species-specific seed tests.
(v) For legumes, use pre-inoculated seed, inoculum-coated seed, or inoculate with the proper viable strain of rhizobia immediately before planting. Use native legumes when available and practical.
(vi) Interseeding on rangeland does not meet NRCS Standards and Specifications in all States. Therefore, please check with your State's guidance when considering this practice.

B. Post-seeding management is critical for plant establishment.

The following techniques may be used to foster plant establishment with pollinator considerations:
(i) Implement mowing techniques to minimize weed seed set while allowing early successional seeded species to flower below the mow line.
(ii) Follow livestock exclusion recommendations until plants are fully established (usually after the second year of seeding).
(iii) Use strategic and closely monitored prescribed grazing to eliminate competition from existing vegetation when interseeding, then implement livestock exclusion recommendations until plant establishment.
(iv) Implement PAMS as noted above.

## 645.1314 Additional Resources

A. Some Key USDA Resources on Pollinator Conservation

(1) USDA-NRCS Plant Materials Resources: Pollinator Value of NRCS Plant Releases Used in Conservation Plantings. Plant Materials Publications Relating to Insects and Pollinators.
(2) USDA 2014. Using 2014 Farm Bill Programs for Pollinator Conservation. Biology Technical Note NO. 78. 2nd ed. USDA; South San Francisco, CA, USA.
(3) Conservation Webinars: http://conservationwebinars.net
(4) USDA Plant Database: https://plants.usda.gov/home

B. Plant Identification

(1) Tools used to assess rangeland and pastureland health will help NRCS staff provide guidance to producers. However, additional resources exist that will help NRCS identify plants to assess pollinator habitat conditions, as well as information on how to manage for pollinators.
(2) To assess the availability of host plants and floral resources, it is necessary to be able to identify plants. In addition to working with local experts, extension services, and university staff, multiple tools exist to help with this.

(i) The USDA Plants website; https://plants.usda.gov/home. This website provides illustrations, tips on identification, and a range map for each species. For many plants, plant guides or fact sheets have been developed to provide NRCS field staff with information on the biology and management of these plants.

(ii) NRCS has developed plant guides to assist in the identification of preferred monarch butterfly plants. Most of these plants also have value of pollinators. These guides can be found at the NRCS Monarch Web Page https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207.

(iii) State-level NRCS online plant guides, such as California NRCS eVegGuide.

(iv) Websites of various botanical organizations, particularly:

- Your State's native plant society
- The Ladybird Johnson Wildflower Center: https://www.wildflower.org/plants/
- Calflora: calflora.org

(v) Online apps that identify the organism (plant, animal or fungus) in each photo that you submit to the app. These apps are not 100 percent accurate but are becoming more accurate as they incorporate more photos. Make sure you do not share any of the producer's personally identifiable information with these apps.

C. Evaluating Pollinator Habitat

Some State NRCS offices have developed Pollinator WHEGs (Wildlife Habitat Evaluation Guides). These WHEGs are typically available on each State's online Field Office Technical Guide. Some additional resources to help assess pollinator habitat conditions are:

(i) https://xerces.org/publications/hags/natural-areas-and-rangelands

(ii) https://xerces.org/publications/hags/pollinators-farms-and-agricultural-landscapes

D. Other General Guidance on Conserving Pollinators on Rangelands, Pasturelands, and Farms

(1) Bosworth, Sid. 2018. Developing a Bee-Friendly Pasture System. Forage Legume Pollinator Project, University of Vermont Extension, Burlington, VT. Available online at: http://pss.uvm.edu/beeclover/Articles/Pollinator_Pasture_UVMExt2018.pd

(2) Eric Mader, Matthew Shepherd, Mace Vaughan, Scott Hoffman Black, and Gretchen LeBuhn. 2011. The Xerces Society Guide: Attracting Native Pollinators (protecting North America's bees and butterflies). Storey Publishing, North Adams, MA.

(3) National Strategy to Promote the Health of Honey Bees and Other Pollinators. Available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20Strategy%202015.pdf

(4) The Xerces Society. 2018. Best Management Practices for Pollinators on Western Rangelands: Guidelines Developed for the U.S. Forest Service. 126+vii pp. Portland, OR. The Xerces Society for Invertebrate Conservation. Available online at https://xerces.org/publications/guidelines/best-management-practices-for-pollinators-on-western-rangelands

(5) The Xerces Society. 2020. Rangeland Management and Pollinators: A Guide for Producers in the Great Plains. 6 pp. Portland, OR. The Xerces Society for Invertebrate Conservation. Available online at https://xerces.org/publications/fact-sheets/rangeland-management-and-pollinators.

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# Part 645 – National Range and Pasture Handbook

## Subpart N – Glossary of Terms

### 645.1401 Abbreviations Used in This Glossary:

| Abbr. | Abbreviation |
|---|---|
| e.g. | For example |
| i.e. | That is; in other words |
| Syn. | Synonym |
| n. | Noun |
| v. | Verb |
| vi. | Verb, intransitive |
| vt. | Verb, transitive |

### 645.1402 Definitions of Terms

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| **Abiotic** | Nonliving components of an ecosystem; basic elements and compounds of the environment. |
| **Aboveground Net Primary Production (ANPP)** | Is indicative of an ecosystem's ability to capture solar energy and convert it to organic carbon (or biomass), which may be used by consumers or decomposers, or stored in the form of living and nonliving organic matter. |
| **Abundance** | The total number of individuals of a species in an area, population, or community (SRM 1999). |
| **Accelerated erosion** | Erosion in excess of natural rates, usually as a result of anthropogenic activities. |
| **Accessibility** | The ease with which an area can be reached by people or penetrated and grazed by animals. The ease with which herbivores can reach plants or plant parts. |
| **Acid soil** | A soil that has a pH below 6.6. |
| **Air-dry weight** | The weight of a substance, usually vegetation, after it has been allowed to dry to equilibrium with the atmosphere, usually without artificial heat. |
| **Alkaline soil** | A soil that has a pH above 7.3. |
| **Alkaloids** | Bitter tasting organic compounds of plant origin that have alkaline properties and a complex molecular structure containing nitrogen. They reduce dry matter intake and interfere with digestion of livestock grazing forages containing significant levels of them. |
| **Allelopathy** | Chemical inhibition of one organism by another. |
| **Allocated forage** | The difference of desired amount of residual material subtracted from the total forage. |
| **Allotment** | An area designated for the use of a prescribed number and kind of livestock under one plan of management. |
| **Alluvium** | Sediment deposited by streams and rivers. |
| **Amortization** | The paying off of a financial obligation in equal installments over time. The amortization factor determines the payment to pay off the principle and interest over a given time period. |

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| **Animal-unit** | Denominator for use in calculating the Animal-unit-equivalent of different kinds and classes of domestic livestock and of common wildlife species. Generally, one mature cow of approximately 1,000 pounds and a calf as old as 6 months. Abbr. AU. |
| **Animal-unit-equivalent** | A number relating the forage dry matter intake of a particular kind or class of animal relative to one AU. Abbr. AUE. |
| **Animal-unit-month** | The amount of forage required by an animal unit for one month. Abbr. AUM. |
| **Animal-unit-year** | The amount of forage required by an animal unit for one year, equal to 12 AUMs. The NRCS uses 10,950 pounds of air-dry or 9,490 pounds of oven-dried forage as required pounds of forage to equal an animal unit year. Abbr. AUY. |
| **Annual plant** | A plant that completes its life cycle and dies in one year or less. |
| **Annual production** | The net quantity of aboveground vascular plant material produced within a growing season. Synonym: net aboveground primary production. |
| **Annual range** | Range on which the principal forage plants are self-perpetuating annual, herbaceous species. |
| **Apparent trend** | An interpretation of trend based on observation and professional judgment at a single point in time in relation to an ecological site reference state (typically historic plant community) or another identified plant community state. (see Trend) |
| **Aquifer** | A geologic formation capable of transmitting water through its pores at a rate sufficient for water supply purposes. The term water-bearing is sometimes used synonymously with aquifer when a stratum furnishes water for a specific use. Aquifers are usually saturated sands, gravel, fractures, caverns, or vesicular rock. |
| **Arid** | A term applied to regions or climates where lack of sufficient moisture severely limits growth and production of vegetation. The limits of precipitation vary considerably according to temperature conditions, with an upper annual limit for cool regions of 10 inches or less and for tropical regions as much as 15 to 20 inches. |
| **Ash** | The remaining residue after all the combustible material from a feed stuff has been burned off in a furnace at 500 to 600°C. Nutritionally ash values have little importance. |
| **Aspect** | The predominant direction of slope of the land. |
| **Assessments** | The act of assessing the physical condition of resources or extent of management applied. Assessments are part of the inventory process that provide a rating of deviation from what is happening on site to some value that is considered normal or within the natural range of variation for the site. Assessments are the estimation or judgement of the status of ecosystem structure, function or processes, and can be conducted by gathering, synthesizing and interpreting information from inventories. |
| **Association** | (Syn.) Plant association. |
| **At risk** | Rangelands that have a reversible loss in productive capability and increased vulnerability to irreversible degradation based upon an evaluation of current conditions of the soil and ecological processes. An “at risk” designation may point out the need for additional information to better quantify the functional status of an attribute. |

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| **Attribute of rangeland health** | A complex variable that represents the status of a suite of interrelated ecological properties (e.g., species composition) and processes (e.g., water cycle, energy flow, and nutrient cycle) that are essential to ecosystem function. The three attributes that collectively define rangeland health include soil/site stability, hydrologic function, and biotic integrity. |
| **AU** | Abbr. for Animal-unit. (Usually no periods). |
| **AUM** | Abbr. for Animal-unit-month. (Usually no periods). |
| **Autogate** | See cattleguard. |
| **AUY** | Abbr. for animal-unit-year. (Usually no periods). |
| **Available forage** | (Animal oriented.) That portion of the forage production that is accessible for use by a specified kind or class of grazing animal. (Plant and animal oriented.) It is the consumable forage stated in digestible dry matter per land unit area that can be removed by grazing livestock without damage to the forage plants. See Usable forage; same except stated as dry matter per land unit area. |
| **Available water** | The portion of water in a soil that can be absorbed by plant roots. |
| **Available water holding capacity** | The volume of water available to plants when the soil including fragments is at field capacity. |
| **Baler** | A machine that picks up a windrow of forage, compresses it, forms it into a rectangular or cylindrical bale, wraps it, and discharges it either onto the ground or into a trailing, convenient hauling vehicle. Bale size is highly variable among models. |
| **Band** | Any number of sheep handled as a unit attended by a herder. See Flock. |
| **Bare ground** | Exposed mineral soil not covered by vegetation (live or dead and basal and canopy cover), gravel/rock, visible biological soil crusts, or litter. |
| **Bare ground patch** | An area where bare ground is concentrated. Bare ground patches may include some ground cover (e.g., plants, litter, rock, and visible biological soil crusts) within their perimeter, but there is proportionally much more bare soil than ground surface cover. |
| **Barren** | (1) Any area devoid of vegetation or practically so. (2) A term to describe a mature female animal that is incapable of producing offspring. |
| **Barrier** | A physical obstruction that limits movement. |
| **Basal area** | The cross-sectional area of the stem or stems of a plant or of all plants in a stand. Herbaceous and small woody plants are measured at or near the ground level; larger woody plants are measured at breast or other designated height. (Syn.) basal cover. |
| **Benchmark** | (1) A permanent reference point. (2) In range inventory, it is used as a point where changes in vegetation through time are measured. (3) In soils, it is used to designate a major soil series that is representative of similar soils. (4) In economics, data that are used as a base for comparative purposes with similar data. (5) A surveyor's mark made on a permanent landmark that has known position and altitude. |
| **Biennial** | A plant that lives for 2 years, producing vegetative growth the first year, usually blooming and fruiting in the second year, and then dying. |

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| **Biogeochemical cycle** | The cyclical system through which a given chemical element is transferred between biotic and abiotic components of the biosphere. There are five biogeochemical cycles: carbon cycle, nitrogen cycle, oxygen cycle, phosphorus cycle, and the water cycle. |
| **Biological diversity** | The variety and variability of the world's organisms, the ecological complexes in which they occur, and the processes and life support services they mediate. |
| **Biological soil crust** | Microorganisms (e.g., algae, cyanobacteria), and nonvascular plants (e.g., mosses, lichens) that grow on or just below the soil surface. Synonym: microbiotic crust and cryptogamic crust. |
| **Biomass** | The total amount of living plants and animals above and/or below ground in an area at a given time. |
| **Biomass (plants)** | The total amount of living plants above and below ground in an area at a given time (SRM 1999). As used in this technical reference, biomass refers only to parts of standing living plants (standing biomass) above ground, and not the roots. |
| **Biome** | A major biotic unit consisting of plant and animal communities having similarities in form and environmental conditions, but not including the abiotic portion of the environment. |
| **Biota** | All the species of plants and animals occurring within an area or region. |
| **Biotic integrity** | The capacity of the biotic community to support ecological processes within the natural range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below ground; one of the three attributes of rangeland health. |
| **Biotype** | A group of individuals within a population occurring in nature, all with essentially the same tolerance ranges. A species usually consists of many biotypes. See Ecotype. |
| **Blowout** | (1) A hollow or depression of the land surface, which is generally saucer or trough-shaped, formed by wind erosion, especially in an area of shifting sand, loose soil, or where vegetation is disturbed or destroyed (SSSA 1997). In this technical reference, blowouts are included with windscoured areas. (2) A breakthrough or rupture of a soil surface attributable to hydraulic pressure, usually associated with sand boils. |
| **Body condition score (BCS)** | A rating system used to evaluate the overall health and well-being of livestock has become a widely used method of determining when supplemental feeding should be used. A BCS of 5 usually indicates an animal in average condition. BCS systems usually go from 1 to 9 or 10, with 1 being extremely poor and 9 or 10 being excessively fat. |
| **Boot stage** | Growth stage when a grass seedhead is enclosed by the sheath of the uppermost (flag) leaf. |
| **Bovine fat necrosis** | Several physiological disorders in cattle caused by necrotic or hard fat lesions in the abdominal cavity. Ingestion of highly fertilized endophyte fungus infected tall fescue seems to cause the disorder. |
| **Brand** | (1) (v) To mark the skin or wool of an animal in a distinctive pattern by use of a hot or cold iron, chemical, paint, or other means to designate ownership or to identify individual animals for registration or management purposes. (2) (n) The mark so made. |

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| **Break even** | An improvement practice breaks even when added returns equal added costs at an acceptable rate of return. |
| **Breeding herd** | The animals retained for breeding purposes to provide for the perpetuation of the herd or band. Excludes animals being prepared for market. |
| **Browse** | (n) The portion of woody plant biomass accessible to herbivores (v.) To search for or consume browse. |
| **Browse line** | A well-defined height to which browse has been removed by animals. |
| **Brush** | Various species of shrubs or small trees usually considered undesirable for livestock or timber management. The same species may have value for browse, wildlife habitat, or watershed protection. |
| **Brush control** | Reduction of unwanted woody plants through fire, chemicals, mechanical methods, or biological means to achieve desired land management goals. |
| **Brush management** | Manipulating woody plant cover to obtain desired quantities and types of woody cover and/or to reduce competition with herbaceous understory vegetation, in accordance with overall resource management objectives. |
| **Bunchgrass** | A grass having the characteristic growth habit of forming a bunch; lacking stolons or rhizomes. |
| **Burn** | An area over which fire has recently passed. |
| **Butte** | An isolated hill with relatively steep sides. See Mesa. |
| **C-3 plant** | A plant employing the pentose phosphate pathway of carbon dioxide assimilation during photosynthesis; a cool-season plant. |
| **C-4 plant** | A plant employing the dicarboxylic acid pathway of carbon dioxide assimilation during photosynthesis; a warm-season plant. |
| **Cabling** | The use of a large cable pulled between two large tractors (usually crawler tractors) to pull down or uproot brush. See Chaining. |
| **Cactus** | A spiny, succulent plant of the Cactaceae family. |
| **Calf crop** | The number of calves weaned from a given number of cows exposed to breeding, usually expressed in percent, i.e., number of calves weaned divided by number of cows exposed x 100. Calves weaned. |
| **Caliche** | (1) A layer in the soil horizon more or less cemented by secondary carbonates of calcium or magnesium precipitated from the soil solution. It may occur as a soft, thin soil horizon; as a hard, thick bed just beneath the solum; or as a surface layer exposed by erosion. Often used for road material or as a filler to build up areas in heavily traveled areas, such as pens or troughs. Not a geologic deposit. (2) Alluvium cemented with sodium nitrate, chloride, and/or other soluble salts. |
| **Calorie** | The amount of heat required to raise the temperature of one gram of water 1°C measured from 14.5 to 15.5 °C. |

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| **CAM plant** | A plant employing the crasulacean acid metabolism pathway of carbon dioxide assimilation during photosynthesis. |
| **Canopy** | (1) The vertical projection downward of the aerial portion of vegetation, usually expressed as a percent of the ground so occupied. (2) A generic term referring to the aerial portion of vegetation. |
| **Canopy cover** | The percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. (Syn.) crown cover. |
| **Carrier** | (1) Material used to dilute the active ingredient in a chemical formulation. (2) Material used to carry a pesticide to its target. (3) Plant or animal carrying an infectious disease agent internally but showing no marked symptoms. |
| **Carrying capacity** | The average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives for the unit. In addition to site characteristics, it is a function of management goals and management intensity. The amount of forage produced annually in a management unit is only one attribute used to determine carrying capacity. The forage also has to be available to the animals. On many rangelands, the carrying capacity may be less than forage production would indicate because parts of the management unit are inaccessible to grazing animals. In essence, forage is present but unavailable. |
| **Catchment basin** | See Guzzler. |
| **Cation exchange capacity** | The amount of exchangeable cations that a soil can adsorb at pH 7.0. |
| **Cattle walkway** | (Syn.) walkway. |
| **Cattleguard** | A device or structure, at points where roads or railroads cross a fence line, that is so designed that vehicular travel is uninterrupted, but crossing by all kinds of livestock is restricted. (Syn.) autogate. |
| **Cell** | A grazing arrangement comprised of numerous subdivision (pastures or paddocks) often formed by electrical fencing, with a central management to facilitate livestock management and movement to the various subdivisions. Normally used to facilitate a form of short duration grazing. |
| **Certified seed** | Seed produced from foundation or registered seed that is available for consumer use. It carries a tag signifying it is high quality seed. |
| **Chaining** | Similar practice as cabling except a large ship anchor chain with each chain link weighing 80 to 100 pounds is used. See Cabling. |
| **Chaparral** | (1) A shrub community. (2) A dense thicket of stiff or thorny shrubs or dwarf trees, common to the Southwest United States. |
| **Chemical soil crust** | A soil surface layer, ranging in thickness from a few millimeters to a few centimeters, that is formed when chemical compounds become concentrated on the soil surface. They can reduce infiltration and increase overland water flow similar to physical crusts. They are usually identified by a white color on the soil surface. |

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| **Chiseling** | Breaking or loosening the soil, without inversion, with a chisel cultivator or chisel plow. A practice used for grassland or pasture renovation. |
| **Class of animal** | Description of age and/or sex-group for a particular kind of animal; e.g., cow, calf, yearling, ewe, doe, or fawn. |
| **Claypan** | A dense compact layer in the subsoil having a much higher clay content than the overlying material from which it is separated by a sharply defined boundary; formed by downward movement of clay or by synthesis of clay in place during soil formation. Claypans are usually hard when dry and plastic and sticky when wet. They usually impede the movement of water and air. See Hardpan. |
| **Climate** | The average or prevailing weather conditions of a place over a period of years. |
| **Closed range** | Any range on which livestock grazing or other specified use is prohibited. See Livestock exclusion. |
| **Commercial** | (1) Livestock raised primarily for meat, milk, wool, or other animal-derived products. (2) The label applied to a producer of such animals. See Seedstock for contrasting term. |
| **Common use** | (1) Grazing the current year's forage production by more than one kind of grazing animal either at the same time or at different seasons. (2) More than one operator running livestock on the same area at the same time. |
| **Community** | An assemblage of populations of plants and/or animals in a common spatial arrangement. |
| **Community pathway** | Community pathways describe the causes of shifts between community phases. Community pathways can include the concepts of episodic plant community changes, as well as succession and seral stages. Community pathways can represent both linear and nonlinear plant community changes. A community pathway can be reversible in part by changes in natural disturbances, weather variation, or changes in management. |
| **Community phase** | A unique assemblage of plants and associated dynamic soil property levels that can occur within a state. |
| **Community (plant community)** | An assemblage of plants occurring together at any point in time, while denoting no particular ecological status. A unit of vegetation. |
| **Compaction layer** | A near-surface layer of dense soil caused by impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density. |
| **Companion crop** | A crop sown with another crop (i.e., perennial forage) that is allowed to mature and provide a return in the first year. |
| **Competition** | A process of struggling between or among organisms of the same species (intraspecific) or different species (interspecific) for light, water, essential elements, or space within a trophic level, resulting in a shortage of essential needs for some individuals or groups. |
| **Composition** | (Syn.) Species composition. |
| **Compound interest** | Compound interest is computed for one period and immediately added to the principal, thus resulting in a larger principal on which interest is computed for the following period. |

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| **Concentrate feed** | Grains or their products and other processed food materials that contain a high proportion of nutrients and are low in fiber and water. |
| **Concentrates** | Feeds low in crude fiber (less than 10% on a dry matter basis), low in moisture, and highly digestible. Protein concentrates are of plant or animal origin that contain > 20 percent protein. |
| **Conservation** | The use and management of natural resources according to principles that assure their sustained productivity. |
| **Conservation Assessment Ranking Tool (CART)** | CART evaluates resource concerns, existing conditions based on resource inventory questions along with existing practices and planned condition, based on planned practices. The CART data is geo-spatially reference to planning land units (PLUs) within a client's conservation desktop (CD) practice schedule in the client's case file. CART data is stored in the National Planning and Agreements Database (NPAD), allowing the data to be queried for analytical purposes. |
| **Conservation district** | A subdivision of a State, Indian Tribe, or territory, organized pursuant to the State or territorial soil conservation district law, as amended, or Tribal law. They may be called soil conservation districts, soil and water conservation districts, resource conservation districts, land conservation committees, natural resource districts, or similarly legally constituted body. |
| **Conservation Effects Assessment Project (CEAP)** | CEAP quantifies the environmental effects of conservation practices and programs. The process includes research, modelling, assessment, monitoring and data collection. |
| **Conservation plan** | A record of the client's decisions and supporting information for treatment of a unit of land for one or more identified natural resource concerns as a result of the planning process. The plan describes the schedule of implementation for practices and activities needed to address identified natural resource concerns and takes advantage of opportunities. The needs of the client, the resources, and Federal, State, Tribal, and local requirements will be met. |
| **Constancy** | The percentage occurrence of a species within a given community type. |
| **Consumers** | Heterotrophic organisms, chiefly animals, that ingest other organisms or particulate organic matter. |
| **Consumption** | Dietary intake based on amounts of specific forages and other feedstuffs or amounts of specific nutrients. |
| **Continuous grazing** | The grazing of a specific unit by livestock throughout a year or for that part of the year during which grazing is feasible. The term is not necessarily synonymous with yearlong grazing since seasonal grazing may be involved. Also referred to as continuous stocking. |
| **Continuous set stocking** | Allowing a fixed number of animals unrestricted access to an area of grazing land for the whole or substantial part of a grazing season. |
| **Contour furrow** | A plowed or listed strip, commonly 8 to 18 inches deep and wide, made parallel to the horizontal contour for the purpose of water retention and reduction of soil erosion. |

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| **Control** | (1) Manipulation and management for reduction of noxious plants, a term of many degrees ranging from slightly limiting to nearly complete replacement. (2) Untreated areas or animals used for research, comparison, or evaluation of treatment responses. |
| **Controlled breeding** | (1) Controlling the time of breeding of livestock to synchronize the period of optimum growth for the animals with the period of peak quality and optimum growth of forage. (2) A planned program whereby livestock males and females are brought together for breeding purposes, so that off-springs are born during a desired period. |
| **Controlled burning** | (Syn.) Prescribed burning. |
| **Convective precipitations** | Occurs in the form of light showers and heavy cloudbursts or thunderstorms of extremely high intensity. Most convective storms are random and last less than one hour and usually contribute little to overall moisture storage in the soil. |
| **Converted rangelands** | Converted rangelands can include lands seeded to native species, and/or introduced hardy and persistent plant species (grasses, grass-like plants, forbs, shrubs, and trees). |
| **Cool-season plant** | A plant that generally makes the major portion of its growth late in fall, in winter, and in early spring. Cool-season species generally exhibit the C-3 photosynthetic pathway. |
| **Coordinated resource management** | A specific application of the planning process that utilizes a variety of clients, stakeholders, organizations, agencies, and others, and a variety of land ownerships, to address a multitude of resource or resource related problems, opportunities, or concerns. CRM is frequently accomplished through "consensus" involving participants that may or may not be land managers or have decision-making authority for the planning area involved. The planning area encompasses the geographical area defined by the parties involved in the CRM effort. |
| **Core methods** | Sampling protocols that generate indicators that represent the minimum information necessary to describe three key ecosystem attributes: soil and site stability, watershed function, and biotic integrity. Specific methods were identified in conjunction with the Bureau of Land Management Assessment, Inventory, and Monitoring Strategy and the Natural Resources Conservation Service's National Resources Inventory. |
| **Corral** | An enclosure or pen for handling livestock. |
| **Cover** | (Syn.) Foliar cover, see Basal area. |
| **Cover type** | The existing vegetation of an area. |
| **Creep feeding** | Supplemental feeding of suckling livestock in such a manner that the feed is not available to the mothers or other mature livestock. |
| **Creep grazing** | The practice of allowing juvenile animals to graze areas that their dams cannot access at the same time. |
| **Critical area** | An area to be treated with special consideration because of inherent site factors, size, location, condition, values, or significant potential conflicts among uses. |
| **Crop residue** | The portion of a crop remaining after harvest of seed or other primary plant parts. It may be managed for grazing and/or ground cover and to replenish soil organic matter levels. |

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| **Crop rotation pasture** | Cropland pasture where livestock are stocked on forages grown in a designed crop rotation cycle with other cultivated crops. Livestock move from crop field to crop field as the stand life of the forage and crop rotation dictate. Depending on the forage stand life and length of the crop rotation, livestock entry may occur seasonally on the same field, or take several years to cycle around the crop fields being grazed in rotation. |
| **Cropland** | Land used primarily for the production and harvest of annual or perennial field, forage, food, fiber, horticultural, orchard, vineyard, or energy crops. |
| **Crude fiber** | Fiber made up primarily of plant structural carbohydrates, such as cellulose and hemicellulose, but it also contains some lignin. |
| **Crude protein** | A calculated portion from the nitrogen content of a feedstuff, using the Kjeldahl procedure. The crude protein content is made up of those compounds defined as proteins and designated true proteins, as well as nonprotein nitrogen compounds such as free amino acids, amides of amino acids, ammonium salts or urea. The protein content of feedstuffs is currently estimated only on the basis of crude protein. |
| **Cryptogam** | A plant in any of the groups Thallophytes, Byophytes, Pteridiophytes mosses, lichens, and ferns. |
| **Culm** | The stem of a grass that has elongated internodes between nodes (jointed). |
| **Culmless** | A vegetative tiller of some grasses that holds its growing point close to the ground by not elongating internodes until it is ready to initiate reproductive growth. |
| **Cultivar (derived from cultivated variety)** | A named variety selected within a plant species. Distinguished by any morphological, physiological, cytological, or chemical characteristics. A variety of plant produced and maintained by cultivation which is genetically retained through subsequent generations. |
| **Cultivars** | (1) A variety, strain, or race of plant that has originated and persisted under cultivation or was specifically developed for use as a cultivated crop. (2) For cultivated crops, the equivalent of botanical variety, in accordance with the International Code of Nomenclature of Cultivated Plants-1980. |
| **Cultivated crops** | (1) Crops grown from seed, bulbs, corms, sprigs, crowns, tubers, cuttings, and graftings and cared for by humans for harvest or landscaping. (2) Crops genetically improved or developed by various agronomic or horticultural techniques. |
| **Cultivating tools** | Variously designed machinery used to uproot weeds to keep them from competing with the desired crop. The class of equipment includes field and row crop cultivators, spike and spring tooth harrows, chain drags, and rotary hoes. |
| **Cultural hayland** | A land use subcategory of cropland managed for the production of forage crops that are culturally established and typically machine-harvested. |
| **Cut** | (1) (v) To separate one or more animals from the herd or band. (n) The animal(s) so separated. (2) To reduce livestock grazing, particularly on a public land allotment. |
| **Cyclonic precipitation** | Classified as frontal and non-frontal and is related to the movement of air masses from high pressure to low pressure regions. |
| **DBH** | Abbreviation of diameter-at-breast-height of a tree. |
| **Debris** | Accumulated plant and animal remains. |

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| **Decadent** | The natural aging process in plants characterized by dying plants or plant parts that eventually results in mortality. This technical reference version replaces the term decadent with "dying plants or plant parts." |
| **Deciduous (plant)** | A plant whose parts, particularly leaves, are shed at regular intervals or at a given stage of development. |
| **Decomposer** | Heterotrophic organisms, chiefly the micro-organisms, that break down the bodies of animals or parts of dead plants and absorb some of the decomposition products, releasing similar compounds usable by producers. |
| **Decomposition** | The biochemical breakdown of organic matter into its original compounds and nutrients. |
| **Decreaser** | Plant species that will decrease in relative amount with continued heavy defoliation (grazing). |
| **Deferment** | Generally, deferment implies a nongrazing period less than a calendar year, while rest implies nongrazing for a full year or longer. See Deferred grazing and Rest. |
| **Deferred grazing** | Postponing grazing or resting an area for a prescribed period, usually to meet a specific management objective. |
| **Deferred-rotation** | Any grazing system, that provides for a systematic rotation of the deferment among pastures. The time of the rest period generally changes in succeeding years. |
| **Defoliation** | The removal of plant leaves, i.e., by grazing or browsing, chemical defoliant, or natural phenomena, such as hail, fire, or frost. |
| **Degree of use** | The proportion of current year's forage production that is consumed and/or destroyed by grazing animals. May refer either to a single species or to the vegetation as a whole. (Syn.) Use. |
| **Density** | (1) The number of individuals per unit area. (2) Refers to the relative closeness of individuals to one another. |
| **Depositional area** | Location where windblown soil accumulates; the deposited soil may originate from either on- or offsite. Soil deposition due to water movement is assessed with other soil/site stability indicators. |
| **Describing indicators of rangeland health** | Protocol to describe the soil profile and 17 indicators of rangeland health to assist in the preparation of a reference sheet to conduct future assessments of rangeland health. There is no predefined reference for this protocol. |
| **Desert** | An arid area with insufficient available water for dense plant growth. |
| **Desertification** | The process by which an area or region becomes more arid through loss of soil and vegetative cover. The process is often accelerated by excessive, continuous overstocking and drought. |
| **Describing indicators of pasture health** | Assessment tool recognized in NRCS planning criteria to identify resource concern criteria thresholds. It is designed to provide information about how well ecological processes – such as the water cycle, energy flow, and nutrient cycling – are functioning on pastureland. |

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| **Desirable plants** | Desirable plants are useful forage plants. Although not as highly preferred by grazing animals, they can provide forage. Some of these plants may increase, if the more highly preferred plants are grazed heavily. |
| **Desired plant community** | One of the several plant community types that may occupy an ecological site, the one or combination that meets the minimum quality criteria for the soil, water, air, plant, and animal resources, and that meets the landowner's or manager's objective. |
| **Deteriorated range** | Range on which present vegetation and soil conditions represent a significant departure from natural potential. |
| **Detritus** | Fragmented particulate organic matter derived from the decomposition of debris. |
| **Digestible dry matter (DDM)** | See Digestible organic matter. |
| **Digestible organic matter (DOM)** | A percentage of energy and protein in forages expressed as organic matter intake minus fecal dry matter divided by dry matter intake times 100. |
| **Discount rate** | The interest rate for the opportunity cost of money. The discount rate is determined by summoning the time value of money, the rate of inflation, and the rate of risk. |
| **Disturbance indicators** | Displacement or dislocation of the natural state of a sample site resulting from human-induced, natural events, or other occurrences. |
| **Diurnal** | Active during daylight hours. |
| **Diversity** | A measure of the number of species and their relative abundance in a community. |
| **Dominant** | (1) Plant species or species groups that, by means of their number, coverage, or size, have considerable influence or control upon the conditions of existence of associated species. (2) Those individual animals that, by their aggressive behavior or otherwise, determine the behavior of one or more animals resulting in the establishment of a social hierarchy. |
| **Dormant** | (1) A living plant that is not actively growing aerial shoots. (2) A pesticide application made on crop plants that are not actively growing. |
| **Double sampling** | Double sampling combines the accuracy of harvesting with the speed of estimating to assess biomass. Observers estimate the weight of plant material in multiple plots and then harvest the plant materials from a subset of the plots. The clipped weights obtained from harvesting are used to create a correction factor to adjust the estimated values, which tends to improve the accuracy of the estimations. |
| **Drainage class** | A method of classifying the natural drainage condition of the soil that refers to the frequency and duration of soil wetness. |
| **Drift** | (v) (1) The movement of materials by wind or water. (2) The natural movement of animals. (n) Vegetative material moved and deposited by wind and water. See Spray drift. |
| **Drip line** | The area under the outermost branches of a tree or shrub. |

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| **Drought** | (1) A prolonged chronic shortage of water. (2) A period with below normal precipitation during which the soil water content is reduced to such an extent that plants suffer from lack of water; frequently associated with excessively high temperatures and winds during spring, summer, and fall in many parts of the world. |
| **Dry matter** | The amount of a feedstuff remaining after all the free moisture is evaporated out. The feedstuff is placed in an oven at a temperature of 100 to 105°C. |
| **Dry weight rank** | Determines species composition. It consists of observing various quadrats and ranking the three species which contribute the most weight in the quadrant. Dry weight rank results are expressed only as percentage values. |
| **Dugout** | An artificially constructed depression that collects and stores water and differs from a reservoir in that a dam is not relied upon to impound water. |
| **Dust** | (1) Windblown soil. (2) A formulation that is a finely ground, dry mixture of an inert carrier and a pesticide. Danger of drift and inhalation by user during use. |
| **Ecohydrology** | The study of the functional interrelationships between hydrology and biota at the catchment scale, is a new approach to achieving sustainable management of water. |
| **Ecological processes** | Includes the water cycle (the capture, storage, and redistribution of precipitation), energy flow (conversion of sunlight to plant and then animal matter), and nutrient cycle (the cycle of nutrients, such as nitrogen and phosphorus, through the physical and biotic components of the environment). Ecological processes functioning within a natural range of variability support specific plant and animal communities. |
| **Ecological site** | An ecological site is a conceptual classification of the landscape. It is a distinctive land unit based on a recurring landform with distinct soils (chemical, physical, and biological attributes), kinds and amounts of vegetation, hydrology, geology, climatic characteristics, inherent ecological resistance and resiliency, unique successional dynamics and pathways, natural disturbance regimes, geologic and evolutionary history including herbivore and other animal impacts, and response to management actions and natural disturbances. |
| **Ecological site description** | The documentation of the characteristics of an ecological site. The documentation includes the data used to define the distinctive properties and characteristics of the ecological site; the biotic and abiotic characteristics that differentiate the site (i.e., climate, physiographic characteristics, soil characteristics, plant communities); and the ecological dynamics of the site that describe how changes in disturbance processes and management can affect the site. An ecological site description also provides interpretations about the land uses and ecosystem services that a particular ecological site can support and management alternatives for achieving land management. |
| **Ecology** | The study of the interrelationships of organisms with their environment. |
| **Ecosystem** | Organisms together with their abiotic environment, forming an interacting system, inhabiting an identifiable space. |
| **Ecosystem Dynamics Interpretive Tool (EDIT)** | An information system framework designed to help construct, catalog, and share conceptual models of ecosystem change and ecological site descriptions. |
| **Edaphic** | Refers to the soil. |

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| **Emergency feeding** | Supplying feed to range animals when available forage is insufficient because of heavy storms, fires, or other such emergencies. See maintenance feeding and Supplemental feeding. |
| **Enclosure** | An area fenced to confine animals. |
| **Endemic** | Native to or restricted to a particular area, region, or country. |
| **Energy flow** | Conversion of sunlight to plant and then animal matter; one of the ecological processes. Annual production is an indicator of energy flow because it assesses the conversion of sunlight to plant biomass, which is then available for consumption by animals. |
| **Energy for maintenance** | The amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal body. Maintenance is comprised of the following processes or functions: body temperature regulation, essential metabolic processes, and physical activity. |
| **Ensile** | (1) To preserve a forage crop as silage. (2) The act of placing a forage crop in a silo. |
| **Enterprise** | Any segment of the land unit's business that can be isolated by accounting procedures so revenue and expenses can be allocated to it. |
| **Environment** | The sum of all external conditions that affect an organism or community to influence its development or existence. |
| **Episodic** | Occurring, appearing, or changing at usually irregular intervals. |
| **Erosion** | (v) Detachment and movement of soil or rock fragments by water, wind, ice, or gravity. (n) The land surface worn away by running water, wind, ice, or other geological agents, including such processes as gravitational creep. |
| **Escarpment** | A steep slope or ridge, terminating high lands abruptly, which was formed by erosion or by faulting. |
| **Essential element** | A chemical element that is essential to the life of an organism. |
| **Evaluation area** | The area (generally 1/2 to one acre in size) where the IIRH protocol is applied. |
| **Evaluation matrix** | A matrix used in IIRH to determine indicator departure from the reference sheet ("none to slight" category). A generic evaluation matrix is provided in this technical reference (Table E-B-14), but development and use of ecological site-specific evaluation matrices are strongly recommended. |
| **Evaluator** | The person or persons conducting an assessment of rangeland health in an evaluation area. |
| **Evaporation** | The physical process where water transitions from a liquid to a gaseous state. |
| **Evapotranspiration** | The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. |
| **Evergreen (plant)** | A plant that has leaves all year round and sheds them more or less regularly through all seasons. |

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| **Exclosure** | An area fenced to exclude animals. |
| **Exotic** | An organism or species that is not native to the region in which it is found. |
| **Exposure** | Direction of slope with respect to points of a compass. |
| **Facilitating practices** | A conservation practice that facilitates management or the function of another practice, or both, but does not achieve the desired effects on its own. Example: A fence is a facilitating practice for prescribed grazing. Prescribed grazing helps improve forage for livestock. A facilitating practice is also referred to as a supporting practice. |
| **Fauna** | The animal life of a region. A listing of animal species of a region. |
| **Feed** | (n) Any non-injurious, edible material having nutritive value when ingested. (v) The act of providing feed to animals. |
| **Feed additives** | Materials other than the feeds themselves added to diets; e.g., vitamins, mineral supplements, or antibiotics. |
| **Feedstuffs** | Any substance suitable for animal feed. |
| **Fence** | A structure that acts as a barrier to livestock, wildlife, or people. |
| **Fencing** | Enclosing or dividing an area of land with a suitable structure that acts as a barrier to livestock, wildlife, or people. |
| **Feral** | Escaped from cultivation or domestication and existing in the wild. |
| **Fibrous root system** | A plant root system having a large number of small, finely divided, widely spreading roots, but no large taproots. Typified by grass root system. |
| **Firebreak** | A natural or manufactured barrier used to prevent or retard the spread of fire, that is in existence or made before a fire occurs. It is usually created by the removal of vegetation. See Fireline and Fuel break. |
| **Fireline** | A narrow line, 2 to 10 feet wide, from which all vegetation is removed by soil sterilization, yearly maintenance, treatment with chemical fire retardant, or clearing just before ignition of a prescribed burn. |
| **Fixation** | A soil process that renders available plant nutrients unavailable or fixed in the soil. |
| **Flexibility** | Characteristics of a management plan that allow it to accommodate changing conditions. |
| **Flock** | A group of sheep managed in fenced pastures. See Band. |
| **Flooding** | The temporary covering of the soil surface by water that flows over it from any source, such as a stream, irrigation canal, tidal action, or runoff from adjacent or surrounding slopes. |
| **Flora** | (1) The plant species of an area. (2) A simple list of plant species or a taxonomic manual. |

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| **Floral resources** | Flowers producing nectar and pollen, which serve as food for adult bees and butterflies, and some flies, beetles, wasps, and moths. A key habitat resource necessary to support diverse pollinator communities. |
| **Flowable** | A pesticide formulation that is a finely ground material suspended in a liquid carrier. It is easy to handle and apply. |
| **Flushing** | Improving the nutrition of female breeding animals prior to and during the breeding season to stimulate ovulation. |
| **Fluvial** | Pertaining to or produced by the action of a stream or river. |
| **Foliage** | The green or live leaves of plants; mass leaves or leafage. |
| **Foliar cover** | The percentage of ground covered by the vertical projection of the aerial portion of plants. Small openings in the canopy and intraspecific overlap are excluded. Foliar cover is always less than canopy cover; either may exceed 100 percent. (Syn.) cover. |
| **Food reserves** | The excess carbohydrates in plants produced during photosynthesis and stored in a readily available form in various plant parts. Depending on forage species, they may be stored in the root, stem base, stolon, or rhizome. Often erroneously called root reserves. |
| **Forage** | (n) All browse and herbage that is available and acceptable to grazing animals, or that may be harvested for feeding purposes. (v) Act of consuming forage. (Syn.) graze. |
| **Forage allowance** | Weight of forage per unit of animal demand at any instant of time. It is the inverse of grazing pressure and synonymous with herbage allowance. |
| **Forage crops** | (Specific) Forage plants mechanically harvested before being fed to animals. These crops are fed to animals primarily as hay, haylage, fodder (stover), silage, or green chop. (General) A crop of cultivated plants, whose plant parts, other than separated grain, are produced to be grazed or harvested for use as feed for animals. |
| **Forage harvest management** | The timely cutting and removal of forages from the field as hay, green- chop, or ensilage. |
| **Forage harvester** | A machine that cuts standing forage or picks up windrowed forage and chops it to the desired length of cut for silage and blows the chopped forage into a trailing forage wagon or truck box. |
| **Forage inventory** | An estimate of available forage in each pasture and for the operating unit as a whole; used to project stocking rates and feed requirements for specific time periods (i.e., annually, grazing season, rotation cycle). |
| **Forage production** | Forage production is palatable species of plants utilized for animal(s). Total forage is the total herbaceous and woody palatable plant biomass available to herbivores. |
| **Forage utilization** | Grazing use of current growth, usually expressed as a percent of the current growth (by weight) which has been removed. See Use. |
| **Forage value rating** | A utilitarian rating of forage plants on a particular area for a specific kind of herbivore. Forage ratings are based on preference, quality, nutritional value, and plant maturity. This is not an ecological rating. |

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| **Forb** | Any broad-leafed herbaceous plant other than those in the Gramineae (or Poaceae), Cyperaceae, and Juncacea families. |
| **Forest land (forest)** | A spatially defined site where the historic climax plant community was dominated by a 25 percent overstory canopy of trees, as determined by crown perimeter-vertical projection**.** For conservation planning purposes, Land on which the historic and/or introduced vegetation is predominantly tree cover managed for the production of wood products or non-timber forest products. |
| **Free ranging** | Ability to roam or forage at-will, unrestricted by fences. |
| **Frequency (vegetation metric)** | The ratio between the number of sample units that contains species and the total number of sample units. |
| **Frost heave** | Soil and plants displaced by ice needles and lenses. Primary frost heave is caused by ice needles producing minor soil displacement. Secondary frost heave is caused by ice lenses producing major soil displacement. Primary frost heave tends to displace seedlings. Secondary frost heave can displace mature overwintering plants. The heaving action pushes plants upward. This causes root breakage, desiccation of exposed roots, and often death of susceptible plant species. |
| **Function** | In IIRH this refers to the ecophysiological role that plants and biological soil crusts play on a site. This may include the plant's life cycle (e.g., annual, monocarpic perennial, or perennial), phenology, photosynthetic pathway, nitrogen fixer associations, sprouting ability, and water infiltration. |
| **Functional/structural group** | A suite or group of plant species that, because of similar shoot or root structure, photosynthetic pathways, nitrogen fixing ability, life cycle, etc., are grouped together on an ecological site basis. Plant species (including nonvascular plants such as visible biological soil crusts) that are grouped together on the basis of similar growth forms or ecophysiological roles. |
| **Functionally present** | In IIRH this pertains to the number of plants within a functional/structural group that is necessary to consider the functional/structural group as functioning in an evaluation area. Generally, if only a few individuals in a functional/structural group are present in an evaluation area, that functional/structural group is no longer considered functionally present. The rationale for this determination is that the ecological role of that functional/structural group has been diminished to the degree that it is essentially providing little to no ecological function or reproductive capability. This concept is applied when rating the indicators functional/structural groups and vigor with an emphasis on reproductive capability of perennial plants. |
| **Functioning** | In IIRH, (1) refers to the rangeland health attributes in which the majority (see definition of "preponderance of evidence") of the associated indicators are rated as having little or no deviation from that described in the reference sheet (Appendix 1a and 1b) for the ecological site; (2) refers to the presence and integrity of ecological processes (energy flow, water cycle, and nutrient cycle) being within the range of expectations for the ecological site. |
| **Game** | (1) Wild birds, fish, and other animals hunted. (2) Wildlife species so designated by law and the harvest of which is regulated by law. |
| **Geographic Information System (GIS)** | A spatial type of information management system that provides for the entry, storage, manipulation, retrieval, and display of spatially oriented data. |

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| **Global Positioning System (GPS)** | A computer-based receiver system that uses satellite transmissions to determine precise latitude and longitude readings at any location in a field. This system is used to map crop yield, soil fertility, weed infestations, soil type, and other yield influencing differences. It then forms the basis for variable rate applications of fertilizer and pesticides. Application equipment is guided by a georeferenced program to deliver different application rates as it traverses back and forth across a field. |
| **Graminoid** | Grass or grass-like plant, such as Poa, Carex, and Juncus species. |
| **Grass** | A member of the family Gramineae (Poaceae). |
| **Grassland** | Land on which the vegetation is dominated by grasses, grass-like plants, and/or forbs. |
| **Grasslike plant** | A plant of the Cyperaceae or Juncaceae families that vegetatively resembles a true grass of the Gramineae family. |
| **Graze** | (1) (vi) The consumption of standing forage by livestock or wildlife. (2) (vt) To put livestock to feed on standing forage. |
| **Grazed** | A land use modifier to provide another level of specificity and help denote what the land is managed for. This modifier is used when grazing animals impact how land is managed. |
| **Grazed forest land** | Land that is currently used for forest land and livestock grazing. |
| **Grazer** | A grazing animal. |
| **Grazing** | (vt) To graze. |
| **Grazing behavior** | The foraging response elicited from a herbivore by its interaction with its surrounding environment. |
| **Grazing capacity** | The total number of animals that may be sustained in a given area based on total forage resources available, including harvested roughages and concentrates. See Carrying capacity. |
| **Grazing distribution** | Dispersion of livestock grazing within a management unit or area. |
| **Grazing land** | (1) Collective term used by NRCS for rangeland, pastureland, grazed forest land, native and naturalized pasture, hayland, and grazed cropland. Although grazing is generally a predominate use, the term is used independent of any use. (2) Land used primarily for production of forage plants maintained or manipulated primarily through grazing management. Includes all lands having plants harvestable by grazing without reference to land tenure, other land uses, management, or treatment practices. |
| **Grazing land mechanical treatment** | Renovating, contour furrowing, pitting, or chiseling native grazing land by mechanical means. The purpose of this practice is to improve plant cover and water quality by aerating the soil, increasing infiltration and available moisture, reducing erosion, and protecting low areas or structures from siltation. |
| **Grazing license** | Official written permission to graze a specific number, kind, and class of livestock for a specified period on a defined allotment or management area. |
| **Grazing management** | The manipulation of grazing and browsing animals to accomplish a desired result. |

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| **Grazing management plan** | A program of action designed to secure the best practicable use of the forage resources by manipulation of the grazing animal. |
| **Grazing period** | The length of time that animals are allowed to graze on a specific area. |
| **Grazing permit** | (Syn.) grazing license. |
| **Grazing preference** | (1) Selection of certain plants, or plant parts, over others by grazing animals. (2) In the administration of public lands, a basis upon which permits and licenses are issued for grazing use. |
| **Grazing pressure** | (1) Animal-demand per unit weight of forage at any instant; i.e., AU/T; an animal/forage relationship. (2) The relationship between the amount of forage utilized by grazing animals on a given area. |
| **Grazing season** | (1) The time interval when animals are allowed to use a certain area. (2) On public lands, an established period for which grazing permits are issued. May be established on private land in a grazing management plan. |
| **Grazing system** | A specialization of grazing management that defines systematically recurring periods of grazing and deferment for two or more pastures or management units. Descriptive common names, such as Merrill, Hormay, or South African switchback, may be used. However, the first usage of a grazing system name in a publication should be followed by a description using a standard format. This format shall consist of a numerical description in the following prescribed order: the number of pastures (or units), number of herds, length of grazing periods, length of deferment periods for any given unit in the system followed by an abbreviation of the unit of time used. Examples: **Merrill system** (4-3;12: 4 mo.) is a grazing system with 4 pastures, 3 herds of livestock, a 12-month grazing period, and a 4-month deferment period. **South African switchback** (2-1; 3:3, 6:3, 3:6 mo.) is a grazing system with 2 pastures, 1 herd, and a grazing schedule of 3 months grazing, 3 months deferment, 6 months grazing, 3 months deferment, 3 months grazing, 6 months deferment. **High intensity, low frequency (HILF)** (14-1; 12:156 da.) A grazing system consisting of 14 pastures, 1 herd, a 12-day grazing period, and a 156-day deferment period for each pasture. |
| **Grazing unit** | An area of land which is grazed as an entity. (Syn.) pasture, paddock, range, planning land unit (PLU). |
| **Green chop** | Mechanically harvested forage fed to animals while still fresh. |
| **Gross primary production** | Total amount of organic material produced, both above ground and below ground. |
| **Ground cover** | The percentage of material, other than bare ground, covering the land surface. It may include live and standing dead vegetation, litter, cobble, gravel, stones, and bedrock. Ground cover plus bare ground would total 100 percent. |
| **Ground truth** | Measurements or observations made on the ground for the purpose of verifying interpretations made from aerial photography or remote sensing. |
| **Ground water** | Subsurface water that is in the zone of saturation. The top surface of the ground water is the water table. Source of water for wells, seepage, and springs. |
| **Growing season** | That portion of the year when temperature and moisture permit plant growth. |

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| **Growth form** | The characteristic shape or appearance of a plant. |
| **Grubbing** | The act of removing roots, whether woody or herbaceous, by humans or animal activity. |
| **Gully** | A furrow, channel, or miniature valley, usually with steep sides, through which water commonly flows during and immediately after rains or snowmelt. |
| **Gully erosion** | Occurs when runoff is concentrated at a nickpoint where there is an abrupt change of elevation, slope gradient, and a lack of protective vegetation. |
| **Habitat** | The natural abode of a plant or animal, including all biotic, climatic, and edaphic factors affecting life. |
| **Habitat type** | The collective area which one plant association occupies. The habitat type is defined and described on the basis of the vegetation and its associated environment. |
| **Half-shrub** | A perennial plant with a woody base whose annually produced stems die each year. |
| **Hardiness** | The ability to survive exposure to adverse conditions. |
| **Hardpan** | A hardened soil layer in the lower part of the horizon A or in the B horizon caused by cementation of soil particles with organic matter or with such materials as silica, sesquioxide's, or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not crumble in water. |
| **Harvest** | Removal of animal or vegetation products from an area of land. |
| **Harvest efficiency** | The total percent of vegetation harvested by a machine or ingested by a grazing animal compared to the total amount of vegetation grown in the area in a given year. For continuous grazing, harvest efficiency usually averages: Rangeland, 25 percent; Pastureland, 30 percent; Grazed cropland, 35 percent. |
| **Harvest interval** | The length of time that occurs between forage cuttings. |
| **Hay** | The herbage of grasses, legumes, or comparatively fine-stemmed forbs cut and cured (dried) to preserve forage for later use as livestock feed. |
| **Hay crop** | Forage crops traditionally harvested for dry hay that can also be ensiled. |
| **Haylage** | A fermented product resulting from ensiling forage that ranges from 40 to 55 percent moisture in the absence of oxygen. |
| **Headcut** | Abrupt elevation drop in the channel of a gully that accelerates erosion as it undercuts the gully floor and migrates upstream. |
| **Hedged** | The appearance of woody plants that have been repeatedly browsed so as to appear artificially clipped. |
| **Hedging** | The persistent browsing of terminal buds of browse species causing excessive lateral branching and a reduction in main stem growth. |
| **Heifer** | A female of the cattle species less than 3 years of age that has not borne a calf. |
| **Herb** | Any flowering plant except those developing persistent woody stems above ground. |

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| **Herbaceous** | Vegetative growth with little or no woody component. Nonwoody vegetation, such as graminoids and forbs. |
| **Herbage** | (1) Total aboveground biomass of plants including shrubs regardless of grazing preference or availability. (2) Herbs taken collectively. |
| **Herbage production** | Production of certain herbaceous plants or groups of herbaceous plants. |
| **Herbicide** | A chemical used to kill or inhibit the growth of plants. |
| **Herbivore** | An animal that subsists principally or entirely on plants or plant materials. |
| **Herd** | An assemblage of animals usually of the same species. |
| **Herding** | The handling or tending of a herd. |
| **High intensity, low frequency** | Usually a single herd multi-pasture grazing system, that normally includes a slow rotation for range improvement (usually characterized by relatively long grazing periods and substantially longer rest periods). |
| **Historic plant community** | The plant community that was best adapted to the unique combination of factors associated with the ecological site. It was in a natural dynamic equilibrium with the historic biotic, abiotic, climatic factors on its ecological site in North America at the time of European immigration and settlement. |
| **Home range** | The area over which an animal normally travels in search of food. |
| **Host plant** | A key habitat resource necessary to support diverse pollinator communities. Host plants provide vegetative forage needed for larval development of most butterfly and moth species, as well as for some flies and beetles. |
| **Humus** | The organic fraction of soil in which decomposition is so far advanced that its original form is not distinguishable. |
| **Hybrid** | Offspring of a cross between genetically dissimilar individuals. |
| **Hybrid vigor** | The increased performance (rate of gain) associated with F1 crossbreeding. |
| **Hydrocyanic acid** | A poisonous compound, HCN, produced when forages containing antiquality chemicals called cyanogenic glycosides and the proper enzymes are eaten by a grazing animal. Plants developed cyanogenic compounds as a defense mechanism against herbivore feeding. It is the scientific term for prussic acid. |
| **Hydrologic cycle** | A continuous process by which water is transported from the oceans to the atmosphere, to the land, through the environment, and back to the sea. |
| **Hydrologic function** | The capacity of an area to capture, store, and safely release water from rainfall, runon, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur; one of the three attributes of rangeland health. |
| **Hydrology** | The science dealing with the occurrence of water on the earth and its physical and chemical properties, transformation, combinations, and movements, especially with the course of water movement from the time of precipitation on land and movement to the sea or atmosphere. |

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| **Improved pasture** | Grazing land permanently producing introduced or domesticated native forage species that receives varying degrees of periodic cultural treatment to enhance forage quality and yields and is primarily harvested by grazing animals. |
| **Increaser** | Native plants in Ecological Site reference plant community that increase under excessive continuous grazing by livestock. If heavy grazing continues, livestock will reduce the more palatable plants and shift to the increaser species. |
| **Indicators** | Components of an ecosystem whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (soil/site stability, hydrologic function, and biotic integrity) that is not feasible or too expensive to measure. |
| **Indigenous** | Born, growing, or produced naturally(native) in an area, region, or country. |
| **Infestation** | Invasion by large numbers of parasites or pests. |
| **Infiltration** | The process by which water enters the soil surface and is affected by the combined forces of capillarity and gravity. |
| **Infiltration capacity** | When rainfall during a storm exceed infiltration paucity of the soil, surface runoff or ponding on the soil surface occurs. |
| **Infiltration rate** | Infiltration rate is related to the volume of water moving into the soil profile per unit area of surface area. |
| **Initial stocking rate** | A safe starting stocking rate assumed to ensure against excessive grazing utilization. It is intended as a guide until experienced yields can be determined and realistic stocking rates established for a given area. |
| **Insecticide** | A pesticide used to control or prevent damage by insects. |
| **Integrated pest management** | Controlling pest populations using a combination of proven methods that achieve the proper level of control of them while minimizing harm to other organisms in the ecosystem. Control methods include natural suppression, biological control, resistance breeding, cultural control, and direct control. |
| **Interest** | Interest is the earning power of money; what someone will pay for the use of money. |
| **Internal rate of return** | The compounded interest rate that the practice will return based upon the inputs provided. |
| **Interrill erosion** | The removal of a fairly uniform layer of soil on a multitude of relatively small areas by splash due to raindrop impact and by sheetflow. |
| **Interseeding** | Planting seed in the center of narrow seedbed strips, commonly 6 inches to 6 feet wide and prepared by mechanical or chemical methods. |
| **Introduced species** | A species not a part of the original fauna or flora of the area in question. |
| **Invader** | Plants that are not a part of the original plant community that invade an area as a result of disturbance, or plant community deterioration, or both. (Syn.) Invasive. |
| **Invasion** | The migration of organisms from one area to another area and their establishment in the latter. |

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| **Invasive plants** | Plant species that are typically not found on the ecological site or should only be in the trace or minor categories under the natural disturbance regime and have the potential to become a dominant or codominant species on the site if their establishment and growth are not actively controlled by natural disturbances or management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are ruderal plants and not invasive plants. |
| **Inventory** | The identification of attributes, features, and other data pertaining to natural resources and special environmental concerns on and surrounding a planning area. |
| **Jointed** | A grass stem that has distinct, elongated internodes between nodes. |
| **Key grazing area** | A relatively small portion of a pasture or management unit selected because of its location, use, or grazing value as a monitoring point for grazing use. It is assumed that key areas, if properly selected, will reflect the current grazing management over the pasture or management unit as a whole. |
| **Key species** | Key grazing species are forage species whose use serves as an indicator of the degree of use of associated species. They are species that must, because of their importance, be considered in the management program. |
| **Kind of animal** | An animal species or species group, such as sheep, cattle, goats, deer, horses, elk, antelope. |
| **Lamb crop** | The number of lambs produced by a given number of ewes, usually expressed in percent of lambs weaned of ewes bred. |
| **Land treatments** | A wide range of vegetation and soil manipulations, such as use of mechanical equipment, herbicides, prescribed fire, or seeding. |
| **Landscape** | Large, connected geographical regions that have similar environmental characteristics and that may consist of part or all of one or more watersheds. |
| **Leaf area index (LAI)** | Sum of leaf area expressed as a percentage of ground surface. Leaf area index may exceed 100 percent. |
| **Lentic** | A riparian system characterized by still water (such as lakes, ponds, or swamps). |
| **Lessee** | One who has specified rights or privileges under lease. (Syn.) permittee. |
| **License** | See Grazing license or Permit. |
| **LiDAR** | A surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths is used to make digital 3-D representations of the target. |
| **Life-form** | Characteristic form or appearance of a species at maturity, e.g., tree, shrub, herb. |
| **Lime** | (1) Calcium oxide. (2) All limestone-derived materials applied to neutralize acid soils. |
| **Limiting factor** | Any environmental factor that exists at suboptimal level and thereby prevents an organism from reaching its full biotic potential. |

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| **Linear extensibility percent** | The unit of measurement that determines soil shrink-swell classes. It is the linear expression of the volume difference of natural soil fabric at one-third bar or one-tenth bar water content and oven dryness. It equals the moist length minus the dry length value sum divided by the dry length times 100. |
| **Litter** | The uppermost layer of organic debris on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material. |
| **Litter movement** | Change in the location of litter due to wind or water. |
| **Livestock** | Domestic animals used for the production of goods and services. |
| **Livestock exclusion** | Land closed to grazing by domestic livestock. |
| **Livestock management** | Application of technical principles and business methods to livestock production. |
| **Livestock operation** | (Farm) See Ranch. |
| **Livestock production** | (1) The weight, number of animals, etc., that a rangeland area, seeded pasture, or management system produces. (2) The business of producing livestock. |
| **Lotic** | A riparian system characterized by actively moving water. |
| **Maintenance** | Condition in which a nonproductive animal neither gains nor loses body energy reserves. |
| **Maintenance feeding** | Supplying feed to range animals when available forage does not meet their minimum daily requirement. This may be necessitated by excessive grazing, inclement weather, or the inability of the site to produce the desired quality forage. |
| **Major Land Resource Area (MLRA)** | Broad geographic areas that are characterized by a particular pattern of soils, climate, water resources, vegetation, and land use. Each MLRA in which rangeland and forest land occur is further broken into range sites. |
| **Management area** | An area for which a single management plan is developed and applied. |
| **Management plan** | A program of action designed to reach a given set of objectives. |
| **Management practice** | A conservation practice that requires regular input from the land manager. Examples include nutrient management, residue management, integrated pest management, etc. (See also "structural practice.") |
| **Management unit** | A subdivision of a management area. |
| **Marker** | (1) A colored or otherwise marked sheep in a range band. (2) Dye, foam, or paper strips to indicate area covered in earlier pass of sprayer. (3) An infertile (vasectomized) male animal, often equipped with a dye marker, used to identify ovulating females for artificial insemination. |
| **Marking** | Any method, other than branding, of placing a sign on an animal for the purpose of identification. For example: ear slits, tags, wattles. See Brand, Earmarking, and Tagging. |

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| **Marsh** | Flat, wet, treeless areas usually covered by standing water and supporting a native growth of grasses and grass-like plants. |
| **Mature soil** | A soil with well-developed characteristics produced by the natural processes of soil formation and in equilibrium with its environment. See Soil. |
| **Maximum economic yield** | The yield reached where the last increment of an input, such as fertilizer, just pays for itself by producing a yield increment of equal value. |
| **Meadow** | An area of perennial herbaceous vegetation, usually grass or grasslike, used primarily for hay production. |
| **Mesa** | A flat-topped mountain, or other elevation bounded on at least one side by a steep cliff. Local in Southwest. |
| **Metric units** | (see table below) |

| To Convert: | To: | Multiply by: |
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| Kilograms per hectare | Pounds per acre | 0.891 |
| Kilograms | Pounds | 2.2046 |
| Hectares | Acres | 2.471 |
| Pounds per acre | Kilograms per hectare | 1.12 |
| Pounds | Kilograms | 0.4536 |
| Acres | Hectares | 0.4047 |

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| **Migrant** | One that moves from place to place. |
| **Minor** | In IIRH, species or functional/structural groups within a plant community with less size per unit area than subdominant plants and generally greater than 1% and less than 10% of the community composition; elimination of these species or groups from the community would have a minor impact on the composition of the remaining groups. |
| **Monitoring** | The orderly collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives. This process must be conducted over time in order to determine whether or not management objectives are being met. |
| **Morphology** | The form and structure of an organism, with special emphasis on external features. |
| **Mott** | A group of trees and/or shrubs. |
| **Mottling** | Variation of coloration in soils as represented by localized spots, patches, or blotches of contrasting color. Commonly develops under alternating wet and dry periods with associated reduction and oxidation environments. Mottling generally indicates poor aeration and impeded drainage. |
| **Mower-conditioner** | A pull-type or self-propelled machine that has a mower unit mounted in front of a conditioner unit for one pass mowing and conditioning of forages being prepared for harvest. Both units are enclosed in the same housing. |
| **Mulch** | (n) (1) A layer of dead plant material on the soil surface. (2) An artificial layer of material, such as paper or plastic, on the soil surface. (v) Cultural practice of placing rock, straw, asphalt, plastic, or other material on the soil's surface as a mulch. |
| **Multiple use** | Use of land for more than one purpose; i.e., grazing of livestock, wildlife production, recreation, watershed, and timber production. Not necessarily the combination of uses that will yield the highest economic return or greatest unit output. |

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| **National Resources Inventory (NRI)** | Grazingland On-Site Study collects and produces scientifically credible information on the status, condition, and trends of land, soil, water, and related resources on the Nation's non-federal lands in support of efforts to protect, restore, and enhance the lands and waters of the United States. |
| **Native pasture** | See Naturalized pasture. |
| **Native species** | A species which is a part of the original fauna or flora of the area in question. See Indigenous. |
| **Natural disturbance regime** | The kind, frequency, and intensity of natural disturbance events that would have occurred on an ecological site prior to European influence (ca. 1600) in North America (Winthers et al. 2005). Natural disturbances include, but are not limited to, native insect outbreaks, wildfires, native wildlife activities (herbivory, burrowing, etc.), indigenous human activities, and weather cycles and extremes (including droughts and unusual wet periods, temperatures, and snow and wind events). |
| **Natural range of variability** | The deviation of characteristics of biotic communities and their environment that can be expected given natural variability in climate and natural disturbance regimes. The natural range of variability does not include influences of nonnative species and also does not encompass soil degradation, such as accelerated erosion, organic matter loss, changes in nutrient availability, or soil structure degradation, beyond what would be expected to occur under the natural disturbance regime. |
| **Naturalized pasture** | Naturalized pasture is cleared, converted, past cultivation, and "old-field" or "go-back land." It is forestland and cropland that primarily contain introduced species that are largely adapted and have become established without agronomic and cultural inputs, persist under the current conditions of the local environment, and are stable over long time periods. |
| **Naturalized species** | An introduced species that has become adapted to a new climate, different ecological site, or a different environment and can perpetuate itself in the community without cultural treatment. |
| **Nematodes** | Tiny, tubular, unsegmented, eel-like, soil-borne worms that feed on plant roots or parasitize grazing animals. |
| **Net energy (NE)** | Energy available to the animal for the maintenance or various productive purposes. |
| **Net primary production** | The net increase in plant biomass within a specified area and time interval. It is the amount of carbon uptake during photosynthesis after subtracting plant respiration. This measure is an important indicator for studying the health of plant communities. |
| **Net present value** | The difference between returns and costs when compared in present dollars. Value of today's dollar=Present value. |
| **Niche** | The ecological role of a species in a community. |
| **Nitrogen fixation** | The biological reduction of molecular nitrogen to chemical forms that can be used by organisms in the synthesis of organic molecules. |
| **Non-consumed plants** | Non-consumed plants are unpalatable to grazing animals, or they are unavailable for use because of structural or chemical adaptations. They may become abundant if more highly preferred species are over utilized or grazed out. |

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| **Nonjointed** | See Culmless. |
| **Nonprotein nitrogen** | Sources other than natural protein, such as urea, biuret, and ammonia hydroxide. |
| **Normalized Difference Vegetation Index (NDVI)** | A measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves lengths are absorbed, and others are reflected). |
| **Noxious weed** | An unwanted plant specified by Federal or State laws as being especially undesirable, troublesome, and difficult to control. It grows and spreads in places where it interferes with the growth and production of the desired crop. |
| **Nurse crop** | A temporary crop seeded at or near the time primary plant species are seeded to provide protection and otherwise ensure establishment of the latter. (Syn.) companion crop. |
| **Nutrient** | Any food constituent or ingredient that is required for or aids in the support of life. |
| **Nutrient cycle** | The cycle of nutrients, such as nitrogen and phosphorus, through the physical and biotic components of the environment; one of the ecological processes. |
| **Nutrient management** | Managing the amount, form, placement, and timing of plant nutrient applications to optimize plant growth, provide safe nutritious food, and minimize environmental degradation. |
| **Nutrition** | Ingestion, digestion, and/or assimilation of food by plants and animals. |
| **Nutritive value** | Relative capacity of a given forage or other feedstuff to furnish nutrition for animals. In range management, the term is usually prefixed by high, low, or moderate. |
| **Open** | A term commonly used to describe a nonpregnant female animal. |
| **Open range** | (1) Rangeland that has not been fenced into management units. (2) All suitable rangeland of an area upon which grazing is permitted. (3) Untimbered rangeland. (4) Rangeland on which the livestock owner has unlimited access without benefit of land ownership or leasing. |
| **Operating unit** | (Syn.) Ranch, (Syn.) Planning Area (NPPH). |
| **Opportunity cost** | When money is used for a particular purpose, the opportunity to use it or invest it in some other way is foregone. The expected return from the lost opportunity from another investment (i.e., savings account, certificate of deposit, IRA) is the opportunity cost of using it in the manner chose. |
| **Organic matter** | Living plant tissue and decomposed or partially decomposed material from living organisms. |
| **Organism** | Any living entity: plant, animal, fungus. |
| **Orographic precipitation** | Results when moist air is lifted over mountains or other natural barriers. Important factors in the orographic process include elevation, slope, aspect or orientation of slope and distance from the moisture source. |
| **Outcrop** | The exposure of bedrock or strata projecting through the overlying cover of detritus and soil. |

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| **Oven-dry weight** | The weight of a substance after it has been dried in an oven at a specific temperature to equilibrium. |
| **Overgrazing** | Grazing that exceeds the recovery capacity of the individual species or the plant community. |
| **Overland flow** | Movement of water over the land's surface. Overland flow occurs when rainfall or snowmelt intensity exceeds soil infiltration capacity and water accumulates on the soil and starts moving downslope toward a drainage network. Sometimes referred to as sheetflow. The path that the overland flow takes constitutes the water flow patterns. See Runoff. |
| **Overstocking** | Placing a number of animals in a given area that will result in overuse if continued to the end of the planned grazing period. |
| **Overstory** | The upper canopy or canopies of plants. Usually refers to trees, tall shrubs, and vines. |
| **Overuse** | Utilizing an excessive amount of the current year's plant growth which, if continued, will result in deterioration. |
| **Overwintering sites** | A key habitat resource necessary to support diverse pollinator communities. The great majority of insect pollinators do not migrate and are full-year residents. In most U.S. states, cold winter temperatures restrict insect activity, and those insects need somewhere to safely survive the winter while immobile. |
| **Paddock** | (1) One of the subdivisions or subunits of the entire pasture unit. (2) A relatively small enclosure used as an exercise and saddling area for horses, generally adjacent to stalls or a stable. (Syn.) pasture. |
| **Palatability** | The relish with which a particular species or plant part is consumed by an animal. |
| **Pan (soils)** | Horizon or layer in soils that is strongly compacted, indurated, or very high in clay content. |
| **Partial budgeting** | Economic evaluation of a conservation practice or resource management system can be estimated through partial budgeting. Partial budgeting examines only the change in costs, returns, and benefits resulting from the practice. |
| **Pasture condition scoring** | Assessment tool recognized in NRCS planning criteria to identify resource concern criteria thresholds. It is used for assessing ecological condition on pastureland through the visual evaluation of 10 indicators, which rate pasture vegetation and soils. |
| **Pasture planting** | Establishing adapted herbaceous species on land to be treated and grazed as pasture. |
| **Pasture/Pastureland** | Land composed of introduced or domesticated native forage species that is used primarily for the production of livestock. Pastures receive periodic renovation and cultural treatments, such as tillage, fertilization, mowing, weed control, and may be irrigated. Pastures are not in rotation with crops. |
| **Peak standing crop** | The greatest amount of plant biomass above ground present during a given year. |
| **Pedestaled** | A condition where the soil has eroded from around individual plants or other objects, such as small rocks, leaving them on small pedestals of soil. Sometimes the result of frost heaving. |

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| **Pellets** | A pesticide formulation similar to granules except pellets are usually more uniform, of a specific weight or shape, and greater than 10 cubic millimeters in size. Often used as rodenticide and slug baits. |
| **Percent use** | Grazing use of current growth, usually expressed as a percent of the current growth (by weight) that has been removed. See Degree of use. |
| **Percolation** | Downward movement of water through the soil profile. |
| **Perennial plant** | A plant that has a life span of three or more years. |
| **Permanent water** | A watering place that supplies water at all times throughout the year or grazing season. |
| **Permit** | See Grazing license. |
| **Permittee** | One who holds a permit to graze livestock on State, Federal, or certain privately-owned lands. (Syn.) Lessee. |
| **Pesticide** | Any chemical agent such as herbicide, fungicide, or insecticide, used for control of specific organisms. |
| **Phenology** | The study of periodic biological phenomena that are recurrent, such as flowering, or seeding, especially as related to climate. |
| **Photo point** | An identified point from which photographs are taken at periodic intervals. |
| **Photo sensitization** | A noncontagious disease resulting from the abnormal reaction of light-colored skin to sunlight after a photodynamic agent has been absorbed through the animal's system. Grazing certain kinds of vegetation or ingesting certain molds under specific conditions causes photo sensitization. |
| **Physical crust** | Thin surface layers induced by the impact of raindrops on bare soil causing the soil surface to seal and absorb less water. |
| **Pitting** | Making shallow pits or basins of suitable capacity and distribution on range to reduce overland flow from rainfall and snowmelt. |
| **Plain** | A broad stretch of relatively level treeless land. |
| **Planned grazing system** | A system in which two or more grazing units are rested and grazed in a planned sequence over a period. Planned grazing systems are designed and applied to meet the needs of the vegetation, the animals, and the overall objectives of the operator. |
| **Planned trend** | The change in plant composition within an ecological site from one plant community type to another relative to management objectives and to protecting the soil, water, air, plant, and animal resources. Planned trend is described as moving towards or away from the desired plant community or objective. |
| **Plant association** | A particular type of plant community, which has been repeatedly described over a geographic area that has relatively consistent floristic composition, uniform physiognomy, and distribution that is characteristic of a particular habitat. |
| **Plant community type** | A classification based on inherent attributes and characteristics of the vegetation structure, growth form, and plant species that can repeatedly occur over a geographic area. |

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| **Plant mortality** | As used in this technical reference, this term refers to the prevalence of dead plants in an evaluation area. |
| **Plant succession** | (Syn.) succession. |
| **Plant vigor** | Plant health. |
| **Poisonous plant** | A plant containing or producing substances that cause sickness, death, or a deviation from the normal state of health of animals. See Toxic plant species. |
| **Pollination** | The transfer of pollen grains from a plant's anther (the pollen producing part of the flower) to a stigma (the pollen-receiving part of a flower). There are 3 major types of pollination (self-pollination, wind-pollination, animal pollination). |
| **Pond** | A water impoundment made by constructing a dam or an embankment, or by excavating a pit or dugout usually to supply drinking water for livestock and or wildlife. |
| **Ponding** | Water standing in a closed depression that is removed by percolation, transpiration, evaporation, or a combination of these processes. |
| **Potential Natural Community (PNC)** | The biotic community that would become established on an ecological site if all successional sequences were completed without interferences by man under the present environmental conditions. Natural disturbances are inherent in its development. The PNC may include acclimatized or naturalized nonnative species. |
| **Prairie** | An extensive tract of level or rolling land that was originally grass-covered and treeless. |
| **Precipitation** | The primary input of the hydrologic cycle. The three major categories of precipitation are convective, orographic and cyclonic. |
| **Preference** | See Grazing preference. |
| **Preferred plants** | Preferred plants are species that are preferred by animals and are grazed first by choice. These plants are generally more sensitive to grazing misuse than other plants and decline under continued heavy grazing. |
| **Preplant** | A herbicide applied on the soil surface before seeding or transplanting. |
| **Preponderance of evidence (IIRH)** | The rating of an attribute of rangeland health by observing where the distribution of indicators for each attribute fall under the five departure categories, while also taking into account local knowledge and other information. |
| **Prescribed burn** | A prescribed burn is a thoughtfully planned out with written prescriptions that describes the objectives of the burn unit, firebreaks, fuel considerations, acceptable weather parameters that include (wind speed and direction, temperature, and relative humidity, and smoke management), labor and equipment required, notifications to neighbors and civil authorities, ignition procedures, contingency plans, and mop-up and monitoring procedures. The prescribed burn is only ignited when all the procedures and considerations are in adherence to the burn plan prescriptions. |
| **Prescribed grazing** | The controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective. Syn Managed grazing. |
| **Primary practice** | A practice resulting in treatment of the identified resource concerns. |

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| **Primary production** | The conversion of solar energy to chemical energy through the process of photosynthesis. It is represented by the total quantity of organic material produced within a given period by vegetation. |
| **Primary productivity** | The rate of conversion of solar to chemical energy through the process of photosynthesis. It is represented by the total quantity of organic material produced within a given period by vegetation. |
| **Producer** | Rancher or stock farmer. |
| **Productivity** | The rate of production per unit area, usually expressed in terms of weight. |
| **Proper Functioning Condition (PFC)** | An assessment for riparian areas. The protocol addresses the physical functioning of perennial or intermittent lotic (flowing water) riparian systems, such as rivers or streams. |
| **Proper grazing use** | Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation. |
| **Proper stocking** | Placing a number of animals in a given area that will result in proper use at the end of the planned grazing period. |
| **Proper use** | A degree of utilization of current year's growth that, if continued, will achieve management objectives and maintain or improve the long-term productivity of the site. Proper use varies with time and systems of grazing. |
| **Prussic acid** | A poison, hydrocyanic acid, released when forages containing cyanogenic glycosides and the proper enzymes are chewed by a grazing ruminant. |
| **Pure live seed** | Purity and germination of seed expressed in percent; may be calculated by this formula: P.L.S. = % germination x % purity x 100. See Seed purity. |
| **Qualitative data** | Observational data derived from visual observations and recorded descriptively but not measured (e.g., descriptive or nonnumerical data). |
| **Quantitative data** | Data derived from measurements, such as counts, dimensions, weights, etc., and recorded numerically; may include ratios or other values. Qualitative numerical estimates, such as ocular cover and production estimates, are often referred to as semiquantitative. |
| **Ranch** | An establishment or firm with specific boundaries, together with its lands and improvements, traditionally used for the grazing and production of domestic livestock and/or wildlife. A ranch may also have nontraditional uses and produce other goods and services as well as environmental and social benefits. |
| **Rancher** | One who owns, leases, or manages a ranch. |
| **Range** | Land on which the historic and/or introduced vegetation is predominantly grasses, grass-like plants, forbs or shrubs managed as natural ecosystem. Range land may include natural grasslands, savannas, shrublands, tundra, alpine communities, marshes and meadows. |

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| **Range improvement** | (1) Any structure or excavation to facilitate management of rangeland or livestock. (2) Any practice designed to improve range condition or facilitate more efficient utilization of the rangeland. (3) An increase in the grazing capacity of rangeland; i.e., improvement of rangeland condition. |
| **Range management** | The art and science of manipulating, using, and conserving native grazing land resources to benefit society. |
| **Range plan** | (Syn.) management plan. |
| **Range readiness** | The defined stage of plant growth at which grazing may begin under a specific management plan without permanent damage to vegetation or soil. Usually applied to seasonal range. |
| **Range resources** | (Syn.) related resources. |
| **Range seeding** | The process of establishing vegetation by the artificial dissemination of seed. |
| **Rangeland** | Rangeland is a land cover or use composed of grasses, grass-like plants, forbs, shrubs, and trees that is typically unsuited to cultivation because of physical limitations such as low and erratic precipitation, rough topography, poor drainage, or cold temperatures. Rangeland can include the following: (i) natural lands that have not been cultivated and consist of a historic complement of adapted plant species; and (ii) natural (go-back lands, old-field) or converted revegetated lands that are managed like native vegetation. Note: The USDA-NRCS rangeland Natural Resources Inventory (NRI) includes this designation in their definition of rangeland. In assessing rangeland conditions and health, keeping these designations separate would provide for more detailed information about rangeland trends and health. |
| **Rangeland Analysis Platform (RAP)** | An online app providing vegetation maps (30m resolution) across rangelands of the western U.S. from 1986-present. Products leverage satellite data, NRI, and other plot data to produce maps of annual percent cover of perennial forbs and grasses, annual forbs and grasses, shrubs, trees, and bare ground, as well as herbaceous production (lbs/ac) every 16 days and annually. |
| **Rangeland Brush Evaluation Tool (RaBET)** | Estimates foliar cover of woody plant species. |
| **Rangeland ecological site** | An ecological site is a conceptual division of the landscape. It is defined as a distinctive kind of land based on recurring soil, landform, hydrology, geology, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances. |
| **Rangeland health** | The degree to which the integrity of the soil, vegetation, water, and air as well as the ecological processes of the rangeland ecosystem is balanced and sustained. Integrity is defined as maintenance of the structure and functional attributes characteristic of a particular locale, including the natural range of variability. |
| **Rangeland hydrology** | Rangeland Hydrology is founded on basic biological and physical principles and is a specialized branch of science, which studies land use effects on infiltration, runoff, sedimentation, and nutrient cycling (hydrologic assessments) in natural and reconstructed ecosystems. |

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| **Rangeland inventory** | (1) The systematic acquisition and analysis of resource information needed for planning and for management of rangeland. (2) The information acquired through rangeland inventory. |
| **Rangeland trend** | The direction of change in an existing plant community relative to the historic plant community for the ecological site. |
| **Rangeland trend worksheet** | A rating of the direction of change that may be occurring on a site, either towards a desirable condition or away and degrading from a desirable condition. |
| **Reclaim** | To make a site usable again for a particular land use or crop. |
| **Reclamation** | Restoration of a site or resource to a desired condition to achieve management or stated goals. See revegetation. |
| **Reconnaissance** | A general examination or survey of a region with reference to its main features, usually as a preliminary to a more detailed survey. |
| **Recovery period** | The length of time occurring between grazing periods on rotationally stocked pastures. Synonymous with rest period that is animal-oriented terminology. Although relieved of grazing pressure, the forages are recovering their photosynthetic area early on, and near the end of the recovery period they are replenishing food reserves and resuming root growth. |
| **Recreation area** | A land area reserved and managed for developed and/or undeveloped recreation. |
| **Recruitment** | The successful entry of new individuals into the breeding population. |
| **Reference sheet (IIRH)** | A form that is a component of an ecological site description that describes the status of each indicator within the natural disturbance regime for the reference state. It is the primary reference for all assessments of rangeland health and is required to conduct an assessment. |
| **Reference state** | The state (see definition of “state”) where the functional capacities represented by soil/site stability, hydrologic function, and biotic integrity are functioning at a sustainable/resilient level under the natural disturbance regime. This state usually includes more than one community phase, but is not limited to, what is often referred to as the potential natural plant community. |
| **Rejuvenation (browse)** | Treatments, such as mechanical, pyric, or even chemical, applied to woody plants to encourage new growth as sprouts or seedlings available for browsing. |
| **Related resources** | Those resources that bear relationship to one another because of common location and interdependency, such as range, game, recreation, watershed, soil, or timber. |
| **Relative dominance (composition)** | The percent of cover or production represented by a species or life form expressed relative to the total cover or production. It can also be based on biomass. |
| **Relative feed value (RFV)** | An index that ranks hay crops relative to the digestible dry matter intake of full bloom alfalfa (RFV = 100). |
| **Relict area** | A remnant or fragment of the historic plant community that remains from a former period when it was more widely distributed. |

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| **Remote sensing** | Methodology for data collection, analysis, and the parameterization of environmental models from satellite data. Remote sensing requires an interdisciplinary knowledge to be able to interpret the data received and make it operational. |
| **Remote sensing integration** | Refers to the simultaneous use of field and remote-sensing data for inventory, assessment and monitoring. |
| **Reseeding** | (Syn.) range seeding. |
| **Resident species** | Species common to an area without distinction as to being native or introduced. |
| **Residual stubble (grazing height)** | The height of the forage stand after being grazed, whether intermittently or continuously. When grazed continuously, monitoring must be done regularly as it means at any moment in time under that stocking method. |
| **Resilience** | (1) The ability of a plant community to recover to its former state after it has been altered. (2) The ability of an agroecosystem to return to some previous state or other successional alternative following disturbance, such as fire, plow out, and drought. |
| **Resistance** | (1) A measure of the amount of stress a plant community can endure before it is displaced by a given type of disturbance. (2) Site immunity to being impacted by catastrophic events that have the potential of creating long-term declines in productivity. The basic components, climate and soil, dictate the brittleness of a land-based ecological community. |
| **Resource Management System (RMS)** | An RMS is a combination of conservation practices and resource management activities that treats all identified resource concerns for soil, water, air, plants, animals and energy to a level that meets or exceeds the planning criteria in the FOTG. |
| **Rest** | The absence of grazing by livestock to benefit plants for regrowth between grazing periods, for critical periods of plant growth and development, or for critical periods of plant establishment. Generally, deferment implies a nongrazing period less than a calendar year, while rest implies nongrazing for a full year or longer. (Syn.) deferment. |
| **Rest period** | A period of deferment included as part of a grazing system. |
| **Rest-rotation** | See Grazing system. |
| **Restricted area** | An area on which grazing tenure is limited. |
| **Retrogression** | (Syn.) rangeland degeneration. |
| **Revegetation** | Establishing or re-establishing desirable plants in areas where the plant community is not adequate to meet management objectives by management techniques alone. See Range seeding. |
| **Rhizome** | A horizontal underground stem that usually sends out roots and aboveground shoots from the nodes. |
| **Rill** | A small, intermittent watercourse with steep sides, usually only several centimeters deep. Rills generally are linear erosion features running parallel to a slope. |
| **Riparian** | Area, zone, and/or habitat adjacent to streams, lakes, or other natural free water, which have a predominant influence on associated vegetation or biotic communities. |

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| **Riparian community type** | A repeating, classified, defined, and recognizable assemblage of riparian plant species. |
| **Riparian ecosystems** | Ecosystems that occur along watercourses or waterbodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. |
| **Riparian species** | Plant species occurring within the riparian zone. Obligate species require the environmental conditions within the riparian zone; facultative species tolerate the environmental conditions, therefore may also occur away from the riparian zone. |
| **Riparian vegetation** | Plant communities in the riparian zone comprised of riparian species. |
| **Risk** | The variability of outcomes. In evaluating the economics of a conservation practice or RMS, risk is the probability that a conservation or RMS will be unsuccessful. |
| **Rock fragments** | The unattached pieces of rock 2 millimeters or larger in diameter contained in or lying on the soil. |
| **Rodent** | Any animal of the order Rodentia, and commonly includes the order Lagomorpha, many of which influence rangeland by such habits as grazing and burrowing. Important rangeland rodents include pocket gophers, prairie dogs, ground squirrels, certain terrestrial mice, kangaroo rats, jack rabbits, and marmots. |
| **Rotation grazing** | A type of grazing system and involves moving grazing animals from one pasture to another to achieve a desired management objective. |
| **Roughage** | Plant materials containing a low proportion of nutrients per unit of weight. Generally bulky and coarse, high in fiber, and low in total digestible nutrients. Roughage may be classed as either dry or green. |
| **Ruderal** | A plant inhabiting disturbed sites. |
| **Rumen** | The large, first compartment of the stomach of a ruminant from which ingestion is regurgitated for re-chewing and in which digestion is aided by symbiotic action of microbes. |
| **Ruminant** | Even-toed, hoofed mammals that chew the cud and have a 4-chamber stomach; i.e., ruminantia. |
| **Runoff** | The movement of water from a watershed including both surface and subsurface flow, usually expressed in acre-feet of water yield. |
| **Saltation** | A particular type of momentum-dependent transport involving the rolling, bouncing, or jumping action of soil particles 0.1 to 0.5 mm in diameter by wind, usually at a height of $<$ 15 cm above the soil surface, for relatively short distances; the rolling, bouncing, or jumping action of mineral grains, gravel, stones, or soil aggregates affected by the energy of flowing water; the bouncing or jumping movement of material downslope in response to gravity. |
| **Salting** | (1) Providing salt as a mineral supplement for animals. (2) Placing salt on the range in such a manner as to improve distribution of livestock. |
| **Sample** | Part of a population taken to estimate a parameter of the whole population. |

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| **Savannah** | A grassland with scattered trees, either as individuals or clumps; often a transitional type between true grassland and true forest. |
| **Scrub** | Vegetation dominated by low growing woody plants, often forming a dense thicket. |
| **Seasonal distribution** | (1) The progressive grazing in a sequence of moves from one part of a range to another as vegetation develops. (2) The normal occurrence of precipitation at different periods of the year. |
| **Seasonal distribution of growth or availability** | The tabular or graphical display of monthly increments of total annual forage production available for grazing. It may record growing forage production throughout its growing season or the deferment and release later in the year of accumulated grazeable forage mass to grazing animals. |
| **Seasonal grazing** | Grazing restricted to a specific season. |
| **Seasonal use** | (1) Synonymous with seasonal grazing. (2) Seasonal preference of certain plant species by animals. |
| **Seed** | A fertilized ripened ovule of a flowering plant. |
| **Seed scarification** | Mechanical or acid treatment of seedcoats to improve moisture absorption and enhance germination. |
| **Seed, dormant** | Live seed in a non-germinative condition because of internal inhibitions in the seed; i.e., hard seed, or unfavorable environmental conditions. |
| **Seed, hard** | Live seed in a physiological condition that prevents or delays germination, even when a favorable environment exists. |
| **Seedbank** | Seeds stored in the soil, generally as hard seed, that are viable and will germinate given the proper conditions. This seedbank is principally built up by seed produced by plants growing on or adjacent to the site over many years. Species long gone may still be represented if their seed is especially long-lived. |
| **Seedbed preparation** | Soil treatment prior to seeding to: enhance soil surface layer for seed deposition and optimum opportunity for generation and seedling growth, reduce or eliminate existing vegetation, reduce the effective supply of weed seed, modify physical soil characteristics, and enhance temperature and water characteristics of the microenvironment. |
| **Seedhead** | The inflorescence (flowering part) of a grass where the seed will develop. |
| **Seep** | Wet areas, normally not flowing, often created when the elevation of the lateral flow of underground water intersects ground level, as on a hillslope. Occasionally seeps occur from water arising from an underground source. |
| **Selective grazing** | The grazing of certain plant species, individual plants, or plant parts on rangeland to the exclusion of others. |
| **Semiarid** | A term applied to regions or climates where moisture is normally greater than under arid conditions, but still definitely limits the production of vegetation. The upper limit of average annual precipitation in the cold, semiarid regions is as low as 15 inches, whereas in warm, tropical regions it is as high as 45 to 50 inches. |

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| **Senesce** | The yellowing and withering of older, lower leaves of plants as they become shaded by higher, younger leaves. Nutrients in these older leaves are translocated to younger tissue. |
| **Seral** | Refers to species or communities that are eventually replaced by other species or communities within a sere. |
| **Seral stages** | The developmental stages of an ecological succession. |
| **Sere** | All temporary communities in a successional sequence. |
| **Short-duration grazing** | A grazing system with five or more pastures where the rest period is usually at least four times greater than the grazing period. See Grazing system. |
| **Shrub** | A plant that has persistent, woody stems, a relatively low growth habit, and generally produces several basal shoots instead of a single bole. It differs from a tree by its low stature and non-arborescent form. Maximum height is generally 4 meters. |
| **Silage** | Forage preserved in a succulent condition by organic acids (lactic acid primarily) produced by partial anaerobic fermentation of sugars in the forage. |
| **Similarity index** | A mathematical comparison between two plant communities. |
| **Simple Interest** | Simple Interest is money paid or received for the use of money, generally calculated over a base period of one year at a set interest rate. |
| **Site** | See Ecological site. |
| **Slope** | A slant or incline of the land surface, measured in degrees from the horizontal, or in percent (defined as the number of feet or meters change in elevation per 100 of the same units of horizontal distance); may be further characterized by direction (exposure). |
| **Sod** | Vegetation that grows to form a mat of soil and vegetation. (Syn.) turf. |
| **Sod grasses** | Stoloniferous or rhizomatous grasses that form a sod or turf. |
| **Soil** | (1) The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (2) The unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro and micro-organisms, and topography, all acting over a period of time, producing soil, which differs from the material from which it was derived in many physical, chemical, biological, and morphological properties and characteristics. |
| **Soil aggregates** | A group of primary soil particles that cohere to each other more strongly than to other surrounding particles. |
| **Soil amendments** | Any material, organic or inorganic, applied to the soil to make it more conducive to vigorous plant growth. Amendments may contain important fertilizer elements, but the term commonly refers to added materials other than fertilizer. |
| **Soil crusts** | Biotic and abiotic components found on the surface of soils, including biological, physical, vesicular, and chemical crusts (see respective definitions in this glossary). |

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| **Soil erosion** | The detachment of soil by wind and water. |
| **Soil health** | The condition of the soil and its potential to sustain biological functions, maintain environmental quality, and promote plant and animal health. |
| **Soil map unit** | A map unit is a collection of soil areas or miscellaneous areas delineated in a soil survey. They may encompass one or more kinds of soil or one or more kinds of soil and a miscellaneous area, such as rock outcrop. They are identified by a unique map symbol in a survey area. There are four kinds of map units; consociations, complexes, associations, and undifferentiated groups. |
| **Soil map unit components** | The components of a map unit are: (1) The named soil(s) or miscellaneous areas that are dominant and co-dominant in extent. (2) Similar soils or miscellaneous areas that may be extensive, but not as extensive as the named components. (3) Dissimilar soils or miscellaneous areas that are minor in extent. Soil map unit components are rated and assigned to forage suitability groups. |
| **Soil quality** | Soil quality relates to quantifiable natural properties that are inherent for a particular soil type e.g., soil physical/chemical characteristics and historical soil-forming factors, which are fixed by nature. |
| **Soil reaction** | Numerical expression in pH units of the relative acidity or alkalinity of a soil. The range in soil pH is 1.8 to 11.0. A pH of 7.0 is neutral. |
| **Soil series** | Represents a three-dimensional soil body having a unique combination of properties that distinguish it from neighboring series. For U.S. soil maps, the soil series has served as the fundamental mapping concept. |
| **Soil structure** | The combination or arrangement of primary soil particles into secondary units or peds. The secondary units are characterized on the basis of size, shape, and grade (degree of distinctiveness). |
| **Soil surface loss and degradation** | The reduction in soil surface depth, organic matter, porosity, and structure as a result of wind or water erosion. Soil deposition over the surface horizon can also degrade the soil surface. |
| **Soil surface resistance to erosion** | The ability of a surface soil to resist erosion by water. Resistance increases in part with increasing soil organic matter or the presence of biological soil crusts. |
| **Soil survey** | The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are classified according to the kind and intensity of field examination. |
| **Soil test** | A chemical and physical analysis of a soil used to estimate its nutrient supplying power. It must use chemical extraction techniques appropriate for the elements being extracted and the soil being examined. For the results to be interpreted properly, the test procedures must also be calibrated against nutrient rate experiments in the field and in the greenhouse. |
| **Soil texture** | The relative proportions of the various soil separates (sand, silt, and clay) in a soil. |
| **Soil/site stability (IIRH)** | The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water and to recover this capacity when a reduction does occur; one of the three attributes of rangeland health. |

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| **Solution** | A pesticide formulation where the active ingredient is very soluble in water. It is a liquid that contains the active ingredient and additives. |
| **Species** | A taxon or rank species; in the hierarchy of biological classification, the category below genus. |
| **Species composition** | The proportions of various plant species in relation to the total on a given area. It may be expressed in terms of cover, density, weight, etc. |
| **Species importance curve** | A graphic representation that displays relative species abundance (production), a component of biodiversity. Individual species production is usually the best indicator of resource partitioning in the plant community. The x axis presents the ranking of species from most dominant to least, and the y axis is usually a log scale of production. Other importance values such as foliar cover may also be studied on the y axis. The shape of the curve is an indication of dominance and diversity among species (see Whittaker 1965). Species importance curves are useful in comparing ecological state changes or differences among sites (beta diversity) or monitoring change in species and individual production or cover over time. |
| **Spot grazing** | Repeated grazing of small areas while adjacent areas are less intensely grazed. |
| **Spring** | Flowing water originating from an underground source. |
| **Spring development** | Improving spring and seeps by excavating, cleaning, capping, or providing collection and storage facilities. |
| **Stage of maturity (forage)** | The developmental status of a forage crop used to describe a point in time in its progress towards maturity and assess its readiness for harvest as an edible forage or for its seed. |
| **Stand** | (1) An existing plant community with definitive bounds that is relatively uniform in composition, structural, and site conditions; thus, it may serve as a local example of a community type. (2) An acceptable level of new plants following a seeding or planting operation. |
| **Standing crop** | Standing crop is the amount of plant biomass present above ground at any given point in time (It is often modified to include above ground and below ground portions and further may be modified by the descriptors “dead” or “live” to more accurately define the specific type of biomass. |
| **Standing dead vegetation** | The total amount of dead plant material, in aboveground parts, per unit of space, at a given time. This component includes all standing dead vegetation produced in the previous (not the current) growing season that is not detached from the plant and is still standing. |
| **State** | An ecological state is a suite of temporally related plant community phases and associated dynamic soil properties that produce persistent characteristic structural and functional ecosystem attributes. |
| **State-and-transition model (STM)** | A state-and-transition model (STM) describes the temporal dynamics of an ecological site. They describe the reference state and multiple states and community phases and the transitions between states. |
| **Stem** | The culm or branch of a plant. |

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| **Stock** | (1) Abbreviated word for livestock. (2) To place animals on a discrete unit of grazing land. The term graze is often erroneously used in place of stock where the animal is the object of the verb, not the subject. |
| **Stocking** | The human placement of animals onto a management unit so they can graze or browse the plant resource. The term grazing is often erroneously used in place of stocking. Cattle have only one grazing method, while people have devised several stocking methods. Some stocking methods actually prevent livestock from grazing certain areas for a time. |
| **Stocking density** | The relationship between number of animals and area of land at any instant of time. It may be expressed as animal-units per acre, animal-units per section, or AU/ha. |
| **Stocking rate** | The number of specific kinds and classes of animals grazing or utilizing a unit of land for a specific period of time. May be expressed as animals per acre, hectare, or section, or the reciprocal (area of land/animal). When dual use is practiced (e.g., cattle and sheep), stocking rate is often expressed as animal units per unit of land or the reciprocal. |
| **Stockpiling** | Allowing standing forage to accumulate for grazing at a later period, often for fall and winter grazing after dormancy. |
| **Stolon** | A horizontal stem which grows along the surface of the soil and roots at the nodes. |
| **Stream Visual Assessment Protocol, V2 (SVAP2)** | A stream assessment tool for qualitatively evaluating the condition of aquatic ecosystems associated with wadable streams and used to determine the presence of a resource concern, or to document current condition of a suspected resource concern in NRCS planning. |
| **Structure (vegetation)** | Refers to plant growth forms (e.g., trees, vines, shrubs, grasses, forbs, and nonvascular plants, such as visible biological soil crusts) within the community. Structure may be subdivided to group species with similar growth forms based on height, growth patterns (bunch, sodforming, or spreading through long rhizomes or stolons), root structure (fibrous or tap), rooting depth, or sprouting ability. |
| **Stubble** | The basal portion of herbaceous plants remaining after the top portion has been harvested either mechanically or by grazing animals. |
| **Subdominant** | Species or functional/structural groups within a plant community with less size per unit area than dominant plants and generally greater than 10% of the community composition; elimination of these species or groups from the community would have a relatively major impact on composition of the remaining groups. |
| **Subunit** | The subdivisions of a single grazing system. See Paddock and Pasture. |
| **Succession** | A directional, cumulative change of species that colonize and propagate in a given environment through time. |
| **Succulent** | Plant with fleshy structures as an adaptation for storing water. Succulents commonly found on rangelands include cacti, Euphorbia spp., and Sedum spp., which may comprise a separate functional/structural group because most succulent species photosynthesize through the crassulacean acid metabolism (CAM) pathway, an adaptation for minimizing water loss through transpiration. |
| **Suitability** | (1) The adaptability of an area to grazing by livestock or wildlife. (2) The adaptability of a particular plant or animal species to a given area. |

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| **Summer range** | Rangeland, particularly in the mountainous Western States, that is grazed primarily during the summer growing season. |
| **Supplement** | Nutritional additive (salt, protein, phosphorus) intended to remedy deficiencies of the range diet. |
| **Supplemental feeding** | Supplying concentrates or harvested feed to correct deficiencies of the range diet. Often erroneously used to mean emergency feeding. |
| **Supporting practice** | Supporting practices facilitate a primary conservation practice and may not have a direct effect on the identified resource concern. |
| **Surface runoff** | Occurs when rainfall rate exceeds infiltration capacity, and the soil becomes saturated. |
| **Swale** | An area of low and sometimes wet land. |
| **Swath** | A strip of cut herbage lying on the stubble left by the cutter bar, blade, flail, rotary drum, or disc blade setting of the mower, mower-conditioner, binder, swather, or small grain head on a combine. |
| **Tame pasture** | Implies the forages growing on the land unit have been purposely cultivated by people as opposed to being wild growth of random origin. In permanent pastures it is often a combination of the two mechanisms and, therefore, a rather subjective and imprecise term. Synonymous with improved pasture. |
| **Terracettes** | "Benches" of soil deposition (may include incorporated litter or gravel) that form behind or between obstacles (persistent litter, rocks, or plant bases) caused by water (not wind) movement. Does not include horizontal paths caused by livestock or wildlife trailing on steeper slopes. |
| **Thermoneutral zone (comfort zone)** | Within a certain range of ambient temperature, the heat produced by normal metabolism of a resting animal is minimal and is enough to cover the heat loss. |
| **Threshold** | A transition boundary that an ecosystem crosses resulting in a new stable state that is not easily reversed without significant inputs of resources. |
| **Tiller** | (1) An erect shoot that arises from the crown of a grass. (2) A grass that is growing tillers. (3) The asexual development of a new plant from a meristematic region of the parent plant. |
| **Time value of money** | Money has value today and in the future; thus, the value of money is measured for some number of periods in the future. These periods may be years, months, weeks, or days. |
| **Total annual production** | Total Annual Production is all aboveground plant biomass produced during a single growing year, including woody material and regardless of palatability or accessibility to grazing animals. Total annual production is expressed in pounds per acre (lb/ac). |
| **Total digestible nutrients (TDN)** | The total digested energy in a feedstuff expressed in units of weight or percent. |
| **Toxic plants** | Toxic plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. They may become abundant if unpalatable and if the more highly preferred species are removed from the community. |

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| **Trace element** | An element essential for normal growth and development of an organism, but required only in minute quantities. |
| **Trail** | A well-defined path created by repeated passage of animals. |
| **Trailing** | (1) Controlled directional movement of livestock. (2) Natural trailing is the habit of livestock or wildlife repeatedly treading in the same line or path. See Drive. |
| **Trampling** | Treading underfoot; the damage to plants or soil brought about by movements or congestion of animals. |
| **Transitions** | Transitions are simply the mechanisms by which state shifts occur and are commonly initiated by a trigger (e.g., wildfire, drought, long-term flooding, invasive plants, grazing). A transition from one state to another is associated with "crossing a threshold." |
| **Tree** | A woody perennial, usually single stemmed plant that has a definite crown shape and reaches a mature height of at least 4 meters. The distinction between woody plants known as trees and those called shrubs is gradual. Some plants, such as oaks (Quercus spp.) may grow as either trees or shrubs. |
| **Trend** | A rating of the direction of change occurring on an ecological site. See Rangeland trend and Planned trend. |
| **Trough** | (1) A large container with necessary controls and valves that provides drinking water for livestock and wildlife. (2) A feeding container that holds livestock feed and/or minerals for consumption by livestock and some wildlife species. |
| **Turf** | (Syn.) sod. |
| **Type line** | The boundary line that separates two distinctive vegetation types on a map or photograph. |
| **Understory** | Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs, and low shrubs under a tree or shrub canopy. |
| **Undesirable plants** | Undesirable plants are species that are not readily eaten by animals and species that conflict with or do not contribute to the management objective. These plants are relatively unpalatable to grazing animals and may become more abundant if the preferred species are over utilized or grazed out. |
| **Ungulate** | A hoofed animal, including ruminants, but also horses, tapirs, elephants, rhinoceroses, and swine. |
| **Use** | (1) The proportion of current year's forage production that is consumed or destroyed by grazing animals. May refer either to a single species or to the vegetation as a whole. (Syn.) degree of use. (2) Utilization of land for a purpose, such as grazing, bedding, shelter, trailing, watering, watershed, recreation, forestry, and wildlife habitat. |
| **Utilization** | (Syn.) use. |
| **Variable cost** | Expenses that change with the number of animals in the herd. Examples of variable costs include supplemental feed, veterinary services and supplies, and labor. |
| **Vascular plant** | Plants with vessels that conduct sap throughout the plant. |

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| **Vegetation states** | The various plant communities produced by an ecological site within given site characteristics. |
| **Vegetation type** | A kind of existing plant community with distinguishable characteristics described in terms of the present vegetation that dominates the aspect of physiognomy of the area. |
| **Vegetative** | Relating to nutritive and growth functions of plant life in contrast to sexual reproductive functions. (adj.) Of or relating to vegetation. |
| **Vegetative state** | Stage of maturity prior to the appearance of inflorescences. In grasses, it is prior to boot stage. In legumes, it is prior to the appearance of buds. |
| **Vigor** | Relates to the relative robustness of a plant in comparison to other individuals of the same species. It is reflected primarily by the size of a plant and its parts in relation to its age and the environment in which it is growing. (Syn.) plant vigor. |
| **Walkway** | An earthen embankment constructed to improve the accessibility of marsh rangeland. See Stock trails and walkways. |
| **Warm-season plant** | A plant that makes most or all its growth during the spring, summer, or fall and is usually dormant in winter. (2) A plant that usually exhibits the C-4 photosynthetic pathway. |
| **Water cycle** | The capture, storage, and redistribution of precipitation; one of the ecological processes. Synonym: hydrologic cycle. |
| **Water flow patterns** | Paths that water takes as it moves across the soil surface during periods when surface water from rain or snowmelt exceeds soil infiltration capacity. Sometimes referred to as sheetflow or overland flow. |
| **Water potential** | The thermodynamic state of the water in a cell, organism, or soil equal to the difference in free energy per unit volume between matrically bound, pressurized, or osmotically constrained, water and that of pure water. |
| **Watershed** | (1) A total area of land above a given point on a waterway that contributes runoff water to the flow at that point. (2) A major subdivision of a drainage basin. |
| **Watershed management** | The management of land for optimum production of high-quality water, regulation of water yields, and for maximum soil stability, along with other goods and services from the land. |
| **Waterway** | A way or channel for water. |
| **Weather** | The current state of the atmosphere with regard to wind, temperature, cloudiness, moisture, pressure, etc. In this technical reference, the term recent weather is used and is defined as weather conditions over the past 2 years. |
| **Weed** | (1) Any growing unwanted plant. (2) A plant having a negative value within a given management system. |
| **Well** | A water source developed by drilling vertically through soil, subsoil, and geological strata to intercept underground water storage or stream areas. |
| **Well horizontal** | A water source developed by drilling horizontally into a hillside to intercept a perched water table or underground water source. |

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| **Wetland communities** | Plant communities that occur on sites with soils typically saturated with or covered with water most of the growing season. |
| **Wetlands** | Areas characterized by soils that are usually saturated or ponded; i.e., hydric soils, and that support mostly water-loving plants; i.e., hydrophytic plants. |
| **Wildlife** | Undomesticated vertebrate animals considered collectively, with the exception of fish. |
| **Windrow** | (1) Curing herbage dropped or raked into a narrow swath sized to be picked up easily by the head of a baler, combine, or forage harvester. (2) To cut or rake into windrows. |
| **Winter range** | Range that is grazed during the winter months. |
| **Woody** | A term used in reference to trees, shrubs or browse that characteristically contain persistent ligneous material. |
| **Xeric** | Having very little moisture; tolerating or adapted to dry conditions. |
| **Yearling** | An animal approximately one year of age. A short yearling is from 9 to 12 months of age and a long yearling is from 12 to 18 months. |
| **Yearlong grazing** | Continuous grazing for a calendar year. |
| **Yield** | (1) The quantity of a product in a given space and/or time. (2) The harvested portion of a product. |