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National Range and Pasture Handbook

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Foreword

The National Range and Pasture Handbook (NRPH) constitutes Natural Resources Conservation Service (NRCS) basic policy 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 may also serve as a general reference for grazing lands resource information. It was prepared primarily for NRCS use, but others who are interested in grazing lands conservation may find it useful.

The NRPH was developed by NRCS grazing lands specialists using their experience and many textbooks, scientific publications, manuals, and other references. The authors of the National Range and Pasture Handbook thank the many authors of these references for their work and contribution. The NRPH does not use scientific reference notations or citations in the text unless a direct quote is used. It does list references in a reference section. This format was chosen to make the NRPH a resource manager, field-user friendly, easy-to-read handbook and reference.

There are 634 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 are 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, through conservation districts, at the request of the cooperator (the owners or managers of these lands). This technical assistance provides a source of expertise to guide cooperators in solving resource problems and in sustaining or improving their grazing lands resources and operations. Guidance for developing conservation plans with cooperators on grazing lands is based on current NRCS policy relative to consideration of all soil, water, air, plant, and animal resources, as well as, the cooperator's objectives.

This handbook replaces the National Range Handbook (1976), which was only applicable to rangelands and other native grazing lands. In addition to providing guidance for rangelands, the NRPH includes information and guidance for pasturelands, haylands, grazed forests, grazed croplands, and naturalized pastures. The ecological principles used in the former handbook are updated, and new ecological principles have been added. New technology is included for enterprise diversification and grazing lands hydrology. Technical guidance for livestock husbandry, nutrition, and behavior science, as well as wildlife habitat management has been expanded. Economic analysis tools and their interpretations are explained.

This handbook, along with other appropriate NRCS technical and policy guidance manuals and handbooks, contains information to assist the NRCS conservationist in providing technical assistance to cooperators in all phases of the planning and application process. The NRPH deals with the policy and procedures for the study, inventory, analysis, treatment, and management of the grazing lands resources.

The appendixes in this handbook are to be considered an official part of the handbook. As time passes and the need arises, more appendixes will be added.

This handbook is included in the references section (Section I) of the Field Office Technical Guide in all NRCS field office locations with grazing lands.

Acknowledgments

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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Chapter 1 NRCS Authority, Mission, Goal, and Policies for Private Grazing Lands Assistance

Contents:

Chapter 1 — NRCS Authority, Mission, Goal, and Policies for Private Grazing Lands Assistance

600.0100 Authority

The Soil Conservation Act of 1935 provides the basic authority for programs of the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS). This act declares that it is the policy of Congress to control and prevent soil erosion and thereby preserve the natural resources on farm, grazing, and forest lands of the Nation. It authorizes the Natural Resource Conservation Service to carry out conservation measures on the land and to assist land users in conducting conservation activities (Public Law 46, 74th Congress).

NRCS responsibility and programs were broadened by the Watershed Protection and Flood Prevention Act, Public Law 566, 1954, as amended, and the Food and Agricultural Act of 1962, Public Law 87-703, as amended. The 1996 Farm Bill authorizes a Conservation for Private Grazing Lands technical assistance program (Title III, H.R. 2854 Section 386).

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 No. 4, Title 9, Administrative Regulations, May 17, 1954, and Comptroller General's Opinion B-115665 of October 1, 1953, 33CG:133).

600.0101 Mission

To provide quality assistance to the owners and managers of rangeland, pastureland and other grazed lands using appropriate science and technology to manage, enhance, and, where necessary, restore these grazing land ecosystems.

600.0102 Goal

The goal of NRCS grazing lands activities is to provide for the management, enhancement, and, where necessary, the 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:

- Protection of grazing lands ecosystems
- Prevention of soil erosion
- Maintenance or enhancement of soil quality
- Sustained forage and livestock production
- Improved water yield and quality
- Diverse wildlife habitat
- Aesthetics and open space
- Quality recreational opportunities

600.0103 Policies

NRCS policy is to maintain high standards of technical quality in all activities related to grazing lands. This handbook contains general NRCS policy for grazing lands, background information, and how-to information for applying this policy. In addition, the NRCS policy specific to grazing lands that is in the General Manual and other policy documents is summarized below.

(a) State supplements

State conservationists and their grazing lands specialists may supplement this handbook. Supplements should be used to further explain NRCS policy, provide additional details for technical procedures described in this handbook, or to provide additional guidance in planning and applying conservation practices on grazing lands. Copies of state-level supplements should be sent to the NRCS national program leader for range and pasture and to the director of the NRCS Grazing Lands Technology Institute.

(b) Technical guides

State conservationists, assisted by grazing land specialists and other NRCS personnel, prepare and keep current technical guides for grazing lands. These guides contain standards needed to:

- Evaluate the potential of rangeland, grazed forest land, and native and naturalized pasture by identifying and describing ecological sites and other interpretive groupings.
- Determine the similarity index of rangeland in relation to its potential and to assess the forage value rating on all grazing lands.
- Identify stable and sustainable ecological states for rangeland that provide identified and desired benefits, and describe appropriate management inputs to achieve them.
- Develop sound specifications for conservation practices for all grazing lands.

- Help landowners and managers select and apply the conservation practices needed to improve and conserve the soil, water, air, plant, and animal resources of their land for all acceptable uses.
- Assist landowners to develop Resource Management Systems (RMS) that meet locally established quality criteria for their resources that prevent degradation and permit sustainable use.

(c) Interdisciplinary action

Line officers, rangeland management specialists, pasture management specialists, agronomists, biologists, foresters, soil scientists, hydrologists, animal scientists, economists, and other specialists work together to provide coordinated guidelines for use and management of grazing lands. Most land has the potential for more than one use, which is best recognized and provided for through multidisciplinary action.

(d) Soil surveys

The *National Soil Survey Handbook* provides policy and procedures for making soil surveys on grazing lands, making interpretations from soil surveys for potential native plant communities, and publishing soil surveys.

The *National Planning Procedures Handbook* outlines procedures for using information about soils in resource conservation planning.

(e) Plants

NRCS policy states that communications about, reference to, and the collection of data about plant species be based upon the information maintained in the National PLANTS information system. The NRCS standard for plant species names, symbols, and basic attributes is maintained in PLANTS, which can be accessed though FOCS PLANTS and the Internet (http://plants.usda.gov).

(f) Technical assistance

Technical assistance to land users is to be provided according to the provisions in the *National Planning Procedures Handbook* (NPPH). The NPPH gives guidance to NRCS planners for providing alternatives and assistance to address all resources during the conservation planning process on all land units.

(1) Assistance to users

To achieve the conservation objectives for individual operating units, NRCS assists users of grazing lands in developing and implementing their conservation plans on the basis of a scientific inventory of soil, water, plant, animal, and wildlife habitat resources. The objective is to help all users of grazing lands become conservationists. Group planning and application assistance, as well as assistance to communities and units of government, are provided as appropriate to supplement work with individual users of grazing lands.

(2) Guidance on stocking rates

NRCS is responsible for:

- Providing cooperators with information on initial stocking rates applicable to different kinds of grazing lands and the current status of the plant cover.
- Explaining to cooperators how to use this information to initiate sound grazing management.
- Encouraging cooperators to plan long-term operations based on proper use of forage and to make timely adjustments in grazing use to ensure efficient harvest while maintaining or improving the plant community.

(3) Followup assistance

Followup assistance is needed to ensure progress in implementing conservation plans, especially those relating to grazing management practices. District conservationists assure that enough time is scheduled to provide cooperators adequate assistance in applying planned conservation practices and in keeping their conservation plans current.

(4) Assistance on federally administered public land

Under specific circumstances NRCS furnishes technical assistance on public land under Federal management. Such assistance is provided through respective soil and water conservation districts in accordance with agreements with all agencies concerned.

(i) Developing and revising ecological site descriptions on lands administered by BLM and BIA—The NRCS, Bureau of Indian Affairs (BIA) and Bureau of Land Management (BLM) each have statutory authority and responsibilities for rangeland and forest land inventory, appraisal, and monitoring. Accurate ecological site descriptions are necessary to carry out those responsibilities. NRCS policy is to cooperate with the BLM and BIA in the development and refinement of ecological site descriptions.

Local NRCS, BIA, and BLM employees jointly determine when new or revised sites are necessary. When a revision is needed, the NRCS district conservationist in concert with appropriate BLM or BIA program managers establishes an interagency team that includes essential resource specialists.

Drafts of revised or new site descriptions are sent to the appropriate BLM, BIA, and NRCS state offices. The NRCS state conservationist is responsible for sending the draft site descriptions to the appropriate BLM or BIA office along with a copy of all correspondence pertaining to the site description. New site descriptions are field tested for at least 1 year prior to final adoption or approval by NRCS. During this time field offices may proceed with mapping of the site, being careful to maintain identity of the site in question so that the soils can be correctly assigned at a later date.

When revising draft site descriptions, field office or area office personnel must remember the need for interstate and intrastate correlations. Consultation with the Forest Service, Extension Service, and academia may also be advisable.

BIA and BLM field office employees may draft proposed revisions or new site descriptions based on preliminary, informal discussions with their counterparts in NRCS when they need revisions or new site descriptions and NRCS is unable to provide assistance because of budgetary or staffing constraints. These draft descriptions are sent to the appropriate NRCS office(s) for concurrence and processing.

(5) Project plans and environmental assessments

Line officers schedule grazing land specialists to work with project leaders to provide grazing land resource information and interpretations for inclusion in work plans along with other resource information. Appropriate procedures are described in the *National Planning Procedures Handbook* and *National Watersheds Manual.* If procedures are developed on an interagency basis, NRCS procedures and standards are to be clearly presented to participating-agency representatives and used to the fullest extent practicable.

(g) Grazing lands applications

The Grazing Lands Applications (GLA) planning software is a decision-support system planning tool that can be used in the NRCS planning process on all grazing lands. NRCS employees may begin using GLA for all planning and application activities on grazing lands upon receipt of formal training. Professional judgment and experience are used to determine if computerized assistance is needed and whether additional or alternative tools are appropriate.

(h) Prescribed burning

NRCS supports and encourages prescribed burning on rangeland, pastureland, forest land, hayland, Conservation Reserve Program (CRP) land, and wildlife land to meet specific resource management objectives. The NRCS policy on prescribed burning on grazing lands is in appendix A of this handbook. The national standard for prescribed burning is in the *National Handbook of Conservation Practices.*

(i) Riparian area recognition and management

Riparian areas are natural ecosystems that occur along watercourses or waterbodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics, which are strongly influenced by free or unbound water in the soil. Riparian areas are not a separate land use, but exist within all land types and uses. Complete NRCS policy on riparian areas is in General Manual, 190-ECS, Issue-8, Part 411.

(j) Resource interpretations

Ecological sites are the interpretive units for native grazing lands. Primary productivity in kinds, proportions, and amounts (air-dry weight) of plants is the major criterion for identifying and describing these sites. For pasture, hayland, and grazed cropland, the potential to produce vegetation can be interpreted through suitability groups or on appropriate grouping of soils.

(k) Relations

(1) General

Under the guidance of line officers, grazing land specialists establish and maintain effective working relationships with agencies, organizations, and institutions and help them to understand NRCS objectives and procedures. Needed agreements or commitments are made by line officers responsible for the work. Effective relationships with academic departments; producer, conservation, and environmental organizations; personnel in other agencies; and soil and water or resource conservation districts are important in furthering NRCS programs dealing with grazing lands.

(2) Relationship of NRCS and grazing land consultants

Consultants in grazing land management provide expertise and services for a fee to grazing land owners and cooperators. Consultants, among other things, increase the awareness and interest of livestock operators in grazing management and grazing systems. This increased interest has, in many locations, created additional demands for NRCS technical assistance.

Field offices provide a list of available consultants upon request to conservation district cooperators and other clientele. NRCS does not endorse or exclusively recommend any one vendor, contractor, consultant, grazing system or method, service offered by a consultant, or trade name product. It is important that NRCS personnel avoid preferential treatment or the appearance of it.

Some consultants offer range management training. NRCS employees may participate in this nongovernment training, within budgetary constraints, when it satisfies a training need and is advantageous to the Service.

Chapter 2 Grazing Lands Resources

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Chapter 2 Grazing Lands Resources

600.0200 Extent

Of all lands in the United States, 59 percent are privately owned, 6 percent are owned by state and local governments, 2 percent are Native American lands, and 33 percent are publicly owned Federal lands. For the purpose of this handbook, the term *private grazing land* represents all non-Federal grazing lands.

Forty-seven percent of all private land in the U.S. is grazed land; while 25 percent is ungrazed forest land; 24 percent is ungrazed cropland; and 4 percent is other land.

There are about 634 million acres of non-Federal grazing land in the United States. Rangeland comprises 401 million acres, and pastureland comprises 130 million acres while grazed forest land and hayland comprise 64 and 39 million acres, respectively. The amount of grazed cropland varies annually.

600.0201 Uses and benefits

Grazing lands ecosystems are a complex set of interactions between soil, water, air, plant, and animal resources; temperature; topography; fire; and humans. Any influences exerted on one of these components affects the others. These ecosystems provide water, forage, fish and wildlife populations, wildlife habitat, mineral deposits, wood, landforms, atmospheric visibility, and biological processes. Depending upon the management applied, some of the benefits and services that are derived or directly obtained are:

- Water for domestic, municipal, industrial, and commercial uses
- Livestock products
- Flood protection
- Waste assimilation
- Scenery
- Recreation
- Wood products
- Minerals
- Ecological continuity

The many uses and values of private grazing lands make them extremely important, not only to the landowners, but to the entire nation. Private grazing lands greatly increase the U.S. land area that can be used to produce plants for food purposes. Many native grazing lands will not support cultivated crop production because of soil characteristics, topography, and climatic constraints. They do support vegetation that can be grazed by livestock to transform this renewable resource into food and fiber products.

Proper management is essential for the sustainable production of food and fiber, as well as supporting a wide diversity of other uses. Healthy grazing lands provide an economic base for many regions of our country.

Many benefits of good grazing land management are measured in qualitative terms, such as better air quality, improved water quality, improved wildlife habitat, and a quality recreational experience. These benefits, whether obtained directly or derived indirectly from grazing lands, do not have established market values. This makes the total value of grazing land benefits and services difficult to ascertain. Some of the benefits are easier valued (e.g., livestock forage, wood products), and others are more difficult to value (e.g., scenery, water quality, recreation). The estimated value of forage used by the livestock industry in 1996 was $2.5 billion.

600.0202 Native grazing lands in the United States

(a) Rangeland

Rangeland is a kind of land on which the historic climax vegetation was predominantly grasses, grass-like plants, forbs, or shrubs. Rangeland includes land revegetated naturally or artificially to provide a plant cover that is managed like native vegetation. Rangelands include natural grasslands, savannas, most deserts, tundra, alpine plant communities, coastal and freshwater marshes, and wet meadows.

Non-Federal rangelands comprise 63 percent of the non-Federal grazing lands in the United States. There are more than 400 million acres of non-Federal rangeland in the U.S. They provide numerous products and have many values and uses. Rangelands are a primary source of forage for domestic livestock and for wildlife. Rangelands provide water for urban, rural, domestic, industrial, and agricultural use. They provide wildlife habitat, areas for natural recycling, purification of the air, and carbon sequestration. Rangelands have aesthetic value, provide open space, and buffers for urban areas. They are a vital link in the enhancement of rural social stability and economic vigor.

(b) Forest land

Forest land traditionally provides a diverse range of commodity and non-commodity products and values, including wood products, grazing for wildlife and livestock, high quality water, wildlife and fish habitat, recreational opportunities, and aesthetic and spiritual values. Forest land is often closely associated with or inseparable from other land resources, such as rangeland, pastureland, riparian areas, cropland, and urban-forest interfaces.

Over 60 million acres of privately owned and managed forest lands in the United States produce understory vegetation that is used for the production of livestock. Forest land that naturally has widely spaced trees, such as ponderosa pine and some southern pines, normally produces a crop of forage each year. These forested areas are defined and described as grazed forest lands.

Grazed forest lands comprise about 10 percent of the total U.S. grazing land resources that are not in Federal ownership. These forested areas have considerable value and uses. Production of wood products is a primary use of these lands. They also produce forage for livestock and wildlife and provide habitat for many game and non-game species of wildlife. The forested areas are important locations for outdoor recreation including fishing, camping, and hiking. In western regions they are important snowfall accumulation zones and play a critical role in maintaining summer streamflows. In western mountains they provide critical summer forage supplies when other grazing resources are dry and dormant. Many also supply wood products, such as timber, firewood, poles, and posts, and edible products, such as pinenuts.

Forest land of such species as fir, spruce, hemlock, and Douglas-fir, and many hardwood forests generally maintain a dense stand of trees. As a result, a grazed understory is produced only periodically following such activities as clearcutting, selective logging or thinning, or fire.

(c) Native and naturalized pasture

Native and *naturalized pasture* are defined as forest land and naturalized open areas other than rangeland that are used primarily for the production of forage for grazing by livestock and wildlife. Overstory trees, if present, are managed to promote naturally occurring native and introduced understory forage species occurring on the site. These lands are managed for their forage value through the use of grazing management principles. These lands do not receive the cultural management received by pastureland (see section 600.0203(b)).

Native and naturalized pasture provides a valuable source of forage for livestock and wildlife. It also provides habitat for many species of wildlife and adds diversity to watershed landscapes.

Native and naturalized pasture may be virtually free of tree growth or may have a partial, or rarely, a full stand of trees.

Areas identified as native and naturalized pasture include:

- Forest land depleted of trees by harvesting, fire, or other disturbances. (The management objective is not to restore the tree stand, but to develop and manage understory vegetation.)
- Forest land on which trees have been removed or extensively thinned for the specific purpose of increasing the grazing resource.
- Certain noncommercial deciduous forest land maintained primarily for grazing.
- Forest land that was previously cleared and managed as cropland or pastureland, but has reverted to a voluntary stand of native and/or naturalized vegetation.

Native and naturalized pasture may be stable, or it may naturally revert back to a forest dominated plant community unless practices are applied to keep it in a herbaceous state.

600.0203 Forage croplands and pasturelands

(a) General

Forage croplands and pasturelands are agricultural lands devoted, entirely or partially, to the production of introduced or native forage crops for livestock feeding. They receive cultural treatment to enhance forage quality and yields. The livestock raised on these lands may be pastured, be confined and fed stored forages, or be fed by both methods. Cultural treatments are the human inputs of labor, material, and skill to raise a crop. On forage producing lands, they include at least one of the following practices: clipping, crop residue management, crop rotation, drainage, fertilization, irrigation, landclearing, mechanical harvest, pest control (e.g., brush, diseases, insects, and weeds), planting, rock picking, selection of new species and/or cultivars, soil amendment applications (e.g., compost, gypsum, lime, and manure), and tillage.

Manipulation of grazing intensity, duration, and distribution is not considered a cultural treatment for purposes of definition of forage cropland and pastureland.

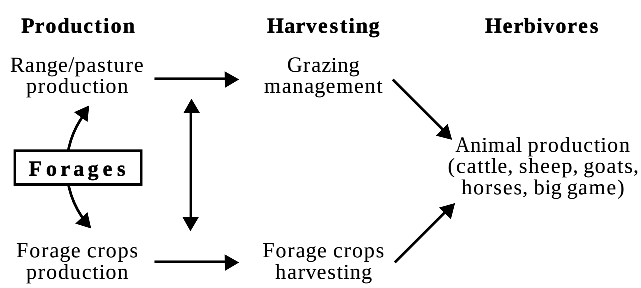
Forage cropland is forage plants mechanically harvested before being fed to animals. Forage crop production occurs primarily on cropland and hayland, which generally are machine harvested, but may be grazed. Pastureland is principally harvested by grazing animals, but may be machine harvested to accumulated stored forage. As shown by the vertical arrow in figure 2–1, the land uses serve a dual use purpose in many instances.

Forage croplands and pasturelands are the plant, soil, and water resource base of a farming system called grassland agriculture. This farming system emphasizes the importance of forages in livestock production and land management. The forage croplands and pasture are raised to provide feed to livestock and to protect the air, soil, and water resources from degradation. The forage crops are central to the cropping rotation strategy employed by the land unit manager. The other crops, if any, are in the rotation to provide a more balanced livestock feed ration, prepare the ground for a new forage seeding, or diversify farm income.

Forage crops are important to the crop rotation mix for several environmental reasons:

- Once established, most provide an erosion resistant cover.
- Their root systems, especially of the perennial species, promote soil aggregation that improves soil aeration, tilth, and moisture conditions.
- With time, they increase soil organic matter content, primarily through the production of root biomass. This sequesters carbon dioxide, a greenhouse gas.
- In rotation with other crops, they can break up life cycles of some weed, insect, and disease pests, thus decreasing reliance on chemical controls.
- Legume forage crops provide fixed nitrogen to grass species grown in association with them or to later crops in the rotation.
- They restore microfauna populations often lost under intensive row crop production by providing a more stable and inviting soil habitat.
- They can add to landscape diversity.
- Depending on management, spatial arrangement with other land uses, and wildlife species present, they can add a source of wildlife food, cover, and habitat diversity.
- Depending on position on the landscape, length of time and sequencing in the crop rotation, and plant architecture and physiology, they can act as nutrient sinks and sediment traps to protect surface and ground water from unwanted contaminants.

Figure 2–1 Two track production-harvesting system of forage conversion by herbivores on forage crops and pasturelands (Vallentine 1990)



(b) Pastureland

Pastureland, often called improved pasture, or tame pasture, is defined as grazing land permanently producing introduced or domesticated native forage species receiving varying degrees of periodic cultural treatment to enhance forage quality and yields. It is primarily harvested by grazing animals. Permanent pastureland in this context means the present operator has no desire to change the land use or rotate crops in the field.

Pastureland does not include native or naturalized pasture that is permanent pastureland receiving no recent cultural management. Pastureland also does not include rotational pasture that is part of a cropland rotation. Pastureland may be machine harvested when and where the need arises, site conditions permit, and the forage type is of sufficient stature, quantity, and quality to permit efficient machine harvest preserving. If part of the annual growth is machine harvested, but regrowth is available and used for grazing during the majority of the growing season, the primary land use is pasture. If the machine harvesting schedule results in little or no appreciable regrowth for grazing, the primary land use is then cropland or hayland. If the crop being mechanically harvested is other than a forage crop, but is grazed either before or after harvest, the primary land use is cropland.

According to the 1992 National Resources Inventory, pastures comprise 21 percent, or about 126 million acres, of the private grazing lands resource. This is total permanent pasture including improved, native, and naturalized pasture.

(c) Cropland and hayland

Cropland is defined as land used for the production of cultivated crops, including forage crops, and harvested primarily by human labor and equipment. As a secondary use, cropland can be grazed by livestock. Cropland producing machine harvested forage crops may also be grazed. Grazing occurs on this cropland either as an emergency procedure after a drought or other unanticipated shortfall or as part of a planned pasture rotation system. Cropland producing grazable residue is often grazed following harvest.

Forage can be defined as the edible parts of plants, other than separated grain, that can provide standing feed for grazing animals or be harvested for feeding. Crops that are sometimes classified as grain crops are also forages, such as corn and sorghum grown for silage. Small grains may also be ensiled or baled as cured hay. In this context they are as much forages as alfalfa, bermudagrass, or any other grass or legume typically regarded as a forage crop.

Cropland as a grazable resource has five main forage categories:

- Mechanically harvested forages
  - — Legume-grass
  - — All grass
  - — All legume
- Pre-harvest cropland pasture
- Post-harvest cropland pasture
- Supplemental or emergency cropland pasture
  - — Summer annuals
  - — Winter annuals
- Crop-rotation pasture

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National Range and Pasture Handbook

Chapter 3 Ecological Sites and Forage Suitability Groups

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Chapter 3 Ecological Sites and Forage Suitability Groups

Landscapes are divided into basic units for study, evaluation, and management. On rangelands and forest lands, these units are called ecological sites; while on forage croplands and pasturelands, they are forage suitability groups. This chapter provides an explanation and understanding of these basic units, as well as instructions on how to develop an ecological site description and a forage suitability group description.

Chapter 3 is divided into two basic sections. Section 1 deals with ecological sites for native grazing lands. Ecological site descriptions contain information about soils, physical features, climatic features, associated hydrologic features, plant communities possible on the site, plant community dynamics, annual production estimates and distribution of production throughout the year, associated animal communities, associated and similar sites, and interpretations for management.

Section 2 of this chapter deals with forage suitability groups for agronomically managed grazing lands. Forage suitability groups (FSG) condense and simplify soils information. They provide the soil and plant science information for planning. The forage suitability groups description contains the soil map units that make up the FSG, adapted forage species and planting mixtures, limitations of the FSG, conservation problems associated with the various limitations, annual forage production estimates, and distribution of production during the growing season.

Chapter 3 Ecological Sites and Forage Suitability Groups

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Section 1 Ecological Sites for Rangeland and Forest Land

Chapter 3 — Ecological Sites and Forage Suitability Groups

Section 1 — Ecological Sites for Rangeland and Forest Land

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600.0300 Rangeland ecological sites

(a) Definition

Rangeland landscapes are divided into ecological sites for the purposes of inventory, evaluation, and management. An ecological site, as defined for rangeland, is a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.

An ecological site is the product of all the environmental factors responsible for its development, and it has a set of key characteristics that are included in the ecological site description. Ecological sites have characteristic soils that have developed over time throughout the soil development process. The factors of soil development are parent material, climate, living organisms, topography or landscape position, and time. These factors lead to soil development or degradation through the processes of loss, addition, translocation, and transformation.

An ecological site has a characteristic hydrology, particularly infiltration and runoff, that has developed over time. The development of the hydrology is influenced by development of the soil and plant community.

An ecological site has evolved a characteristic plant community (kind [cool season, warm season, grassland, shrub-grass, sedge meadow] and amount of vegetation). The development of the vegetation, the soil, and the hydrology are all interrelated. Each is influenced by the others and influences the development of the others. The plant community on an ecological site is typified by an association of species that differs from that of other ecological sites in the kind and/or proportion of species, or in total production.

Most ecological sites evolved with a characteristic kind of herbivory (kinds and numbers of herbivores, seasons of use, intensity of use). Herbivory directly influences the vegetation and soil, both of which influence the hydrology.

An ecological site evolved with a characteristic fire regime. Fire frequency and intensity contributed to the characteristic plant community of the site.

Soils with like properties that produce and support a characteristic native plant community are grouped into the same ecological site.

An ecological site is recognized and described on the basis of the characteristics that differentiate it from other sites in its ability to produce and support a characteristic plant community.

600.0301 Plant community development and dynamics

(a) Succession and retrogression

Succession is the process of soil and plant community development on an ecological site. Retrogression is the change in species composition away from the historic climax plant community because of management or severe natural climatic events.

Succession occurs over time and is a result of interactions of climate, soil development, plant growth, and natural disturbances. Plant succession is defined as the progressive replacement of plant communities on an ecological site that leads to development of the historic climax plant community.

Primary succession is the formation process that begins on substrates having never previously supported any vegetation (lava flows, volcanic ash deposits, etc.). Secondary succession occurs on previously formed soil from which the vegetation has been partially or completely removed.

In some locations, primary succession was never completed before the site was disturbed by human intervention. An example is the historic lakebed of Lake Bonneville in the Great Basin area of Utah, Nevada, and Idaho.

Ecological site development, along with associated climatic conditions and normal disturbances (occurrence of fire, grazing, flooding) remaining within normal ranges, produces a plant community in dynamic equilibrium with these conditions. This plant community is referred to as the historic climax plant community. Vegetation dynamics on an ecological site includes succession and retrogression. The pathway of secondary succession is often not simply a reversal of disturbances responsible for retrogression and may not follow the same pathway as primary succession.

(b) Historic climax plant communities

The historic climax plant community for a site in North America is the plant community that existed at the time of European immigration and settlement. It is the plant community that was best adapted to the unique combination of environmental factors associated with the site. The historic climax plant community was in dynamic equilibrium with its environment. It is the plant community that was able to avoid displacement by the suite of disturbances and disturbance patterns (magnitude and frequency) that naturally occurred within the area occupied by the site. Natural disturbances, such as drought, fire, grazing of native fauna, and insects, were inherent in the development and maintenance of these plant communities. The effects of these disturbances are part of the range of characteristics of the site that contribute to that dynamic equilibrium. Fluctuations in plant community structure and function caused by the effects of these natural disturbances establish the boundaries of dynamic equilibrium. They are accounted for as part of the range of characteristics for an ecological site. Some sites may have a small range of variation, while others have a large range. Plant communities that are subjected to abnormal disturbances and physical site deterioration or that are protected from natural influences, such as fire and grazing, for long periods seldom typify the historic climax plant community.

The historic climax plant community of an ecological site is not a precise assemblage of species for which the proportions are the same from place to place or from year to year. In all plant communities, variability is apparent in productivity and occurrence of individual species. Spatial boundaries of the communities; however, can be recognized by characteristic patterns of species composition, association, and community structure.

(c) State and transition models

A state and transition model will be used to describe vegetation dynamics and management interactions associated with each ecological site. The model provides a method to organize and communicate complex information about vegetation response to disturbances (fire, lack of fire, drought, insects, disease, etc.) and management.

A state is a recognizable, relatively resistant and resilient complex with attributes that include a characteristic climate, the soil resource including soil biota, and the associated aboveground plant communities. The soil and vegetative components are inseparably connected through ecological processes that interact to produce a sustained equilibrium that is expressed by a specific suite of plant communities. The primary ecological processes are water cycle, nutrient cycle, and the process of energy capture. Each state has distinctive characteristics, benefits, and values depending upon the intended use, products, and environmental effects desired from the site.

Two important attributes of a state are resistance and resilience. Resistance refers to the capability of the state to absorb disturbance and stresses and retain its ecological structure. Resilience refers to the amount of disturbance or stress a state can endure and still regain its original function after the disturbances and stresses are removed.

States are relatively stable and resistant to change caused by disturbances up to a threshold point. A threshold is the boundary between two states such that one or more of the ecological processes has been irreversibly changed. Irreversible implies that restoration cannot be accomplished through natural events or a simple change in management. Active restoration (brush management, range planting, prescribed burning, etc.) must be accomplished before a return to a previous state is possible. Additional thresholds may occur along the irreversible portion of a transition causing a change in the trajectory toward another state as illustrated in figure 3–1. Once a threshold is crossed, a disequilibrium among one or more of the primary ecological processes exists and will be expressed through changes in the vegetative community and eventually the soil resource. A new stable state is formed when the system reestablishes equilibrium among its primary ecological processes.

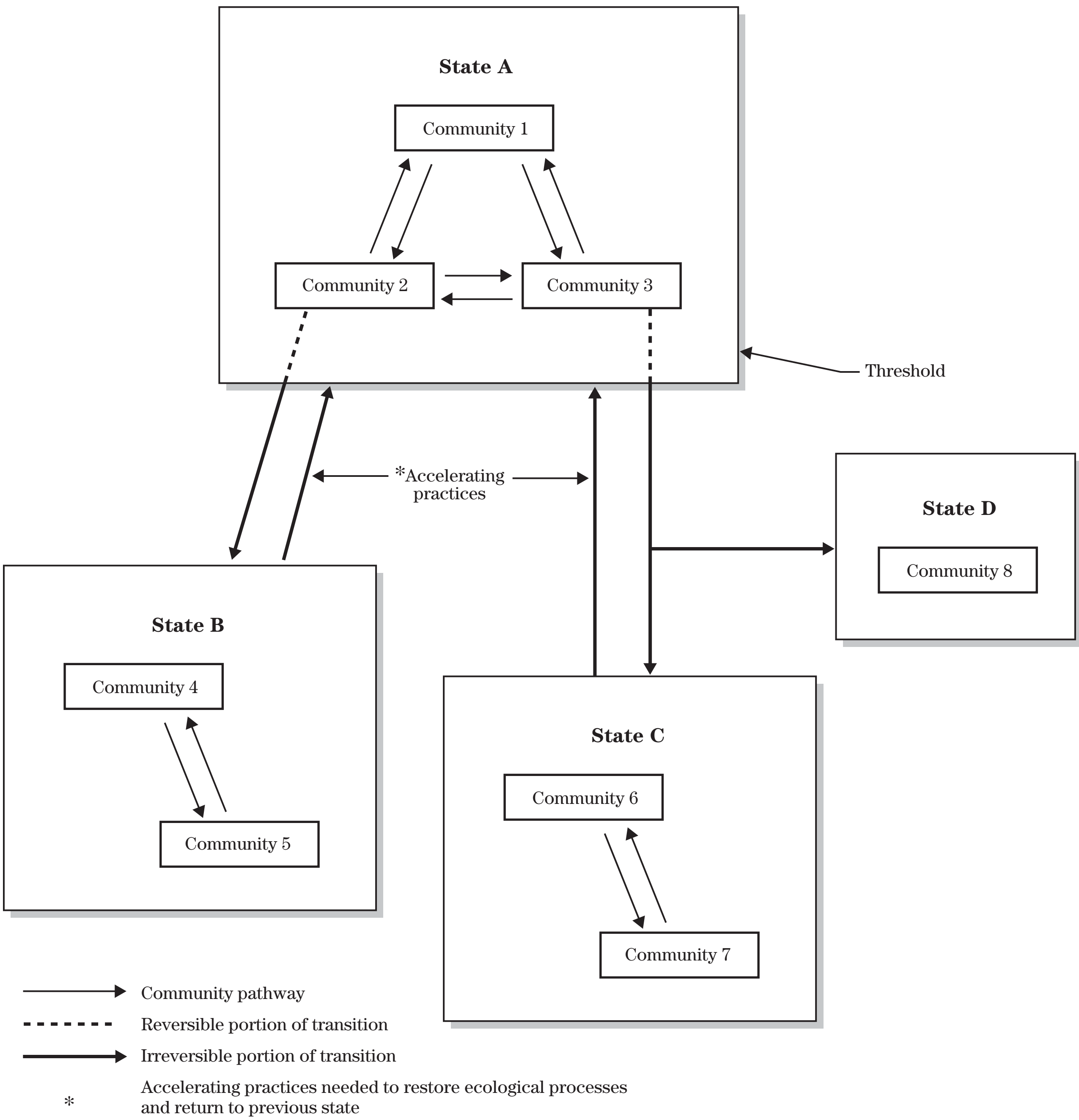
Transition is the trajectory of system change between states that will not cease before the establishment of a new state. A transition can be triggered by natural events, management actions, or both. Some transitions may occur very quickly and others over a long period. Two phases of a transition are recognized: reversible and irreversible. Prior to crossing a threshold, a transition is reversible and represents an opportunity to reverse or arrest the change. Vegetation management practices and, if needed, facilitating practices are used to reverse the transition. Once a threshold is crossed, the transition is irreversible without significant inputs of management resources and energy. Significant inputs are associated with accelerating practices, such as brush management and range planting.

States are not static, as they encompass a certain amount of variation because of climatic events, management actions, or both. Dynamics within a state do not represent a state change since a threshold is not crossed. To organize information for management decisionmaking purposes, these different expressions of dynamics within the states may need to be described. These different vegetative assemblages within states will be referred to as plant communities and the change between these communities as community pathways.

Figure 3–1 illustrates the different components of a state and transition model diagram for an ecological site. States are represented by the large boxes and are bordered by thresholds. The small boxes represent plant communities with community pathways representing the cause of change between communities. The entire trajectory from one state to another state is considered a transition (i.e., from State A to State B). The portion of the transition contained within the boundary of a state is considered reversible with a minimum of input from management. Once the transition has crossed the threshold, it is not reversible without substantial input (accelerating practices). The arrow returning to a previous state (State B to State A) is used to designate types of accelerating practices needed. Additional thresholds occurring along a transition may change the trajectory of a transition (from State C to State D).

The first state described in an ecological site description is the historic climax plant community or naturalized plant community. From this state, a "road map" to other states can be developed. Each transition is to be identified separately and described, incorporating as much information as is known concerning the causes of change, changes in ecological processes, and any known probabilities associated with the transitions. Plant communities and community pathways within states may be described as needed.

Figure 3–1 Example of state and transition model diagram for an ecological site



(d) Naturalized plant communities

Ecological site descriptions are to be developed for all identified ecological sites. In some parts of the country, however, the historic climax plant community has been destroyed, and it is impossible to reconstruct that plant community with any degree of reliability. In these regions, site descriptions will be developed using the naturalized plant communities for the site. The use of this option for ecological site descriptions is limited to those sites where the historic climax plant community has been destroyed and cannot be reconstructed with any degree of reliability. Examples of the areas in the United States where this may be used are the State of Hawaii, the Caribbean Area, and the annual grasslands of California. Approval to describe additional rangeland ecological regions in this way must be obtained from the national program leader for range and pasture.

(e) Permanence and change of ecological site potential on rangeland

Retrogression can occur on a given ecological site resulting in a number of different states depending on the type of disturbance(s), the sequence of disturbances, climatic variations, and other variables. Many states that are considered vegetative expressions of degraded historic climax plant communities are stable and can persist for many years without evidence of secondary succession. This persistence certainly extends beyond practical timeframes for use and management planning. As long as the physical environment supporting these states remains similar to that unique mix of conditions required by the historic climax plant community, change to another ecological site is not recognized. The ecological potential for the site is not considered to have been altered merely because the present state is stable and can persist for many years.

Severe physical deterioration can permanently alter the potential of an ecological site to support the original plant community. Examples include permanently lowering the water table, severe surface drainage caused by gullying, and severe soil erosion by water or wind. When the ecological site's potential has significantly changed, it is no longer considered the same site. A change to another ecological site is then recognized, and a new site description may need to be developed based on its altered potential.

Some ecological sites have been invaded by or planted to introduced species. The introduced species may become well established or naturalized to the site. They may dominate the site, or they may continue to occupy part of the site even when secondary succession has restored the plant community to near historic climax conditions. In these cases of invasion or introduction of introduced species, a change in ecological site is not recognized because the edaphic and climatic potential for the site has not been altered.

600.0302 Determining the characteristic vegetation states of an ecological site

Where possible, the historic climax plant community for each ecological site is to be determined. Where it is not possible to determine the historic climax plant community, the naturalized plant community will be described. In addition to the historic climax plant community or naturalized plant community, other known states occurring on the site are to be included in the ecological site description.

The description of each state should be considered as an approximation and subject to modification as additional knowledge is gained. Every effort should be made to examine plant communities within the ecological site's area of occurrence during different seasons and in different years. This is necessary to adequately describe the vegetation dynamics within a site.

Characteristics of a state obtained from a single source or site are not conclusive for describing the state. In evaluating plant information, consideration must be given to many factors including:

- Effects of fire or lack of fire
- Impacts of grazing or lack of grazing
- Impacts of rodent concentrations
- Impacts of insects
- Soil erosion or deposition by wind and/or water
- Drought or unusually wet years
- Variations in hydrology and storm events
- Plant disease
- Introduced plant species

The following methods are used in determining the characteristic states of an ecological site:

- Identification and evaluation of reference sites with similar plant communities and associated soils. When describing the historic climax plant community, the reference sites should not have been subjected to abnormal disturbances (or the lack of normal disturbance). The productivity and the species composition of the plant community should be evaluated.
- Interpolation and extrapolation of plant, soil, and climatic data from existing historic reference areas along a continuum to other points on that continuum for which no suitable reference community is available.
- Evaluation and comparison of the same ecological sites occurring in different areas, but that have experienced different levels of disturbance and management. Further comparison should be made with areas that are not disturbed. Projecting the response of plant species to given disturbances and relating the present day occurrence of species on a site to past disturbances (type and extent of disturbance, frequency, and magnitude) provides a basis for approximating certain vegetative characteristics of the plant community.
- Evaluation and interpretation of research data dealing with the ecology, management, and soils of plant communities.
- Review of historical accounts, survey and military records, and botanical literature of the area.

The NRCS Ecological Site Inventory Information System (ESIS)-Ecological Site Inventory (ESI) database can provide useful data in identifying plant communities. This database can be accessed on the Internet at

http://plants.usda.gov/esis

(a) Differentiation between ecological sites

When writing an ecological site description, the following criteria are used to differentiate one ecological site from another:

- Significant differences in the species or species groups that are in the historic climax plant community.
- Significant differences in the relative proportion of species or species groups in the historic climax plant community.
- Significant differences in the total annual production of the historic climax plant community.
- Soil factor differences that determine plant production and composition, the hydrology of the site, and the functioning of the ecological processes of the water cycle, nutrient cycles, and energy flow.

Initial guidelines for determining significant differences follow:

- Presence (or absence) of one or more species that make up 10 percent or more of the historic climax plant community by air-dry weight.
- A 20 percent (absolute) change in composition, by air-dry weight, between any two species in the historic climax plant community.
- A difference in average annual herbaceous production of
  - — 50% @ 200–500 lb/ac
  - — 30% @ 500–1,000 lb/ac
  - — 20% @ 1,000 lb/ac or greater
- Any differences in guidelines above, either singly or in combination, great enough to indicate a different use potential or to require different management are basis for establishing or differentiating a site.

The above guidelines for initial comparisons are not definitive for site differentiation or combination. The differences between sites may be finer or broader than these guidelines. Rationale and the site features listed in the respective ecological site descriptions should readily and consistently distinguish the differences.

Differences in kind, proportion, and/or production of species are the result of differences in soil, topography, climate, and other environmental factors. Slight variations in these factors are not criteria for site differentiation; however, individual environmental factors are frequently associated with significant differences in historic climax plant communities. The presence or absence of a water table within the root zone of highly saline soil in contrast to a nonsaline soil is dramatically reflected in plant communities that such soils support. Marked changes in soil texture, depth, and topographic position usually result in pronounced differences in plant communities, total production, or both. Therefore, such contrasting conditions in the soil characteristics, climate, topography, and other environmental factors known to be associated with a specific ecological site can be used as a means of identifying the site when the historic climax plant community is absent.

Generally, one species or a group of species dominates a site. Dominant status does not vary from place to place or from year to year. Because of their stability in the historic climax plant community, dominant species can often be used to distinguish sites and to differentiate one site from another. When dominant species are in equal proportion, species in minor proportions can be used to distinguish sites.

In evaluating the significance of kinds, proportion, and production of species or species groups that are dominant in a historic climax plant community, and given different soil characteristics, the relative proportion of species may indicate whether one or more ecological sites are involved. For example, in one area the historic climax plant community may consist of 60 percent big bluestem and 10 percent little bluestem, and in another area it may consist of 60 percent little bluestem and 10 percent big bluestem. Thus, two ecological sites are recognized. Although the production and species are similar, the proportion's difference distinguishes them as separate sites.

The effect of any single environmental factor can vary, depending on the influence of other factors. For example, soil depth is more significant on a site that receives extra water from runoff or in a high precipitation zone, than on an upland site in a low precipitation area. An additional 2 inches of annual rainfall may be highly important in a section of the country that has an arid climate, but of minor significance in a humid climate. A difference in average annual production of 100 pounds per acre, dry weight, is of minor importance on ecological sites capable of producing 2,000 pounds per acre. This difference, however, is highly significant on sites capable of producing only 200 to 300 pounds per acre. Similar variations in degree of significance apply to most factors of the environment. Consequently, in identifying an ecological site, consideration must be given to its environment as a whole as well as to the individual components.

Where changes in soils, aspect, topography, or moisture conditions are abrupt, ecological site boundaries are distinct. Boundaries are broader and less distinct where plant communities change gradually along broad environmental gradients of relatively uniform soils and topography. Making distinctions between ecological sites along a continuum is difficult. Thus, the need for site differentiation may not be readily apparent until the cumulative impact of soil and climatic differences on vegetation is examined over a broad area. Although some plant communities may appear to be along a continuum, distinctive plant communities can be identified and described.

At times, normally less frequently occurring plants may increase on a site, or the site may be invaded by plants not formerly found in the historic climax plant community. The presence or absence of these plants may fluctuate greatly because of differences in microenvironment, weather conditions, or human actions. Consequently, using them for site identification can be misleading, so they should not be used to differentiate sites. Site differentiation, characterization, and determination are based on the plant community that develops along with the soils. A study of several locations over several years is needed to differentiate and characterize a site.

Availability and accessibility to domestic livestock grazing are not factors in ecological site determination and differentiation. Site differentiation is based on those soil characteristics, response to disturbance, and environmental factors that directly affect the nature of the historic climax plant community composition and production.

(b) Assembly of ecological site data

To evaluate plant communities and to make meaningful distinctions between ecological sites, the data collected at each location must be recorded in an orderly manner. Complete data on species, composition, production, soils, topography, climate, and other pertinent factors should be recorded carefully. Using plant association tables to assemble data makes it possible to readily identify the important similarities and differences. Exhibit 3.1–1 is a recording of production and composition data from sample locations that includes four identified soils on which the plant community was assumed to be climax. Exhibit 3.1–2 illustrates the means by which these data are used to group similar plant communities into ecological sites. It also illustrates that composition and production of the historic climax plant community on one soil is consistently comparable and that different soils can be grouped into a single ecological site. The occurrence in three plant communities of Idaho fescue, a significant difference in forb and shrub components, and a significant difference in production indicate two different sites.

The Ecological Site Inventory database contains information about species composition and production that has been collected on specific ecological sites. The Ecological Site Inventory database should be used in conjunction with other supporting data for the documentation, modification, and creation of ecological site descriptions.

A documentation file containing all supportive information used for the development and modification of ecological site descriptions will be established and maintained in the state office.

600.0303 Name, number, and correlation of ecological sites

The demand for broader interpretation of rangeland resources, the increasing uses to which ecological site information is being applied, the Ecological Site Information System, and computerized programs for soil classification have created a need for a standardized system of naming or numbering ecological sites.

(a) Naming ecological sites on rangeland

Ecological sites are named to help users recognize the different sites in their locality. Names of ecological sites should be brief and should be based on such readily recognized permanent physical features as the kinds of soil, climate, topography, or a combination of these features. Some examples of ecological site names based on these criteria are Deep Sand, Sandy, Sandy Plains, Limestone Hills, Clay Upland, Saline Lowland, Gravelly Outwash, Level Winding Riparian, Pumice Hills, Sub-irrigated, Wet Meadows, Fresh Marsh, and Sandy Savanna.

Names depicting landforms and using physiographic features that are complexes of ecological sites generally should not be used. Because of vegetation changes or absence in some places, plant names alone are unsuitable ecological site names.

Ecological sites having similar soils and topography may exhibit significant differences in their historic climax plant communities because of climatic differences. For example, the average annual precipitation of the sandy plains of the Oklahoma Panhandle ranges from 16 to 23 inches. Quantitative evaluation indicates that the amount of vegetation produced in areas where precipitation is 16 to 19 inches is significantly less than that produced in areas where precipitation is 20 to 23 inches. Thus two ecological sites are recognized and can be distinguished by the inclusion of the precipitation zone (PZ) in the name of the sites; e.g., Sandy Plains Ecological Site 16-19 PZ and Sandy Plains Ecological Site 20-23 PZ.

The limited number of permanent physiographic features or other features that can be used in naming ecological sites makes repeated use of these terms inevitable. Deep sands, for example, occur in areas of widely divergent climate and support different historic climax plant communities. The name Deep Sand is appropriate for each of these areas, but obviously, it is used throughout the country to designate several ecological sites. Where this occurs within a major land resource area, the applicable precipitation zone or other differentiating factors are to be included as part of the name. Sites that have the same name, but are in different major land resource areas are different sites.

(b) Numbering ecological sites

Ecological sites are numbered for use in the Ecological Site Information System. The ecological site number for rangelands consists of five parts:

1. The letter **R** identifies the type of ecological site as rangeland. This designation precedes the 10-character site number, but is not actually a part of the number.
2. A three-digit number and a one-digit letter Major Land Resource Area (MLRA).
3. A single letter Land Resource Unit (LRU), where applicable.
4. A three-digit site number, assigned by the state.
5. A two-digit letter state postal code.

If the MLRA is only two numbers and no letters, insert a zero in the first space followed by the two numbers. The letters A, B, C, etc., following the MLRA, represent the MLRA subdivisions. Where no MLRA subdivision exists, put an **X** in the fourth space to denote that there is no MLRA subdivision. For states using LRU's, enter appropriate letter in the space provided. Insert a **Y** when LRU's are not used. The next three digits represent the individual ecological site number and are assigned by the state. The first and second digits should be filled with 0's rather than left blank. The final two letters are the state's two-letter postal code. An example ecological site number for rangeland is:

R070CY123NM

(c) Correlating ecological sites

Soil-ecological site correlation establishes the relationship between soil components and ecological sites. Ecological sites are correlated on the basis of soils and the resulting differences in species composition, proportion of species, and total production of the historic climax plant community. Sometimes it is necessary to extrapolate data on the composition and production of a plant community on one soil to describe the plant community on a similar soil for which no data are available. The separation of two distinct soil taxonomic units does not necessarily delineate two ecological sites. Likewise, some soil taxonomic units occur over broad environmental gradients and may support more than one distinctive historic climax plant community. Changes may be brought about by other influences, such as an increase or decrease in average annual precipitation.

Ecological sites are to be correlated between states. Only one name should be given to a single site that occurs in adjacent states within the same MLRA.

The following procedures for soil-ecological site correlation are compatible with procedures in National Soil Survey Handbook, Part 627.

(1) Responsibilities of state conservationists

- Maintain all ecological site descriptions within their state.
- Propose and develop new sites.
- Consult with administrators of cooperating agencies for correlating all sites within their states.
- Designate which state is responsible for maintaining and updating ecological site descriptions when a site occurs in more than one state.

(2) Responsibilities of field personnel

- Collect the necessary documentation for each site.
- Propose draft descriptions for consideration and approval by the appropriate state technical specialist.

(3) Guidelines for internal consistency of soil-ecological site correlation

These guidelines ensure that site characteristics are compatible within each feature and between individual features.

- Portray each individual feature with the narrowest feasible range of characteristics that accurately describes the site.
- Check that all combinations of features are compatible with the range of characteristics that are described for each individual feature. Coordinate the soil moisture and temperature with the climatic features described. Review the compatibility of listed plant species and the soil properties listed under soil features. Check for other apparent inconsistencies.

(4) Guidelines for correlation between ecological sites

- Make comparisons with existing site descriptions when proposing new sites, reviewing existing sites, or correlating between soil survey areas, major land resource areas, or states.
- Compare all sites that have two or more major species in common and all sites that have the same soil family, groups of similar families, or other taxa.

Soil-ecological site correlation normally takes place in conjunction with progressive soil surveys. However, ecological site correlation may also be necessary because of updates or revisions of ecological site descriptions.

600.0304 Ecological site descriptions on rangeland

An ecological site description is prepared for each ecological site that is identified (exhibit 3.1–3). Descriptions should clearly present the features that characterize the site. They are to address all the resources of the site that are important for identifying, evaluating, planning, developing, managing, and monitoring rangeland resources. Descriptions are developed as part of Ecological Site Information System (ESIS) using the ecological site description format for rangelands. ESIS – Ecological Site Description database is the official repository for all data associated with rangeland ecological site descriptions. The state office is responsible for entry and maintenance of site descriptions in this database. A Technical Support Reference (appendix B) and User's Guide (appendix C) for the Ecological Site Description database are in the appendix of this handbook. This database can be accessed at the following Internet site:

http://plants.usda.gov/esis

The description includes the information that follows, as appropriate, along with other pertinent information:

(a) Heading

All ecological site descriptions will identify USDA and Natural Resources Conservation Service.

(b) Ecological site type

All ecological site descriptions will identify whether it is rangeland or forest land.

(c) Ecological site name

The full name of the site should be placed on each page of the description. Refer to section 600.0303(a) for guidance on naming ecological sites on rangeland.

(d) Ecological site ID

The site number begins with an R followed by the site 10-digit number. This number is placed on each page of the description. Refer to section 600.0303(b) for guidance on numbering ecological sites.

(e) Major land resource area

List the major land resource area code and common name.

(f) Physiographic features

Describe the position of the site on the landscape. In reference to the historic climax plant community, does the site typically generate runoff, receive runoff from other sites, or receive and generate runoff. Most of the information for this section can be obtained from the National Soils Information System (NASIS). Physiographic features include:

- Landform (refer to NASIS for list of possible landform types)
- Aspect
- Site elevation
- Slope
- Water table
- Flooding
- Ponding
- Runoff class

(g) Climatic features

Climatic information will be developed and included in the description of the site. Climatic features that typify the site, relate to its potential, and characterize the dynamics of the site, such as storm intensity, frequency of catastrophic storm events, drought cycles, should be included. Climatic features include:

- Frost-free period
- Freeze-free period
- Mean annual precipitation
- Monthly moisture and temperature distribution
- Location of climate stations

(h) Influencing water features

Include information regarding water features where the plant community is influenced by water or water table from a wetland or stream associated with the site. Water features include the Cowardin wetland classification system and Rosgen stream classification system. Enter the system(s), associated subsystem(s), and class(es). If a riverine system is influencing the site, then enter the Rosgen stream code. More than one stream type may be associated with the site.

(i) Representative soil features

Briefly describe the main properties of the soils associated with the site. Give special attention to properties that significantly affect plant, soil, and water relationships and the site hydrology. Describe the extent of rills and gullies found in historic climax plant community. Rills and gullies are inherent to some geologic formations. Describe extent of waterflow patterns across the soil surface during overland flow. Soils with inherently high erodibility and low vegetation cover may have a large number of natural flow patterns. Describe amount and patterns of pedestalling and terracettes caused by wind or water inherent to the historic climax plant community. Describe size and frequency of wind scoured areas. Describe how susceptible the site is to compaction. Describe expected nature of surface organic layer of historic climax plant community. Describe the expected physical and chemical crusts that might be present. Most of the information for this section can be obtained from the National Soils Information System (NASIS). Representative soil features include:

- Parent materials
- Surface texture
- Subsurface Texture
- Surface fragments
- Subsurface fragments
- Drainage class
- Permeability Class
- Depth
- Electrical conductivity
- Sodium adsorption ratio
- Calcium Carbonate Equivalent
- Soil reaction (pH)
- Available waterholding capacity

(j) Plant communities

Include in this section:

- Description of the vegetation dynamics of the site
- State and Transition Model diagram
- Description of the common states that occur on the site and the transitions between the states. If needed, describe the plant communities and community pathways within the state.
- Plant community composition
- Ground cover and structure
- Annual production
- Growth curves
- Photos of each state or community

(1) Ecological dynamics of the site

Describe the general ecological dynamics of the site. States could be described at the level of growth form, lifeform, or functional group. Describe the changes that are expected to occur because of variation in the weather, and what effects this might have on the dynamics of the site. Include the assumptions made of how the site developed (fire frequency, native herbivory). Other information regarding the dynamics of the site in general should be included.

(2) Plant communities

The first plant community entered into site description should be the interpretative community. This plant community will be either the historic climax plant community or, where applicable, the naturalized plant community for the site. **The first sentence in this section will clearly state whether the interpretative plant community is the historic climax or naturalized plant community.**

Describe other states and plant communities that may exist on the site. One or more plant communities for each state can be described. If only one plant community is described for a state, the community narrative can be used to describe the dynamics of that state. If more than one plant community is described for each state, the amount of detail entered into site description is determined by site description authors. As a minimum, information should be entered into the community narrative describing dynamics of the plant community and causes of community pathway changes. Identify and describe the thresholds between states. Provide information that will aid in the identification and evaluation of how the ecological processes of the site are functioning. These processes include the water cycle, nutrient cycle, and energy flow. Explain what causes shifts or changes, and what effect these changes will have on these ecological functions. Describe changes in hydrologic and erosion characteristics of the site resulting from changes in states. Describe amount and distribution of litter expected. Describe the patterns of plant mortality. Some plants have been found to be cyclic, going through cycles of large-scale mortality followed by recruitment.

Information in regards to transitions between states should be described in the plant community narrative. Incorporate as much information as is known concerning the causes of change and any know probabilities associated with the transitions.

(i) Plant community composition—A detailed species composition list will be entered for the historic climax plant community or naturalized plant community. A detailed species composition list needs to be developed for any other states or plant communities that are considered desired plant communities, and a similarity index calculation is made. List the major plant species and their normal relative production, expressed in pounds air-dry weight (pounds per acre per year), in the total plant community. Species should be listed by group, common name, scientific name, pounds per acre allowable for group, and pounds per acre by species.

If plant groups are used, plant groupings must identify whether individual species within the group will have a production limitation or whether a single species can account for the entire group allowable. Numerous items must be considered when placing plant species into groups for the purpose of ecological site description development. Some of these items are kind of plant, structure, size, rooting structure, life cycle, production, niche occupied, and photosynthetic pathways. Plant groups include cool-season tall grasses, cool-season midgrasses, warm-season tall grasses, warm-season midgrasses, warm-season short grasses, annual grasses, perennial forbs, biennial forbs, annual forbs, shrubs, half-shrubs, deciduous trees, evergreen trees, cacti, yucca and yucca-like plants, succulent forbs, and leafy forbs. This list is not exhaustive, and the professionals describing the site may identify other items or situations and, therefore, identify other groups.

Professional judgment must be used when grouping plants in ecological site descriptions. Group plants in the manner that best describes the site. For instance, two or three groups of warm-season midgrasses may be described because of different niches occupied and differences in production, structure, elevation, and climatic adaptations in the area of the site.

(ii) Ground cover and structure—Soil surface cover is the percentage of the soil surface actually occupied by vegetative basal cover, biological crusts, litter, surface fragments, water, and bare ground.

Ground cover (vertical view) is the percentage of material, other than bare ground, that protects the soil surface from being hit directly by a raindrop. This would include first contact with plant canopy cover, biological crust, litter, surface fragments, bedrock, and water.

Structure of canopy cover – Canopy cover is the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. List the average height and canopy cover for each level of vegetative stratification.

Refer to figure 3–2 for information needed in ground cover and structure section of the site description.

Figure 3–2 Ground cover and structure

Soil Surface Cover

Basal cover				Non-vascular plants	Biological crust	Litter	Surface fragments >1/4 & 3"	Surface fragments >3"	Bedrock	Water	Bare ground
Grass/ grasslike	Forb	Shrub/ vine	Tree								
___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ grasslike	Forb	Shrub/ vine	Tree	Non-vascular plants	Biological crust	Litter	Surface fragments >1/4 & 3"	Surface fragments >3"	Bedrock	Water	Bare ground
___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___	___ to ___

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines/Liana	Trees
0.5 feet	________ to ________	________ to ________	________ to ________	________ to ________
>0.5 – 1 feet	________ to ________	________ to ________	________ to ________	________ to ________
>1 – 2 feet	________ to ________	________ to ________	________ to ________	________ to ________
>2 – 4.5 feet	________ to ________	________ to ________	________ to ________	________ to ________
>4.5 – 13 feet	________ to ________	________ to ________	________ to ________	________ to ________
>13 – 40 feet	________ to ________	________ to ________	________ to ________	________ to ________
>40 – 80 feet	________ to ________	________ to ________	________ to ________	________ to ________
>80 – 120 feet	________ to ________	________ to ________	________ to ________	________ to ________
>120 feet	________ to ________	________ to ________	________ to ________	________ to ________

***(iii) Total annual production*—**Show total annual production as median air-dry production and the fluctuations to be expected during favorable, normal, and unfavorable years. In areas where examples of the historic climax plant community are not available, cite the highest production in plant communities for which examples are available.

***(iv) Plant community growth curves*—**Describe a growth curve for the state or plant community that you are describing, in percent growth by month (fig. 3–3). This includes the curve name and number.

Name—Enter a brief descriptive name for each curve.

Number—The number is to be used only one time in each state. The first two digits are for the state postal code, and the last four digits enter numbers from 0001 to 9999.

(k) Site interpretations

This section includes the site interpretations for the use and management of the site. The information includes animal community, hydrologic functions, recreational uses, wood products, other products, and other information.

Animal community—Includes information regarding wildlife and livestock interpretations.

(1) Wildlife interpretations
An introductory paragraph will be developed that provides general information about the ecological site. The information should relate to the entire site. Information in this paragraph is not specific to any particular plant community. The following information will be described:

- Landscape descriptions
- Area sensitive species
- Transitory/migratory animals
- Invasive species (plants and animals)
- Thresholds by animal species
- Species guilds, keystone species
- Aquatic elements/inclusions; e.g., mineral springs/seeps, riparian areas
- Essential habitat elements across plant communities/sites
- Potential species, e.g., extirpated, historical, incidental

The following information will be shown in the order listing lowest trophic level to highest trophic level. Specific species related to the plant community should be described along with any known interactions.

- Invertebrates (includes edaphic if known)
- Fish
- Reptiles/amphibians—according to scale
- Birds—migrant and resident, also guilds
- Mammals—nongame/game, species of interest
- Essential habitat elements; e.g., lek sites
- Variations impacting wildlife

(2) Livestock Interpretations
General descriptions for use of this site by livestock, domesticated wildlife, wild horses, and burros should be included. Suitability of this site for grazing by kind and class of livestock and potential management problems that exist (poisonous plants, topography, and physical barriers) should be described. Describe wildlife-livestock interactions and competition. Include forage preferences for livestock and wildlife by plant species and/or various parts of a plant species for each month of the year.

Figure 3–3 Plant community growth curves

Name:
Number:
Description:

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

Hydrologic functions—Indicate changes in hydrology functions that may occur with the shift to different plant communities that can occur on the site. For each plant community, describe the changes in infiltration and runoff characteristics expected because of changes in plant species composition and soil surface characteristics. For example, with plant community composition shifts from blue grama to buffalograss, runoff is typically accelerated because of a shift in plant growth form and root morphology characteristics. Information about water budgets for each plant community can be included.

Recreational uses—Indicate the potential uses that the site can support or that may influence the management of the site. List special concerns that will maintain the recreational potentials or site conditions that may limit its potential. Also list plant species that have special aesthetic values, uses, and landscape value.

Wood products—Indicate use or potential uses of significant species that may influence the management of the site.

Other products—Indicate the use or potential uses of other products produced on the site. These may include such things as landscape plants, nuts and berries, mushrooms, and biomass for energy potentials.

Other information—Other pertinent, interpretive, and descriptive information may be included.

(l) Supporting information

Record information about the relationship of this site to other ecological sites and the documentation and references used to develop the ecological site description.

Associated sites—Identify and describe the sites that are commonly located in conjunction with the site.

Similar sites—Identify and describe sites that resemble or can be confused with this site.

Inventory data references—Enter a listing of inventory plots supporting the site description. Record the data source and sample identification of each inventory plot used in the development of the site description.

State correlation—Enter the states with which this site has been correlated.

Type locality—Enter location of a typical example of the site. Indicate township, range, section, or longitude, latitude, and specific location.

Relationship to other established classification systems—Enter a description of how this ecological site description may relate to other established classification systems.

Other references—Record other reference information used in site development or in understanding ecological dynamics of the site.

(m) Site description approval

Authorship—Original authors' names and date. Revision authors' names and revision date.

Site approval—Indicate site approval by the state technical specialist. The state specialist responsible for Field Office Technical Guide rangeland information must review and approve all site descriptions before they are distributed.

(n) Revising ecological site descriptions

Analysis and interpretation of new information about the soil, vegetation, and other onsite environmental factors may reveal a need to revise or update ecological site descriptions. Because the collection of such information through resource inventories and monitoring is a continuous process, site descriptions should be periodically reviewed for needed revision. It is especially important that site descriptions be reviewed when new data on composition, production, or response to disturbance become available. Documented production and composition data, along with related soil, climate, and physiographic data, will be the basis of the site description revisions or new site descriptions.

(o) Developing new site descriptions

A new site description should be prepared when data analysis or new information reveals that a different or new ecological site exists. Generally, enough land area must be identified to be of importance in the management or study of the site before a new site will be developed and described. A new ecological site may be differentiated from an existing site when sufficient erosion or other action has occurred to significantly alter the site's potential.

600.0305 Rangeland ecological sites and soil surveys

NRCS policy dictates mapping of soils and the publication of soil surveys that contain essential information for use in conservation and resource planning activities. These surveys must meet the requirements of the National Cooperative Soil Survey program (see National Soil Survey Handbook, part 606).

The National Soil Survey Handbook, parts 622 and 627, establishes responsibility for planning soil surveys on rangeland. Soil scientists and rangeland management specialists work together to map soils and ecological sites in rangeland areas. Essential activities include development of soil survey work plans, determination of composition of soil mapping units, preparation of map legends, determination of mapping intensity, and necessary field reviews.

(a) Using soil surveys to identify ecological sites

Where Order II soil surveys are completed and ecological site interpretations have been made, boundaries of ecological sites can generally be determined directly from the soil map.

Order III mapping describes individual soil and plant components at association or complex levels. This requires that mapping unit descriptions be developed that describe each association component and assign locations and percentages to each. Individual ecological sites must be described at a level equivalent to the individual components of the Order III soils map.

(b) Soil interpretations for rangeland use in published soil surveys

The National Soil Survey Handbook establishes NRCS policy and procedures for preparing soil interpretations for rangeland. The criteria for developing interpretations are the responsibility of grazing lands discipline leaders. Part 644 outlines policy and procedure for publishing soil surveys, and part 651 outlines policy for preparing advanced soil reports.

Each ecological site will be assigned a unique number that distinguishes it from all other ecological sites. Refer to section 600.0303(b) of this chapter for guidance. This 10-character number will be correlated to each soil series or taxonomic unit that occurs within the ecological site. This number and site name will be input into NASIS or other applicable soils database.

600.0306 Forest land ecological sites

(a) General

The guidance for preparing forest land ecological site descriptions is in the National Forestry Manual, part 537.3. The NRCS state grazing lands specialist will work with the state forester to develop understory plant community descriptions, forage preference ratings, and other appropriate information for each forest site that is suited to grazing. This information will be included in the Field Office Technical Guide.

Forest land ecological site descriptions normally characterize the mature forest plant community that historically occupied the site as well as the other states that commonly occupy the site. An example forest land ecological site description is in the National Forestry Manual, part 537.4, exhibit 537-14.

(b) Separating forest lands from rangelands in areas where they interface

Guides will be developed, as necessary, to separate rangelands from forest lands in areas where they interface. In North America, they are separated based on the historic kind of vegetation that occupied the site. Forest land ecological sites are assigned and described where the historic vegetation was dominated by trees. Rangeland ecological sites are assigned where overstory tree production was not dominant in the climax vegetation.

An example of this type guide is Inventorying, Classifying, and Correlating Juniper and Pinyon Plant Communities to Soils in Western United States (GLTI 1997).

600.0307 Native and naturalized pasture

The historic climax plant community for land managed as native and naturalized pasture was forest land or naturally open land other than rangeland. Many native and naturalized pasture plant communities closely resemble the understory of grazed forest land that has an open or sparse canopy occurring on similar soils. Therefore, ecological site descriptions for forest land will be used as interpretive units for native and naturalized pasture occurring on forest soils.

If forest land ecological site descriptions have not been developed, or if they do not adequately serve the purpose, forage suitability groups will be developed as the basic interpretive or suitability grouping for native and naturalized pasture. Forage suitability groups consist of one or more soils capable of producing similar kinds and amounts of herbaceous vegetation. These soils are also capable of producing similar kinds and amounts of overstory trees.

If forest land ecological site descriptions are to be used for native and naturalized pastures, they must have details about the herbaceous native and naturalized plant community, its production potential, and other pertinent features. Development of forest land ecological sites will follow guidance in the National Forestry Manual. The natural tree overstory part of the description will be omitted only if not known. The state forester and state grazing lands specialist, working as a team, have the responsibility of identifying and describing forest land ecological sites with native and naturalized pasture. Assistance from soil scientists and biologists will be requested as needed.

A forest land ecological site description will be prepared for each native and naturalized pasture site that is identified and named. Descriptions should clearly describe the important features of the site. All significant resources of the site will be described and characterized in sufficient detail to provide guidance for expert planning, managing, and monitoring of the native and naturalized pasture communities.

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 3 Ecological Sites and Forage Suitability Groups

Section 1 Ecological Sites for Rangeland and Forest Land

Exhibits

Plant Association Table (First Assemblage)

(T means trace; dashes mean did not occur)

Species	Production at location number 1	2	3	4	5	6	7
	Pounds per acre (air-dry)						
bluebunch wheatgrass	910	1,190	1,690	960	1,380	1,260	1,620
Sandberg bluegrass	110	120	260	95	185	70	375
Thurber needlegrass	15	T	—	15	—	10	—
needleandthread	10	—	—	10	—	T	—
cheatgrass	10	—	T	—	—	T	T
Pacific fescue	—	15	T	—	T	—	T
squireltail	—	—	T	—	—	T	—
Idaho fescue	—	—	400	—	460	—	250
lineleaf fleabane	15	15	—	20	—	15	25
snow eriogonum	15	15	50	15	50	T	25
cluster phlox	15	25	—	30	—	15	—
longleaf phlox	10	—	50	25	50	T	25
yarrow	20	15	50	20	50	15	30
pussytoes	T	15	—	—	—	T	—
arrowleaf balsamroot	—	—	50	—	25	—	50
hangingpod milkvetch	—	—	25	—	25	—	25
silky lupine	—	—	25	—	25	—	25
specklepod loco	—	—	T	—	25	—	25
indianwheat	—	10	—	—	—	—	—
tarweed	—	—	—	T	—	T	—
tapertip hawksbeard	—	—	50	—	50	—	25
filaree	—	—	—	—	—	T	—
gray rabbitbrush	10	T	T	5	T	15	T
gray horsebrush	—	—	T	—	T	—	T
Total	**1,140**	**1,420**	**2,650**	**1,195**	**2,325**	**1,400**	**2,500**
Soil Taxonomic Unit No.	1	2	3	1	4	1	3

Plant Association Table (Final Assemblage)

(T means trace; dashes mean did not occur)

Species	Production at location number						
	1	2	3	4	5	6	7
	Pounds per acre (air-dry)						
bluebunch wheatgrass	910	1,190	960	1,260	1,690	1,380	1,620
Sandberg bluegrass	110	120	95	70	260	185	375
Thurber needlegrass	15	T	15	10	—	—	—
needleandthread	10	—	10	T	—	—	—
cheatgrass	10	—	—	T	T	—	T
Pacific fescue	—	15	—	—	T	T	T
squireltail	—	—	—	T	T	—	—
Idaho fescue	—	—	—	—	400	460	250
lineleaf fleabane	15	15	20	15	—	—	25
snow eriogonum	15	15	15	T	50	50	25
cluster phlox	15	25	30	15	—	—	—
longleaf phlox	10	—	25	T	50	50	25
yarrow	20	15	20	15	50	50	30
pussytoes	T	15	—	T	—	—	—
arrowleaf balsamroot	—	10	—	—	—	—	—
hangingpod milkvetch	—	—	T	T	—	—	—
silky lupine	—	—	—	T	—	—	—
specklepod loco	—	—	—	—	50	25	50
indianwheat	—	—	—	—	25	25	25
tarweed	—	—	—	—	25	25	25
tapertip hawksbeard	—	—	—	—	50	50	25
filaree	—	—	—	—	50	50	25
gray rabbitbrush	10	T	5	15	T	T	T
gray horsebrush	—	—	—	—	T	T	T
Total	**1,140**	**1,420**	**1,195**	**1,400**	**2,650**	**2,325**	**2,500**
	Site No. 1				Site No. 2		
Soil Taxonomic Unit No.	1	2	1	1	3	4	3

Exhibit 3.1–3 Rangeland Ecological Site Description Example

(Data presented in this rangeland ecological site description are examples for content and format only.)

United States Department of Agriculture
Natural Resources Conservation Service

ECOLOGICAL SITE DESCRIPTION

ECOLOGICAL SITE CHARACTERISTICS

Site Type: Rangeland

Site Name: Loamy Upland 12 – 16 PZ

Site ID: R041XC313AZ

Major Land Resource Area: 041 — Southeastern Arizona Basin and Range

Physiographic Features

This site occurs on old fan and stream terraces.

Land Form: (1) Fan terrace
(2) Stream terrace

	Minimum	Maximum
Elevation (feet):	3300	5000
Slope (percent):	1	8
Water Table Depth (inches):	0	0
Flooding:		
Frequency:	none	none
Duration:	none	none
Ponding:		
Depth (inches):	0	0
Frequency:	none	none
Duration:	none	none
Runoff Class:	slow	slow
Aspect:	No influence on this site	

Climatic Features

Precipitation in the subresource area ranges from 12 to 16 inches yearly in the eastern part with elevations from 3,600 to 5,000 feet. Precipitation in the western part ranges from 13 to 17 inches yearly with elevations from 3,300 to 4,500 feet. Winter-summer rainfall ratios are 40:60 in the west side of the resource area to 30:70 in the eastern part of the area. Summer rains originate in the Gulf of Mexico and are convective, usually brief, intense thunderstorms and occur between July and September. 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 1 day. May and June are the driest months of the year. Humidity is generally very low. Temperatures are mild. Freezing temperatures are common at night from December through April; however, temperatures during the day are frequently above 50 degrees Fahrenheit. Occasionally in December to February, brief periods of 0 degrees Fahrenheit temperatures may be experienced some nights. During June and rarely during July and August, some days may exceed 100 degrees Fahrenheit. The cool-season plants start growing early in spring and mature in early summer. The warm-season plants take advantage of the summer rains and are growing and nutritious from July through August. Warm-season grasses may remain green throughout the year.

	Minimum	Maximum
Frost-free period (days):	170	220
Freeze-free period (days):	180	225
Mean annual precipitation (inches):	12	17

Monthly precipitation (inches) and temperature (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precip. Min.	0.30	0.20	0.24	0.07	0.06	0.12	2.71	1.59	0.54	0.12	0.27	0.24
Precip. Max.	1.26	1.08	1.02	0.60	0.49	1.00	4.94	4.79	2.56	2.07	1.25	1.97
Temp. Min.	29	31	36	42	50	58	65	63	57	46	35	29
Temp. Max.	62	67	72	79	86	95	94	91	88	80	70	63

Climate Stations:
(1) 29334, Willcox, Arizona. Period of record 1961–2000.
(2) 28619, Tombstone, Arizona. Period of record 1961–2000.
(3) 22659, Douglas, Arizona. Period of record 1961–2000.

Influencing Water Features

No water features influence this site.

Wetland Description:	System	Subsystem	Class
(Cowardin System)	none		

Stream Types:
(Rosgen System) none

Representative Soil Features

Soils all have argillic horizons 4 inches below the surface. Plant-soil moisture relationships are good. Soil surface is dark colored and has a crumbly structure. Rills, gullies, wind-scoured areas, pedestals, and soil compaction layers are not present on the site. An argillic (clay) horizon at shallow depths is a strong textural contrast to the surface and should not be confused with a compacted layer. Bulk density of the surface soil should be no more than 1 gram per cubic centimeter. Terracettes are common on moderate slopes, especially where long-lived halfshrubs (false mesquite and ratany species) intercept waterflow patterns. Because this site occurs on older surfaces and can have slopes up to 14 percent, natural flow patterns can occur, but at very low densities, and they are not actively eroding. Bare ground should be no more that 30 percent. Gravel and rock cover can range from 10 to 50 percent.

Predominant Parent Materials:
Kind: alluvium
Origin: mixed

Surface Texture: (1) sandy loam
(2) loam
Surface Texture Modifier: none
Subsurface Texture Group: sandy
Surface Fragments - 3 inches (% cover): 5
Surface Fragments >3 inches (% cover): 5
Subsurface Fragments < = 3 inches (% Volume): 0
Subsurface Fragments > 3 inches (% Volume): 0
Drainage Class: somewhat poorly drained
Permeability Class: moderate

	Minimum	Maximum
Depth (inches):	60	60
Electrical Conductivity (mmhos/cm):	0	0
Sodium Adsorption Ratio:	10	20
Calcium Carbonate Equivalent (percent):	1	2
Soil Reaction (1:1 Water):	6.0	7.0
Soil Reaction (0.1M $CaCl_2$):	NA	NA
Available Water Capacity (inches):	1.5	3.0

PLANT COMMUNITIES

Ecological Dynamics of the Site

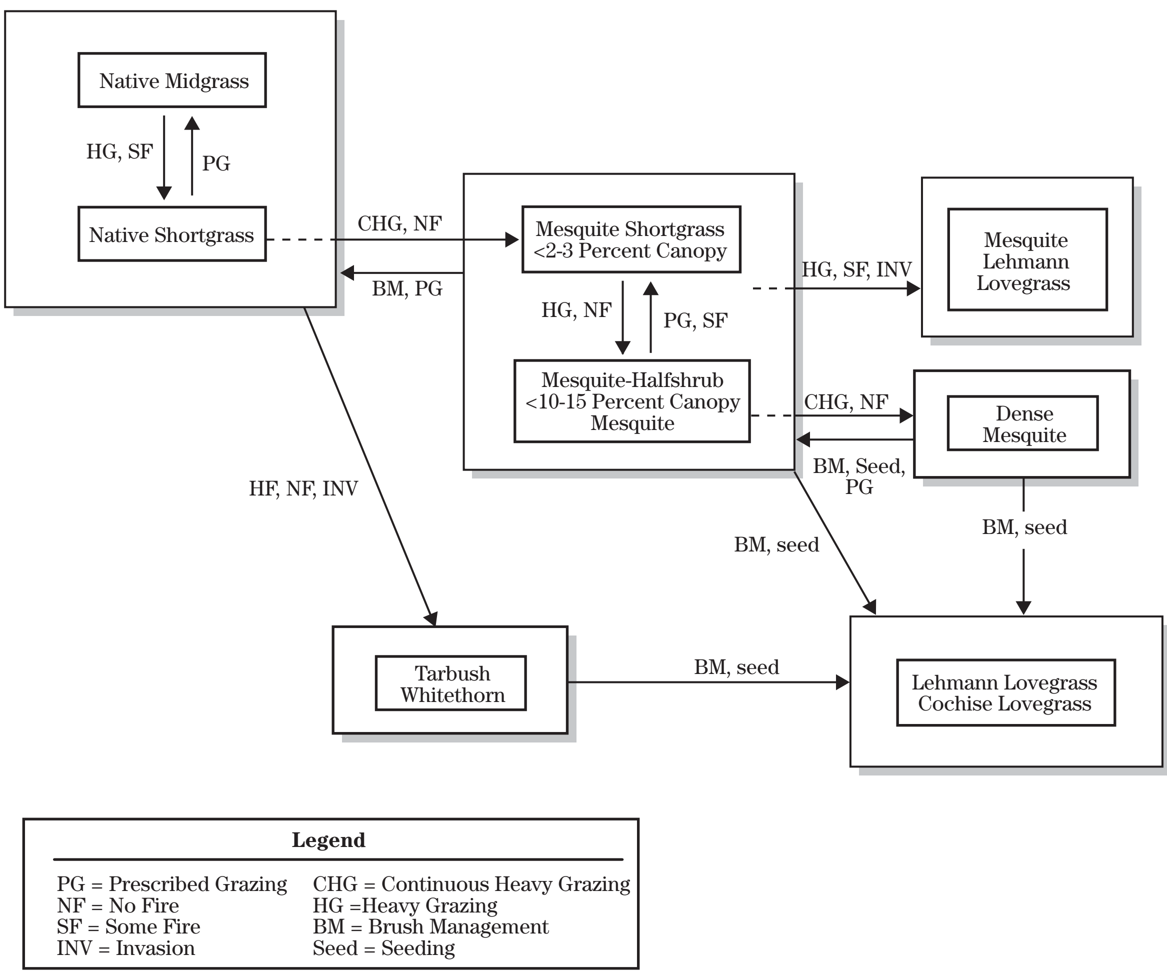
The historic climax plant community is an even mixture of perennial mid and short grasses well dispersed throughout the site. Natural fire was important in the development of the historic climax plant community. The amount of basal cover of grasses and half shrubs is uniform across the site. Warm-season perennials in both a mid- and short-grass group can dominate the plant community. A cool-season group of low-growing, sprouting shrubs is also important on the site. Annuals are uncommon except in mild, wet winters. Cacti and succulents occur in minor amounts. Cryptogams occur in trace amounts.

Natural plant mortality is very low. Major species produce seeds and vegetative structures each year in normal years. Periodic severe drought occurs once each decade and can impede reproduction. The plant community on this site can lose considerable perennial grass cover in severe drought.

The standing crop of herbaceous vegetation from the previous year decomposes quickly in a wet July and August because of intense biological activity. Standing crop of previous year vegetation can persist through a dry summer, slowly oxidizing. Litter is mainly herbaceous material and should provide from 20 to 40 percent soil cover from winter through early summer. Peak amounts of litter are in May or June. The previous year's litter decomposes rapidly in a wet July and August, and no litter is on the ground in September during these years. Litter amounts increase from fall through winter and spring as the peak standing crop of grasses weathers during the year. No noxious or invasive species occur in the historic climax plant community.

Lehmann lovegrass can invade and dominate the plant community. Mesquite can invade and dominate the plant community. With continuous heavy grazing, perennial grasses, such as blue grama, hairy grama, sprucetop grama, sideoats grama, and plains lovegrass, decrease. Under such circumstances, curly mesquite, threeawn species, and in places, false mesquite increase. As woody species increase, mesquite forms the over story with snakeweed and burroweed in the understory. Cholla and pricklypear can also increase. Mesquite tends to be short because of the presence of clay horizons at shallow depths in the soils. Where halfshrubs dominate the understory, the potential production of perennial grasses is about 10 percent greater than the present production of halfshrubs once they are removed from the plant community by fire or other brush management.

State and transition diagram



Native Midgrass Plant Community

The interpretive plant community for this site is the historic climax plant community. This is a mixture of native midgrasses. This community 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 of this site is that of open grassland. This plant community evolved through the Holocene in the absence of grazing by large herbivores and with fire frequency of every 10 to 20 years. It exists all across the upper end of this land resource unit (LRU) especially on moderate slopes with very gravelly surface.

Native Midgrass Plant Species Composition:

			Group Allowable		Annual Production (lb/ac)	
Group	Common Name	Scientific Name	Low	High	Low	High
	GRASSES /GRASSLIKE					
1	Cane beardgrass	*Bothriochloa barbinoides*	400	500	400	500
	Plains lovegrass	*Eragrostis intermedia*			400	500
	Sideoats grama	*Bouteloua curtipendula*			400	500
2	Blue grama	*Bouteloua gracilis*	150	250	150	250
	Black grama	*Bouteloua eriopoda*			150	250
	Hairy grama	*Bouteloua hirsuta*			150	250
	Sprucetop grama	*Bouteloua chondrosioides*			150	250
	Wolftail	*Lycurus phleoides*			150	250
3	Arizona muhly	*Muhlenbergia arizonica*	10	50	10	50
	Curly mesquite	*Hilaria mutica*			10	50
	Rothrock grama	*Bouteloua rothrockii*			10	50
	Sand dropseed	*Sporobolus cryptandrus*			10	50
	Slender grama	*Bouteloua repens*			10	50
4	Bottlebrush squirreltail	*Sitanion hystrix*	10	50	10	50
	Fall witchgrass	*Leptoloma cognatum*			10	50
	Fluffgrass	*Erioneuron pulchellum*			10	50
	Green sprangletop	*Leptochloa dubia*			10	50
	Hall's panic	*Panicum hallii*			10	50
	Pima pappusgrass	*Pappophorum vaginatum*			10	50
	Purple grama	*Bouteloua radicosa*			10	50
	Red grama	*Bouteloua trifida*			10	50
	Slim tridens	*Tridens muticus*			10	50
	Spike dropseed	*Sporobolus junceus*			10	50
	Spike pappusgrass	*Enneapogon desvauxii*			10	50
	Vine mesquite	*Panicum obtusum*			10	50
5	Harvard threeawn	*Aristida harvardii*	50	100	50	100
	Mesa threeawn	*Aristida gentilis*			50	100
	Poverty threeawn	*Aristida divaricata*			50	100
	Purple threeawn	*Aristida purpurea*			50	100
	Red threeawn	*Aristida longiseta*			50	100
	Spidergrass	*Aristida ternipes*			50	100
	Wooton threeawn	*Aristida pansa*			50	100
	Wright's threeawn	*Aristida wrightii*			50	100

Native Midgrass Plant Species Composition—Continued

Group	Common Name	Scientific Name	Group Allowable Low	Group Allowable High	Annual Production (lb/ac) Low	Annual Production (lb/ac) High
6	Arizona cottontop	*Digitaria californica*	50	100	50	100
	Bush muhly	*Muhlenbergia porteri*			50	100
	Crinkle awn	*Trachypogon secundus*			50	100
	Plains bristlegrass	*Setaria vulpiseta*			50	100
	Purple muhly	*Muhlenbergia rigida*			50	100
	Tanglehead	*Heteropogon contortus*			50	100
7	Arizona brome	*Bromus arizonicus*	10	50	10	50
	Arizona panic	*Brachiaria arizonica*			10	50
	Desert lovegrass	*Eragrostis pectinacea*			10	50
	Featherfinger grass	*Chloris virgata*			10	50
	Mexican sprangletop	*Leptochloa uninervia*			10	50
	Needle grama	*Bouteloua aristidoides*			10	50
	Prairie threeawn	*Aristida oligantha*			10	50
	Red sprangletop	*Leptochloa mucronata*			10	50
	Six weeks fescue	*Vulpia octoflora*			10	50
	Six weeks grama	*Bouteloua annua*			10	50
	Six weeks threeawn	*Aristida adscensionis*			10	50
	Spreading lovegrass	*Eragrostis pectinacea*			10	50
	FORBS					
8						
	Arizona cudweed	*Pseudognaphalium arizonicum*	10	50	10	50
	Dyschoriste	*Dyschoriste decumbens*			10	50
	Sida	*Sida stipularis*			10	50
	Spreading fleabane	*Erigeron divergens*			10	50
	Orange flame flower	*Talinum aurantiacum*			10	50
	Hairy evolvulus	*Evolvulus arizonicus*			10	50
9	American vetch	*Vicia americana*	100	150	100	150
	Anoda	*Anoda spp.*			100	150
	Arizona snakecotton	*Froelichia arizonica*			100	150
	Ayenia	*Ayenia* spp.			100	150
	Hairyseed bahia	*Bahia absinthifolia*			100	150
	Bluedicks	*Dichelostemma capitatum*			100	150
	Wire lettuce	*Stephanomeria pauciflora*			100	150
	Evening primrose	*Oenothera primiveris*			100	150
	Desert globemallow	*Sphaeralcea ambigua*			100	150
	Desert marigold	*Baileya multiradiata*			100	150
	Desert windflower	*Anemone tuberosa*			100	150
	Dogbane dyssodia	*Dyssodia papposa*			100	150
	Slender goldenweed	*Machaeranthera gracilis*			100	150
	Hog potato	*Hoffmannseggia glauca*			100	150
	Dutchman's pipe	*Aristolochia watsonii*			100	150
	Leatherweed croton	*Croton pottsii*			100	150
	New Mexico silverbush	*Argythamnia neomexicana*			100	150
	Pink perezia	*Acourtia wrightii*			100	150
	Rockcress	*Arabidopsis* spp.			100	150

Native Midgrass Plant Species Composition—Continued

Group	Common Name	Scientific Name	Group Allowable Low	Group Allowable High	Annual Production (lb/ac) Low	Annual Production (lb/ac) High
	Slender janusia	*Janusia gracilis*			100	150
	Slim vetch	*Vicia ludoviciana*			100	150
	Small matweed	*Guilleminea densa*			100	150
	Spiny goldenweed	*Machaeranthera pinnatifida*			100	150
	Texas dogweed	*Thymophylla acerosa*			100	150
	Trailing four o'clock	*Allionia incarnata*			100	150
	Twinleaf senna	*Senna bauhinioides*			100	150
	Ragweed	*Ambrosia confertiflora*			100	150
	Yerba-de-venado	*Porophyllum gracile*			100	150
10	Arizona gumweed	*Grindelia arizonica*	10	50	10	50
	Aster	*Aster* spp.			10	50
	Ball clover	*Gomphrena nitida*			10	50
	Blanketflower	*Gaillardia* spp.			10	50
	Breadroot	*Psoralidium* spp.			10	50
	Bull filaree	*Erodium texanum*			10	50
	Sage	*Salvia* spp.			10	50
	Cinchweed	*Pectis papposa*			10	50
	Cryptantha	*Cryptantha* spp.			10	50
	Desertpeony	*Acourtia* spp.			10	50
	Desert indianwheat	*Plantago ovata*			10	50
	Western fiddleneck	*Amsinckia tessellata*			10	50
	Buckwheat	*Eriogonum* spp.			10	50
	Gordon bladderpod	*Lesquerella gordonii*			10	50
	Goldeneye	*Heuchera longiflora*			10	50
	Ground cherry	*Physalis* spp.			10	50
	Greeneyes	*Berlandiera lyrata*			10	50
	Hairy bowlesia	*Bowlesia incana*			10	50
	Hairypod pepperweed	*Lepidospartum latisquamum*			10	50
	Honeymat	*Tidestromia lanuginosa*			10	50
	Lambsquarter	*Chenopodium* spp.			10	50
	Lewis blue flax	*Linum lewisii*			10	50
	Lipstick plant	*Plagiobothrys arizonicus*			10	50
	Loco weed	*Astragalus* spp.			10	50
	Arizona maresfat	*Lotus salsuginosus*			10	50
	Mojave lupine	*Lupinus sparsiflorus*			10	50
	Medium pepperweed	*Lepidium virginicum*			10	50
	New Mexico thistle	*Cirsium neomexicanum*			10	50
	Orange caltrop	*Kallstroemia grandiflora*			10	50
	Carelessweed	*Amaranthus palmeri*			10	50
	Patota	*Monolepis nuttalliana*			10	50
	Pectocarya	*Pectocarya* spp.			10	50
	Phlox	*Phlox* spp.			10	50
	Pinnate tansy mustard	*Descurainia pinnata*			10	50
	Purslane	*Portulaca* spp.			10	50
	Rattlesnake carrot	*Daucus pusillus*			10	50
	Ragged jatropha	*Jatropha macrorhiza*			10	50
	Red mariposa lily	*Calochortus kennedyi*			10	50

Native Midgrass Plant Species Composition—Continued

Group	Common Name	Scientific Name	Group Allowable Low	Group Allowable High	Annual Production (lb/ac) Low	Annual Production (lb/ac) High
	Scorpionweed	*Phacelia* spp.			10	50
	Sego lily	*Calochortus nuttallii*			10	50
	Silverleaf nightshade	*Solanum elaeagnifolium*			10	50
	Spiderling	*Boerhavia* spp.			10	50
	Spiderwort	*Tradescantia* spp.			10	50
	Tepary bean	*Phaseolus acutifolius*			10	50
	SHRUBS					
11	Desert zinnia	*Zinnia acerosa*	50	100	50	100
	False mesquite	*Calliandra eriophylla*			50	100
	Range ratany	*Krameria erecta*			50	100
	Spreading ratany	*Krameria lanceolata*			50	100
	Shrubby buckwheat	*Eriogonum wrightii*			50	100
	Slender janusia	*Janusia gracilis*			50	100
	Texas zinnia	*Zinnia grandiflora*			50	100
12	Broom snakeweed	*Gutierrezia sarothrae*	10	20	10	20
	Burroweed	*Isocoma tenuisecta*			10	20
	Threadleaf snakeweed	*Gutierrezia microcephala*			10	20
13	Banana yucca	*Yucca baccata*	10	20	10	20
	Arizona acacia	*Acacia greggii*			10	20
	Fourwing saltbush	*Atriplex canescens*			10	20
	Greythorn	*Ziziphus obtusifolia*			10	20
	Knifeleaf condalia	*Condalia spathulata*			10	20
	Longleaf Mormon tea	*Ephedra trifurca*			10	20
	Menodora	*Menodora scabra*			10	20
	Sacahuista	*Nolina microcarpa*			10	20
	Soaptree yucca	*Yucca elata*			10	20
	Tarbush	*Flourensia cernua*			10	20
	Velvetpod mimosa	*Mimosa dysocarpa*			10	20
	Whitethorn acacia	*Acacia constricta*			10	20
	Wait-a-bit	*Mimosa aculeaticarpa*			10	20
	Western honey mesquite	*Prosopis glandulosa* var. *torreyana*				10
20						
	Whitestem paperflower	*Psilostrope cooperi*			10	20
	Wolfberry	*Lycium* spp.			10	20
	Yerbe-de-pasmo	*Baccharis pteronioides*			10	20
	Velvet mesquite	*Prosopis velutina*			10	20
14	Christmas cholla	*Opuntia leptocaulis*	10	50	10	50
	Coryphantha	*Coryphantha* spp.			10	50
	Engelmann pricklypear	*Opuntia engelmannii*			10	50
	Fishhook barrel cactus	*Ferocactus wislizeni*			10	50
	Hedgehog cactus	*Echinocereus* spp.			10	50
	Jumping cholla	*Opuntia fulgida*			10	50
	Ocotillo	*Fouquieria splendens*			10	50
	Palmer agave	*Agave palmeri*			10	50

Native Midgrass Plant Species Composition—Continued

Group	Common Name	Scientific Name	Group Allowable Low	Group Allowable High	Annual Production (lb/ac) Low	Annual Production (lb/ac) High
	Pencil cholla	*Opuntia arbuscula*			10	50
	Pincushion cactus	*Mammillaria* spp.			10	50
	Staghorn cholla	*Opuntia versicolor*			10	50
	TREES					
15	Blue paloverde	*Cercidium floridum*	10	20	10	20
	Littleleaf paloverde	*Parkinsonia microphylla*			10	20
	Mexican paloverde	*Parkinsonia aculeata*			10	20
	Oneseed juniper	*Juniperus monosperma*			10	20

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & ²3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
10 to 15	1 to 2	3 to 5	0 to 1	to	to	55 to 60	1 to 5	1 to 5	to	to	10 to 15

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & ²3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
35 to 40	3 to 5	10 to 15	0 to 1	to	to	25 to 35	1 to 3	1 to 3	to	to	5 to 8

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
²0.5 feet	to	to	to	to
>0.5 Ð ²1 feet	to	to	to	to
>1 Ð ² 2 feet	8 to 10	3 to 5	10 to 15	to
>2 Ð ² 4.5 feet	35 to 40	to	to	to
>4.5 Ð ² 13 feet	to	to	to	0 to 1
>13 Ð ² 40 feet	to	to	to	to

Annual Production by Plant Type:

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	700	800	1,000
Forb	100	125	200
Shrub/Vine	75	100	150
Tree	5	15	25
Total	880	1,040	1,375

Plant Growth Curve:

Growth Curve Number: AZ0001
Growth Curve Name: Native/midgrass
Growth Curve Description: Native plant community with high similarity index and average growing conditions

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	3	2	2	20	20	18	10	5	5

Native Shortgrass Plant Community

This plant community exists in the upper end of the LRU. It is especially common on nearly level slopes with little or no gravel cover. It is characterized by a cover of short grama grasses (blue, black, sprucetop), curly mesquite, and shrubs like calliandra and krameria. It is stable unless basal cover falls below 5 to 6 percent on 2 to 3 percent slopes. Production is less than historic climax plant community as more shallow-rooted plants cannot fully exploit the soil, water, and nutrients in average or better growing seasons. This plant community is excellent for livestock grazing, but lacks midgrass cover needed by some wildlife species (antelope fawns). The grass cover is easily thinned by drought, but recovers rapidly. The transition includes heavy grazing with some occurrence of fire. The water cycle has been altered, as has the mineral cycle.

Native Shortgrass Plant Species Composition:

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	GRASSES /GRASSLIKE					
1	Cane beardgrass	*Bothriochloa barbinoides*	15	50	15	50
	Plains lovegrass	*Eragrostis intermedia*			15	50
	Sideoats grama	*Bouteloua curtipendula*			15	50
2	Blue grama	*Bouteloua gracilis*	300	400	300	400
	Black grama	*Bouteloua eriopoda*			150	250
	Hairy grama	*Bouteloua hirsuta*			150	250
	Sprucetop grama	*Bouteloua chondrosioides*			150	250
	Wolftail	*Lycurus phleoides*			150	250
3	Arizona muhly	*Muhlenbergia arizonica*	15	50	15	50
	Curly mesquite	*Hilaria mutica*			15	50
	Rothrock grama	*Bouteloua rothrockii*			15	50
	Sand dropseed	*Sporobolus cryptandrus*			15	50
	Slender grama	*Bouteloua repens*			15	50
4	Bottlebrush squirreltail	*Sitanion hystrix*	10	50	10	50
	Fall witchgrass	*Leptoloma cognatum*			10	50
	Fluffgrass	*Erioneuron pulchellum*			10	50
	Green sprangletop	*Leptochloa dubia*			10	50
	Hall's panic	*Panicum hallii*			10	50
	Pima pappusgrass	*Pappophorum vaginatum*			10	50

Native Shortgrass Plant Species Composition—Continued

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	Purple grama	*Bouteloua radicosa*			10	50
	Red grama	*Bouteloua trifida*			10	50
	Slim tridens	*Tridens muticus*			10	50
	Spike dropseed	*Sporobolus junceus*			10	50
	Spike pappusgrass	*Enneapogon desvauxii*			10	50
	Vine mesquite	*Panicum obtusum*			10	50
5	Harvard threeawn	*Aristida harvardii*	15	100	15	100
	Mesa threeawn	*Aristida gentilis*			15	100
	Poverty threeawn	*Aristida divaricata*			15	100
	Purple threeawn	*Aristida purpurea*			15	100
	Red threeawn	*Aristida longiseta*			15	100
	Spidergrass	*Aristida ternipes*			15	100
	Wooton threeawn	*Aristida pansa*			15	100
	Wright's threeawn	*Aristida wrightii*			15	100
	FORBS					
6	Arizona cudweed	*Pseudognaphalium arizonicum*	15	50	15	50
	Dyschoriste	*Dyschoriste decumbens*			15	50
	Sida	*Sida stipularis*			15	50
	Spreading fleabane	*Erigeron divergens*			15	50
	Orange flame flower	*Talinum aurantiacum*			15	50
	Hairy evolvulus	*Evolvulus arizonicus*			15	50
7	Arizona gumweed	*Grindelia arizonica*	10	50	10	50
	Aster	*Aster* spp.			10	50
	Ball clover	*Gomphrena nitida*			10	50
	Blanketflower	*Gaillardia* spp.			10	50
	Breadroot	*Psoralidium spp.*			10	50
	Bull filaree	*Erodium texanum*			10	50
	Sage	*Salvia* spp.			10	50
	Cinchweed	*Pectis papposa*			10	50
	Cryptantha	*Cryptantha* spp.			10	50
	Desertpeony	*Acourtia* spp.			10	50
	Desert indianwheat	*Plantago ovata*			10	50
	Western fiddleneck	*Amsinckia tessellata*			10	50
	Buckwheat	*Eriogonum* spp.			10	50
	Gordon bladderpod	*Lesquerella gordonii*			10	50
	Goldeneye	*Heuchera longiflora*			10	50
	Ground cherry	*Physalis* spp.			10	50
	Greeneyes	*Berlandiera lyrata*			10	50
	Hairy bowlesia	*Bowlesia incana*			10	50
	Hairypod pepperweed	*Lepidospartum latisquamum*			10	50
	Honeymat	*Tidestromia lanuginosa*			10	50
	Lambsquarter	*Chenopodium* spp.			10	50
	Lewis blue flax	*Linum lewisii*			10	50
	Lipstick plant	*Plagiobothrys arizonicus*			10	50

Native Shortgrass Plant Species Composition—Continued

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	Loco weed	*Astragalus* spp.			10	50
	Arizona maresfat	*Lotus salsuginosus*			10	50
	Mojave lupine	*Lupinus sparsiflorus*			10	50
	Medium pepperweed	*Lepidium virginicum*			10	50
	New Mexico thistle	*Cirsium neomexicanum*			10	50
	Orange caltrop	*Kallstroemia grandiflora*			10	50
	Carelessweed	*Amaranthus palmeri*			10	50
	Patota	*Monolepis nuttalliana*			10	50
	Pectocarya	*Pectocarya* spp.			10	50
	Phlox	*Phlox* spp.			10	50
	Pinnate tansy mustard	*Descurainia pinnata*			10	50
	Purslane	*Portulaca* spp.			10	50
	Rattlesnake carrot	*Daucus pusillus*			10	50
	Ragged jatropha	*Jatropha macrorhiza*			10	50
	Red mariposa lily	*Calochortus kennedyi*			10	50
	Scorpionweed	*Phacelia* spp.			10	50
	Sego lily	*Calochortus nuttallii*			10	50
	Silverleaf nightshade	*Solanum elaeagnifolium*			10	50
	Spiderling	*Boerhavia* spp.			10	50
	Spiderwort	*Tradescantia* spp.			10	50
	Tepary bean	*Phaseolus acutifolius*			10	50
	SHRUBS					
8	Desert zinnia	*Zinnia acerosa*	10	30	10	30
	False mesquite	*Calliandra eriophylla*			10	30
	Range ratany	*Krameria erecta*			10	30
	Spreading ratany	*Krameria lanceolata*			10	30
	Shrubby buckwheat	*Eriogonum wrightii*			10	30
	Slender janusia	*Janusia gracilis*			10	30
	Texas zinnia	*Zinnia grandiflora*			10	30
9	Broom snakeweed	*Gutierrezia sarothrae*	5	15	5	15
	Burroweed	*Isocoma tenuisecla*			5	15
	Threadleaf snakeweed	*Gutierrezia microcephala*			5	15
	TREES					
10	Blue paloverde	*Cercidium floridum*	1	5	1	5
	Littleleaf paloverde	*Parkinsonia microphylla*			1	5
	Mexican paloverde	*Parkinsonia aculeata*			1	5
	Oneseed juniper	*Juniperus monosperma*			1	5

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
10 to 15	1 to 2	5 to 10	0 to 1	to	to	35 to 40	1 to 5	1 to 5	to	to	20 to 25

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
35 to 40	3 to 5	10 to 15	0 to 1	to	to	15 to 25	1 to 2	1 to 2	to	to	5 to 8

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	35 to 40	to	to	to
>1 – 2 feet	5 to 10	3 to 5	to	to
>2 – 4.5 feet	to	to	10 to 15	to
>4.5 – 13 feet	to	to	to	0 to 1
>13 – 40 feet	to	to	to	to

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	345	572	650
Forb	15	30	50
Shrub/Vine	15	25	50
Tree	1	3	5
Total	376	630	755

Plant Growth Curve:

Growth Curve Number: AZ0002
Growth Curve Name: Native/Shortgrass
Growth Curve Description: Native plant community with low similarity index dominated by mesquite and cacti, and average growing conditions.

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	10	15	25	10	5	5	5	5	5

Native Shortgrass

Mesquite Shortgrass Plant Community

This plant community exists all across the LRU. Mesquite canopy ranges from 1 to 10 percent. The understory is a continuous cover of short grama grasses and/or curly mesquite. It is stable unless basal cover falls below 5 to 6 percent on 2 to 3 percent slopes. Production is less than the historic climax plant community. Mesquite exploits the soil, water, and nutrients earlier in the spring and to a greater depth than shallow-rooted, warm-season grasses. Grass cover is easily thinned by drought and slow to recover because of the presence of mesquite. It is good for livestock grazing, but tree cover can interfere with livestock handling operations. The presence of mesquite allows species, such as mule deer and javelina, to use this site, but detracts from its value as antelope habitat. The transition includes heavy grazing, no fires, and proximity to mesquite in bottomlands. The ecological processes of water cycle, nutrient cycle, and energy flow are severely altered.

Mesquite Shortgrass Plant Species Composition:

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	GRASSES /GRASSLIKE					
1	Cane beardgrass	*Bothriochloa barbinoides*	15	50	15	50
	Plains lovegrass	*Eragrostis intermedia*			15	50
	Sideoats grama	*Bouteloua curtipendula*			15	50

Mesquite Shortgrass Plant Species Composition—Continued

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
2	Blue grama	*Bouteloua gracilis*	300	400	300	400
	Black grama	*Bouteloua eriopoda*			150	250
	Hairy grama	*Bouteloua hirsuta*			150	250
	Sprucetop grama	*Bouteloua chondrosioides*			150	250
	Wolftail	*Lycurus phleoides*			150	250
3	Arizona muhly	*Muhlenbergia arizonica*	15	50	15	50
	Curly mesquite	*Hilaria mutica*			15	50
	Rothrock grama	*Bouteloua rothrockii*			15	50
	Sand dropseed	*Sporobolus cryptandrus*			15	50
	Slender grama	*Bouteloua repens*			15	50
4	Bottlebrush squirreltail	*Sitanion hystrix*	10	50	10	50
	Fall witchgrass	*Leptoloma cognatum*			10	50
	Fluffgrass	*Erioneuron pulchellum*			10	50
	Green sprangletop	*Leptochloa dubia*			10	50
	Hall's panic	*Panicum hallii*			10	50
	Pima pappusgrass	*Pappophorum vaginatum*			10	50
	Purple grama	*Bouteloua radicosa*			10	50
	Red grama	*Bouteloua trifida*			10	50
	Slim tridens	*Tridens muticus*			10	50
	Spike dropseed	*Sporobolus junceus*			10	50
	Spike pappusgrass	*Enneapogon desvauxii*			10	50
	Vine mesquite	*Panicum obtusum*			10	50
5	Harvard threeawn	*Aristida harvardii*	15	100	15	100
	Mesa threeawn	*Aristida gentilis*			15	100
	Poverty threeawn	*Aristida divaricata*			15	100
	Purple threeawn	*Aristida purpurea*			15	100
	Red threeawn	*Aristida longiseta*			15	100
	Spidergrass	*Aristida ternipes*			15	100
	Wooton threeawn	*Aristida pansa*			15	100
	Wright's threeawn	*Aristida wrightii*			15	100
	FORBS					
6	Arizona cudweed	*Pseudognaphalium arizonicum*	10	30	10	30
	Dyschoriste	*Dyschoriste decumbens*			10	30
	Sida	*Sida stipularis*			10	30
	Spreading fleabane	*Erigeron divergens*			10	30
	Orange flame flower	*Talinum aurantiacum*			10	30
	Hairy evolvulus	*Evolvulus arizonicus*			10	30
7	Arizona gumweed	*Grindelia arizonica*	10	20	10	20
	Aster	*Aster* spp.			10	20
	Ball clover	*Gomphrena nitida*			10	20

Mesquite Shortgrass Plant Species Composition—Continued

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	Blanketflower	*Gaillardia* spp.			10	20
	Breadroot	*Psoralidium* spp.			10	20
	Bull filaree	*Erodium texanum*			10	20
	Sage	*Salvia* spp.			10	20
	Cinchweed	*Pectis papposa*			10	20
	Cryptantha	*Cryptantha* spp.			10	20
	Desertpeony	*Acourtia* spp.			10	20
	Desert indianwheat	*Plantago ovata*			10	20
	Western fiddleneck	*Amsinckia tessellata*			10	20
	Buckwheat	*Eriogonum* spp.			10	20
	Gordon bladderpod	*Lesquerella gordonii*			10	20
	Goldeneye	*Heuchera longiflora*			10	20
	Ground cherry	*Physalis* spp.			10	20
	Greeneyes	*Berlandiera lyrata*			10	20
	Hairy bowlesia	*Bowlesia incana*			10	20
	Hairypod pepperweed	*Lepidospartum latisquamum*			10	20
	Honeymat	*Tidestromia lanuginosa*			10	20
	Lambsquarter	*Chenopodium* spp.			10	20
	Lewis blue flax	*Linum lewisii*			10	20
	Lipstick plant	*Plagiobothrys arizonicus*			10	20
	Loco weed	*Astragalus* spp.			10	20
	Arizona maresfat	*Lotus salsuginosus*			10	20
	Mojave lupine	*Lupinus sparsiflorus*			10	20
	Medium pepperweed	*Lepidium virginicum*			10	20
	New Mexico thistle	*Cirsium neomexicanum*			10	20
	Orange caltrop	*Kallstroemia grandiflora*			10	20
	Carelessweed	*Amaranthus palmeri*			10	20
	Patota	*Monolepis nuttalliana*			10	20
	Pectocarya	*Pectocarya* spp.			10	20
	Phlox	*Phlox* spp.			10	20
	Pinnate tansy mustard	*Descurainia pinnata*			10	20
	Purslane	*Portulaca* spp.			10	20
	Rattlesnake carrot	*Daucus pusillus*			10	20
	Ragged jatropha	*Jatropha macrorhiza*			10	20
	Red mariposa lily	*Calochortus kennedyi*			10	20
	Scorpionweed	*Phacelia* spp.			10	20
	Sego lily	*Calochortus nuttallii*			10	20
	Silverleaf nightshade	*Solanum elaeagnifolium*			10	20
	Spiderling	*Boerhavia* spp.			10	20
	Spiderwort	*Tradescantia* spp.			10	20
	Tepary bean	*Phaseolus acutifolius*			10	20
	SHRUBS					
8	Desert zinnia	*Zinnia acerosa*	15	50	15	50
	False mesquite	*Calliandra eriophylla*			15	50
	Range ratany	*Krameria erecta*			15	50
	Spreading ratany	*Krameria lanceolata*			15	50

Mesquite Shortgrass Plant Species Composition—Continued

Group	Common name	Scientific name	Group allowable Low	Group allowable High	Annual production (lb/ac) Low	Annual production (lb/ac) High
	Shrubby buckwheat	*Eriogonum wrightii*			15	50
	Slender janusia	*Janusia gracilis*			15	50
	Texas zinnia	*Zinnia grandiflora*			15	50
9	Broom snakeweed	*Gutierrezia sarothrae*	0	5	0	5
	Burroweed	*Isocoma tenuisecta*			0	5
	Threadleaf snakeweed	*Gutierrezia microcephala*			0	5
10	Banana yucca	*Yucca baccata*	15	150	15	150
	Arizona acacia	*Acacia greggii*			15	150
	Fourwing saltbush	*Atriplex canescens*			15	150
	Greythorn	*Ziziphus obtusifolia*			15	150
	Knifeleaf condalia	*Condalia spathulata*			15	150
	Longleaf Mormon tea	*Ephedra trifurca*			15	150
	Menodora	*Menodora scabra*			15	150
	Sacahuista	*Nolina microcarpa*			15	150
	Soaptree yucca	*Yucca elata*			15	150
	Tarbush	*Flourensia cernua*			15	150
	Velvetpod mimosa	*Mimosa dysocarpa*			15	150
	Whitethorn acacia	*Acacia constricta*			15	150
	Wait-a-bit	*Mimosa aculeaticarpa*			15	150
	Western honey mesquite	*Prosopis glandulosa* var. *torreyana*			15	150
11	Christmas cholla	*Opuntia leptocaulis*	10	20	10	20
	Coryphantha	*Coryphantha* spp.			10	20
	Engelmann pricklypear	*Opuntia engelmannii*			10	20
	Fishhook barrel cactus	*Ferocactus wislizeni*			10	20
	Hedgehog cactus	*Echinocereus* spp.			10	20
	Jumping cholla	*Opuntia fulgida*			10	20
	Ocotillo	*Fouquieria splendens*			10	20
	Palmer agave	*Agave palmeri*			10	20
	Pencil cholla	*Opuntia arbuscula*			10	20
	Pincushion cactus	*Mammillaria* spp.			10	20
	Staghorn cholla	*Opuntia versicolor*			10	20
	TREES					
12	Blue paloverde	*Cercidium floridum*	10	20	10	20
	Littleleaf paloverde	*Parkinsonia microphylla*			10	20
	Mexican paloverde	*Parkinsonia aculeata*			10	20
	Oneseed juniper	*Juniperus monosperma*			10	20

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
5 to 10	1 to 2	3 to 5	0 to 1	to	to	35 to 40	1 to 5	1 to 5	to	to	30 to 35

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
45 to 50	3 to 5	15 to 20	0 to 1	to	to	10 to 15	1 to 2	1 to 2	to	to	8 to 10

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	45 to 50	to	to	to
>1 – 2 feet	to	3 to 5	to	to
>2 – 4.5 feet	to	to	10 to 15	to
>4.5 – 13 feet	to	to	5 to 8	to
>13 – 40 feet	to	to	to	1 to 2

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	345	570	650
Forb	15	30	50
Shrub/Vine	40	150	225
Tree	10	15	20
Total	390	765	945

Plant Growth Curve

Growth curve number: AZ0003
Growth curve name: Mesquite/Shortgrass
Growth curve description: Native plant community with low similarity index dominated by mesquite and average growing conditions.

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	5	10	10	25	10	10	5	5	5

Mesquite shortgrass

Mesquite-Halfshrub Plant Community

This plant community exists in the lower and mid parts of the LRU. Mesquite canopy is from 5 to 15 percent. Understory is a diverse mixture of cacti, burroweed, broom snakeweed, and other shrubs. Perennial grasses are in trace amounts. The community is poor for livestock grazing, poor for some wildlife species (pronghorn antelope and scaled quail), and good for other wildlife species, such as mule deer, javelina, and Gambel's quail. Transition is from mesquite shortgrass with continued heavy grazing and absence of fire. Ecological processes are severely altered, and site has lost recovery mechanisms.

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ grasslike	Forb	Shrub/ Vine	Tree								
1 to 2	1 to 2	5 to 8	0 to 1	to	1 to 2	20 to 25	5 to 8	1 to 5	to	to	45 to 50

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
10 to 15	3 to 5	25 to 30	0 to 1	to	to	5 to 10	1 to 2	1 to 2	to	to	25 to 35

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	3 to 5	to	to	to
>1 – 2 feet	5 to 10	to	to	to
>2 – 4.5 feet	to	3 to 5	15 to 20	to
>4.5 – 13 feet	to	to	10 to 15	to
>13 – 40 feet	to	to	to	1 to 2

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	30	125	250
Forb	10	20	30
Shrub/Vine	500	590	695
Tree	10	15	25
Total	550	750	1,000

Plant Growth Curve

Growth curve number: AZ0004
Growth curve name: Mesquite/cacti
Growth curve description: Native plant community with low similarity index dominated by mesquite and cacti, and average growing conditions.

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	3	5	10	25	15	13	8	3	3

Mesquite-halfshrub

Dense Mesquite Plant Community

This community occurs across the LRU, especially in historic heavy use areas, such as homesteads, horse pastures, along streams with perennial flow and watering locations, and archaeological sites. Mesquite canopy is from 15 to 30 percent. Understory consists of low shrubs, perennial grasses, and annual species. Community is poor for livestock grazing and poor habitat for most wildlife species. However, in southern Arizona, the oldest and largest mule deer bucks use mesquite thickets as hiding and escape cover. Frequently so much of the soil surface has been lost under this condition that the site will not respond to treatment. Transition is from mesquite shortgrass with excessive grazing and no fires.

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
0 to 1	to	5 to 8	0 to 1	to	to	25 to 30	5 to 8	1 to 5	to	to	40 to 50

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
3 to 5	0 to 1	25 to 30	3 to 5	to	to	10 to 15	3 to 5	1 to 2	to	to	30 to 40

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	to	to	to	to
>1 – 2 feet	1 to 3	0 to 1	to	to
>2 – 4.5 feet	1 to 2	to	3 to 5	to
>4.5 – 13 feet	to	to	20 to 30	to
>13 – 40 feet	to	to	to	3 to 5

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	30	70	100
Forb	5	10	15
Shrub/Vine	485	525	575
Tree	10	15	20
Total	530	620	700

Plant Growth Curve

Growth curve number: AZ0005
Growth curve name: Native 5
Growth curve description: Native plant community dominated by mesquite and average growing conditions.

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	10	10	15	20	5	10	10	3	2	5

Dense mesquite

Tarbush/Whitethorn Plant Community

Community occurs in the eastern part of the LRU in areas where loamy upland is adjacent to limy sites and naturally support tarbush and whitethorn. Canopy cover exceeds 10 percent. The understory consists of shrubs and perennial grasses and annuals. This plant community is poor for livestock grazing and poor habitat for most wildlife species. The site is not stable. Surface soil has been lost, so the site will not respond to treatment. Transition is from native midgrass with heavy grazing, no fires, and a proximity to tarbush and whitethorn.

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
0 to 1	0 to 1	3 to 5	0 to 1	to	1 to 2	25 to 30	5 to 8	1 to 5	to	to	50 to 60

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
5 to 8	3 to 5	15 to 25	0 to 1	to	to	15 to 20	3 to 5	1 to 2	to	to	30 to 40

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	to	to	to	to
>1 – 2 feet	3 to 5	3 to 5	to	to
>2 – 4.5 feet	3 to 5	to	3 to 5	to
>4.5 – 13 feet	to	to	20 to 25	to
>13 – 40 feet	to	to	to	1 to 2

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/grasslike	60	150	200
Forb	15	40	50
Shrub/vine	500	580	630
Tree	15	20	30
Total	590	790	910

Plant Growth Curve

Growth curve number: AZ0006
Growth curve name: Native 6
Growth curve description: Plant community dominated by tarbush and whitethorn and average growing conditions.

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	5	10	25	15	15	5	5	3	2

Tarbush/whitethorn

Mesquite/Lehmann Lovegrass Plant Community

Community has developed from mesquite native grasslands in the last 30 years. Livestock grazing, fire, and drought have enhanced invasion of Lehmann lovegrass. Mesquite canopy is less than 10 percent. Lehmann production equals or exceeds native grass production. Species diversity is reduced. Under mesquite/native grass conditions, it is common to find 40 to 50 perennial species. Under Lehmann dominance, that figure is 20 to 30 species. Community is good for livestock grazing and such wildlife as mule deer and Gambel's quail. Transition is from mesquite short grass with heavy grazing, some fires, and a Lehmann lovegrass seed source.

Structure and Cover

Soil Surface Cover

Basal Cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
10 to 15	to	1 to 2	to	to	to	65 to 70	1 to 5	1 to 5	to	to	5 to 10

Ground Cover

Vegetative Cover						Non-Vegetative Cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
55 to 60	0 to 1	10 to 15	0 to 1	to	to	10 to 15	1 to 2	1 to 2	to	to	5 to 8

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	to	to	to	to
>1 – 2 feet	to	0 to 1	to	to
>2 – 4.5 feet	55 to 60	to	5 to 10	to
>4.5 – 13 feet	to	to	5 to 7	to
>13 – 40 feet	to	to	to	1 to 2

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	1,215	1,330	1,450
Forb	15	25	50
Shrub/Vine	55	75	180
Tree	10	15	20
Total	1,295	1,445	1,700

Plant Growth Curve

Growth curve number: AZ0007
Growth curve name: Mesquite Lehmann lovegrass
Growth curve description: Plant community dominated by mesquite with an understory of Lehmann lovegrass, average growing conditions

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	15	20	25	10	5	3	2	2	3

Mesquite/lehmann lovegrass

Lehmann, Boers, Wilmans, and/or Cochise Lovegrass Plant Community

Community exists where mechanical brush management was used to control mesquite, tarbush, whitethorn and cacti, and lovegrass species seeded. Community has a great deal of stability. Communities produce more than native grass communities by 20 to 50 percent. Plant species diversity is low. The transition is mesquite halfshrub/ cacti or dense mesquite with mechanical brush management and seeding of lovegrass species. The ecological processes are functioning similar to the historic climax plant community.

Structure and Cover

Soil Surface Cover

Basal cover				Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
Grass/ Grasslike	Forb	Shrub/ Vine	Tree								
15 to 20	to	1 to 2	to	to	to	65 to 70	1 to 5	1 to 5	to	to	5 to 10

Ground Cover

Vegetative cover						Non-Vegetative cover					
Grass/ Grasslike	Forb	Shrub/ Vine	Tree	Non-Vascular Plants	Biological Crust	Litter	Surface Fragments >1/4 & 3"	Surface Fragments >3"	Bedrock	Water	Bare Ground
65 to 70	1 to 2	3 to 5	0 to 1	to	to	10 to 15	1 to 2	1 to 2	to	to	5 to 8

Structure of Canopy Cover

	Grasses/Grasslike	Forbs	Shrubs/Vines	Trees
0.5 feet	to	to	to	to
>0.5 – 1 feet	to	to	to	to
>1 – 2 feet	to	1 to 2	3 to 5	to
>2 – 4.5 feet	65 to 70	to	to	to
>4.5 – 13 feet	to	to	to	0 to 1
>13 – 40 feet	to	to	to	to

Annual Production by Plant Type

Plant Type	Annual Production (lbs/ac) Low	RV	High
Grasses/Grasslike	1,265	1,415	1,550
Forb	15	30	50
Shrub/Vine	15	50	100
Total	1,295	1,495	1,700

Plant Growth Curve

Growth curve number: AZ0008
Growth curve name: Cochise and Lehmann lovegrass
Growth curve description: Plant community dominated by Lehmann and Cochise lovegrass, average growing conditions

Percent Production by Month

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	5	5	15	15	20	10	15	3	3	2	2

Lehmann, Boers, Wilmans, and/or Cochise lovegrass

ECOLOGICAL SITE INTERPRETATIONS

Animal Community

The plant community on this site is suitable for grazing by all classes of livestock at any season. With thin, coarse-textured surface over argillic horizons, these soils become less effective in catching summer rainfall if the grass cover is disturbed or depleted. With a good grass cover, the clayey subsoil releases moisture slowly to the plants over the summer. Lehmann lovegrass can invade this site slowly, but seldom forms a monotype. At the first sign of invasion, proper use of the native perennials must be practiced to avoid letting lovegrass spread. Herbaceous forage will be deficient in protein in winter. This site has no natural surface water associated with it; therefore, water development for livestock is necessary for utilization of this site.

Initial starting stocking rates will be determined with the landowner or decisionmaker. They will be based on past use histories and type and condition of the vegetation. Calculations used to determine an initial starting stocking rate will be based on forage preference ratings.

This site is important for many wildlife species. Major species include desert mule deer, pronghorn antelope, Gambel's quail, scaled quail, and blacktailed jackrabbit. This site has no natural surface water associated with it. Water developments are important to these and other wildlife on this site. Being an open grassland, this site is also home to a variety of small herbivores, birds, and their associated predators. With the exception of pronghorn antelope, this site is mainly a forage area for larger wildlife species. The value of this site for food or cover requirements for specific wildlife species changes with the changes in the vegetation that occur from one plant community to another. Each plant community and each animal species must be considered individually.

Plant Preferences by Animal Kind

Common name	Scientific name	Plant part	Forage preferences* J	F	M	A	M	J	J	A	S	O	N	D
Animal Kind: Cattle														
Sideoats grama	*Bouteloua curtipendula*	leaf	D	D	D	P	P	P	P	D	D	D	D	D
Plains lovegrass	*Eragrostis intermedia*	entire	D	D	D	P	P	P	P	D	D	D	D	D
Cane beardgrass	*Bothriochloa barbinoides*	leaf	P	P	P	P	D	D	D	D	U	U	U	U
Blue grama	*Bouteloua gracilis*	leaf	P	P	P	P	D	D	U	U	U	U	U	U
Sprucetop grama	*Bouteloua chondrosioides*	leaf	P	P	P	P	P	P	P	P	P	P	P	P
Curly-mesquite	*Hilaria mutica*	leaf	P	P	P	N	N	U	U	U	U	U	U	U
Hairy grama	*Bouteloua hirsuta*	leaf	D	D	D	D	D	D	D	U	U	U	U	U
Spider grass	*Aristida ternipes*	leaf	U	U	U	U	U	U	U	U	U	D	D	D
Red threeawn	*Aristida longiseta*	entire	N	N	N	N	N	N	D	D	D	D	D	N
False mesquite	*Calliandra eriophylla*	leaf	D	D	D	D	D	D	D	D	D	D	D	D
Range ratany	*Krameria erecta*	leaf	N	N	N	N	N	N	N	N	D	D	D	D
Animal Kind: Desert Mule Deer														
Sida	*Sida stipularis*	leaf	P	P	P	P	P	P	P	P	P	P	P	P
Hairy evolvulus	*Evolvulus arizonicus*	leaf	P	P	P	N	N	U	U	U	U	U	U	U
Dyschoriste	*Dyschoriste decumbens*	leaf	D	D	D	D	D	D	D	U	U	U	U	U
Spreading fleabane	*Erigeron divergens*	entire	N	N	N	N	N	N	D	D	D	D	D	N
Desert globemallow	*Sphaeralcea ambigua*	leaf	P	P	P	P	P	N	N	N	N	N	N	N
Hog potato	*Hoffmannseggia glauca*	leaf	N	N	N	N	N	N	N	N	D	D	D	D
False mesquite	*Calliandra eriophylla*	stem	D	D	D	D	D	D	D	D	D	D	D	D
Range ratany	*Krameria erecta*	stem	N	N	N	N	N	N	N	D	D	D	D	D
Yerbe-de-pasmo	*Baccharis pteronioides*	stem	D	D	D	D	D	N	N	N	N	N	N	N
Staghorn cholla	*Opuntia versicolor*	fruit	P	P	P	P	D	D	D	D	D	D	D	D
Engelmann pricklypear	*Opuntia engelmannii*	fruit	N	N	N	N	N	N	N	D	D	D	D	D
Ocotillo	*Fouquieria splendens*	flower	D	D	D	D	D	P	P	P	P	P	P	P
Fishhook barrel cactus	*Ferocactus wislizeni*	fruit	N	N	N	E	N	N	N	N	N	D	D	D
Palmer agave	*Agave palmeri*	flower	N	N	N	N	N	N	D	D	P	P	P	P

* Legend: P=Preferred D=Desirable U=Undesirable E=Emergency N=Nonconsumed T=Toxic

Plant Preferences by Animal Kind—Continued

Common name	Scientific name	Plant part	Forage preferences*											
			J	F	M	A	M	J	J	A	S	O	N	D
Animal Kind: Pronghorn Antelope														
Sida	*Sida stipularis*	leaf	P	P	P	P	P	P	P	P	P	P	P	P
Hairy evolvulus	*Evolvulus arizonicus*	leaf	P	P	P	N	N	U	U	U	U	U	U	U
Dyschoriste	*Dyschoriste decumbens*	leaf	D	D	D	D	D	D	D	U	U	U	U	U
Spreading fleabane	*Erigeron divergens*	entire	N	N	N	N	N	N	D	D	D	D	D	N
Desert globemallow	*Sphaeralcea ambigua*	leaf	P	P	P	P	P	N	N	N	N	N	N	N
Hog potato	*Hoffmannseggia glauca*	leaf	N	N	N	N	N	N	N	N	D	D	D	D
False mesquite	*Calliandra eriophylla*	stem	D	D	D	D	D	D	D	D	D	D	D	D
Range ratany	*Krameria erecta*	stem	N	N	N	N	N	N	N	D	D	D	D	D
Yerbe-de-pasmo	*Baccharis pteronioides*	stem	D	D	D	D	D	N	N	N	N	N	N	N
Staghorn cholla	*Opuntia versicolor*	fruit	P	P	P	P	D	D	D	D	D	D	D	D
Engelmann pricklypear	*Opuntia engelmannii*	fruit	N	N	N	N	N	N	N	D	D	D	D	D
Ocotillo	*Fouquieria splendens*	flower	D	D	D	D	D	P	P	P	P	P	P	P
Fishhook barrel cactus	*Ferocactus wislizeni*	fruit	N	N	N	E	N	N	N	N	N	D	D	D
Palmer agave	*Agave palmeri*	flower	N	N	N	N	N	N	D	D	P	P	P	P
Animal Kind: Gambel and Scaled Quail														
Sida	*Sida stipularis*	leaf	P	P	P	P	P	P	P	P	P	P	P	P
Hairy evolvulus	*Evolvulus arizonicus*	leaf	P	P	P	N	N	U	U	U	U	U	U	U
Dyschoriste	*Dyschoriste decumbens*	leaf	D	D	D	D	D	D	D	U	U	U	U	U
Spreading fleabane	*Erigeron divergens*	entire	N	N	N	N	N	N	D	D	D	D	D	N
Desert globemallow	*Sphaeralcea ambigua*	leaf	P	P	P	P	P	N	N	N	N	N	N	N
Hog potato	*Hoffmannseggia glauca*	leaf	N	N	N	N	N	N	N	N	D	D	D	D
False mesquite	*Calliandra eriophylla*	stem	D	D	D	D	D	D	D	D	D	D	D	D
Range ratany	*Krameria erecta*	stem	N	N	N	N	N	N	N	D	D	D	D	D
Zinnia	*Zinnia* spp.	stem	P	P	P	P	P	P	P	P	P	P	P	P
Yerbe-de-pasmo	*Baccharis pteronioides*	stem	D	D	D	D	D	N	N	N	N	N	N	N
Staghorn cholla	*Opuntia versicolor*	fruit	P	P	P	P	D	D	D	D	D	D	D	D
Engelmann pricklypear	*Opuntia engelmannii*	fruit	N	N	N	N	N	N	N	D	D	D	DD	
Ocotillo	*Fouquieria splendens*	flower	D	D	D	D	D	P	P	P	P	P	P	P
Fishhook barrel cactus	*Ferocactus wislizeni*	fruit	N	N	E	N	N	N	N	N	N	D	D	D
Palmer agave	*Agave palmeri*	flower	N	N	N	N	N	N	D	D	P	P	P	P

* Legend: P=Preferred D=Desirable U=Undesirable E=Emergency N=Nonconsumed T=Toxic

Hydrology Functions

The hydrology of this site is characterized by high-intensity thunderstorms during summer months and, in winter, by low-intensity frontal storms. Sixty to 70 percent of the annual moisture occurs during the summer months. The site has a porous soil surface that is resistant to erosion when perennial vegetation cover is sufficient to protect the site from damage. As basal cover is reduced, the surface soil is exposed to accelerated erosion and can be quickly lost. The clayey subsoil is more resistant to erosion, but is not able to sustain the original plant community. Deteriorated sites are characterized by low infiltration and excessive runoff. This site naturally delivers water to adjacent sites downstream by overland flow. Concentrated flow patterns are common and can easily become rills and gullies if cover is lost.

Recreational Uses

This site is used for hunting, hiking, horseback riding, and off-road driving activities.

Wood Products

Considerable amounts of mesquite occupy several present-day plant communities. Wood products potential is low on this site as mesquites remain small and shrubby in stature because of the nature of the soils in this site.

Other Products

None

Other Information

None

SUPPORTING INFORMATION

Associated Sites

Site Name	Site ID	Site Narrative
Limy 12–16PZ	R041XC320AZ	This site is found in the field to be associated with the Limy Upland 12–16PZ and the Loamy Bottom sites.
Loamy Bottom	R041XC344AZ	

Similar sites

Site Name	Site ID	Site Narrative
Limy 12–16 PZ	R041XC320AZ	With the historic climax plant community, this site is not similar enough to any other site to cause a problem or concern. As this site deteriorates it may easily be confused with other deteriorated sites, such as Limy Upland. Many sites will deteriorate into similar plant communities.

State Correlation

This site has been correlated with the following states: NM, CA, UT.

Inventory Data References

The historic climax plant community has been determined by study of rangeland relict areas or areas protected from excessive grazing. Trends in plant communities going from heavily grazed areas to lightly grazed areas, seasonal use pastures, and historical accounts have also been used. The following transect and clipping data also document this site. There are 21 permanent transect locations on this site.

Data Source	Number of Records	Sample Period	State	County
Range 417	43	1972–1985	Arizona	Cochise
AZ Range 1	31	1970–1985	Arizona	Pima

Type Locality

State:	AZ	State:	AZ
County:	Pima	County:	Santa Cruz
Township:	21S	Township:	23S
Range:	8E	Range:	14E
Section:	19	Section:	13
General Description:	Buenos Aires NWR	General Description:	Santa Cruz
State:	AZ	State:	AZ
County:	Cochise	County:	Pinal
Township:	18S	Township:	10S
Range:	28E	Range:	13E
Section:	2	Section:	2
General Description:	Oak Ranch	General Description:	Tom Mix Hwy ROW
State:	AZ		
County:	Cochise		
Township:	21S		
Range:	19E		
Section:	17		
General Description:	Ft. Huachuca		

Relationship to Other Established Classifications

1. A.W. Küchler's Potential Natural Vegetation as unit number 58 Grama - Tobosa Shrubsteppe
2. Society for Range Management's Rangeland Cover Types as unit number 505 Grama - Tobosa Shrub

Other References

None

Site Description Approval

Author		Date	Approval	Date
Original WHN	SCS	1976	DGF Regional Range Conservationist	1976
Revised DGR	SCS	1987	KDW Regional Range Conservationist	1996

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 3 Ecological Sites and Forage Suitability Groups

Section 2 Forage Suitability Groups

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Section 2 Forage Suitablity Groups

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600.0308 Introduction

(a) Definition

Forage suitability groups (FSG's) are composed of one or more individual soil map unit components having similar potentials and limitations for forage production. Soils within a forage suitability group are sufficiently uniform to:

- Support the same adapted forage plants under the same management conditions
- Require similar conservation treatment and management to produce the forages selected in the quality and quantity desired
- Have comparable potential productivity

(b) Purpose

Forage suitability groups order, condense, and simplify soils information. They are interpretive reports providing the soil and plant science basis for planning individual tracts of grazing land where detailed soil mapping has been done. FSG's list the soil map unit components contained in them. They identify adapted forage species and seeding mixtures that will grow on those soils without corrective treatment. They may also identify other forages that could be grown after applying certain practices to correct limiting soil features found within a group.

FSG reports state which limitations are present and their severity, associated management problems, and conservation and management practices needed to overcome the limitations. They also should identify any over-riding limitation that precludes expansion of the list of adapted species. For instance, if the soil will frost heave, alfalfa will not be suitable for the soil even if it was fertilized, limed, and drained to support alfalfa.

FSG's also give total yearly forage production estimates for the forages commonly raised on the soils within the FSG. They display the distribution of production on pasture by forage species or commonly associated mixtures during the growing season, when reliable figures are available. This is useful for planning pasture availability throughout the grazing season.

600.0309 Indexing forage suitability groups

FSG's will be established for each Major Land Resource Area (MLRA) having significant forage production. Sort all soil map unit components in the MLRA by the pertinent soil factors described in this section into like groups. Adjacent MLRA's with similar FSG's are listed in the FSG documentation at the end of the report. Adjacent MLRA's with significant forage production that have many, if not all, of the same soil series and similar climatic conditions of an MLRA with developed FSG's may simply have FSG reports copied from the MLRA with developed FSG's and edited as needed. The new FSG reports are numbered to contain the proper MLRA identifier.

A state interested in developing FSG's shall assume leadership responsibility for MLRA's that are wholly contained within the state's boundaries or where the majority of the land area of the MLRA is in the state. Where an MLRA lies across state boundaries, state specialists are encouraged to form a multistate team to develop one set of FSG's per MLRA. All states where the MLRA occurs should be aware of the development of FSG's specific to the MLRA. Everyone with an interest should participate in the correlation and development of the FSG's to ensure they are comfortable with the final product. Where MLRA's lie across regional boundaries, develop a coordinated approach with approval of the involved regional conservationists.

Base FSG's on the best data available. Form a multidisciplinary FSG team of specialists. This team should review the soil factors and their rating criteria in this section of the handbook and determine which soil factors are critical to forage production and survival in the selected MLRA. They either use the nationally established breakpoints for limitation categories for each soil factor or adjust them to better fit and describe the data array for the region. Some data can come directly from the National Soil Survey Information System database. However, data specific to the area is best collected from land grant universities or Agricultural Research Service laboratories in or near the selected MLRA. The team should be knowledgeable personnel from those institutions, Extension forage specialists, NRCS grazing land specialists, NRCS plant material specialists, NRCS soil scientists, NRCS district conservationists working in high workload grazing land management regions, and, when available, forage researchers from private research facilities. Ascertain which forage species are best adapted to each FSG. Consult the NRPH Forage Suitability Group tables in this section on forage suitability and tolerance to soil conditions: drainage, pH, inundation period, salt, and available aluminum, or other references as needed.

Determine potential forage yield by FSG for each adapted species. Forage production data exists in published and unpublished forms. Conduct literature reviews to gather published data and ask research agronomists and grassland farmers and ranchers for unpublished production records. Hay production or stocking rate information often can be used to construct a productivity rating for a forage crop on a soil map unit component. Where no information is available for specific soil map unit components, forage species, or both, initiate clipping studies to provide production data. This, of course, creates a need for interim FSG's until data are collected and collated for publishing. Once information is assembled, designate a principal author. This person will write the FSG's in their entirety and send out a draft to all other team members for review and comment. Once consensus is reached, publish the FSG's.

The initial correlation and interpretive report of an FSG should be considered the best possible at the time of completion. When new data become known, revise the FSG accordingly. Notify team of proposed changes through a review and approval process to ensure the revised FSG is accepted by consensus.

FSG names are based primarily on soil features and limitations. Suggested naming convention hierarchy is depth, drainage class, texture, permeability, available water holding capacity, soil-forming materials, slope range, and any other significant soil feature that sets the FSG apart from others. An example is: *Deep*, *well drained*, *silty*, *acidic glacial till soils with moderate permeability and high AWC*, *level to undulating.* Include topographic characterization only if meaningful. If all the soil map unit components in the group lie on a flood plain, ridgetop, or other specific landscape position, a describing word or two can be included in the FSG name. MLRA's that have distinct precipitation zones because of orographic influences, or temperature zones due to elevation or latitude, should have FSG's developed for each distinct zone or Land Resource Unit (LRU). FSG names should then be modified to indicate the zone. For example, *Level to undulating*, *deep*, *well drained*, *medium textured*, *acidic soils with natural high fertility*, *20-30" PZ (precipitation zone)*.

MLRA's should be subdivided only when climatic differences are real. The differences are only real when they are greater than year-to-year variations within the MLRA, are consistent, and can be delineated on a map with certainty. If consensus is hard to reach on where to delineate zone boundaries, there may be no need to subdivide an MLRA.

In some cases adjacent MLRA's have many similarities in all environmental factors. Many MLRA's were split out only to show a difference in agricultural use or to delineate a major topographic feature. This is especially true of those MLRA designations made in the 1981 revision of Agricultural Handbook 296. In those instances forage adaptation and production may vary little from MLRA to MLRA.

Numbering of FSG's is done the same as for ecological sites. The number consists of five parts.

- The letter **G** identifies it as a forage suitability group. This designation precedes a 10-character forage suitability group number, but is not actually a part of the number.
- A 3-digit number coupled with one letter for MLRA. Code to an **X** if no MLRA letter is assigned. If a subdivision of MLRA is needed, procedures for establishing and revising MLRA's are in part 649.04 of the National Soil Survey Handbook.
- Use a single letter for the LRU where applicable. Insert a **Y** when no LRU is delineated.
- A 3-digit FSG number.
- A 2-digit letter state postal code.

If the MLRA number is only one or two digits, precede it with enough zeros to make a three-digit number. For states using LRU's, enter appropriate letter in the space provided. The next three digits representing the FSG should have three digits entered even if one or two zeros precede other numbers. This numbering convention must be strictly adhered to for automation purposes. A change in the length or alphanumeric convention of any of the above parts renders the code unreadable.

600.0310 Forage suitability group report content

Once the FSG groupings are completed, develop reports describing them and interpreting their value for forage and livestock production. Forage suitability group reports should be brief, but informative. See the example displayed as an exhibit. They should address the major factors that set one group apart from another. The report should make clear which soil map unit components are included in the FSG and the forages that are best adapted to the group for the soil survey area of interest. Forage yields should be given based on the level of management and the harvest method, cutting, and timing regime indicated. Level of management could be stated based on some level of nutrient availability or application rate. Examples are soil pH range and level of soil P and K availability (such as optimum or low for each nutrient). It might also give a rate of N application for all-grass stands based on production targets. It should include drainage or irrigation status for FSG's that ordinarily would benefit from such treatment and routinely receive it in the MLRA associated with the group. Harvest method indicates whether it is grazed or mechanically harvested. When the harvest method is grazing, harvest regime identifies the grazing methods commonly used and at some descriptive level of grazing pressure. When mechanically harvested, the regime might be given as the number of cuttings taken and when.

(a) FSG report

(1) Header
Identify USDA and NRCS to the left top. The forage suitability number and report name are on the right.

(2) Name
Enter the full report name of the FSG centered under the header.

(3) Number
Enter the code starting with alpha character **G** followed by the 10-digit alphanumeric code for the FSG.

(4) Major land resource area(s)
List the code and common name. If further broken down into LRU's, then indicate which LRU is represented.

(5) Physiographic features
Describe the landform(s) that the group of soils occupies. If there are any distinctive features that can impact treatment measures significantly, describe them to alert user of their presence. Examples of specific features are incised channels, seeps, slips, cliffs, and rock outcrops.

(6) Climatic features
Describe the climate for the MLRA or LRU being represented. This climatic information should relate to forage adaptation and production. Pertinent climatic data are:

- freeze-free period (28 °F) in days (9 years in 10 at least),
- last killing freeze in spring (28 °F) date,
- first killing freeze in fall (28 °F) date,
- last frost in spring (32 °F) date (1 year in 10 later than),
- first frost in fall (32 °F) date (1 year in 10 earlier than),
- length of growing season (32 °F) in days (9 years in 10 at least),
- growing degree-days (40 °F),
- growing degree-days (50 °F)
- average annual minimum temperature range (plant hardiness zone),
- average July temperature (°F),
- mean annual precipitation (inches),
- growing season mean precipitation (inches),
- monthly precipitation range (inches),
- monthly temperature range (°F),
- potential evapotranspiration,
- relative humidity (% actually held compared to potential),
- incidence of cloudiness (mean cloudy days per month),
- average number of days between 0.1 inch or greater rain events,
- days of snow cover of 1 inch or greater (where appropriate), and
- climate station(s) whose data are presented in FSG.

(7) Soil properties

This section expands upon the FSG name. More precise information on the following characteristics should be given. To be brief, much of this information is listed in bullet form. See exhibit section for a forage suitability group report (exhibit 3.2–1). The section should describe:

- surface soil textures,
- parent material,
- slope range covered,
- depth to first root-restrictive layers,
- type of restrictive layer (in nonprofessional's terms),
- drainage class,
- permeability class,
- depth to seasonal water table (if any),
- available water capacity range,
- natural pH range (root zone),
- salt content (when applicable),
- sodium adsorption ratio or exchangeable sodium percentage (when applicable),
- degree of stoniness (if present),
- frequency and duration of flooding or ponding (if any),
- cation exchange capacity (CEC) and organic matter content ranges,
- natural P and K reserves (if known),
- aluminum toxicity potential (if any),
- frost action class (where applicable), and
- trafficability issues.

(8) Soil map unit component list

List the **soil map unit components** in the group for the applicable soil survey area(s). Include soil map unit symbol and soil component names.

(9) Adapted forage species list

Indicate which forage species are best adapted to the soil and climatic conditions stated in the FSG report. Species should be listed by the common name used in the MLRA. To increase the usefulness of this list, consider listing commonly formulated forage mixtures as well. Forage mixtures listed should contain only those species adapted to the soil conditions stated in the report. If forage mixtures are not listed here, they should appear in the management section.

(10) Production estimates

Estimate total annual yields of the forages and forage mixtures listed. These estimates should be based on the soil conditions presented in the report and the various levels of management achievable under those conditions. Present these levels of management generically as low and high. Define these two levels of management in the management interpretations section for the FSG being presented. Table 3–1 defines low and high management from a broad national perspective. These definitions may be tailored to be more specific at the MLRA level. The planner must realize that producers may do a number of management factors at the high level and others at the low level. This allows a middle management to result and various shades of management style in between all three levels. If the specialist desires to list only the highest probable yield possible, this may be done and the low yield entry deleted. For MLRA's where irrigated pasture and forage crops are common, a second column for irrigated crop yields at both levels of management intensity is recorded. Again, the high management only or optimum yield can be a single entry for irrigated production.

Production estimates should be broken down by harvest method: forage crops or pasture. If a species is grazable or machine harvestable, give production estimates under each category. Others are only best harvested either by grazing or by machine harvest. For instance, the hay-type alfalfas do not persist well under most grazing regimes, but those developed for pasture use do.

State pasture forage production levels in animal unit months (AUM's). An AUM equals 790 pounds of dry matter consumed.

Forage crop production figures are entered in pounds per acre on an as fed basis. For instance, in the example, corn silage on a dry matter basis yields only 14,000 pounds per acre of dry matter under dryland high management, since it is about two-thirds water. List only the commonly grown forages unless a promising new forage needs promotion.

Example:

Forage crop	Dryland high (lb/ac)	Dryland low (lb/ac)	Irrigated high (lb/ac)	Irrigated low (lb/ac)
	-------- management intensity --------			
Alfalfa	8,000	4,000	12,000	9,000
Clover, red or Ladino	6,000	3,000	11,000	8,000
Corn silage	42,000	28,000	60,000	40,000
Legume-grass	8,000	4,000	13,000	10,000

Pasture	Dryland high (AUM/ac)	Dryland low (AUMs/ac)	Irrigated high (AUM/ac)	Irrigated low (AUMs/ac)
	---------- management intensity ----------			
Tall fescue-K. blue-red clover	7.0	2.5	10.0	7.0
Orchard-K. blue-white clover	4.0	2.0	6.0	4.0
Tall fescue-Ladino clover	8.0	3.0	11.0	8.0
Switchgrass	11.0	6.0	---	---

1 AUM = 790 lb

Table 3–1 Impact of management on yields of forage crops and pasture [1/]

Management factor	Low management	High management
Nitrogen rates per year	None spread as manure or fertilizer.	Maximum annual rate applied [2/] for crop and area, split applied.
Available phosphorus	Soil tests low or deficient.	Soil tests optimum or higher.
Available potassium	Soil tests low or deficient.	Soil tests optimum or higher.
Soil pH	pH too low or high for crop.	pH optimum for crop.
Salinity (EC)	Yield 80% of normal or worse due to soil salt concentrations.	Salinity (EC) reduced to levels that do not reduce yield.
Sodium adsorption ratio (SAR)	Greater than 25.	Less than 13.
Irrigation water management	Often untimely, and inadequate for yield or salinity control.	Adequate and timely. Salinity of water compensated for.
Drainage	Inadequate.	Optimum for soil conditions.
Insect and disease control	Inadequate or often untimely.	Adequate and timely.
Plant desirability	Remaining forage species less productive than site permits.	Planted or desired forage species in proportions desired.
Plant cover	Open stand, bare ground or weedy patches between forage plants.	Complete canopy cover or optimum stem count for crop.

Table 3–1 Impact of management on yields of forage crops and pasture—Continued

Management factor	Low management	High management
Plant vigor	Off-color, spindly plants, slow recovery after harvest.	Good color, robust plants.
Soil compaction	Compaction restricts root growth and water infiltration.	Compaction is weakly present or destroyed as needed.
Sheet and rill erosion	Erosion rates exceed T.	Erosion rates below T.
Pasture only		
Percent legume	Less than 20% in WS [3/] grass; less than 30% in CS [3/] grass.	More than percentages at left, but less than 60% of dry wt. yield.
Livestock concentration areas areas	Denuded areas > 10%.	Minor bare spots or heavy use surfaced.
Severity of use	Grazed as low as livestock can at all times. Or, ungrazed or lightly grazed areas > 50%.	Grazing and clipping managed to keep forage in a vegetative, fast growth stage as is possible.
Noxious weed control	Inadequate or often untimely.	Adequate, few or none present.
Forage crops only		
Weed control	Inadequate; losing desirable species and forage quality.	Adequate and timely during establishment and production.
Planting and harvesting operations	Often untimely resulting in diminished stands and quality.	Timely and fitted to near ideal soil and crop conditions.

1/ Adapted from Fehrenbacher et al., 1978, Soil Productivity in Illinois, IL Coop. Ext. Cir. 1156.

2/ This must be in coordination with percent legume. Little N is needed when legumes meet minimum criteria set under low management, percent legume. Thus, N applications could be zero if legumes make up a significant portion of the stand. Alternatively, legume content could be low if N is applied instead.

3/ CS = cool-season. WS = warm-season.

(11) Growth curves

For pastured forages, display their growth curve or seasonal distribution of production or availability if reliable data are available for the MLRA or LRU being represented. See figure 3–4 for format. Combine species with similar seasonal distribution of growth data to cut down on redundancy and data display. If same growth curve is used for the one species, identify all species having this common growth curve.

(12) Soil limitations

Identify soil limitations that will adversely affect forage production or impact management flexibility. Examples of the first effect are:

- Acidic or alkaline soils will reduce most forage yields unless corrected with soil amendments that correct the pH to a range acceptable for the species desired.
- FSG's having low available water capacity (AWC) cannot be expected to yield as well as high AWC groups.

Examples of the second effect are:

- Low CEC FSG's require more frequent additions of K fertilizers at lower rates than high CEC FSG's.
- Slope steepness may require more involved fencing layouts and more frequent watering facilities to distribute grazing pressure evenly. Otherwise, pasture utilization rates suffer. Slope may also limit the ability to lime and fertilize fields that are extremely steep. As slopes steepen, the hazard of erosion increases for fields that may be tilled to introduce a new forage stand. To minimize the erosion hazard, tillage and planting options become narrower for steeper sloped FSG's.

If an easily corrected limitation makes the soil suited to other forage species, list those species in this section. Over-riding limitations should also be identified, if there are any. These limitations are so severe that few, if any, management or treatment measures can correct them for a particular forage species or a grazing land resource. Example situations include:

- Extremely steep land should be avoided for crop production for a number of reasons.
- Some land is in naturalized pasture rather than improved pasture because of extreme slope steepness, surface stoniness, droughtiness, topographic reasons, or any combination of these and other soil limitations.
- Northern soils prone to frost heave severely reduce over-wintering taprooted forages and small grain production.

For more guidance on writing this section of the FSG report, refer to the appropriate soil property in this chapter that is to be rated and managed in the MLRA.

Figure 3–4 Growth curve

Growth curve number: PA12081/
Growth curve name: Tall fescue, 120-140 day growing season2/
Growth curve description: Tall fescue dominated pasture, <5% legume3/

Percent production by month4/

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	0	0	5	32	27	12	5	16	3	0	0

1/ Use number only once in each state. The first 2 digits are for the state postal code, and for the last 4 digits, enter numbers from 0001 to 9999.
2/ Enter a brief descriptive name for each forage species or mixture for which data are available.
3/ Describe pasture type more fully by listing major botanical components.
4/ Include percent of growth or availability by month.

(13) Management Interpretations

Information in this subsection is used to plan the use and management of soils for forage crops or pasture. This section conveys the importance of all the soil and climate data presented at first in a forage suitability group report. This section must make good interpretative use of that data for the forage suitability group report to convey much useful information to the end user. Management interpretations are based on the soil and climatic conditions described in the FSG's and whether the forage is grazed or mechanically harvested. These management interpretations will be primarily agronomic and grazing ones, but may include some agricultural engineering ones as well when appropriate. Examples of agronomic interpretations are

- seedbed preparation needs and planting depths and timing influenced by soil and climatic limitations;
- soil fertility recommendations based on soil CEC, native fertility, pH, salinity, and rainfall patterns; and
- forage crop harvest alternatives based on climatic constraints.

Grazing management interpretation examples are deferring grazing to avoid compacting wet soils, suggested modifications to rotational pasture layouts because of slope steepness or irregular terrain, and distance to drinking water based on terrain. Agricultural engineering interpretations could include fence design modifications required due to soil depth or terrain features, irrigation alternatives and modifications based on soil and climate requirements or topographic position, and drainage design alternatives of seasonally wet soils not considered to be protected wetlands. See table 3–2 for agronomic interpretations of common soil limitations that occur throughout the United States. Management intensities of low and high are used in the Production Estimates section, describe those levels of management now by land use. Refer to table 3–1 for general guidance as to what is meant by low and high management inputs on a broader national scale. When the management interpretations are not influenced by harvest method, write management recommendations in a general section. For instance, the need for lime is dependent on soil pH status and the forage species desired, not on whether the forages are harvested with machinery or by a grazing animal.

When management is influenced by harvest method, indicate in the subheading of this section whether it is pasture or forage crops. For example, nutrient management is different for pasture versus cropped land. In a pasture setting, nutrients are recycled on the same field. Depending on fencing and watering strategies, grazing method used, and the presence or absence of shady areas, nutrient distribution may vary considerably over the field. Yet, little phosphorus (P) and potassium (K) are removed from the system. In some cases more P and K may enter the field than leave it. This depends on the level of supplemental feeding while the animals are on pasture. Nitrogen (N) is generally the limiting nutrient unless legumes are present and make up at least 25 percent of the stand. Nitrogen is concentrated at urine spots and dung areas, so it takes years for even distribution of N to occur. Much excreted N is also lost to volatilization, runoff, and leaching in humid and subhumid areas because of its placement. On cropped land, the nutrients are removed completely with the harvest. They may or may not be returned to field. Depending on how efficiently the animal waste is collected, stored, and transferred back to the field, the amount of nutrients returned to that field from animal waste can range from overapplied to none at all. Stored forages fed to pastured cattle would create an animal waste source that is economically uncollectable and a net gain in nutrients to the pasture. For intensively managed cropland and hayland, therefore, a balanced fertilizer program is followed annually to maintain soil fertility levels.

Statements made in this section should be concise and accurate, but remain generic. For example, an FSG naturally low in a nutrient should state that it needs to be applied. If the FSG also has low CEC soils and high permeability, those nutrient applications may need to be split applied during the growing season. The FSG report should also indicate how that might differ for a legume versus a grass, or a warm-season grass versus a cool-season grass. It is impossible to state how much. First, it is field specific. It is forage species and species mixture specific. It is also dependent on the desired yield goal of different land managers and the amount of effort they are each willing to extend to other management practices that impact forage yield.

If a management measure needs to be qualified, cite an existing job sheet that goes into more detail. For instance, liming is generally a good practice for acidic soils. However, the forage being grown, yield goal desired, and the current soil pH of a particular field also dictate the level of liming or the need to lime at all. An FSG may contain acidic soils; however, the pH of the plow layer may differ due to different management histories of forage crop and pasture lands. On acid soils, different fields have received from one to several lime additions, while others may never have. Even the type of lime needs specifying if calcium and magnesium levels in the soil need balancing. Only a field specific soil test can indicate this. Reserve this amount of detail to an appropriate job sheet on liming.

Table 3–2 Agronomic interpretations of soil limitations

Soil limitation	Agronomic interpretations
Seasonal high water table >60 days in most years or permanent high water table	Denitrification frequently occurs in anaerobic subsoil. Tillage and harvest opera tions and forages with water intolerant roots affected by excess rain or elevated water table unless drainage is improved. Subirrigated forage crops need special fertilizer management to avoid soil nutrient losses and deferment from traffic when soils are saturated at surface.
Ustic, aridic, or xeric soil moisture regimes (subsoil dry >90 successive days each year within the 8- to 24-inch soil layer)	Irrigation required for optimum forage production. Fallow/crop production. Drought tolerant forage selection for dryland.
Low CEC (Plow layer CEC <4 meq/100g soil of effective CEC, or CEC <7 meq/100g soil by sum of cations at pH 7, or CEC <10 meq/100g soil of effective CEC at pH 8.2	Low ability to hold nutrients K, Ca, and Mg from leaching. Split apply K and N fertilizers when high application rates are recommended. Potential danger of overliming.
Aluminum (Al) toxicity, >60% Al saturation of the effective CEC, pH <5	Lime or apply gypsum to reduce exchangeable Al to a soil depth of at least 20 inches so that it no longer restricts root growth and nutrient uptake. Select Al tolerant species/varieties.
Acid soils, 10% to 60% Al saturation of the effective CEC within 20 inches of soil surface; pH 5–6	Lime to raise pH to the level needed to grow the forage crop desired. Acid soils over dolomitic limestone may be calcium deficient requiring calcitic lime applications. Select species adapted to acid soils.
High phosphorus (P) fixation	Requires high P application rates or band-applied superphosphate or ammonium phosphate. Can absorb large quantities of high P animal wastes without loss to runoff once incorporated. Most legumes difficult to establish and maintain.
Clays with high shrink-swell	Tillage difficult when too wet or too dry. Bunch grasses more adapted than sod formers. P deficiency common. Legume choices limited.

Table 3–2 Agronomic interpretations of soil limitations—Continued

Soil limitation	Agronomic interpretations
Low potassium (K) reserves, <2% of base saturation	Potential K-Mg-Ca soil imbalance. Need frequent applications of K, especially to retain legumes.
Calcareous soils, free $CaCO_3$ within 20 inches of soil surface, or pH >7.3	Potential micronutrient deficiency—Cu, Fe, Mn, Mo, Zn. P deficiency possible. Water soluble P fertilizers needed.
Sodic soils, > 15% Na-saturation of CEC or sodium adsorption ratio (SAR) > 13 within 20 inches of soil surface	Applications of acidifying soil amendments, lime, or gypsum depending on class of sodic soil, and applications of irrigation water and drainage.
Low AWC (available water capacity)	Irrigation where rainfall is insufficient and/or infrequent. Use of water efficient forages, such as warm-season species.
Slope, >25% land is	Machinery operations difficult impeding use of agronomic practices. Erosion hazard high if soil tilled or bared by animal traffic. Grazing may be uneven when flatter available and more accessible.
Flooding or ponding duration, > 7 days	Select species tolerant of prolonged flooding. Defer grazing until soil is firm and regrowth is well established. Once soil is firm, chop uniformly any silt-damaged standing forage back onto field. Ensile overmature standing forage with minimal silt damage. Mix this low quality forage with less mature forage from an unflooded field. Topdress fertilize fields harvested prior to flood if regrowth is short and yellow. Silt deposition greater than 2 to 3 inches may require reestablishment of forage stand in those areas. Restore damaged drainage facilities. Remove sand or gravel deposits or spread and mix with underlying soil.
Frost heave, high	Avoid planting taprooted forage crops or winter small grains where climate and soils cause frost heave to be almost an annual occurrence.

(14) Management dynamics
Describe the effect each management practice pertinent to the FSG has on forage species survival or vigor. How does each practice impact maintaining the forage species or mixture of species desired at the site? Describe patterns of community change symptomatic of a management input and the reasons change occurred. Include a description of how some plant species can invade or increase on the site because of a management decision. Also, describe the interactions of an established mixture of plant species and how to use them to maintain the desired mixture. This can be involved because of the management options available to producers on forage crop and pasture lands.

The main intent of this section is to show how forage plants respond to management stimuli. The most successfully applied management practices work with the ecosystem and support it. Management practices applied without regard to the ecosystem generally are economically ineffective, often lead to environmental degradation, and may fail to achieve the intended production goal as well. This section is optional. Develop only if it has instructional value for the FSG being described. This section gives the reasons for doing the management action.

(15) FSG documentation
Similar FSG's—Identify and describe FSG's, including similar FSG's in adjoining MLRA's, that resemble or can be confused with the current FSG. Note specific difference and contrasting management options to address difference. If from an adjoining MLRA, there may be no differences to point out.

Supporting data for FSG development—Include research references used, clipping study information, and farmer information, such as hay records or grazing information.

Site approval—Indicate FSG approval. Each FSG team will determine approval procedures for the MLRA.

(b) Revising forage suitability groups

Analysis and interpretation of new information about soil, plant adaptation, production, and management may indicate a need to revise or update FSG's. Because collection of such data is a continuing process, FSG's should be periodically reviewed for needed revision. When new data on plant adaptation, production, or management indicate a need for revision, it should be completed as soon as possible. Documentation of plant adaptation, production, and management will be the basis of the revision.

600.0311 Climatic factors that influence forage production

Climatic factors that influence forage production are numerous. Not only do they influence forage selection, growth, and yield in concert with the soil resource, they also influence how and when seedings and harvests can be made. In preparing the FSG report, the climate station(s) used to characterize the climatic data in the report need to be identified. List its station identification number and location and identify the 30-year period used to generate the climatic data.

To make good agronomic management recommendations in forage suitability group reports, the agronomist must be aware of how climate affects forage crop and pasture management. This subsection provides an overview of the important climatic factors nationwide. Table 3–3 lists the different agronomically significant climatic data elements and states the major reasons for their importance to forage production.

(a) Freeze-free period

Freeze-free period is the number of days where the air temperature does not fall below 28 degrees Fahrenheit at the 90 percent probability level. This is the growing season for cool-season perennial forage crops in temperate regions. As indicated by the National Water and Climate Center, three temperature indices are commonly used to define the growing season. This is the intermediate threshold temperature. It is labeled as the freeze-free period to avoid using the same terminology twice. See length of growing season in this section. A killing freeze (Am. Meteorological Soc. 1996) or moderate freeze (28 °F. or less) in the fall is widely destructive to most vegetation effectively ending the growing season for cool-season perennials. The last killing freeze in the spring marks the beginning of any significant cool-season grass growth. Some cold-tolerant grasses, such as tall fescue, may tiller and grow slowly before this date, but the forage mass produced is minimal.

The 90 percent probability level was selected based on the advice of Supplement number 1, Climatography of the U.S., Number 20, Freeze/Frost Data (1988). For agriculture interpretations, it is better to know that there is only a 10 percent chance that the freeze-free period will be shorter than the length given at the 90 percent probability than at an equal chance, 50 percent probability, used to determine the WETS growing season. Late spring freezes can cause severe injury or death to some perennial and annual forage crops that prematurely initiate growth because of warm weather before the killing freeze. Perennial ryegrass is a prime example. This growing season length combined with growing degree-day data sets the number of grazing or harvest cycles that are possible based on forage regrowth potential. However, cold-hardy brassicas and stockpiled fescue can extend the grazing season past the end of this growing season. Brassicas tend to keep growing past the killing freeze date in the fall.

Last killing freeze in spring and first killing freeze in fall at 28 degrees Fahrenheit at the 90 percent probability approximates times when cool-season forages can be planted. The last killing freeze in spring has only 1 chance in 10 of occurring later than the date indicated in the FSG report. Similarly, the first killing freeze in fall only has 1 chance in 10 of occurring earlier than the date indicated in the FSG report. Spring seeded cool-season forage crops can be planted slightly before the last killing freeze in spring if soil conditions permit and forage germination is delayed until past that date, or a companion crop canopy protects young seedlings. Summer-fall seeded cool-season perennial forage crops should be planted to emerge and grow for at least 6 weeks before the first killing freeze in the fall. Seedlings should be 3 to 4 inches tall before the first killing freeze in the fall. In Southern States where last killing freeze occurrence is early in the year (if at all), warm-season perennial forage crops are planted as early as the ground can be prepared.

(b) Frost-free period

Last frost in spring and first frost in fall at 32 degrees Fahrenheit at the 90 percent probability approximates when annual warm-season forage crops can be first planted and are most likely to be killed each year, respectively. Therefore, it is called a killing

Table 3–3 Climatic factors and their importance to forage production

Climatic factor	Primary importance
Freeze-free period (28 °F) in days	Approximate growing season for CS [1/] forages.
Last killing freeze in spring (28 °F) date	With soil temperature sets CS [1/] spring planting date.
First killing freeze in fall (28 °F) date	With ample timely rainfall sets CS [1/] summer planting date.
Last frost in spring (32 °F) date	With soil temperature sets WS [1/] spring planting date.
First frost in fall (32 °F) date	Most annual forages and weeds are killed on this date.
Length of growing season in days	Annual forage crop days to maturity selection.
Growing degree-days (40 °F)	CS [1/] forage first harvest date and number of harvests.
Growing degree-days (50 °F)	WS [1/] forage first harvest date and number of harvests.
Average annual min. temp. (plant hardiness zone)	Winterkill hazard for a specific species/cultivar.
Average July temperature	Heat-stress on a specific species/cultivar.
Mean annual precipitation (inches)	General guide to moisture abundance, species selection.
Growing season mean precipitation (inches)	Moisture guide for species selection and irrigation need.
Monthly precipitation range and average (inches)	Probability of having too little or too much.
Monthly temperature range and average (°F)	Indicates amount of heat for growth and curing.
Potential evapotranspiration (inches)	Need for irrigation water for optimum yields.
Relative humidity (%)	Influences foliar disease severity and cut forage drying rate.
Incidence of cloudiness (mean cloudy days per month)	Affects forage quality and drying rate.
Average number of days between ≥ 0.1 inch rain events	Affects forage quality and selection of harvest method.
Days of snow cover of 1 inch or greater (where appropriate)	With average minimum temperature affects winterkill hazard.

1/ CS = cool-season. WS = warm-season.

frost by the American Meteorological Society (1996). Here the risk of crop failure is critical so NOAA again recommends the 90 percent probability. Therefore, the last frost in spring has only 1 chance in 10 of occurring later than the date indicated in the FSG report. Similarly, the first frost in fall only has 1 chance in 10 of occurring earlier than the date indicated in the FSG report. The last frost in spring date is the earliest possible planting date to avoid a killing frost wiping out an emerged warm-season forage crop seeding. Warm-season forages need appropriately warm soil temperatures as well for good germination. Cold-tolerant forage crops can be planted before this date, especially if accompanied by a companion crop that canopies and thus protects them from frost. It is also important to know when the first killing frost occurs to ensure there is time for the annual warm-season forage crop to mature or to maximize harvestable yield prior to its being killed by frost. If a killing frost strikes prematurely, quality of the forage or grain is substantially lowered. This is especially critical for crop selection of late-planted annual forage crops often used as emergency or supplemental forage crops. Either the crop has to mature quickly, or it must withstand frosts and grow well during cool weather. The first frost in fall also effectively ends the growing season for warm-season perennial forage crops and most annual weeds. It often marks the beginning of cool-season forage production in climates where killing freezes seldom or never occur. Tropical areas are frost-free.

(c) Growing season length

The length of the agronomic growing season in days is set at 32 degrees Fahrenheit at the 90 percent probability. Growing season is the part of the year when the temperature of the vegetal microclimate remains high enough to allow aboveground plant growth. It is the interval between the last killing frost of spring and the first killing frost of fall, or the frost-free period. This killing frost can occur at aboveground air temperatures as high as 36 degrees Fahrenheit. Most thermometers used to monitor air temperature are 5 feet above the ground. Ground surface temperature at crop level is often 4 to 8 degrees Fahrenheit lower than that at the thermometer. Therefore, the data entry in the FSG report may, in fact, be shorter than that indicated by the last frost in spring and first frost in fall dates, respectively.

This is the growing season length used by agronomists to determine crop maturity zones for such crops as corn and soybeans. Since corn and several other annuals are often forage crops, the frost-free period is the critical growing season length to record in the FSG report. To ensure the frost-free period is long enough for the annual forage crop to mature or be in a harvestable state before the killing frost occurs is a significant planning tool. It also reflects the effective growing season for warm-season perennial forages.

(d) Growing degree-days

Growing degree-days are recorded for forage crops at two base levels, base 40 degrees Fahrenheit and base 50 degrees Fahrenheit. The 40 degrees Fahrenheit base is used to calculate growing degree-days for cool-season forage crops. The 50 degrees Fahrenheit base is used to calculate growing degree-days for warm-season crops. Although for some warm-season forage crops, such as sorghum and sudangrass, a base temperature of 60 degrees Fahrenheit is more appropriate. Some crops, such as corn, have growing degree-days calculated using a minimum and a maximum apparent temperature limit for growth. The limits are 50 degrees Fahrenheit and 86 degrees Fahrenheit. Growth essentially ceases below 50 degrees Fahrenheit and above 86 degrees Fahrenheit. Any daily temperature extreme that does not fall within those limits is ignored, and the limit exceeded is put in its place in the equation. Growing degree-day units (GDU) per day for corn = $[T_{max} (\leq 86) - T_{min} (\geq 50)] / 2 - \text{base } (50)$.

Climatography of the United States No. 20 has GDU's published for 40, 50, 60, and 50/86 degrees Fahrenheit. Yearly GDU accumulations along with soil water availability govern the growth rate of plants. Cumulative GDU data can be used as a guide to select annual crop varieties that will mature before a killing frost, schedule crop harvest, and classify regional agricultural climatology. Yearly GDU accumulations for the United States begin on March 1 in the Climatography of the United States No. 20. National Water and Climate Center TAPS station data displays monthly growing degree-day data.

When dealing with an annual crop, GDU accumulation must begin at the planting date so the base GDU accumulation up to planting time is subtracted from the GDU accumulated after planting to monitor crop growth progress using GDU's. Growing degree-day accumulations have been used to schedule nitrogen fertilizer applications to cool-season grasses in Western Europe and the United Kingdom. It is called the T-sum 200 method. N fertilizer is spread when 200 heat units (GDU) of average daily temperatures in degrees Celsius base 0 degrees Celsius (32 °F) are reached from a start date of January 1. It works well for cool, humid regions. In more arid, warmer regions, fall and early spring applications on cool-season grasses are best since their growth ceases during the summer unless irrigated. Here T-sum 200 would recommend an incorrect timing of spring N applications and fail to suggest a fall application altogether. In humid, warm regions, late fall and late winter applications on cool-season grasses are best since their growth occurs during the winter months. Here, the T-sum 200 method could only work using a different starting date for the fall application and would need to be tested.

(e) Average annual minimum temperature

Average annual minimum temperature determines the plant hardiness zone designation for an area. This temperature is the average value of the lowest temperature recorded each year for the years of record, 1974 to 1986. Many MLRA's have more than one plant hardiness zone if they extend north to south very far, have significant elevational differences within them, or have large bodies of water that moderate near shore climates. The source for this information is in the USDA Plant Hardiness Zone Map, Miscellaneous Publication 1475, dated 1990. This map along with days of snow cover greater than 1 inch data help determine whether perennial forage crops can winter over without being killed or severely weakened. It determines the extent of their range of adaptability to cold weather. Some MLRA's that are extremely cold, but have snow cover most of the winter, can support forage crops that would be killed where the ground lies open most of the winter. For example, orchard-grass can survive in Maine in the interior under the snow cover, but winterkills occur readily along the Atlantic Coast where the snow cover is light or absent most of the winter. Where snow cover is nonexistent or rare, then only the average annual minimum temperature determines the winter survival rate of a forage crop and its varietal selection. Bermudagrass varietal selection has been done to make it more winter-hardy, for instance. This factor also interacts with humidity, wind, soil moisture, soil type, and winter sunshine. Most of the information on winter hardiness is observational using trial and error. Forage crops with a consistent stand loss or failure history winter after winter should not be recommended for planting in that MLRA.

(f) Average July temperature

Average July temperature is the opposite of the average annual minimum temperature. Some forage crops do not do well under intense heat. Cool-season forage crops cease to grow much above 86 degrees Fahrenheit. This heat combined with high humidity makes several cool-season forage species susceptible to virulent foliar diseases, reducing their stands or their quality. So much so, that selecting forage species more tolerant of the heat and humidity, generally warm-season grasses of the tropics or subtropics, is simpler. If cool-season forages are grown in areas of high summer heat and humidity, but cool winters, they generally are winter annuals used to extend the grazing season to a year-round scenario. If they are perennials, they need to be varieties that are summer-dormant, winter-growing ecotypes. Mediterranean ecotype orchardgrass is an example of a summer-dormant, winter-growing cool-season forage. Endophyte infected tall fescue acts in a similar fashion.

(g) Mean annual and growing season mean precipitation

Mean annual and growing season mean precipitation are indicators of adaptability range of forage crops. The western edge of the primary range of climatic adaptation of many introduced European forage crops is at the 98 degrees west meridian. They are also adapted to areas west of the Cascade Mountains in Washington and Oregon. In other places west of the 100th meridian, they may grow well at higher elevations or on irrigated lands. The reverse can be said for many native forage species of the Great Plains. The eastern edge of their primary area of climatic adaptation is at the 100th meridian. Mean annual precipitation is a less precise measure of adaptation in that most of the precipitation can be skewed to the nongrowing season in colder climates so that it is less effective for growing crops. Mean annual precipitation is used to delineate climatic moisture regimes of wet, humid, subhumid, semiarid, and arid. Arid regions have annual precipitation of 10 inches or less. Semiarid regions have an annual precipitation range of 10 to 20 inches, subhumid 20 to 40 inches, humid 40 to 60 inches, and wet greater than 60 inches. Growing season mean precipitation when coupled with soil available water holding capacity and potential evapotranspiration can predict the occurrence of soil moisture deficits that prevent crops from producing optimum yields. In areas where this deficit in crop moisture is large, irrigation is practiced where it is cost-effective and a source of irrigation water exists. Growing season mean precipitation of 20 inches is roughly the isoline that divides the United States between extensive irrigated acres and acres with little irrigation except on very low water holding capacity soils or specialty and turf crops.

(h) Monthly precipitation range

Monthly precipitation range in inches shows the normal range at the 2-year-in-10 probability. In most climates the range is important because it shows the uncertainty of dependable rainfall and the possibility of it being overly abundant at other times. Species selection can be based on drought tolerance where it is obvious that inadequate rainfall occurs from time to time and droughty soils are commonplace. When monthly rainfall amounts appear excessive, it is obvious that machinery and livestock movement may be slowed and damage can occur to waterlogged soils. Heavy monthly rainfall interfers with harvests unless they can be done quickly between rainfall events. Monthly rainfall data also shows the yearly distribution of rainfall. Coupled with temperature data, some forage production strategies can be explored to take advantage of the distribution as it presents itself. An example is growing winter forage crops where the winters are mild and winter moisture is abundant and perhaps is mostly lost to crop production by the summer growing season. The average monthly precipitation can be displayed to show how much the minimum and maximum deviate from the norm.

(i) Monthly temperature range

Monthly average minimum and maximum temperature range in degrees Fahrenheit at the 2-year-in-10 probability. Again, the monthly average temperature can be displayed to show how much the minimum and maximum deviate from the norm. These monthly temperatures bolster the growing season length data and hint at growing degree-day unit accumulation throughout the year. The best forage crop growing areas have average monthly mean temperatures between 50 degrees Fahrenheit and 68 degrees Fahrenheit for 4 to 12 months out of the year. Spring oats or barley, often used as a companion crop for forage seedings north of the 39th parallel, has its seeding date target set by the monthly average air temperature of 50 degrees Fahrenheit. Oats seedings should begin 2 weeks before the month that has an average air temperature of 50 degrees Fahrenheit. Forage seedings would then be planted with the oats using a drill with a small seed-planting unit attachment on it.

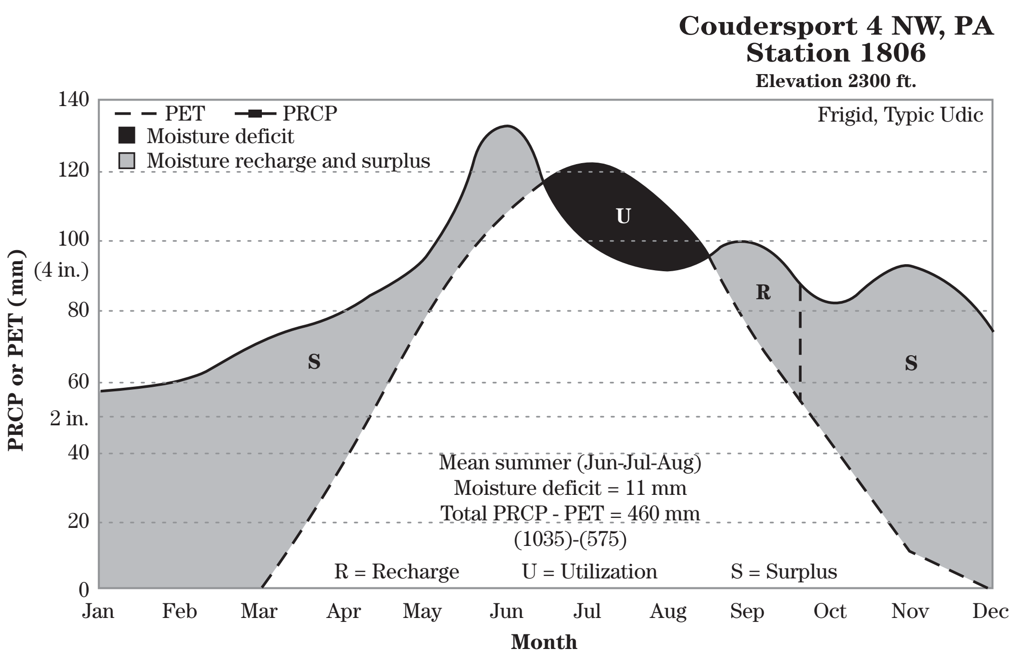
(j) Potential evapotranspiration

Potential evapotranspiration (PET) is the combined yearly loss of water from a given area that would evaporate from the soil-plant surface and transpire from a full plant canopy where the supply of water is unlimited. Actual evapotranspiration (AET) is the amount of water evaporated from the soil-plant surface and transpired by plants if the total amount of water is limited. An incomplete plant canopy may exist that would limit transpiration as well. AET is commonplace in dryland forage crop production in climates where growing season rainfall is sporadic enough to cause plant available soil moisture to be depleted. Plants undergo water stress, wilt, and consequently are unable to use as much water as they could. These problems are most serious in low water holding capacity soils and in climates where significant rainfall events can be several days apart. PET for various regions may be converted to estimates of the evapotranspiration of specific forage crops by using a derived specific constant for each crop, K_c (crop factor). For example, alfalfa has a K_c of 90 to 105. It, therefore, gives an estimate of how much irrigation water would be necessary to grow a forage crop for the year. PET can be derived from pan evaporation data retrieved from climatic stations collecting that information on a monthly basis to plot its distribution curve throughout the year. This plot along with a plot of monthly precipitation averages will show seasonal deficits and surpluses of precipitation versus loss and use through PET. Depending on the soil water holding capacity and its runoff potential, the data plot can indicate how much water is available for leaching and for crop production. It can also show how much of a shortfall in water can occur on a particular forage suitability group during the peak evapotranspiration period. See figure 3–5 for an example of this concept.

(k) Relative humidity

Relative humidity is expressed as a percentage measure of the amount of moisture in the air compared to the maximum amount of water vapor the air can hold at the same temperature and pressure. It greatly affects the drying rate of machine-harvested forage crops. Relative humidity is but one climate element that determines the most feasible method of harvesting a forage crop while optimizing forage quality. Incidence of cloudy weather and average number of days between 0.1-inch or greater rainfall events also determine whether forage crops are better conserved as silage, haylage, or dry hay. High humidity slows the drying rate considerably and can prevent dry hay from reaching a moisture content that is low enough to keep well in storage without

Figure 3–5 A plot of PET versus precipitation on a soil with an 8-inch AWC [1/] [2/]



Moisture balance for Coudersport 4 NW, Pennsylvania, based on a period of 1961–1990. PET calculated b Newhall Simulation Model (Van Wambeke et al., 1992)

1/ Note the water deficit for growing a crop during mid-summer. Yields are reduced without supplemental water or timely rainfalls in wetter summers.

2/ Adapted from Penn State University Experiment Station, Bulletin 873, Soil Climate Regimes of Pennsylvania.

preservatives or mechanical drying. The National Climatic Data Center of NOAA has compiled average relative humidity for selected climate stations over the United States for morning and afternoon hours. High nighttime humidity tends to produce heavy dew once the dew point (temperature at which water vapor in the air begins to condense on surfaces) is reached. This may linger well into the afternoon on very humid days, delaying the drying rate of cut forage considerably. Hot, humid climates also make a favorable environment for foliar diseases, especially ones caused by fungi and viruses. This makes many cool-season grasses poor choices for forage production that produce thin stands and low quality forage because of heavy foliar disease attack.

(l) Incidence of cloudiness

Incidence of cloudiness is expressed as the mean number of days per month by category of cloudiness. The cloudiness is determined for daylight hours only since the concern is about the quality of solar radiation. The three categories are clear, partly cloudy, and cloudy. For agronomic purposes, only the number of cloudy days recorded are of concern. Its main importance is its impact on the drying rate of cut forage crops. On a dry soil with an air temperature of 80 degrees Fahrenheit, drying takes more than twice as long under cloudy skies than on a sunny day. This can delay drying of hay by 2 days if there are only 8 hours of effective drying time per day. If the soil is wet from a previous rain event, drying time escalates further. Prolonged cloudy weather can also cause accumulation of nitrates in highly nitrogen-fertilized forages as well when the weather is cool. The levels may become high enough to poison livestock. The National Climatic Data Center of NOAA has compiled mean number of cloudy days for selected climate stations over the United States. It is in a table that also includes the number of clear and partly cloudy days.

(m) Average number of days between rain events

Average number of days between rain events of 0.1 inch or greater is derived information. The National Water and Climate Center in its TAPS database compiles the this information by month. To convert that information to the requested FSG data element, simply divide the total number of days during the harvest season months by the total number of rainy days in those months and round to the nearest whole number. This average, based on random probabilities, is going to be fairly accurate. However, it should be evaluated to make sure it truly reflects the normal time interval between rain events for the MLRA. This information is extremely important in making recommendations on forage harvest management. Management recommendations to speed drying should be made, such as using mower conditioners, tedders, chemical desiccants, and lacerators. Where relative humidity and incidence of cloudiness are high and time intervals between rain events are short, haymaking is impossible while still maintaining forage quality. Forage harvest alternatives of haylage or silage should be suggested in the FSG management section.

(n) Days of snow cover

Days of snow cover of 1 inch or greater is also available from the National Water and Climate Center's TAPS station data at the bottom of the table. This climate data element requires some interpretation to be useful. Winters are often said to be open, that is, with little snow cover. If this is accompanied by freezing temperatures, forages that are not cold tolerant can winterkill. Snow offers insulation to plants from freezing air temperatures. A snow cover of 4 inches with air temperatures to minus 13 degrees Fahrenheit kept soil temperatures below it from dropping. Snow cover must remain in late winter and early spring when plants have a lower cold resistance and severe temperature fluctuations above and below freezing are still possible. The author of the FSG report must decide whether snow cover is effective in keeping some forage crops from winterkilling. There is no general rule of thumb. While snow cover insulates plants and protects them from freezing temperatures, it can also lead to snow mold outbreaks in susceptible forage species. Where this is a problem, it should be noted in the management section of the FSG report.

600.0312 Soil factors that influence forage production

Landscape and soil properties from soil survey information that have a significant and direct effect on forage plant production and their management nationally are:

- Slope
- Drainage class
- Available water capacity
- Flooding and ponding, frequency and duration
- Soil reaction, acid and alkaline Soils
- Salinity
- Native fertility as measured by cation exchange capacity (CEC) and organic matter content
- Frost heave potential
- Trafficability as characterized by the Unified Soil Classification, surface rock cover, and drainage class
- Surface rock fragments
- Shrink-swell
- Depth to restrictive layers

Other measurable soil properties have an indirect effect on forage production and management. They help define or modify other soil properties; however, they, themselves, do not focus on an attribute of forage production clearly enough to be useful in assigning a soil map unit component to a suitability group. Soil texture is an example. It influences plant growth by impacting soil aeration, water intake rate, available water capacity, cation exchange capacity, permeability, erodibility, workability or trafficability, and in the case of surface stones, the amount of surface soil area upon which plants can grow. For FSG's, texture is an important soil property, but it is nonspecific. It is not precise enough to be of value in creating like soil capability groups. In some cases, a soil textural class may have some good features as well as bad, making it impossible to rate it overall. A sandy loam may have great permeability and trafficability, but have low water holding capacity and native fertility. Instead, those soil properties it does influence will be rated separately since specific values for them can be gathered from soil interpretation records.

600.0313 Landscape properties influencing forage suitability groups

As organized, the first two properties listed in the introduction of this part, slope and drainage class, are landscape properties.

(a) Slope

Slope has an impact on grazing lands for both humans and livestock. Coupled with aspect, it has a profound effect on plant growth. However, soil map units over much of the United States can each lie on many different aspects. Aspect, therefore, cannot be used to evaluate into which FSG a soil map unit component belongs. On a field-by-field basis, some further interpretation can be made if a predominant aspect exists.

(1) Limitation categories

For FSG's, slope classes are combined to form three limitation categories:

- **Slight**—nearly level, gently sloping, and undulating
- **Moderate**—strongly sloping, rolling, moderately steep, and hilly
- **Severe**—steep and very steep

(2) Importance to management considerations

The slope limitation categories are set up for two reasons. First, livestock tend to decrease their movement as slope increases. Grazing pressure on hilly ground becomes uneven as livestock ignore steeper areas in favor of more easily accessed areas. Watering facilities need to be more closely spaced as the landscape becomes more rugged. If not, overgrazing occurs near the water supply and more remote areas are lightly grazed, if at all. To overcome this limitation, more fencing and walkways are required to distribute grazing pressure evenly. Steep, hilly ground requires more troughs and pipeline to get water within the closer distances needed to keep livestock performance at an optimum level. As slope increases, trailing along walkways and fences will cause a heightened concentrated flow erosion hazard. Layout and construction of fences and walkways become more difficult, increasing expenses associated with their construction and maintenance. For instance, the need for more fence brace-assemblies increases as the topography becomes more rolling. Walkways may need to be paved, lengthened to reduce grade, and intersected with dips to reduce the length water travels down them.

The second reason involves machinery traffic movement on grazing land fields. In the slight category, machinery traffic is generally unrestricted by nearly level to undulating slopes. Renovation, mechanical harvest, fertilizing, liming, and clipping can be done readily.

In the moderate category, all the above machinery operations can still be done, but much more care must be taken to avoid accidents. Equipment maintenance increases as more strain is placed on transmissions and other components.

Steep to very steep slopes generally preclude wheeled power equipment. Track equipment can operate much more safely. Therefore, over much of the country, slopes greater than 30 percent generally preclude much agronomic improvement of the grazing land resource. This is primarily because of the lack of cost effective tracked vehicles to do specialized operations, such as liming and fertilizing fields.

(b) Drainage class

The second landscape property is drainage class. This factor along with available water capacity, flooding, and ponding deal with water supply issues that affect forage production and management. Too much or too little water has a tremendous impact on forage growth. It is often the overriding limiting environmental factor. Water is the major ingredient needed for plant growth. Much of it is transpired and lost to the atmosphere with less than 1 percent of the water taken up by plant roots used to produce food. It takes 300 to 1,000 pounds of water to produce just 1 pound of dry matter.

Because water use efficiency varies greatly among forage species, species selection can be done based on the availability of soil stored water. Warm-season species are more efficient water users than cool-season species. The range in dry matter production per inch of water in central Alabama, for example, goes from a high of 1,646 pounds for coastal bermuda-grass (warm-season species) to a low of 436 pounds for red clover (cool-season species).

Drainage class describes the frequency and duration of periods of water saturation or partial saturation of a nonirrigated and undrained soil. This is extremely important in species adaptation and selection. Some species have a broad spectrum of adaptation to soil drainage conditions. Others have a narrow band of adaptation. Some seeding mixtures have an even narrower band of suitability because one species or another in the mix may disappear because it is poorly adapted to the drainage conditions at the site. There is no reason to recommend a forage mix for a site, if one or more species will not compete successfully with others in the mix because of the adverse drainage conditions. Table 3–4 lists the forage species suitability based on drainage class.

(1) Drainage class suitability and productivity categories

The seven natural drainage classes must all stand alone because they influence productivity as well as suitability. They cannot be categorized using more generalized modifiers or lumped together. For instance, an excessively drained soil and a somewhat poorly drained soil may both have the same yield potential, but not for the same species. Well-drained soils and moderately well drained soils may have the same general suitability for the specie(s) in question, but the yield potential is unlikely to be the same.

The seven drainage classes defined in chapter 3 of the Soil Survey Manual are excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained.

Table 3–4 Forage species suitability based on soil drainage class [1/] [2/]

Species suited to all drainage classes:

Redtop	Reed canarygrass

Species and forage mixtures suited to all drainage classes except very poorly drained:

Arrowleaf clover	Cicer milkvetch	Switchgrass
Bahiagrass	Indiangrass	Tall fescue
Big bluestem	Kleingrass	Wheatgrass, slender
Caucasian bluestem	Smooth bromegrass	

Species and forage mixtures suited to excessively drained to moderately well drained soils (wet soil intolerant):

Alfalfa	Guineagrass	Sainfoin
Alyceclover	Hop clover	Sericea lespedeza
Bermudagrass, coastal	Jointvetch *(Aeschynomene falcata)*	Sirarto
Black medic	Little bluestem	Stylo
Cluster clover	Orchardgrass	Sudangrass or sudan-sorghum hybrids
Crimson clover	Pearl millet	Sweet clover
Crownvetch	Perennial peanut	Weeping lovegrass
Elephantgrass	Prairiegrass (*Bromus willdenowii*)	Winter small grains
Foxtail millet	Rose clover	

Species and forage mixtures suited to well drained soils to somewhat poorly drained soils (intolerant to dry or wet soils):

Annual lespedeza	Dallisgrass	Timothy
Bermudagrass, common	Kentucky bluegrass	Wheatgrass, pubescent
Carpon desmodium	Red clover	Wheatgrass, tall
Crabgrass	Rhodesgrass	

Species and forage mixtures suited to well drained to poorly drained soils (forages preferring high moisture soil regime):

Alemangrass [3/]	Bur clover	Rescuegrass *(Bromus catharticus)*
Alsike clover	Digitgrass	Singletary pea (also called caleypea or roughpea)
American jointvetch *(Aeschynomene americana)*	Eastern gamagrass	Strawberry clover
	Ladino clover	Vetch, hairy
Annual ryegrass	Lappa clover	Wheatgrass, thickspike
Ball clover	Limpograss	Wheatgrass, western
Bentgrass	Meadow foxtail	White clover
Berseem clover	Perennial ryegrass	
Birdsfoot trefoil	Persian clover	

Species and forage mixtures suited to well drained and moderately well drained soils only:

Brassicas (forage kale, rape, swedes, and turnip)	Kikuyugrass	Vetch, big flower
Chicory	Soybean	Vetch, common
Corn, silage or grazed stalks	Spring small grains	Wheatgrass, bluebunch
Field pea (Austrian winter and newer varieties)	Subterranean clover	Wheatgrass, crested
Greenleaf desmodium	Velvetbean	Wheatgrass, intermediate

See footnotes at end of table.

Table 3–4 Forage species suitability based on soil drainage class (continued)

Species and soil drainage class suitability range

Species	Drainage class range [4/]	Species	Drainage class range [4/]
Alemangrass	WD - VPD	Guineagrass	ED - MWD
Alfalfa	ED - MWD	Hop clover	ED - MWD
Alsike clover	WD - PD	Indiangrass	ED - PD
Alyceclover	ED - MWD	Jointvetch *(Aeschynomene falcata)*	ED - MWD
American jointvetch *(Aeschynomene americana)*	WD - PD	Kentucky bluegrass	WD - SPD
Annual lespedeza	WD - SPD	Kikuyugrass	WD - MWD
Annual ryegrass	WD - PD	Kleingrass	ED - PD
Arrowleaf clover	ED - PD	Ladino clover	WD - PD
Bahiagrass	ED - PD	Lappa clover	WD - PD
Ball clover	WD - PD	Limpograss	WD - PD
Bentgrass	WD - PD	Little bluestem	ED - MWD
Bermudagrass, coastal	ED - MWD	Meadow foxtail	WD - PD
Bermudagrass, common	WD - SPD	Orchardgrass	ED - MWD
Berseem clover	WD - PD	Pearl millet	ED - MWD
Big bluestem	ED - PD	Perennial peanut	ED - MWD
Birdsfoot trefoil	WD - PD	Perennial ryegrass	WD - PD
Black medic	ED - MWD	Persian clover	WD - PD
Brassicas (forage kale, rape, swedes, and turnip)	WD - MWD	Prairiegrass (*Bromus willdenowii*)	ED - MWD
Bur clover	WD - PD	Red clover	WD - SPD
Carpon desmodium	WD - SPD	Redtop	ED - VPD
Caucasian bluestem	ED - PD	Reed canarygrass	ED - VPD
Chicory	WD - MWD	Rescuegrass (*Bromus catharticus*)	WD - PD
Cicer milkvetch	ED - PD	Rhodesgrass	WD - SPD
Cluster clover	ED - MWD	Rose clover	ED - MWD
Corn, silage or grazed stalks	WD - MWD	Sainfoin	ED - MWD
Crabgrass	WD - SPD	Sericea lespedeza	ED - MWD
Crimson clover	ED - MWD	Singletary pea (also called caleypea or roughpea)	WD - PD
Crownvetch	ED - MWD	Siratro	ED - MWD
Dallisgrass	WD - SPD	Smooth bromegrass	ED - PD
Digitgrass	WD - PD	Soybean	WD - MWD
Eastern gamagrass	WD - PD	Spring small grains	WD - MWD
Elephantgrass	ED - MWD	Strawberry clover	WD - PD
Field pea (Austrian winter and newer varieties)	WD - MWD	Stylo	ED - MWD
Foxtail millet	ED - MWD	Subterranean clover	WD - MWD
Greenleaf desmodium	WD - MWD	Sudangrass or sudan-sorghum hybrids	ED - MWD
		Sweet clover	ED - MWD

See footnotes at end of table.

Table 3–4 Forage species suitability based on soil drainage class (continued)

Species and soil drainage class suitability range

Species	Drainage class range 4/	Species	Drainage class range 4/
Switchgrass	ED - PD	Wheatgrass, crested	WD - MWD
Tall fescue	ED - PD	Wheatgrass, intermediate	WD - MWD
Timothy	WD - SPD	Wheatgrass, pubescent	WD - SPD
Vetch, big flower	WD - MWD	Wheatgrass, slender	ED - PD
Vetch, common	WD - MWD	Wheatgrass, tall	WD - SPD
Vetch, hairy	WD - PD	Wheatgrass, thickspike	WD - PD
Velvetbean	WD - MWD	Wheatgrass, western	WD - PD
Weeping lovegrass	ED - MWD	White clover	WD - PD
Wheatgrass, bluebunch	WD - MWD	Winter small grains	ED - MWD

1/ Sources: Farm Soils, Worthen & Aldrich, 1956; FORADS database, 1990; Forages, Volume 1, 1995; Forage and Pasture Crops, 1950; Forage Plants and Their Culture, 1941; Southern Forages, 1991.

2/ Species shown must also be adapted to the climate found at the site. Some are not cold tolerant while others are not tolerant to hot and humid, or arid conditions.

3/ Thrives in ponded areas and on very poorly drained soils.

4/ Drainage class symbols:
ED—Excessively drained
WD—Well drained
MWD—Moderately well drained
SPD—Somewhat poorly drained
PD—Poorly drained
VPD—Very poorly drained

(2) Importance to management considerations

Most forage crops have been selected that grow best on well-drained soils, the preferred soil drainage class to cultivate. However, this is not universally true for all species selections. Some species have been selected that are adapted to droughty sites and others to very wet sites.

Drainage class also affects the timeliness of planting and harvesting of culturally managed forages. Moderately well drained to very poorly drained soils have varying degrees of wet soil conditions during the year that can delay field work, such as tilling and planting, and grazing by livestock. The wet or seasonally wet soils are easily compacted by wheeled machinery and by livestock hooves. Wheel ruts from machinery tires and pock marks (poaching) from livestock hooves commonly scar the soil surface where traffic by machinery and livestock, respectively, are allowed before the soils have dried to field capacity. This impairs future use and productivity of the soil by:

- Trapping rainfall, thereby increasing soil wetness
- Compacting soils, reducing soil air and restricting root penetration
- Damaging or destroying plants by direct mechanical injury
- Reducing ease of movement by machinery or livestock about the field

Excessively drained to well drained soils can be traversed anytime except under abnormally wet weather. Moderately well drained soils may need to be avoided during wet weather and for a period of up to 1 month afterwards. Somewhat poorly drained soils to poorly drained soils need to be avoided until the seasonal water table has receded down the soil profile to a depth of 12 inches for livestock and 18 inches for machinery. Very poorly drained soils may need to be avoided year-round, unless the vegetation growing on it can support the load put on it by livestock or machinery. Reed canarygrass is one forage that grows well on very poorly drained soils and can support loads well because of its dense and fibrous, diffused root system.

Water management for forage production varies with the drainage class. Excessively drained soils may need irrigation to produce the highest forage yield, even forages tolerant of drought. This is especially true in areas where growing season rainfall amounts are below 18 inches or summer rainfall is inconsistent. Soils that fall in the moderately well drained to very poorly drained classes can produce better forage yields if drained. However, the poorly drained and very poorly drained soils that have not been previously drained may serve as wetlands of value. Artificial drainage of wet soils increases available rooting depth and soil aeration. It allows the roots of most forage plants to respire freely and explore more of the soil mass for nutrients and plant available water. Generally, it is cheaper and easier to select and plant forage species adapted to the soil drainage class found at a site than it is to add or subtract water through irrigation or drainage, respectively. With high yielding and high value forage crops, such as alfalfa, producers often find it economically feasible to irrigate or drain soils to enhance yields.

600.0314 Soil properties influencing forage suitability groups

(a) Available water capacity

Available water capacity (AWC) differs from drainage class in that it deals only with plant available water on a site. AWC is a function of soil texture, organic matter content, salinity, clay type, and rooting depth. Available water capacity, as defined here, is the inches of plant available water held by the soil profile to the depth indicated for the soil moisture regime in which the soil map unit component belongs (table 3–5). Or, it is to the depth the first root restrictive layer is encountered, if less. AWC values should be zero for dense layers from which roots are excluded and zero for all soil layers below them. In some cases where soil internal drainage is poor, the root-restrictive layer very well could be water saturated soil. In other situations it could be a cemented pan or bedrock at a lesser depth than the two depths listed in table 3–5.

From a soil texture standpoint, the silt fraction in a soil has the most influence on AWC: The higher the silt fraction, the higher the AWC. Nonporous rock fragments reduce AWC in proportion to the volume they occupy. On saline soils, AWC is reduced 25 percent for each 4 millimhos per centimeter of conductivity of the saturated extract. In Oxisols and Ultisols, where kaolinite and gibbsite clays are present in high amounts, AWC may be 20 percent lower than in soils having 2:1 lattice clays. Soils high in organic matter have higher AWC than soils that share similar mineralogy, texture, and rooting depth, but are low in organic matter.

Table 3–5 Available water holding capacity limitation categories for forages [1/]

Limitation category [2/]	Soil moisture regimes: Aquic, perudic (in/40 in)	Udic, ustic (in/60 in)	Aridic, xeric [3/] (in/60 in)
Low	< 3	< 4	< 5
Moderate	3–6	4–8	5–10
High	> 6	> 8	> 10

1/ Sources: Cornell U. 1993; Fralish et al. 1978; Stout, Jung, and Shaffer, 1988; and Tisdale, Nelson, and Beaton 1985.
2/ Limited research conducted on available water holding capacity effects on forage production have used only three categories: low, moderate, and high.
3/ Aridic soil moisture regime soils require irrigation for domesticated grasses and legumes.

(1) Available water capacity limitation categories

Agronomically, delineating more than three AWC categories is hard to justify. The categories are low, moderate, and high. Forage researchers studying available water capacity effects on forage yield chose wide ranges in available water to detect statistically significant yield differences among soil series of varying available water holding capacity. For Udic and Ustic soil moisture regimes with up to a 60-inch soil profile, the low water holding capacity category has soils that store less than 4 inches of water in the root zone. In the moderate water holding capacity category, soils store between 4 and 8 inches of water in the root zone. In the high category, the soils hold more than 8 inches of plant available water in the root zone.

For Aridic and Xeric soil moisture regimes, the numbers change to 5 inches for low, 5 to 10 for moderate, and more than 10 inches for high. For aquic and perudic soils, the values are less than 3 inches for low, 3 to 6 inches for moderate, and more than 6 inches for high for a 40-inch soil profile depth. These soils need less water holding capacity because they are generally well supplied with rainfall or have a water table that allows natural subirrigation to occur. See table 3–5.

(2) Importance to management considerations

Available water capacity is significant because large quantities of water are needed to meet the evapotranspiration losses that invariably occur during the growing season. Rainfall alone cannot be depended upon to meet a forage crop's need for water during peak growth periods. This water must be supplied by stored soil water except in the most favorable rainfall areas, where it is abundant and timely during the growing season. Even in the humid Eastern United States, water holding capacity affects forage yield dramatically where summer heat and infrequent significant rain combine to increase forage plant water demand while limiting resupply. For example, moderately well drained soils on uplands that have too much water early in the growing season may have too little water by mid-summer for optimum forage production. This occurs when they have a moderate to low water holding capacity. In this instance, they may have a restrictive soil layer that excludes root growth and causes soil water to perch above it. Once the perched water drains away, the soil reservoir above the restrictive layer does not store sufficient plant available water to meet evapotranspiration needs during prolonged dry, hot weather.

Excessive wetness in the spring results in delays getting livestock or farm machinery on the soil to graze the forage or work the land, respectively. Later, too little water holding capacity to bridge midsummer drought stress results in reduced forage yields.

Low water holding capacity soils, when irrigated, need watering more often at lower dosages. Selecting forage crops that use water more efficiently is critical for maximum production without irrigation on these soils.

(b) Flooding and ponding, frequency and duration

A soil feature that is associated with water impacts on forage production and survival is flooding frequency and duration. Forage plants vary widely in their ability to withstand submergence. A second allied soil feature is seasonal high water table. When the seasonal high water table elevates above the soil surface in closed depressions, it is called ponding. Whether it is called flooding or ponding, standing water impacts forage plants intolerant to the period of submergence similarly. It will either kill or injure them. Where ponding occurs during the winter in climates where ice can form and remain for several days, forage crops can be weakened or killed as a result of toxic levels of carbon dioxide that build up under the ice sheet.

(1) Flooding limitation categories

Established flooding frequency classes are none, very rare, rare, occasional, frequent, and very frequent. For the purpose of FSG's sorting, the number of classes can be reduced to three. Do this by combining **none** with **very rare** and **rare**, leaving **occasional** as a separate category, and combining frequent with **very frequent**.

In the conservation planning of grazing lands, the probability of flood occurring under the **rare** class is too low to be significant to either the forage crop or the means of growing and harvesting it. The flooding frequency for the **occasional** class occurs often enough (about every other year statistically) to be of concern to the landowner and the planner.

The **frequent** and **very frequent** classes occur almost every year under normal rainfall conditions. How often flooding occurs during the year is of minor importance. One event can cause enough harm that ensuing events will have little further impact. Therefore, combining these two classes is acceptable for the purposes of conservation application and planning of grazing lands. Furthermore, submergence duration actually is more important to forage plant survival and health than the frequency of flooding or ponding. If water recedes quickly, little lasting damage occurs. The ponding frequency classes are none, rare, occasional, and frequent.

The flooding or ponding factor is a two-step process in determining to which FSG a soil map unit component belongs. First, there is the process of elimination from considering it to be a limitation or hazard at all. If it is not a feature of the soil map unit component or rarely a feature, place the map unit component into a **none-rare** class. If a soil map unit component has occasional flooding or ponding, then the duration of either becomes important. Forage plants differ widely in their ability to withstand varying lengths of submergence (table 3–6).

Table 3–6 Springtime (< 80 °F) inundation tolerance of selected forage species [1/] [2/]

Species	Average number of days of inundation	Species	Average number of days of inundation
Tolerant of very long flooding (> 30 days)		**Tolerant of long flooding (7 – 30 days)—Cont.**	
American jointvetch	49+	Orchardgrass	15 – 25
Alemangrass	49+	Purpletop	10 – 20
Bermudagrass	45 – 90	Redtop	25 – 35
Buffalograss	45 – 90	Rhodesgrass	15 – 25
Florida paspalum	30 – 60	Ryegrass, annual	15 – 20 [8/]
Reed canarygrass	49+	Ryegrass, perennial	15 – 25
Timothy	49+	Sainfoin	5 – 10 [4/]
Wheatgrass, slender	31 – 35	Siratro	7 – 14
Wheatgrass, western	30 – 60	Switchgrass	15 – 30
		Trefoil, birdsfoot	20 – 30
Tolerant of long flooding (7 – 30 days)		Wheatgrass, crested	7 – 10
Alfalfa	9 – 12		
Alyceclover	7 – 14	**Tolerant of brief flooding only**	
Bahiagrass	15 – 25	Barley	3 – 6
Bluegrass, Canada	25 – 35 [3/]	Bluestem, little	3 – 6
Bluegrass, Kentucky	25 – 35 [3/]	Bluestem, yellow	3 – 6
Bluestem, big	7 – 14	Clover, crimson	3 – 6
Bluestem, silver	5 – 10 [4/]	Elephantgrass	3 – 6
Bromegrass; smooth	24 – 28	Guineagrass	3 – 6
Clover, alsike	10 – 20	Jointvetch (*A. falcata*)	3 – 6
Clover, ladino	10 – 20	Lovegrass, weeping	3 – 6
Clover, red	7 – 15	Oats	3 – 6
Clover, strawberry	10 – 20	Perennial peanut	3 – 6
Clover, sweet	9 – 12	Rye	3 – 6
Clover, white	10 – 20	Stylo	3 – 6
Desmodium, carpon and greenleaf	7 – 14	Wheat	3 – 6
Digitgrass	15 – 25		
Eastern gamagrass	10 – 22		
Fescue, tall	24 – 35 [3/] [5/]		
	10 – 20 [6/]		
Indiangrass	7 – 14		
Johnsongrass	10 – 20		
Kikuyugrass	7 – 14		
Lespedeza, annual	5 – 8 [4/]		
Lespedeza, sericea	10 [7/]		
Limpograss	15 – 25		
Milkvetch, cicer	9 – 12		
Oatgrass, tall	15 – 20		

1/ Sources: Barnes et al. 1995, Bolton and McKenzie 1946, Gilbert 1999, Heinrichs 1970, Rhoades 1964.
2/ Values shown are from research and only reflect flooding tolerance at springtime temperatures.
3/ Straddle tolerance classes, placed in this class to allow for survival under a slightly higher temperature regime.
4/ Straddle tolerance classes, depending on temperature regime, may want to place in tolerance to brief flooding only.
5/ Cool temperature area, less than 80 °F.
6/ Warm temperature area, more than 80 °F.
7/ Summer value, > 80 °F, no spring value given.
8/ Winter value, no spring value given.

Loss of stands because of flooding duration is also temperature dependent. It takes fewer days of submergence to cause stand loss or damage as soil temperature increases. A flooding study done on alfalfa in 1980 found it could endure 14 days of submergence at a soil temperature of 60 degrees Fahrenheit, 10 days at 70 degrees Fahrenheit, 7 to 8 days at 80 degrees Fahrenheit, and 6 days at 90 degrees Fahrenheit. Therefore, the time of year the flood occurs is important, as is the soil temperature regime common to the soil map unit component (fig. 3–6). For forage crop and pasture lands, the soil temperature regimes encountered in the United States are frigid, mesic, thermic, and hyperthermic. These terms are defined in the glossary.

Duration classes as setup by Part 618 of the National Soil Survey Handbook are:

- **Extremely brief**—0.1 to 4 hours (for flooding only)
- **Very brief**—less than 2 days
- **Brief—**2 to 7 days
- **Long**—7 days to 30 days
- **Very long**—more than 30 days

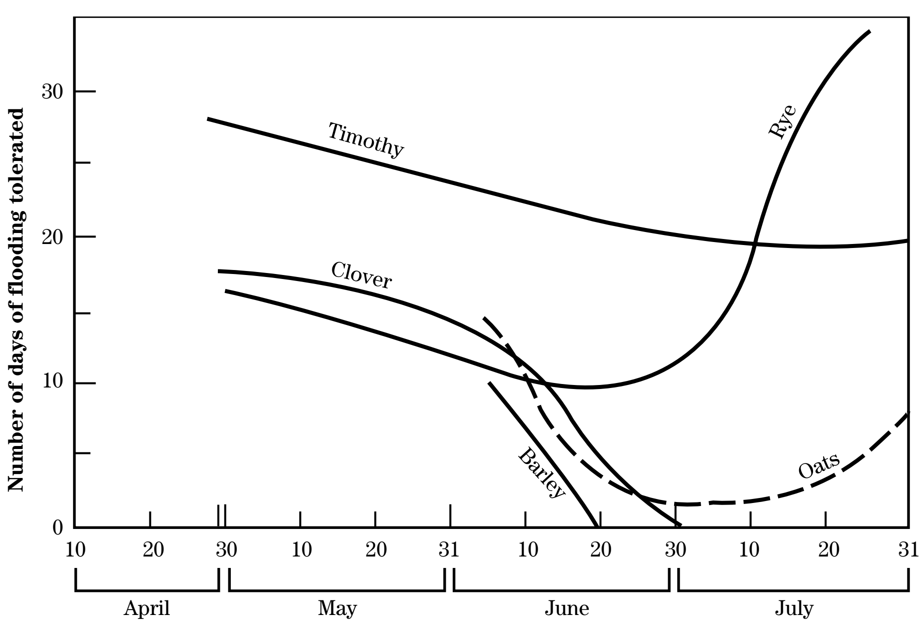
To be useful in determining forage crop survival, a soil temperature range should be specified for the anticipated time of year the flooding or ponding is most likely to occur. If spring flooding is most likely, base forage plant survival on soil temperatures that occur then, such as those shown in table 3–6 except as noted. Grazing land resource managers should be aware that dormant forages are little affected by submergence, provided the water does not turn into ice. Ladino clover is very susceptible to ice injury, for instance, with loss of stand occurring within 12 to 14 days under ice. Severe stand loss of alfalfa can occur after 20 days under ice. Meanwhile, common white clover can survive over 4 weeks of ice cover.

For FSG rating, the duration classes set up by the National Soil Survey Handbook can be condensed into three classes:

- **Brief**—less than 7 days
- **Long**—7 to 30 days
- **Very long**—greater than 30 days

Forage crops generally can withstand flooding for more than 2 days. This does not mean that crop loss associated with flooding will not occur. The aboveground dry matter accumulation before the event may be completely lost as a grazing or harvestable resource, but death of the plant does not occur. A delay in regrowth after the event may also occur.

Figure 3–6 Estimated number of days flooding is tolerated by various crop plants at different times of the growing season under Northern United States conditions, without the plants being destroyed (Source: Luthin 1957)



For assigning high water table soils to the proper FSG, keep in mind that duration of ponding is the length of time soil water is within 6 inches of the soil surface or above. Duration of ponding is in the soil database. Another entry in the soil database shows the span of time, by month, when ponding can occur. Season of occurrence, however, is not an estimate of duration. If duration is not stated, you need to estimate how long the ponded areas remain inundated or saturated.

(2) Importance to management considerations
The destruction of forage crops by inundation is a serious problem on many low-lying fields. Selection of forage species tolerant of the flooding duration that commonly occurs is the most cost-effective approach to dealing with a flooding or ponding problem. Forage crops by themselves are not high value enough to warrant extensive flood control solutions. Depending on their wetland value and the number, depth, distribution, and elevation to an adequate outlet, areas prone to ponding can be reshaped and graded to remove surface water to an outlet. This eliminates or decreases the loss of forage crops where ponding was a problem. In colder climates though, it may not eliminate ice sheet destruction of forage crops. Meltwater is too slow to move out when thaw periods are short.

(c) Soil reaction

Another soil factor affecting FSG's is soil reaction. This is the first factor that deals with a chemical property of the soil. It is also associated with soil water since the chemistry of the soil solution is important to forage growth. Soil reaction is the balance of exchangeable hydroxyaluminum ions, hydrogen ions (H^+), carbonate ions, and hydroxyl (OH^-) ions in the soil solution. Soil reaction is measured in pH units. The pH of a soil solution is the negative logarithm of the concentration of H^+ ion activity in the soil solution. When the soil pH is said to be at absolute neutral, pH = 7.0, an equal number of positively and negatively charged ions are in the soil solution.

(1) Importance to management considerations
Soil reaction is critical for forage growth and production. Some forage crops are tolerant of acid soil conditions. They out-compete forages better suited to alkaline or neutral soils for nutrients. Other forages may be better able to grow under alkaline soil conditions, while still others may only grow best under neutral soil reaction conditions. If the soil reaction is not going to be altered by soil amendments, select forage plants for a seeding mixture based on their ability to all prosper under the pH conditions at the site (table 3–7).

Soil reaction is also an important factor in nutrient and toxic element availability for plant uptake. Very acid soils decrease the solubility of most major plant nutrients as well as some micronutrients, such as molybdenum. Nutrients must be soluble in water to be adsorbed by plant roots. At the same time, very acid soils may release toxic amounts of aluminum, iron, and manganese.

At the other end of the scale, alkaline soils can also decrease plant nutrient solubility, principally phosphorus, boron, copper, iron, manganese, and zinc. Often, the largest problem with these alkaline soils though is their high salt content. The high salt content interferes with water uptake by many forage species and their photosynthetic rate. For instance, sodic soils, soils with a pH greater than 8.5, are generally unproductive for culturally managed forages because of excess sodium and OH^- ions that cause poor soil aggregation and plant root desiccation. Saline and saline-sodic soils are other alkaline soils. They have a pH less than 8.5, but have high amounts of soluble salts that interfere with plant growth. The management needed to address acid soils and alkaline soils is so different that it is best to split soil reaction into two categories: acid soils and alkaline soils.

Critical breakpoints on the pH scale need to be identified in relation to forage plant growth. Many of the agronomically managed forages have a wide range of adaptability to pH. Most prosper in the pH range from 5.6 to 7.3, moderately acid to neutral. As the pH drops below 5.5, strongly acid, increasingly more exchangeable aluminum is released. At pH 4.0, exchangeable aluminum has saturated the cation exchange sites in soils where it is abundant. Few forage plants survive, and none thrive. At pH 8.5 or greater, strongly alkaline, sodium carbonate is present in the soil in amounts that interfere with forage growth.

Table 3–7 Forage species suitability based on soil pH [1/] [2/]

Forage species suited to the narrowest pH range (6.1 – 7.3) near neutral

Cluster clover

Forage species suited to the widest pH range, 4.5–9.0 [3/]
(tolerant of very strongly acid to strongly alkaline soils)

Eastern gamagrass	Rhodesgrass
Redtop	Tall fescue

Forage species suited to a pH range of 5.6–7.3 (tolerant of moderately acid soils)

Brassicas (forage kale, rape, swedes, and turnip)	Soybean
Indiangrass	Sudangrass or sudan-sorghum hybrids
Kentucky bluegrass	

Forage species suited to a pH range of 5.1–7.3 [3/] (tolerant of strongly acid soils)

Alemangrass	Foxtail millet
Alsike clover	Hop clover
American jointvetch (*Aeschynomene americana*)	Jointvetch (*Aeschynomene falcata*)
Bentgrass	Kleingrass
Carpon desmodium	Kura clover
Crabgrass	

Forage species suited to a pH range of 4.5–7.3: [3/] (tolerant of very strongly acid soils)

Alyceclover	Kikuyugrass
Annual lespedeza (*L. striata*)	Sericea lespedeza
Crownvetch	Stylo

Forage species suited to a pH range of 5.6–8.4
(tolerant of moderately acid to moderately alkaline soils)

Annual ryegrass	Persian clover
Arrowleaf clover	Prairiegrass (*Bromus willdenowii*)
Chicory	Rescuegrass (*Bromus catharticus*)
Dallisgrass	Singletary pea (also called caleypea or roughpea)
Elephantgrass	Smooth bromegrass
Field pea (Austrian winter and newer varieties)	Sweet clover
Orchardgrass	Vetch, hairy
Pearl millet	

Forage species suited to a pH range of 6.1–8.4 (tolerant of slightly acid to moderately alkaline soils)

Alfalfa	Meadow and creeping foxtails
Ball clover	Sainfoin
Berseem clover	Wheatgrass, intermediate
Bur clover	Wheatgrass, thickspike
Lappa clover	

See footnotes at end of table.

Table 3–7 Forage species suitability based on soil pH [1/] [2/] —(Continued)

Forage species suited to a pH range of 6.7–9.0 (tolerant of alkaline soils)

Wheatgrass, bluebunch	Wheatgrass, slender
Wheatgrass, crested	Wheatgrass, tall
Wheatgrass, pubescent	Wheatgrass, western

Forage species suited to a wide pH range of 5.1–8.4 [3/]
(tolerant of strongly acid to moderately alkaline soils)

Annual lespedeza (*L. stipulacea*)	Greenleaf desmodium	Siratro
Bahiagrass	Guineagrass	Spring small grains
Big bluestem	Ladino clover	Strawberry clover
Birdsfoot trefoil	Limpograss	Subterranean clover
Black medic	Little bluestem	Switchgrass
Caucasian bluestem	Perennial peanut	Timothy
Cicer milkvetch	Perennial ryegrass	Vetch, common
Coastal bermudagrass	Purpletop	Weeping lovegrass
Corn, silage or grazed stalks	Red clover	White clover
Crimson clover	Reed canarygrass	Winter small grains
Digitgrass	Rose clover	

Species and soil pH suitability range [3/]

Species	Soil pH suitability range	Species	Soil pH suitability range
Alemangrass	5.1 – 7.3	Brassicas	5.6 – 7.3
Alfalfa	6.1 – 8.4	(forage kale, rape, swedes, and turnip)	
Alsike clover	5.1 – 7.3	Bur clover	6.1 – 8.4
Alyceclover	4.5 – 7.3	Carpon desmodium	5.1 – 7.3
American jointvetch	5.1 – 7.3	Caucasian bluestem	5.1 – 8.4
(*Aeschynomene americana*)		Chicory	5.6 – 8.4
Foxtail millet	5.1 – 7.3	Cicer milkvetch	5.1 – 8.4
Annual lespedeza (*L. striata*)	4.5 – 7.3	Cluster clover	6.1 – 7.3
Annual lespedeza (*L. stipulacea*)	5.1 – 8.4	Corn, silage or grazed stalks	5.1 – 8.4
Annual ryegrass	5.6 – 8.4	Crabgrass	5.1 – 7.3
Arrowleaf clover	5.6 – 8.4	Crimson clover	5.1 – 8.4
Bahiagrass	5.1 – 8.4	Crownvetch	4.5 – 7.3
Ball clover	6.1 – 8.4	Dallisgrass	5.6 – 8.4
Bentgrass	5.1 – 7.3	Digitgrass	5.1 – 8.4
Bermudagrass, coastal	5.1 – 8.4	Eastern gamagrass	4.5 – 9.0
Bermudagrass, common	5.1 – 8.4	Elephantgrass	5.6 – 8.4
Berseem clover	6.1 – 8.4	Field pea	5.6 – 8.4
Big bluestem	5.1 – 8.4	(Austrian winter and newer varieties)	
Birdsfoot trefoil	5.1 – 8.4	Greenleaf desmodium	5.1 – 8.4
Black medic	5.1 – 8.4	Guineagrass	5.1 – 8.4

See footnotes at end of table.

Table 3–7 Forage species suitability based on soil pH [1/] [2/] —(Continued)

Species	Soil pH suitability range	Species	Soil pH suitability range
Hop clover	5.1 – 7.3	Sirato	5.1 – 8.4
Indiangrass	5.6 – 7.3	Smooth bromegrass	5.6 – 8.4
Jointvetch (*Aeschynomene falcata*)	5.1 – 7.3	Soybean	5.6 – 7.3
Kentucky bluegrass	5.6 – 7.3	Spring small grains	5.1 – 8.4
Kikuyugrass	4.5 – 7.3	Strawberry clover	5.1 – 8.4
Kleingrass	5.1 – 7.3	Stylo	4.5 – 7.3
Kura clover	5.1 – 7.3	Subterranean clover	5.1 – 8.4
Ladino clover	5.1 – 8.4	Sudangrass or sudan-sorghum hybrids	5.6 – 7.3
Lappa clover	6.1 – 8.4	Sweet clover	5.6 – 8.4
Limpograss	5.1 – 8.4	Switchgrass	5.1 – 8.4
Little bluestem	5.1 – 8.4	Tall fescue	4.5 – 9.0
Meadow and creeping foxtails	6.1 – 8.4	Timothy	5.1 – 8.4
Orchardgrass	5.6 – 8.4	Vetch, big flower	5.1 – 7.3
Pearl millet	5.6 – 8.4	Vetch, common	5.1 – 8.4
Perennial peanut	5.1 – 8.4	Vetch, hairy	5.6 – 8.4
Perennial ryegrass	5.1 – 8.4	Velvetbean	5.1 – 7.3
Persian clover	5.1 – 8.4	Weeping lovegrass	5.1 – 8.4
Prairiegrass (*Bromus willdenowii*)	5.6 – 8.4	Wheatgrass, bluebunch	6.7 – 9.0
Purpletop	5.1 – 8.4	Wheatgrass, crested	6.7 – 9.0
Red clover	5.1 – 8.4	Wheatgrass, intermediate	6.1 – 8.4
Redtop	4.5 – 9.0	Wheatgrass, pubescent	6.7 – 9.0
Reed canarygrass	5.1 – 8.4	Wheatgrass, slender	6.7 – 9.0
Rescuegrass (*Bromus catharticus*)	5.6 – 8.4	Wheatgrass, tall	6.7 – 9.0
Rhodesgrass	4.5 – 9.0	Wheatgrass, thickspike	6.1 – 8.4
Rose clover	5.1 – 8.2	Wheatgrass, western	6.7 – 9.0
Sainfoin	6.1 – 8.4	White clover	5.1 – 8.4
Sericea lespedeza	4.5 – 7.3	Winter small grains	5.1 – 8.4
Singletary pea (also called Caleypea or Roughpea)	5.6 – 8.4		

1/ Sources: Ball, D.M., et al., 1991, Southern forages; Barnes, R.F., et al., 1995, Forages; Brady, N.C., and A.G. Norman, 1957, 1965, 1970, Advances in agronomy, Vols. 9, 17, 22; Brady, Nyle C., 1974, The nature and properties of soils, 8th ed.; Dalrymple, R.L., et al., Crabgrass for Forage 1999; Hanson, A.A., et al., 1988, Alfalfa and alfalfa improvement; Kabata-Pendias, A., and H. Pendias, 1984, Trace elements in soils and plants; Piper, C.V., 1941, Forage plants and their culture; Undersander, D., et al., 1990, Red clover establishment, management, and utilization, UWEX A3492; Wild, Alan, 1988, Russell's soil conditions and plant growth, 11th ed; and Wheeler, W.A., 1950, Forage and pasture crops.

2/ Species shown must also be adapted to the climate at the site. Some are not cold tolerant, while others are not tolerant to hot and humid or arid conditions.

3/ Species listed here may be adversely affected by exchangeable aluminum or manganese on soils high in aluminum or manganese when pH is less than 5.5.

(2) Acid soils

A large part of the United States has a mantle of acid soils. They are soils that, to varying degrees, have been leached of their exchangeable bases (primarily calcium, magnesium, and potassium) by percolating soil water. The primary means to manage acid soils for forage production is to apply lime. This elevates the pH of the soil and the base saturation of the soil's cation exchange sites to a level that optimizes the growth of the selected crop. The hydroxyaluminum and H^+ ions on the cation exchange sites are neutralized by the carbonate and replaced by the bases contained in the lime, calcium alone, or calcium and magnesium. In the Northern United States, lime generally is added to raise acid soils to a slightly acidic o neutral pH, 6.5 to 6.8. However, some forage crops do not need that degree of pH correction. Bermudagrass stands need to be only limed to elevate the pH to 5.5. Lespedeza response to lime amendments is limted above 6.0. On Oxisol, Spodosol, and Ultisol soils in the warm, humid Southern United States, pH values should not be elevated above 6.2. Liming certain soils high in dispersible clays above that level in those soil orders reduced water percolation, soil tilth, growth of forages, and plant uptake of phosphorus and micronutrients.

(i) Acid soil limitation categories—To create FSG's for acid soils, the buffering ability as well as the typical pH range must be considered. Most land grant experiment stations and soil testing laboratories calibrate the lime requirement of the major soil series for the state they serve (fig. 3–7).

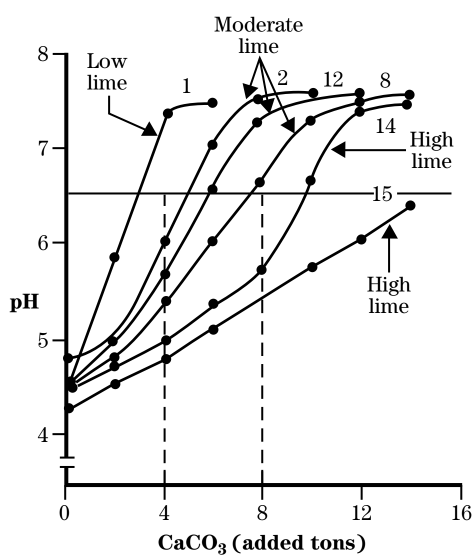
Soil series with similar lime requirements to raise the pH to the appropriate level for the crop to be grown can be grouped together. This may be done with as few as three categores: low, moderate, and high lime requirement. For those states without titration curves as shown in figue 3–7, the following rules-of-thumb can be used with some confidence.

- Soils with a **low** lime requirement have an average cation exchange capacity (CEC) less than 7 milliequivalents per 100 grams of soil (meq/100 g) regardless of pH level, or have a native pH above 6.2 regardless of CEC.
- Soils with a **moderate** lime requirement have an average CEC within the range of 7 to 15 meq/100 g and a native pH between 5.5 and 6.2.
- Soils with a **high** lime requirement have a native pH below 5.5 and a CEC greater than 7, or have a native pH between 5.5 and 6.2 with a CEC greater than 15 meq/100 g.

Figure 3–7 Titration curves for representative soils from Ohio after incubation with $CaCO_3$ for 17 months (adapted from Tisdale 1985)

Example: To raise pH to 6.5, lime requirement rating would be:

Low - 0-4 tons/acre of $CaCO_3$
Moderate - 4-8 tons/acre of $CaCO_3$
High - >8 tons/acre of $CaCO_3$



(ii) Importance to management considerations —Generally, liming soils is an inexpensive practice unless the rate of application exceeds 4 tons per acre or the local price of lime is high as a result of the travel distance to the nearest source of material. The materials used to lime soils are generally inexpensive. They are bulky, requiring heavy equipment to dig, crush, sieve (limestone rock), and load, and heavy trucks to transport to the site andspread. Properly liming soils increases the availability of many essential nutrients needed for plant growth while damping the availability of toxic elements, such as aluminum and manganese. It also tends to impove soil tilth of fine textured soils by increasing soil particle aggregation.

Soil pH response to liming differs from soil to soil depending on the amount of clay and humus particles in each and the number of cation exchange sites presented by these particles. Acid soils act as bffered weak acids and resist sharp changes in pH. Some are more buffered than others are. The degree of buffering is related primarily to the total amount of clay and organic matter in a soil. The nature of the clay lattices and their relative proportion in the soil also affect their buffering activity. Soils having 1:1 type lattice clays have less cation exchange sites than soils with 2:1 type lattice clays. Sands and loamy sands have small amounts of clay and organic matter in them and are, therefore, low in cation exchange capacity and poorly buffered. They require the least amount of lime to achieve desired soil pH levels. Meanwhile, silty clay loams and clay loams generally are highly buffered. Therefore, these soil textures require the most lime to elevate soil pH to a given level.

(iii) Aluminum toxicity associated with acid soils—In areas where some soils, primarily in soil orders Oxisol, Spodosol, and Ultisol of the Southeastern United States, cause plants to exhibit aluminum (Al) toxicity symptoms at low subsoil (subplow layer) pH levels (< 5), it is worthwhile to add this information to FSG's. This occurs on soils or acid mine spoils where exchangeable Al generally occupies more than 60 percent of the effective cation exchange capacity (CEC) of the soil or spoil within the upper 20 inches.

Forage plants differ widely in their ability to tolerate exchangeable and water soluble aluminum present in acid soils. Where acid mine spoils contained 3.9 meq/100 grams of exchangeable Al, 3 ppm of water soluble Al was present. This was enough to be toxic to the somewhat tolerant and intolerant forage species listed in table 3–8. The table lists forage plants according to their tolerance to water soluble Al in soils, as it was the most reliable differentiation measure. Unfortunately, exchangeable Al and the percentage of soil CEC it occupies are all that can be gleaned from soil test results if that. Some soil test reports only list hydrogen (H) ion when, in fact, it is a combination of Al and H. McKee et al. (1982) found no water soluble Al in the soils and spoils they studied that contained only 2.8 meq/100 grams of exchangeable Al. Some forage plants normally can tolerate acid soils. However, in the presence of toxic levels of Al, they either fail to grow or grow poorly. The main effect is the stunting of root growth and confining the root system within the top few inches of soil above the toxic zone of Al. This reduces nutrient and water uptake by the forage crop. Aluminum reduces soil phosphorus availability to plant roots. It also interferes with nutrient and water uptake by roots even within the stunted root mass.

Different soil series cause the same susceptible plant species to express aluminum toxicity symptoms at different concentrations of exchangeable aluminum. Even within the same soil series, site differences in toxicity based on soil exchangeable Al concentrations are often found. This is because of the differences in soil pH and other chemical properties that cause different levels of water soluble Al to be present at a given soil level of exchangeable Al. Within plant species, different cultivars differ widely in their susceptibility to aluminum toxicity. Therefore, use caution in stating what concentration level of exchangeable Al is toxic to a plant specie. It can be site and cultivar dependent.

(iv) Aluminum toxicity limitation categories—For FSG development in regions where aluminum toxicity has been verified, it would be best to create the following categories of limitation: slight, moderate, and severe potential for Al toxicity to occur.

Table 3–8 Forage plant tolerance to water soluble aluminum in soils [1/] [2/]

Very tolerant (persisted at 17 ppm Al3+ and pH 3.3)

Bluestem, big	Limpograss
Bluestem, little	Povertygrass
Eastern gamagrass	Poverty oatgrass
Indiangrass	

Tolerant (persisted at 6 ppm Al3+ and pH 3.3)

Bluestem, Virginia (broomsedge)	Sericea lespedeza
	Weeping lovegrass
Panicgrass	

Somewhat tolerant (persisted at 1–2 ppm Al3+ and pH 4.0)

Alsike clover	Partridge pea
Bentgrass, rough	Perennial ryegrass
Birdsfoot trefoil	Reed canarygrass
Caucasian bluestem	Redtop
Flatpea	Rye, winter
Hairyflower lovegrass	Switchgrass
Millet, Japanese	Tall fescue
Oats	Wheat
Orchardgrass	White clover

Intolerant (persistence reduced at 0.5 ppm Al3+ and pH 4.2)

Alfalfa	Red clover
Annual ryegrass	Sorghum
Barley	Sorghum-sudan hybrids
Cicer milkvetch	Sweet clover, yellow
Creeping foxtail	Timothy
Crownvetch	Trefoil, big
Prairie sandreed	Trefoil, narrowleaf

1/ Sources: G.W. McKee, et al. 1982. Tolerance of 80 plant species to low pH, aluminum, and low fertility. Agron. Ser. No. 69, Pennsylvania State Univ.; C.D. Foy, 1997.

2/ Toxic concentrations listed are for frame of reference only. Cultivars within forage species vary in their reaction to water soluble Al concentrations in the soil as well, either more or less than the stated concentrations. However, the cultivars are tightly grouped enough to rarely end up in a different tolerance category.

National breakpoints for slight, moderate, and severe potential for Al are:

- **Slight—**Exchangeable Al is less than 30 percent of the effective CEC, or soil pH is greater than 5.5 within 20 inches of the soil surface. Some yield reduction of intolerant forage species. No noticeable yield reduction of tolerants.
- **Moderate—**Exchangeable Al is between 30 and 60 percent of the effective CEC, or soil pH is between 5.0 and 5.5 within 20 inches of the soil surface. Intolerant forage species yields reduced by at least half, wilt easily under any moisture stress, and show nutrient deficiency symptoms. Tolerant species have yields losses of 20 to 30 percent.
- **Severe—**Exchangeable Al is either greater than 60 percent of the effective CEC, 67 percent acidity saturation of CEC by sum of cations at pH 7, 86 percent acidity saturation of CEC by sum of cations at pH 8.2, or pH is less than 5.0 on mineral soils or is less than 4.7 on organics within 20 inches of the soil surface. Intolerant species fail to establish, or they are very weak. Tolerant species have yield losses over 30 percent.

(v) Importance to management considerations—The remedial measure for aluminum toxicity is the application of either lime or gypsum. To best alleviate plant symptoms of aluminum toxicity requires displacing exchangeable aluminum with calcium in soils at depth. This allows deeper root penetration by the forage crop. Gypsum is better in this situation because it can be surface applied and leaches downward through the soil. Some believe the gypsum produced as a by-product of phosphorus fertilizer production from fluorapatite rock phosphate is most effective in lowering available aluminum. The fluoride complexes with monomeric aluminum in the soil. The complex formed is leachable and moves out of the root zone. Typical rate of application is 1 to 3 tons per acre.

Lime is slow to move down into the soil profile. It, theefore, must be incorporated with deep tillage equipment to hae any immediate effect on subsoil pH levels. This is expensive and often prohibits the use of this management alternative. To eliminate aluminum toxicity, raise pH levels to 5.6 or 5.7.

(3) Alkaline soils

Alkaline soils occur primarily in areas where rainfall is limited or on highly weathered soils with restricted drainage. They are the converse of acid soils. The lack of percolating soil water results in little leaching of bases to any great depth. Surface evaporation and capillary movement of soil water upward actually concentrate bases and their salts near or at the soil surface. Alkaline soils are broken down further into four categories: calcareous, saine, saline-sodic, and nonsaline-sodic. This categorization is of critical practical importance in selecting proper management practices to make these soils useful to produce culturally managed forage crops.

Calcareous soils contain free calcium carbonates and range in pH from 7.4 to 8.4. They are neither saline nor sodic, but still affect forage suitability and soil management. The carbonates present in alkaline soils reduce phosphorus and micronutrient availability to forage crops not adapted to calcareous soils. Iron and manganese chlorosis of leaves commonly occurs on susceptible forae crops. Copper, zinc, and molybdenum deficiencie are also possible. Nitrogen fertilizers need incorporation into calcareous soils to prevent nitrite buildup or ammonia volatilization.

Saline soils have less than 15 percent of the cation exchange capacity occupied by sodium ions (ESP), the pH is below 8.5, and an electrical conductivity (EC) greater than 2 millimhos per centimeter (decisiemens per meter) at 25 degrees Celsius (fig. 3–8). Neutral soluble salts, chlorides and sulfates of sodium, calcium, and magnesium, cause the conductivity and interfere with the absorption of water by plants. They create a higher osmotic pressure in the soil solution than in the plant cells. This can cause cell collapse and less water uptake. Salts also interfere with nutrient ion exchange between the soil and plant root, causing nutrient deficiencies in the susceptible plant. Ridding these soils of the excess salts makes them productive for culturally managed forages. Where this entails leaching with irrigation water, receiving waterbodies and wetlands become increasingly saltier unless mitigation efforts are in place. Downstream impacts should not be ignored for any soils mentioned in this section.

Saline-sodic soils in their natural state differ from saline soils only in that exchangeable sodium ions occupy more than 15 percent of the cation exchange capacity (fig. 3–8). Sodium concentrations are now high enough to be toxic to most culturally managed forage crops. On these soils the excess salts and sodium must be removed to make the soil suitable for culturally managed forages. If only the salts are leached away, the soil can become quite alkaline unless buffered naturally by gypsum. This causes poor soil tilth making the soil nearly impervious to water, a poor growth medium, and difficult to till. When gypsum is present in the soil, forage plants can tolerate electrical conductivity of 2 dS/m higher than indicated in figure 3–8.

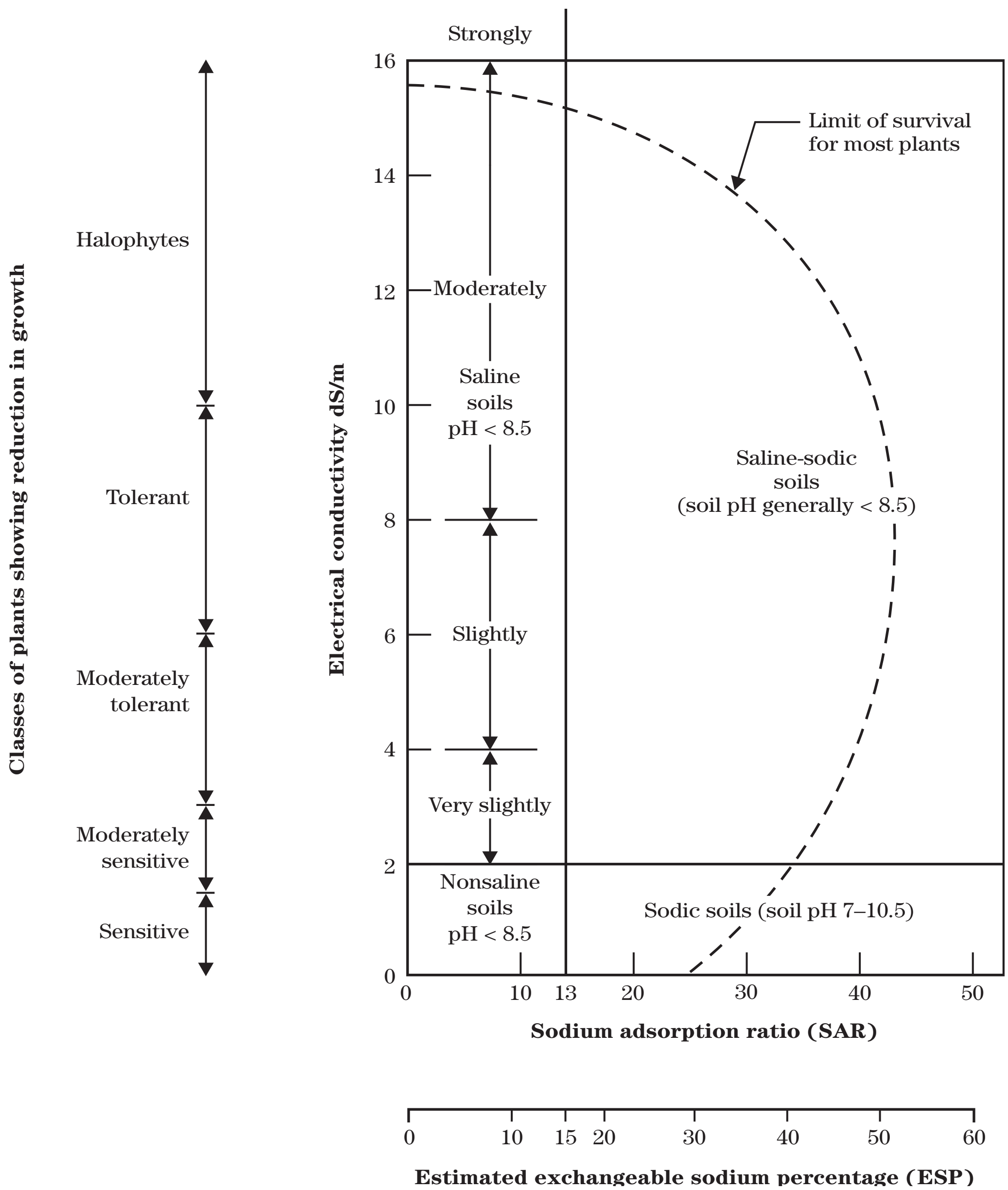
Nonsaline-sodic soils have so few soluble salts that the electrical conductivity is less than 2 millimhos per centimeter. owever, exchangeable sodium exceeds 15 percent of the total exchange capacity of these soils (fig. 3–8). Generally, sodic soils have a pH range of 7.0 to 10.5. Sodium and bicarbonate ions are present in concentrations that are toxic to all culturally managed forages. The bicarbonates are not directly toxic, but induce iron and manganese deficiencies in susceptible plants. The soils also have poor soil tilth because the sodium ions disperse clay and silt particles. When this occurs the soil aggregates are broken down making the soil dense and massive, a poor plant growth medium. These soils, while mostly confined to the arid Western United States, can also occur in depressional areas of highly weathered soils in the Eastern United States. These small depressions are often called slick spots. The soil surface is very black because of disperse organic material being brought to the surface by capillary action. The depressions also occur where saline-sodic soils were leached of their salts. See the paragraph preceding this one. Some nonsaline-sodic soils are actually acid soils, at least in the surface layer. The pH reading can be as low as 6.0. This is due to the absence of soil lime (calcite, aragonite, dolomite, magnesite, or some combination of these).

Alkaline soils have two features, salinity and sodicity, warranting further FSG sorting. Soil salinity is so critical to culturally managed forage crop production that is itdealt with as a separate factor apart from soil reaction. It is described at the end of this part on sodic soil management.

(4) Sodic soils associated with alkaline soils

Sodic soils respond well to treatment with chemical soil amendments and leaching with irrigation water.

Figure 3–8 Classification of nonsaline, saline, saline-sodic, and sodic soils in relations to soil ph, electrical conductivity, sodium adsorption ratio, and exchangeable sodium percentage, and the ranges of plant sensitivity to salinity and sodicity (adapted from Brady and Weil, 1999)



Here, calcium ions are used to displace sodium ions from the cation exchange sites within the top 6 to 12 inches of the soil. The chemical amendment of choice is dependent on the sodic soil class being treated, desired method of application, the cost and availability of the amendment, and to some extent, the speed of reaction with the soil. Chemical amendments generally selected are gypsum, sulfur, sulfuric acid, and lime-sulfur. Another amendment, lime, is used only when the sodic soil being treated contains litle to no native lime and pH readings would be driven below 6.0 by the other amendments.

Of the commonly used chemical amendments, sulfuric acid is the fastest acting. Sulfur is the slowest because soil micro-organisms must oxidize it first. This creates sulfur dioxide that combines with soil water to form sulfuric acid that then dissolves calcium from soil lime. Generally, lime-sulfur can be added to the irrigation water and applied in that manner on irrigated fields. Sulfur or lime must be spread and tilled into the soil. Gypsum can be spread and mixed into the soil, or applied with irrigation water. Sulfuric acid is sprayed on the soil or applied with irrigation water.

(i) Sodic soil limitation categories—Sodic soils are assigned to three classes governed by their response to chemical soil amendments:

- **Class 1** are sodic soils containing lime.
- **Class 2** sodic soils have a pH greater than 7.5, but are nearly free of lime.
- **Class 3** sodic soils have a pH less than 7.5 and no lime.

(ii) Importance to management considerations—Class 1 sodic soils respond well to any of the four amendments (gypsum, sulfur, sulfuric acid, or lime-sulfur). No lime is needed for this class as it is already in the soil.

Class 2 sodic soils may benefit from the addition of lime only if the acidifying amendments (sulfur, sulfuric acid, and lime-sulfur) are used and drive the soil pH below 6.0. The acid neutral amendment, gypsum, will not change the soil pH. In this case, no lime is required for a class 2 sodic soil.

Class 3 sodic soils may indeed be acid soils that have pH readings below 7.0. They can benefit from the addition of lime only. Generally though, lime is used in combination with one of the other sulfurous amendments.

Since sodic soils differ in their response to soil amendments, FSG's should distinguish into which of the three classes each soil series falls.

(d) Salinity

Soil salinity is a soil property of great importance over much of the Western United States where culturally managed forages are grown. It may be a general condition of a particular soil series, or it may occur as a saline seep area. The latter is caused when ground water with excessive salt concentrations draining across a soil or rock layer of low permeability surfaces at contact points between the impermeable layer and the ground surface, at rock fractures below the surface if under hydrostatic pressure, or at abrupt slope breaks. Seven types of seeps have been described and are illustrated in figure 3–9.

Saline soils may need leaching to lower their salt concentrations to levels that the forage crop to be grown will tolerate. This is accomplished best by applying excess irrigation water low in sodium and dissolved salts to cause downward percolation of water through the soil profile. Then, underlying tile drains convey the resultant leachate to an outlet. The soils must be pervious and high in calcium and magnesium. It is often necessary to land level and/or dike irrigated fields to pond water over the entire crop field. This allows for evenly distributed leaching of the soil profile of its excess salts by irrigation water. When growing forage crops, selecting salt tolerant ones (see table 3–9) is useful to protect a producer from crop failures even when saline soils have been leached. These soils tend to become salty again over time, especially if irrigated with water high in soluble salts. Therefore, planting salt-tolerant forage is insurance to guard against a gradual increase in soil salinity before treatment is initiated again. See NRPH chapter 5, section , accelerating practices irrigation water management and soil amendment application for an overview of treatment measures for growing forage crops on saline and sodic soils.

The salt tolerance data in table 3–9 apply to surface-irrigated forage crops and conventional irrigation management. Sprinkler-irrigated forage crops may suffer leaf burn from salt in the spray water contacting leaves and foliar salt uptake. The available data for predicting yield losses from foliar spray effects is limited. Sodium and chloride concentrations of 10 to 20 millimoles per liter in sprinkler irrigation water can cause foliar injury to at least alfalfa, barley, corn, and sorghum. The amount of damage also varies with the weather conditions, spray droplet size, and crop growth stage as well as from the salt concentrations in the irrigation water.

Figure 3–9 Seven geologic conditions for saline-seep development (source: Tanji 1990)

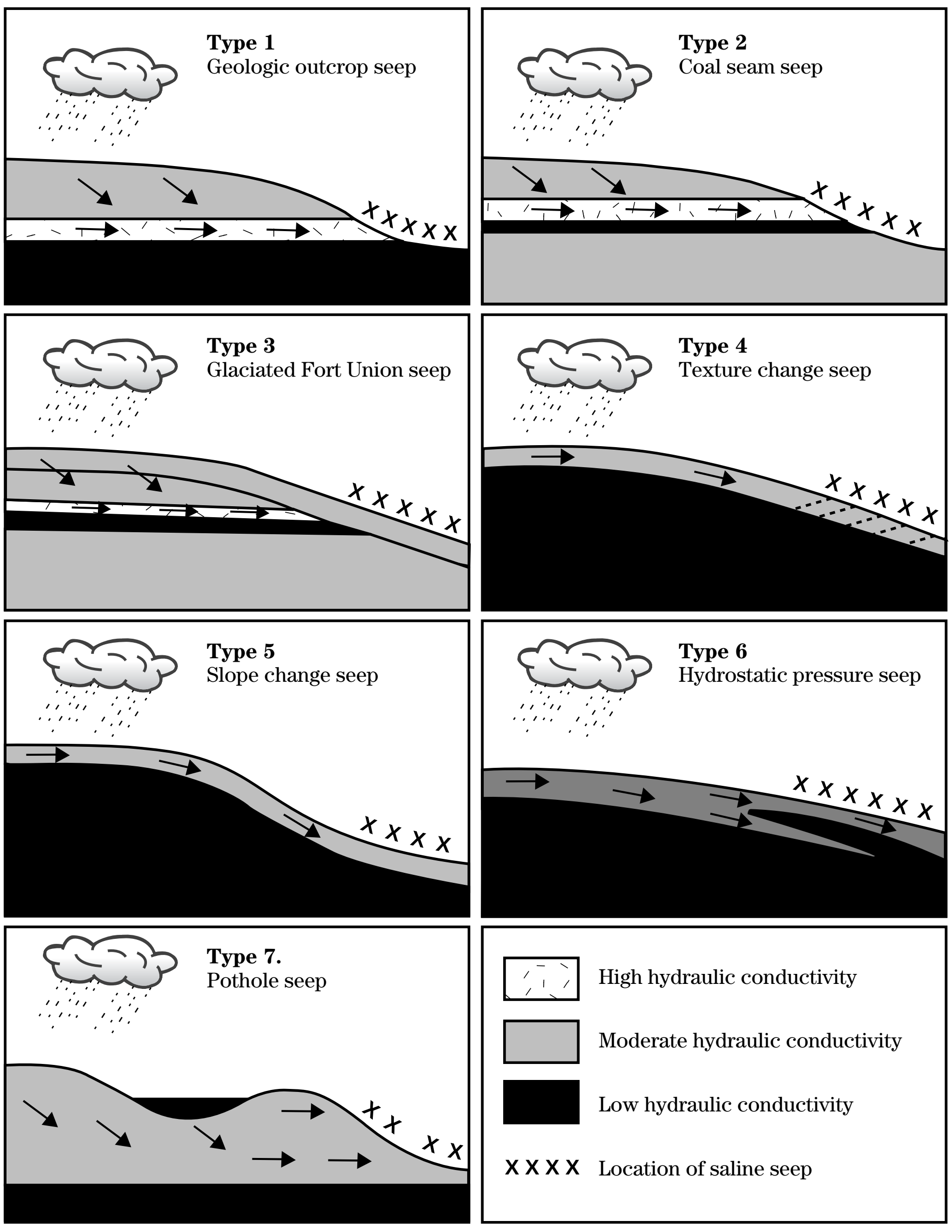


Table 3–9 Salt tolerance of forage grasses and legumes [1/] [2/]

Tolerant, 6–10 dS/m (millimhos/cm)	
Alkaligrass, nuttal	Saltgrass, desert
Alkali sacaton	Wheatgrass, fairway crested
Bentgrass, seaside creeping	Wheatgrass, tall
Bermudagrass	Wheatgrass, western
Crabgrass	Wildrye, Altai
Rape	Wildrye, Canadian
Rescuegrass	Wildrye, Russian
Rhodesgrass	
Moderately tolerant, 3–6 dS/m (millimhos/cm)	
Barley (forage)	Oats (forage)
Bromegrass, mountain	Panicgrass, blue
Bromegrass, smooth	Rye (forage)
Canarygrass, reed	Ryegrass, Italian
Clover, hubam	Ryegrass, perennial
Clover, sour	Sudangrass
Clover, white sweet	Trefoil, broadleaf birdsfoot
Clover, yellow sweet	Trefoil, narrowleaf birdsfoot
Dallisgrass	Wheat (forage)
Fescue, meadow	Wheatgrass, standard crested
Fescue, tall	Wheatgrass, intermediate
Grama, blue	Wheatgrass, slender
Hardinggrass	Wildrye, beardless
Milkvetch, cicer	
Oatgrass, tall	
Moderately sensitive, 1.5–3 dS/m (millimhos/cm)	
Alfalfa	Foxtail, meadow
Bentgrass, colonial	Kale
Bluegrass, Kentucky	Lovegrass species, Lehmann 50% more tolerant than others
Buffelgrass	Orchardgrass
Burnet	Sesbania
Clover, alsike	Siratro
Clover, berseem	Timothy
Clover, ladino	Trefoil, big
Clover, red	Turnip
Clover, strawberry	Vetch, common
Clover, white dutch	
Corn (forage)	

[1/] Sources: Bernstein, L. 1958. Salt tolerance of grasses and forage legumes. USDA AIB 194; Brady and Weil, 1999; Dalrymple et al., 1999; Maas, 1986; Rhoades and Loveday, 1990.

[2/] Brady and Weil, Maas, and Rhoades and Loveday updated original data by Bernstein. Species now appear in alphabetical order with regard to EC tolerance within class. Changes to species rating from the original Bernstein data only made if definitive newer data were presented. Additional species and their ranking added from Rhoades and Loveday table.

In the case of saline seeps, the growth of a deep-rooted forage crop, such as alfalfa, in the recharge area of the seeps actually becomes a treatment option. Another option is to abandon fallow farming if implicated with saline seep development. If crops use enough soil water in the recharge area during the time they are in the crop rotation, they can reduce or stop deep percolation and minimize or prevent saline seep reoccurrence.

(i) Salinity limitation categories—For FSG categorization, four categories of importance are used to determine how soils should be grouped from a salinity standpoint. Soils that have readings less than 2 millimhos per centimeter at 25 degrees Celsius are nonsaline. The four saline soil categories are:

- Very slightly saline—2 to 4 mmhos/cm (dS/m)
- Slightly saline—4 to 8 mmhos/cm (dS/m)
- Moderately saline—8 to 16 mmhos/cm (dS/m)
- Strongly saline—more than 16 mmhos/cm (dS/m)

(ii) Importance to management considerations—Very slightly saline soils can restrict the yields of sensitive forage crops. Slightly saline soils restrict the yield of most forage crops except the most tolerant. Moderately saline soils depress the yields of even salt tolerant forages and may render them less palatable. If the forage accumulates salts in its plant tissue, feeding it to livestock may cause them to scour (diarrhea). Strongly saline soils will not produce acceptable yields of any agronomic forage crop.

(e) Native fertility

Native fertility of soils determines their need for and response to added plant nutrients. The two indicators available nationwide from soil survey information are cation exchange capacity (CEC) and organic matter. Although they do not tell the complete story, they are consistently developed and available for all soil series.

Where available, information on native levels of phosphorus (P) and potassium (K) should be included in FSG reports. This information is available from the soil science department of some land grant universities. Some care must be taken in the use of that information, however. Around the United States, some soils have high levels of total native phosphorus and potassium, while others are quite low. Unfortunately, having a high total content does not necessarily translate into having a high level of available P or K. If soils are rated on their P or K supplying power, then this information could be used with confidence in establishing FSG's on this factor. However, if the soils are low in total P and K, this is a strong indicator that these soils are not particularly fertile mediums for plant growth. Soils of the southeastern and southern coastal plain of the United States are low in both nutrients.

(1) Cation exchange capacity

(i) CEC limitation categories—For FSG categorization, use three categories of soil CEC:

- **Low—**0 to 7 milliequivalents (meq)/100 grams of soil
- **Moderate—**7 to 15 meq/100 grams of soil
- **High—**more than 15 meq/100 grams of soil

The limits of each category may need to change depending upon the observed range of CEC values for all soil series in a state. The ranges given are examples only; however, they are often used as breakpoints for soil fertilizer recommendations.

(ii) Importance to management considerations —CEC is important. It indicates the soil's ability to retain in the rooting zone plant available nutrients that occur as cations. Low CEC soils hold few plant nutrient cations.These soils require frequent additions of smaller amounts of fertilizer than soils with high CEC. For instance, soil test recommendations for K, a cation, limit application rates because of this. Low CEC soils have lower recommended K fertilizer rates stated for them than those for high CEC soils. Putting too much K in the soil can lead to plant nutrient uptake imbalances if it was to occupy more of the exchange sites than is desirable, more than 5 percent K saturation. The optimum level of potassium is 2 to 3.3 percent of the soil's CEC.

Soil nutrient imbalances can adversely affect forage production and, at times, the ruminants feeding on them. Overfertilizing with nitrogen (N) or K may reduce magnesium (Mg) uptake by forages. Freshening cows eating low Mg content forages may get grass tetany, a malady caused by a diet deficient in Mg.

(f) Soil organic matter

(1) Limitation categories

Mineral soils must first be separated from organic soils to deal with soil organic matter influence on FSG's. Freely drained mineral soils are never saturated with water for more than a few days and have less than 20 percent organic carbon by weight. Seasonally saturated or artificially drained mineral soils have less than 12 percent organic carbon, by weight, if the mineral fraction has no clay; less than 18 percent organic carbon, by weight, if 60 percent of or more of the mineral fraction is clay; or a proportional content of organic carbon between 12 and 18 percent if the clay content of the mineral fraction is between zero and 60 percent.

Undrained saturated organic soils, such as peats and mucks, with no clay content must have 12 percent or more organic carbon. As clay content increases from 0 to 60 percent, organic carbon content must increase from 12 to 18 percent as a minimum. If clay exceeds 60 percent, organic carbon must exceed 18 percent for a saturated soil to be considered an organic one. Freely draining organic soils must contain 20 percent or more organic carbon regardless of clay content. Organic soils can be dealt with separately from a fertility standpoint. Generally, they are quite low in P, K, and available copper (Cu), while high in N and calcium (Ca).

Mineral soils can be broken out into four levels of organic matter to form FSG's:

- **Low in organic matter**—less than 1 percent organic matter
- **Moderate—**1 to 4 percent organic matter
- **High**—4 to 10 percent organic matter
- **Very high**—more than 10 percent organic matter

The latter category contains soils with a modifier in the name called mucky. Machinery tires and livestock hooves easily damage wet, mucky soils. To avoid damage to forage crops, defer grazing or machinery entry onto the mucky soil until ry. Organic matter is derived from organic carbon measurements by multiplying organic carbon by a factor of 1.72.

(2) Importance to management considerations

Soil organic matter content is important for a number of soil fertility reasons. It acts as a reservoir that supplies plant nutrients, N, P, sulfur (S), zinc (Zn), and boron (B), to growing forages. All of these nutrients exist as anions in the soil. Farmed soils generally do not have an anion exchange of any great importance. Therefore, these nutrients, as they are released through organic matter decomposition, become available for plant uptake unless fixed or until leached out of the root zone. To a certain extent organic matter content is an overlapping factor with CEC because in many soils it provides the majority of the cation exchange sites. However, it also promotes good soil structure by encouraging soil particle aggregation. This increases soil porosity, promotes water infiltration, increases available water holding capacity, decreases soil crusting, and makes soils less prone to compaction. A soil in good physical condition is more productive. Finally, soil organic matter acts as a buffer against rapid changes in acidity, sodicity, and salinity.

Mineral soils low in organic matter need low rate, split applications of N during the growing season on all grass forage stands. They have little N supplying power or holding ability. For this category in particular and the moderate category, the growing of legumes with grasses is beneficial in providing N to the grasses. Low organic matter soils are not likely to rise significantly in organic matter content when amended with organic materials or left in long-term sod, such as permanent pasture. Where they occur, climatic and soil conditions are too conducive to high rates of decomposition. Soils in the other categories of organic matter content need less frequent applications of N on all grass forage stands. At the very high category, N may be mineralized at levels sufficient to meet the needs of an all grass forage stand.

(g) Frost heave (potential frost action)

In the Northern United States, frost heave potential of soils has a direct bearing on legume and winter small grain survival. (NRCS soil scientists use the term *potential frost action*. Frost heave is a result of frost action.) Taprooted legumes can have their roots snapped in two by frost lenses. Legumes and some grasses are raised out of the soil several inches, exposing the roots. Many of the plants die of dehydration or freezing. The ones that do survive have reduced vigor and can suffer further damage by livestock hooves and machinery traffic. Soil temperatures must drop below 32 °F for frost heave to occur. Frost heave occurs when ice lenses or bands develop in the soil. These lenses drive an ice wedge between two layers of soil near the soil surface. The resultant wedge heaves the overlying soil layer upward, snapping roots. When the ground thaws, the overlying soil layer settles back down leaving the severed roots exposed to the air (fig. 3–10).

The approximate geographic boundary above which frost heave becomes a problem is the 250 degree-day below 32 degree Fahrenheit isoline shown in figure 3–11. This is the number of degree-days below 32 degrees Fahrenheit that can be expected in the coldest 1 year in 10. Silty and very fine sandy soils have the greatest potential to frost heave. They have small enough pores to hold enough water under tension to form an ice lens, but still coarse enough to transmit surrounding super-cooled soil water to the freezing front on either side of the ice lens.

(1) Limitation categories

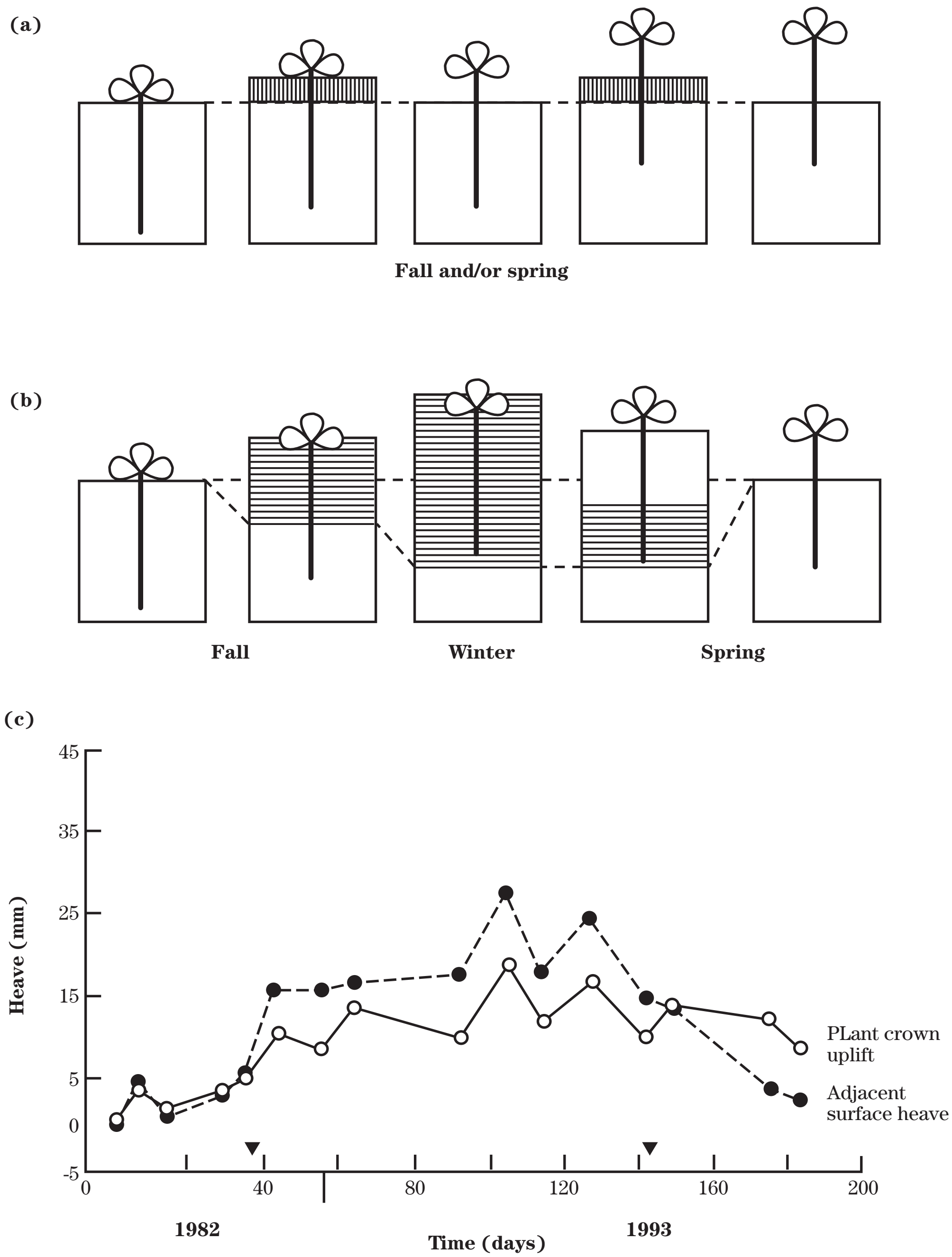
The three classes of frost heave potential are:

- **Low**—Soils are rarely susceptible to the formation of ice lenses. Frost heave of legumes or winter small grains unlikely.
- **Moderate**—Soils are susceptible to the formation of ice lenses, resulting in frost heave. Winters with few freeze and thaw cycles decrease likelihood of legume or winter small grain damage.
- **High—**Soils are highly susceptible to the formation of ice lenses, resulting in frost heave. Some legume or winter small grain plant loss or complete loss is probable yearly.

(2) Importance to management considerations

Do not confuse frost heave mortality with forage crop susceptibility to winter killing. Frost heave will occur no matter what the sugar, soluble protein, and water content of the roots are. The force created by an ice lens, 150 tons per square foot, is far beyond what a healthy root, or even, a reinforced concrete floor can endure. Winter killing results from a physiological condition that a nondormant forage crop or a weakened winter-dormant or cold-hardy forage crop can face. They are either short on plant antifreeze, called electrolytes, or do not have adequate food reserves to meet respiration and regrowth needs until spring green-up.

Figure 3–10 Frost heave of forage plant (source: Perfect, Miller, and Burton 1988)



(a) Incremental frost heave during freeze-thaw cycles.
(b) Large ice lens induced major frost heave.
(c) Typical upward displacement of soil and plant during frost heave season.

Whether a soil above the 250 isoline is prone to frost heave depends on its soil moisture regime and texture class. Family texture classes are assigned by soil moisture regime to the three frost action classes in exhibit 618–5 in the National Soil Survey Handbook. Climates that have little snow cover over winter, ample fall and winter precipitation, and several freeze and thaw cycles increase the incidence of frost heave damage.

Conservation practice measures to moderate frost heave incidence and damage are limited and will work only on soil textures that drain freely after treatment. Lowering the water table on aquic moisture regime soils, such as coarse-loamy, loamy-skeletal, and organic, may move them from the high potential class to the low. The best way to avoid frost heave damage is to select forage species that are less susceptible to its effect. It is best to avoid planting legumes, other tap-rooted forages, and winter small grains on high frost heave potential soils.

On moderate frost heave potential soils, legumes should be planted with grasses. The grass ground cover and root mass tend to insulate the soil. This may reduce the incidence of frost heave of the interplanted legume from year to year. A reduced stand life for the legume in the legume-grass mixture will most likely occur on such soils over those soils with a low frost heave potential. Alfalfa stands, for instance, will most likely remain for only 3 years on moderate frost heave potential soils. The stand life on soils with a low frost heave potential could easily double if managed properly and selected for disease resistance.

Fence maintenance can also increase on soils prone to frost heave. Wood or other wide diameter posts are pushed up similar to plant roots. Once jacked up, soil along the sidewalls of the cavity created under the post falls into the cavity and prevents the post from settling back to its original depth. Eventually the post is jacked partly out of the ground. It then begins to tip and pull out in the direction of the strongest pull by wire tension or dead weight of boards and push by animal pressure.

Figure 3–11 250 degree day Isoline (source: National Soil Survey Handbook, NRCS 1993)

(h) Trafficability

Trafficability is the condition presented by the soil that influences the degree of ease of movement by livestock, humans, or machinery across its surface. Large surface rock fragments (>10 inches) can restrict ease of movement or prohibit it entirely. However, because the fragments also have an impact on productivity, they are covered as a separate factor.

Another factor affecting soil trafficability is soil wetness. Soil that has a high water table, seasonally or year around, and slow water transmission rate can restrict or preclude livestock and machinery movement on it. Trafficability as affected by soil wetness can be rated using the drainage classes mentioned previously.

Another major soil condition that impacts trafficability is its plasticity characteristics. This is measured by determining the liquid limit and the plastic limit of a particular soil. The numerical difference between these two limits determines the plastic index for a soil. The plasticity index and the liquid limit then are used to classify soils under the Unified Soil Classification System. With increasing plasticity index and liquid limit values, trafficability worsens with wetted soils.

The last soil condition impacting trafficability is its organic matter content. Soils high in organic matter have low bearing strength especially when wet. Livestock and machinery sink into the ground easily when traversing wet organic soils. This soil condition is also addressed by the Unified Soil Classification System.

(1) Limitation categories

Trafficability limitation ratings are a composite of four variables: surface stoniness, drainage class, plasticity characteristics, and organic matter content. For FSG's, there is no need to group soils into any more than three groups: slight, moderate, and severe.

(i) Slight—Traffic across soil is unrestricted by surface rocks or wet weather. Includes soils in Unified Soil Classification groups GW, GP, GM, GC, SW, and SP with less than 0.1 percent of surface covered by stones or boulders and regardless of drainage class, and in Unified Soil Classification groups SM and SC that have less than 0.1 percent of surface covered by stones or boulders and are well drained to excessively drained.

(ii) Moderate—One or more of the following conditions exist. Surface stoniness interferes with cultural management of forages, but does not forbid it. Wet weather periods cause some damage to soil surface and forage stands or necessitates some delays in moving livestock and machinery onto the soil. Includes soils in Unified Soil Classification groups GW, GP, GM, GC, SW, and SP with a range of 0.1 to 3 percent of surface covered by stones or boulders and regardless of drainage class; Unified Soil Classification groups SM and SC that are moderately well drained, have a range of 0.1 to 3 percent of their surface covered by stones or boulders, or both; Unified Soil Classification groups CL and ML with a range of surface coverage by stones or boulders up to 3 percent and a range of drainage classes of moderately well drained to excessively drained; and Unified Soil Classification groups CH and MH with a range of surface coverage by stones or boulders up to 3 percent and a range of drainage classes well drained to excessively drained.

(iii) Severe—One or more of the following conditions exist. Surface stoniness forbids or causes excessive hardship in culturally managing forages. Soils are wet for prolonged periods, low in bearing strength, and easily deformed by hooves or machinery tires. It includes Unified Soil Classification groups OL, OH, and PT regardless of surface stone or boulder coverage and drainage class; all Unified Soil Classification groups when more than 3 percent the surface is covered by stones or boulders; Unified Soil Classification groups SM, SC, CL, and ML that are somewhat poorly drained to very poorly drained; and Unified Soil Classification groups CH and MH that are moderately well drained to very poorly drained.

(2) Importance to management considerations

Trafficability decreases under wet soil conditions on susceptible soils, dictating the need to defer grazing of livestock on pastures, hayland, and grazable cropland. Turning livestock into wet fields causes a great deal of poaching. The depressions and compaction left in the soil by livestock hoof imprints only worsen the ability to move about the field. The depressions trap and hold water, keeping the soil wet for a more prolonged period. The roughness created by the depressions slows livestock movement, as they become more tentative about which step to take next. Once poaching is initiated, the situation tends to get worse with time and successive wet periods. Livestock injury can also occur if trafficability becomes so bad as to cause them to sink deeply into the soil with each step taken. Trafficability problems for machinery can delay harvests to the point that forage quality suffers. Forage seedings may also be delayed, jeopardizing stand establishment. Lime and fertilizer may be broadcast only during mid-summer.

Trafficability problems due to wet, pliable soils may be corrected by providing adequate soil drainage where fields are wet over a wide spread area. This will not be done solely for this purpose as it is done to improve production. Cattle walkways and trails need paving materials and/or drainage to traverse wet soil areas to improve trafficability. Surface stoniness management is addressed below.

(i) Surface rock fragments

As mentioned earlier, depending on their size and abundance, surface stones can either restrict or halt the movement of livestock and machinery. They can cause injury to livestock and costly damage to machinery, such as broken sickle bars, broken or bent axles, and tire bruises and ruptures. They also can affect forage production because they occupy space on the ground surface, preventing the growth of forage plants at that location. When small cobbles or channers are widely scattered over the surface, this may not be a problem because forage plants can close their canopy over the stones. Rock fragments greater than 24 inches in diameter that create a very to extremely bouldery surface, however, greatly inhibit forage plant production. They simply occupy space that cannot be closed by converging plant canopies growing in the surrounding finer textured soil areas. This creates unproductive gaps in the forage stand.

The National Soil Survey Handbook, section 618.61, describes five types of surface rock fragments, based on size, kind, roundness, and shape, that impact grazing land suitability. They are:

- **Flat fragments only—**Channers, 0.1 to 6 inches, and flagstones, 6 to 15 inches long.
- **Non-flat fragments only—**Cobbles, 3 to 10 inches.
- **Fragments either flat or non-flat—**Stones, 10 to 24 inches, and boulders, more than 24 inches in diameter.

Surface cobbles and channers on permanent pastures have no great impact on forage production or utilization. They do present problems in renovating pastures and hayland, preparing seedbeds, planting, and seedling emergence of forages on cropland. Any large fraction of the cobbles and channers in or on the soil prematurely wears out soil working machinery. As their presence on the surface increases, the larger rock fragments increasingly impact permanent pastures.

(1) Limitation categories

The six groupings of soils by surface rock fragment content established for determining grazing land suitability are:

- **No Limitation—**No rock fragments of more than 3 inches are on the soil surface.
- **Slight—**Soil surface covered with less than 0.1 percent stones and boulders.
- **Moderate—**Stones or boulders cover from 0.1 to 3 percent of the surface.
- **Severe—**Stones or boulders cover from 3 and 15 percent of the surface.
- **Very severe—**Stones or boulders cover about 15 to 50 percent of the surface. They are so closely spaced that it is possible to step from stone to stone or jump from boulder to boulder nearly always without touching soil.
- **Unsuitable—**Stones or boulders cover more than 50 percent of the surface. Little or no culturally managed forage plants grow on the site other than those that can volunteer from seed or spread by rhizome or stolons from adjacent areas.

(2) Importance to management considerations

Rock picking would be the primary treatment measure to improve conditions for forage production and utilization on stony or bouldery grazing lands. Rock picking generally is cost-effective only up to 3 percent stones and boulders on the surface. Rock picking must be done more than once. When stony soils are cultivated from time to time over the years, more stones are uncovered. Rock picking would be minimal and sporadic for the slight soil group. The moderate soil group would require rock picking after almost all attempts at tillage. The severe soil group contains soil series that are best left as permanent pasture. Removal of some of the larger stones or boulders would improve trafficability to overseed, lime, or fertilize the pasture. The very severe soil group would yield only about 50 percent of the pasture forage produced on a similar nonstony soil. This group would preclude any improvement efforts.

Fence building starting at the moderate and going to the very severe stony soil group would get progressively harder, primarily because of the difficulty setting posts. The slight group still could have posts driven with rather good success. The moderate group would require mostly dug postholes or some rather random settings for driven posts. Building a suspension fence of some type where the number of posts needed is kept to a minimum is a better option on the severe and very severe groups. Postholes of proper depth would be hard to achieve on a soil series in either of these two groups without going to an auger capable of drilling into rock. Fencing contractors in stony locales use these augers, but cost per posthole goes up considerably. For these two groups, it might be worthwhile to drill holes into larger stones or boulders for line posts and set steel T-posts in them with the anchor plates removed. The stones would serve as anchors for the steel T-posts.

Digging trenches in stony soils is also much more difficult, especially if boulders are common. Where stones are large enough to hinder excavation, trench-digging limitations in stony soils will be similar to that of setting fence posts. Trench digging is often needed to bury pipelines for livestock water, to install drain tiles or tubing, to develop springs for livestock water, or to bury insulated electric fencing wire under gate openings. Stony soils not only hinder or preclude excavation; they often times require a granular backfill material to bed the pipe. This prevents a stone in the returned onsite backfill from crushing or deforming the pipe at the time of backfilling or later as the backfill settles around the pipe.

(j) Shrink-swell

Clayey surface soils high in smectite expand when wet and shrink while drying to a very exaggerated state. When dry, 1- to 2-inch-wide cracks commonly occur that run to a depth of 6 to 20 inches. The clay pedestals created are generally 8 to 16 inches wide. Therefore, the vegetation growing under such conditions must have a root structure resistant to such extreme contraction pressures. This condition can worsen on a poorly managed sodic soil. In the presence of ever increasing amounts of sodium, the smectite clay lattice that expands when wetted expands more and more. Soils having this high shrink-swell clay are called Vertisols.

(1) Limitation categories

The pronounced shrinking and swelling of some soils impact their use for forage production in two distinct ways. It influences the selection and establishment of forages on soils with high smectite clay content in the surface layer. It also influences fence design if the surface layer containing the high smectite clay is greater than 12 inches deep. Therefore, three forage suitability group categories are developed:

- **Slight—**Surface soils of kaolinitic mineralogy and clay loams, silty clay loams, and sandy clay loams of smectite mineralogy with a linear extensibility (LE) less than 6 percent.
- **Moderate—**Surface soils of smectite mineralogy with textures of clay, silty clay, and sandy clay with an LE greater than 6 percent, but less than 12 inches thick.
- **Severe—**Surface soils greater than 12 inches in depth with smectite mineralogy clays with an LE greater than 6 percent.

(2) Importance to management considerations

Clay, silty clay, and sandy clay surface soils of smectite mineralogy with an LE greater than 6 percent are poorly suited to growing domesticated grasses and legumes for livestock or wildlife use. The best-adapted forages for this soil condition are drought tolerant, perennial warm season bunchgrasses, annual bunchgrasses, and annual legumes. The latter two can be used to exploit wetter periods of the growing season. They should be selected to achieve their full growth potential before seasonal soil cracking and dry conditions limit plant growth.

Fences are impacted by high shrink-swell soils when the expandable clay layer is greater than 12 inches thick. They tend to tip as the clays expand and contract over time. To avoid this action, the posts must be set extra deep or anchored in place with rock jacks or other devices. Obviously if set deeper, this requires the use of longer posts and takes more time to install them. If anchoring devices are used, they also increase the time of installation as well as adding to the cost of materials. Therefore, construction and maintenance of fences on these soils are costly and time-consuming.

(k) Depth to restrictive layers

Although this soil property is largely accounted for under the available water holding capacity property, there are some additional limitations to forage production that should not be overlooked. Nutrient availability, loss of water to runoff, trench depth for pipelines and drainpipe, and post setting depth are impacted by depth to restrictive layers. Rooting depth does not only affect the amount of soil available for plant roots to explore for water, it also affects the volume of soil available for nutrient uptake by plants and water storage during rain events. Shallow soils produce more runoff than deep soils with the same infiltration rate. Their water storage reservoir is smaller. Therefore, less water is initially available for plant production regardless of the soil's available water holding capacity. Generally, shallow-rooted forage plants have the competitive advantage over deep-rooted forages on soils less than 20 inches deep to a restrictive layer. However, their yield potential is also correspondingly lower.

(1) Limitation categories

Soil depths greater than 40 inches deep to a restrictive layer pose no or slight limitations to forage production. Moderate depth soils, 20 to 40 inches deep, have moderate limitations to forage production. Soil depths less than 20 inches to a restrictive layer have severe limitations to forage production.

(2) Importance to management considerations

All forages have either their entire root mass within 40 inches of the soil surface or more than 90 percent of it. Most fencepost-setting depths do not exceed 40 inches. Trench depths, for drainage pipes, spring developments, and water lines, generally do not need to exceed 40 inches. Therefore, soils that do not have a restrictive layer within a depth of 40 inches pose no particular problem to forage production and grazing management practices.

On moderately deep soils, forage species with deep roots are less adapted and suffer some loss of yield potential. Corner, brace, and end post assemblies of fences need anchoring or angle stays and blocks if set shallower than normal design depths. Otherwise, special tipped posthole augers are needed to drill postholes to entire design depth. As trench depths decrease toward 20 inches, less soil is available to insulate water flowing in pipes laid in them from extreme heat or cold. In cold climates, water lines may need to be evacuated during low use periods or kept continually flowing. During hot weather, livestock water conveyed in shallow waterlines may be warmer than ideal for top production. Less soil cover is also available to protect the lines from crushing when wheel loads pass over them.

Where soils are less than 20 inches deep, high-yielding, deep-rooted forages have very low yield potential and shortened stand life. Shallow-rooted forages with lower yield potentials may need to be selected instead. Establishment of new forage stands on shallow soils may be more difficult because of restricted tillage options, droughtiness, and increased runoff and erosion potential where rainfall events may exceed soil storage capacity. Fencepost settings will be either shallow or set to full depth using rock drilling augers. Either way, fence expense will be high either as a maintenance cost or as an initial construction cost. Pipes laid in trenches less than 20 inches deep are more subject to temperature extremes and crushing by wheel loads. Drainage lines put in at depths less than 20 inches need closer spacing between lines than ones laid deeper. Pipes laid on top of restrictive layers, such as bedrock, often need to be bedded with gravel to prevent unequal load support that can cause a rupture if enough deflection occurs.

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 3 Ecological Sites and Forage Suitability Groups

Section 2 Forage Suitability Groups

Exhibits

Exhibit 3.2–1 Forage Suitability Group Description Example

(Data presented in this forage suitability group description are examples for content and format only.)

United States Department of Agriculture
Natural Resources Conservation Service, PA

G127NY401PA
Deep, channery, well drained, strongly acid, moderately steep upland soils

FORAGE SUITABILITY GROUP
Deep, channery, well drained, strongly acid, moderately steep upland soils

FSG No.: **G127NY401PA**
Major Land Resource Area: 127 – Eastern Allegheny Plateau and Mountains

Physiographic Features

This group of soils lies on hilltops and hillsides. Deeply incised watercourses are often present on the hill slopes occupied by this soil group. These watercourses run the length of the slope and parallel to each other. They may be intermittent or spring-fed.

	Minimum	Maximum
Elevation (feet):	1,200	2,300
Slope (percent):	15	25
Flooding:		
Frequency:	None	None
Duration:	None	None
Ponding:		
Depth (inches):	0	0
Frequency:	None	None
Duration:	None	None
Runoff Class:	High	Very high

Climatic Features

Snowfall ranges from 35 inches in the south to 90 inches in the north. Snow cover at depths greater than 1 inch average a high of 104 days at higher elevations in the north to a low of 20 days at lower elevations in the south. Growing season precipitation ranges between 22 and 32 inches. Average monthly precipitation is rather evenly distributed during the year, ranging from 2.4 inches to 5.3 inches. The lesser amounts of monthly precipitation occur in the winter. Precipitation events of more than 0.1 inch occur about every 3 to 4 days on average during the growing season. Average July temperature ranges from 66 degrees Fahrenheit to 73 degrees Fahrenheit. Relative humidity is high throughout the growing season averaging about 55 percent at mid-afternoon, increasing during the night to 85 percent at dawn. Potential evapotranspiration ranges from 22 to 27 inches.

Freeze-free period (28 deg)(days): (9 years in 10 at least)	105	172
Last killing freeze in spring (28 deg): (1 year in 10 later than)	May 01	Jun 02
Last frost in spring (32 deg): (1 year in 10 later than)	May 14	Jun 22

First frost in fall (32 deg): (1 year in 10 earlier than)	Aug 25	Sep 28
First killing freeze in fall (28 deg): (1 year in 10 earlier than)	Sep 08	Oct 11
Length of growing season (32 deg)(days): (9 years in 10 at least)	72	144
Growing degree days (40 deg):	3,700	5,300
Growing degree days (50 deg):	2,000	2,500
Annual minimum temperature:	–20	–10
Mean annual precipitation (inches):	41	47

Monthly precipitation (inches) and temperature (F):

2 years in 10:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precip. less than	1.38	1.41	1.96	2.04	2.61	2.28	2.70	2.57	2.08	1.64	2.31	2.03
Precip. more than	5.18	5.03	5.39	5.28	5.76	6.96	7.20	5.60	5.26	4.59	5.10	4.71
Monthly average:	3.03	3.00	3.42	3.48	4.00	4.87	4.51	3.92	3.78	3.20	3.78	3.24
Temp. min.	10.5	12.5	21.8	31.7	41.4	49.4	53.5	52.4	45.9	36.6	28.3	17.6
Temp. max.	36.2	39.2	50.0	62.2	73.0	81.8	85.8	83.8	76.8	64.8	52.7	40.3
Temp. avg.	23.2	26.0	35.6	46.9	57.3	65.4	69.4	67.8	61.1	50.2	39.8	28.6

Climate station	Location	From	To
PA4385	Johnstown, PA	1961	1990
PA1806	Coudersport, PA	1961	1987

Soil Properties

The soils in this group are moderately steep, deep, and well drained. Although considered deep, the soils in this group are underlain by sandstone, siltstone, or shale bedrock at depths of 46 to 54 inches. The topsoil is a channery loam to silt loam having 25 percent or more, thin, flat rock fragments as much as 6 inches long. Cation exchange capacity in the topsoil ranges from 12 to 20. Seasonal high water table is at a depth or more than 6 feet.

Drainage class:	Well drained	to	Well drained
Permeability class: (0 – 40 inches)	Moderate	to	Moderate
Frost action class:	Medium	to	Medium

	Minimum	Maximum
Depth:	46	54
Surface fragments >3" (% cover):	25	54
Organic matter (percent):	2.0	4.0
Electrical conductivity (mmhos/cm):	0	0
Sodium adsorption ratio:	0	0
Soil reaction (1:1) Water (pH):	3.6	6
Available water capacity (inches):	4	6
Calcium carbonate equivalent (percent):	0	0

Soil Map Unit List

Soil survey area	Map unit symbol	Soil component name
PA111 Somerset Co.	HaD	Hartleton channery silt loam
PA111 Somerset Co.	HoD	Hazelton channery loam
PA111 Somerset Co.	LeD	Leck Kill channery silt loam

Adapted Species List

The following forage species are considered adapted to grow on the soils in this group at their natural pH levels. If limed, other species can be selected that perform better at higher pH's near neutral. See soil interpretations section for list of those species. The additional forage species listed in the soil interpretations section will grow on the soils in this group, but they will produce less than 75 percent of the yield on sites most favorable to them.

No subjective ranking from the most adapted to the least is given among forage species in these tables. However, stand loss of perennial ryegrass is likely after a severe winter or hot, dry summer. Select cultivars of perennial ryegrass that have demonstrated cold tolerance. Drought tolerance is not a trait with cultivar differences of note.

Little, if any, irrigated forage production is carried on in this MLRA. However, there are periods in the summertime where supplemental irrigation would enhance forage production for several species. Irrigation of some species is considered not applicable for two reasons. If they are warm-species perennials, they would only marginally benefit from irrigation since they are drought and heat tolerant, and would face stiffer competition from cool-season invaders. Long-term stand longevity under irrigation without herbicide control of cool-season invaders is questionable. The other species where irrigation is listed as not applicable are weedy invaders. Although they would benefit from irrigation, there are better producing, more nutritious forages available that better justify the cost of supplemental irrigation. In this climate, irrigation is strictly supplemental and is rarely done because of its cost versus economic return in additional yield.

Cool-season Grasses	Dryland	Irrigated
Bentgrass—grazed only	X	X
Perennial ryegrass	X	X
Redtop	X	X
Reed canarygrass	X	X
Tall fescue	X	X
Timothy	X	X

Warm-season Grasses	Dryland	Irrigated
Big bluestem	X	
Causasian bluestem	X	
Eastern gamagrass	X	
Little bluestem	X	
Purpletop	X	
Switchgrass	X	

Legumes	Dryland	Irrigated
Alsike clover	X	X
Birdsfoot trefoil	X	X
Black medic—grazed only	X	
Crownvetch	X	X
Kura clover	X	X
Ladino clover	X	X
Red clover	X	X
Vetch, common	X	X
White clover	X	X

Other Perennial Forbs	**Dryland**	**Irrigated**
Bedstraw	X	
Chicory	X	X
Dandelion	X	
Plantain, various	X	

Annual Species	**Dryland**	**Irrigated**
Corn, silage (machine harvested)	X	X
Crabgrass	X	
Foxtail millet	X	X
Kale	X	X
Rape	X	X
Sorghum/sudangrass and crosses	X	X
Spring small grains	X	X
Swedes	X	X
Turnip	X	X
Winter small grains	X	X

X = Adapted

Production Estimates

Forage production limited by moderate water holding capacity of the soils and the often sporadic, limited rainfall during July and August combined with high daytime temperatures. Irrigation of switchgrass is not cost effective and may reduce stand life due to likely more rampant cool-season grass invasion. Therefore, no yield estimates are given for irrigated switchgrass.

Forage crop[1/]	**- - - - - Dryland - - - - -**		**- - - - - Irrigated - - - - -**	
	Management Intensity		**Management Intensity**	
	High (lb/ac)	**Low** (lb/ac)	**High** (lb/ac)	**Low** (lb/ac)
Alfalfa	8,000	4,000	12,000	9,000
Clover, red or Ladino	6,000	3,000	11,000	8,000
Corn silage	42,000	28,000	60,000	40,000
Legume-grass	8,000	4,000	13,000	10,000

1/ Production values are on as-fed basis.

Pasture	**- - - - - Dryland - - - - -**		**- - - - - Irrigated - - - - -**	
	Management Intensity		**Management Intensity**	
	High (AUM/ac)	**Low (AUM/ac)**	**High (AUM/ac)**	**Low (AUM/ac)**
Orchard-K. blue-white clover	4.0	2.0	6.0	4.0
Switchgrass	11.0	6.0		
Tall fescue	7.0	2.5	10.0	7.0
Tall fescue-Ladino clover	8.0	3.0	11.0	8.0

1 AUM = 790 lb

Forage Growth Curves

Growth Curve Number: PA1208
Growth Curve Name: Tall fescue, 120–140 day growing season
Growth Curve Description: Tall fescue dominated pasture, <5% legume

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	5	32	27	12	5	16	3	0	0

Growth Curve Number: PA1209
Growth Curve Name: Tall fescue-Ladino clover, 120–140 day growing season
Growth Curve Description: Tall fescue pasture with a Ladino clover component 25–40% by weight

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	15	30	22	8	6	14	5	0	0

Growth Curve Number: PA1205
Growth Curve Name: Orchardgrass-K. Blue-Wh. Clover, 120–140 day growing season
Growth Curve Description: Orchardgrass pasture with K. bluegrass and white clover components 20–30% each by weight

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	15	30	22	8	6	14	5	0	0

Growth Curve Number: PA1213
Growth Curve Name: Switchgrass, 120–140 day growing season
Growth Curve Description: Switchgrass pasture, <5% legume, minor cool-season grass invasion

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	21	32	31	16	0	0	0

Soil Limitations

Primary soil limitation for this group is the acidic nature of the surface and subsurface soil layers. These soils may be near neutral to strongly acid, depending on whether or not these soils have been limed in the past. If lime has been applied to bring the pH up to at least 6.0, then

Kentucky bluegrass,
smooth bromegrass,
orchardgrass,
and alfalfa

are additional climatically adapted forage species selections to those listed under Adapted Species.

Frost heave potential on these soils is moderate. Open winters after wet falls with significant freeze-thaw cycles may cause an occasional loss or reduction of alfalfa stands. Probability of alfalfa stand reduction or loss is once in 5 years on average.

Slopes are moderately steep. Additional caution should be used when driving wheeled equipment as slopes near 25 percent. Potential for severe cattle trail erosion and underutilized pasture areas is high. This is heightened by a single watering facility located at the upper or lower end of pasture more than 800 feet long in the direction of the slope. Fence construction on this soil group requires more line brace assemblies to maintain adequate wire fence tension as more breaks in grade are encountered than on smoother, flatter sloped soil groups.

Channery rock fragments will interfere with post setting and seedbed preparation somewhat. Tillage tools will wear out prematurely. The rock fragments are also largely responsible for the plant available water holding capacity (AWC) to be in the moderate range. The same soils without the channers are in the high AWC range. Forage production on these soils of moderate water holding capacity will be noticeably affected by wet and dry growing seasons. Long-term average yields given above are reflective of a 20 percent decrease in yield over soil groups having a high AWC.

Management Interpretations

For best forage production, lime should be applied occasionally to keep the pH at approximately 6.5 when soil tests indicate a need. Lime requirement for these soils is moderate. From 3 to 6 tons of lime per acre are needed to correct a previously unlimed soil to 6.5. Maintenance applications of 0.5 to 1 ton per acre may be called for intermittently when pH falls to 6.0.

These soils are low in organic matter if tilled for a typical crop rotation grown in the MLRA. On permanent pasture or hayland, these soils may have a moderate organic matter content of 2 to 4 percent. In either case, nonlegume forages respond well to nitrogen fertilizer applications. Split apply nitrogen to grasses based on expected yield for the current cutting or grazing period. Excess nitrogen leaches out of the root zone during winter dormancy or heavy rain events. Fall and winter N loss is due to the 18 to 21 inches of precipitation in excess of what can be held by the soil and not lost to evaporation.

Response to phosphorus (P) fertilizer applications on unfertilized, but limed soils is low to moderate. Liming the soils tend to make the native P more available damping the response to fertilizer P except when applied as a starter fertilizer for a new seeding.

Response to potassium (K) fertilizers is low. These soils naturally tend to have available K in the optimum range or above for their cation exchange capacity values. Legumes harvested for hay benefit most from K fertilization to replace that lost by harvest removal.

When taprooted legumes are grown, a compatible and adapted cool-season grass companion crop should be planted to cut down on frost heave losses or provide a fallback hay or pasture crop. If frost heave reduces the legume stand anyway, the grass will produce some forage. The grass will provide slightly better erosion control cover as well.

Forage yields for this soil group are constrained most by low pH and lack of nitrogen fertilizer applications when legumes are absent from the crop rotation or the forage stand. Second limiting factor is the AWC during dry years or prolonged dry spells during the growing season.

Large cattle and horse pastures with slopes above 15 percent have a worsening distribution of grazing pressure as slopes increase to 25 percent if a single water source is located at either the highest or the lowest elevation. Areas remote to watering facilities (greater than 800 feet away) will be underutilized. Meanwhile, areas within 800 feet of the watering facility will be used with increasing intensity as the watering facility is approached. For even grazing pressure distribution, place watering facilities at intervals along the entire elevational gradient. Paddock layouts should have long axes perpendicular to the slope. Place a portable water trough in each. Sheep grazing pressure distribution is not noticeably affected by elevational differences in a pasture on this soil group unless they choose a bedding ground area on a knoll.

Design cattle lanes serving paddocks to reduce their slope length and steepness while maintaining efficient paddock layout and fence length. When necessary to climb the slope, place regularly spaced waterbars or diversions across the lane to deflect water. Direct and extend them as needed to prevent diverted water from coming back on the lane downslope. Heavy use lanes require surfacing when rilling becomes evident.

Place brace assemblies for wire fences everywhere sharp breaks in grade occur. If steel T-posts or fiberglass rods are used, place a wood post every 50 to 100 feet on hill slopes with vertical curvature to keep the lowest stretched wire parallel with the ground surface while preventing these more flexible and shallower set posts and rods from tipping or bending.

When reseeding forages on these channery soils, drilling is preferred to a broadcast seeding. Drills achieve more uniform stands by deflecting most rock fragments from the drilled row. Broadcast seedings that are lightly tilled or cultipacked afterwards often have channers overlying seeds. Overlying channers cause stem breakage during emergence or prevent seedlings from ever getting to daylight. Untilled broadcast seedings have many exposed seeds. This causes seedlings to emerge unevenly or germinate and desiccate because of poor soil coverage and excessive drying from lying on partly or completely exposed rock fragments. Drill openers and coulters tend to wear out quickly and may break on occasion from rock abrasion.

First cut hay is difficult to field cure without rain damage because of high humidity and significant rain events occurring within 3 days of each other. Later cuttings are less likely to be rain damaged, but in wetter years, may also be damaged by rain and long exposure to sun while field curing. Tedders or inverters promote more even, quicker drying of the hay. An option to consider is harvest as haylage. Haylage production reduces the amount of drying time needed and will thus yield higher quality forage if ensiled and stored properly. Ordinarily, haylage can be wilted and harvested between rain events.

Management Dynamics

Liming these acidic soils allows for a wider selection of suitable forages and leads to increased forage production on previously unlimed soils. Depending on the forage species grown, increasing the surface soil pH to 6.5 will increase yields 20 percent for tall, warm-season perennial grasses to as much as 100 percent for alfalfa. Cool-season grasses will yield 50 percent more. Legume persistence will be increased.

Using facilitating practices of fencing and watering facilities to control livestock movement as mentioned earlier better distributes grazing pressure. This prevents areas of over- and under-utilization from developing. Overutilized areas evolve into low-growing sod formers and weedy rosette plants (dandelions and plantains). Bare areas will appear between plants in advanced stages of decline. Under-utilized areas tend to evolve toward taller-growing species. In more remote areas near wooded borders, woody vegetation, such as blackberry, prickly ash, and sumac, invade. Underutilized areas have more dead leaf and seed stalks than more closely grazed areas.

Since these soils are low in organic matter, they supply little mineralized soil nitrogen. Hence, nonleguminous forages respond well to nitrogen fertilizers. If grasses and nonleguminous forbs are yellowish green and urine spots are much darker green than their surroundings, nitrogen fertilizer is needed. Forage production can double.

FSG Documentation

Similar FSG's:

FSG ID	**FSG Narrative**
G127NY400PA	Deep, well drained, strongly acid, moderately steep upland soils. Nonchannery phase of the same soils on D slopes (15–25 percent). Higher available water capacity gives them production capabilities approximately 25 percent better. The absence of significant amounts of channers makes seedbed preparation easier, requires less equipment maintenance, and improves seedling survival. Post setting is also easier.

Inventory Data References:

Cornell U. Ag. Exp. Sta. Bull. 995—Interpretation of Chemical Soil Tests, FORADS Database-1995, AH 296—Land Resource Regions and Major Land Resource Areas of the United States, Penn State Ag. Exp. Sta. Bull. 873—Soil Climate Regimes of Pennsylvania, Penn State Agronomy Guide 1995-96, Penn State University Soil Characterization Laboratory Database System-1994, Soil Survey of Cameron and Elk Counties, Pennsylvania, and USDA, NRCS National Range and Pasture Handbook.

State Correlation:

This site has been correlated with the following states:
MD
NY
PA
WV

Forage Suitability Group Approval:

Original Author: Jim Cropper
Original Date: 12/1/00
Approval by:
Approval Date:

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 4 Inventorying and Monitoring Grazing Land Resources

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Chapter 4 Inventorying and Monitoring Grazing Land Resources

Chapter 4 includes:

- procedures for vegetation inventory and monitoring on native grazing lands
- procedures for evaluating and rating ecological sites
- information on vegetation sampling techniques

The inventory and monitoring section describes methods of determining production, composition, and utilization. The evaluating and rating of ecological sites section gives procedures for determining trend and similarity index and evaluating rangeland health attributes on rangelands and forage value ratings on grazed forest lands. The Sampling Vegetation Attributes, Interagency Technical Reference, 1996, and Utilization Studies and Residual Measurements, Interagency Technical Reference, 1996, should be used for specific monitoring methods.

600.0400 General

Vegetation sampling is an important activity conducted by Natural Resources Conservation Service (NRCS) range management specialists and pasture management specialists. The data are used to develop inventories for planning, monitor ecological change, provide data to make management decisions for the development of rangeland ecological site descriptions, to obtain data for hydrologic models, for studies of treatment effects, and for many other purposes.

An inventory is defined as the collection, assemblage, interpretation, and analysis of natural resource data for planning or other purposes. Inventories are regularly completed to determine the present status of variables important to NRCS and decisionmakers. These inventories include physical structures, hydrologic features, rangeland ecological sites, animal resources, and other variables pertinent to the planning process. Biomass data collection, production, and composition by species are the standard techniques used by NRCS in characterizing rangeland ecological sites during the inventory process.

Several variables important to rangeland health and trend cannot be quantified using biomass data alone, so other techniques must be used to quantify characteristics of rangeland ecological sites. For instance, cover measurements can be used to quantify ground cover of litter, seedlings, microphytes (algae, lichen, and moss), and the condition of the soil surface. 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.

Monitoring is used to quantify effects of management or environmental variation at a location, through time. Monitoring can be short term, for example, to quantify the amount of biomass used during a grazing event. It can also be long term such as to quantify trend in similarity index on a particular rangeland ecological site. Monitoring techniques are different from those used in inventory because monitoring uses the same location on a repetitive basis. Continued clipping at the same location may eventually impact the productivity of the location, and biomass data collection is labor intensive and time consuming. Therefore, monitoring environmental change using another technique, such as cover, or a combination of techniques, such as cover and density, is often more efficient. Data collections for ecological site descriptions are more involved than planning inventories. These data collections require collection of biomass and cover data, as well as a review of local history related to the historic climax plant community. Data are also collected for use in hydrology assessments. Development of hydrologic models is an important activity in NRCS that requires data collection from a unique set of variables.

Studies of treatment effects are limited in NRCS. These studies involve intensive use of statistical methods and should be done in cooperation with USDA Agricultural Research Service (ARS) or universities familiar with the particular type of study. Data collections for other purposes might include data for:

- coordinating grazing history, stocking rate, and animal performance records in determining guides to initial stocking rates
- preparing soil survey manuscripts and other publications
- analyzing wildlife habitat values
- planning watershed and river basin projects
- assisting and training landowners and operators in monitoring vegetation trends and the impact of applied conservation practices and programs
- exchanging information with research institutions and agencies
- preparing guides and specifications for recreation developments, beautification, natural landscaping, roadside planting, and other developments or practices

600.0401 Inventory

All production and composition data collected by NRCS are based on weight measurements. Weight is the most meaningful expression of the productivity of a plant community or an individual species. It has a direct relationship to feed units for grazing animals that other measurements do not have.

Production is determined by measuring the annual aboveground growth of vegetation. Some aboveground growth is used by insects and rodents, or it disappears because of weathering before production measurements are made. Therefore, these determinations represent a productivity index. They are valuable for comparing the production of different rangeland ecological sites, plant species composition, and similarity index. Production data must 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.

Comprehensive interpretation of plant production and composition determinations requires that data be representative of all species having measurable production. Rangeland and other grazing lands may be used or have potential for use by livestock and wildlife, 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 often is not the same as that for wildlife, recreation, beautification, and watershed protection. Furthermore, the principles and concepts of rangeland ecological site, similarity index, and other interpretations 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.

The procedures and techniques discussed in this section relate primarily to rangeland. Most of them, however, also apply to grazeable forest and native or naturalized pasture. Changes or modifications in procedures required for land other than rangeland are described.

(a) Total annual production

The total production of all plant species of a plant community during a single year is designated total annual production. For specific purposes, production of certain plants or groups of plants can be identified as herbage production for herbaceous species, woody-plant production for woody plants, and production of forage species for plants grazed by livestock. Annual production, approximate production, total production, and production are used interchangeably with total annual production throughout this section.

Total annual production includes the aboveground parts of all plants produced during a single growth year regardless of accessibility to grazing animals. An increase in the stem diameter of trees and shrubs, production from previous years, and underground growth are excluded.

(1) Total forage production

Total annual forage production is the annual production of plant species that are forage plants for the animals of concern. The same site may have different total annual forage production weights for cattle than that for deer. If total annual forage production is used as an inventoried item, then the animal of concern must be identified.

(2) Usable forage production

The usable forage production is that amount of total forage production to be allocated to or expected to be used by livestock or wildlife. When usable forage production is an inventoried item, the animal of concern and the desired use must be specified.

(b) 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 aboveground growth of leaves, stems, inflorescences, and fruits produced in a single year.

(2) Woody plants

(i) Deciduous trees, shrubs, half-shrubs, and woody vines—Annual production includes leaves, current twigs, inflorescences, vine elongation, and fruits produced in a single year.

(ii) 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.

(iii) 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. Until more specific data are available and 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. Adjust this percentage in years of obviously high or low production.

(3) Cacti

(i) 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. Until more specific data are available and if current growth is not readily distinguishable, consider current production as 10 percent of the total weight of pads plus current fruit production. Adjust this percentage for years of obviously high or low production.

(ii) Barrel-type cactus—Until specific data are available, consider annual production as 5 percent of the total weight of the plant, other than fruit, plus the weight of fruit produced in a single year.

(iii) Cholla-type cactus—Until specific data are available and 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.

(c) Methods of determining production and composition

Production and composition of a plant community are determined by estimating, by a combination of estimating and harvesting (double-sampling), or by harvesting. Some plants are on state lists of threatened, endangered, or otherwise protected species. 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 can be obtained. Conservationists determining production should be aware of such plant lists and regulations. Environment Memorandum-1 (rev.) states NRCS policy on activities involving Federal- and state-designated threatened and endangered species.

(1) Estimating (by 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:

- A weight unit is established for each plant species occurring on the area being examined.
- A weight unit can consist of part of a plant, an entire plant, or a group of plants (see exhibit 4–1).
- The size and weight of a unit vary according to the kind of plant. 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
- other considerations:
  - — length, width, thickness, and number of stems, and leaves
  - — ratio of leaves to stems
  - — growth form and relative compactness of species

The following procedure can be used to establish a weight unit for a species.

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 estimates of production.

Step 4. Compute composition on the basis of actual weights to check 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.

(2) Estimating and harvesting (double sampling)

The double-sampling method is to be used in making most production and composition determinations. The procedure is:

Step 1. Select a study area consisting of one soil taxonomic unit. This should be a benchmark soil or taxonomic unit that is an important component of a rangeland ecological site or forest land ecological site.

Step 2. Select plots to be examined at random.

Step 3. The number of plots selected depends on the purpose for which the estimates are to be used, uniformity of the vegetation, and other factors. A minimum of 10 plots should be selected for all data to be used in determining rangeland ecological sites or other interpretive groupings and for data for use in the Ecological Site Information System. If vegetation distribution is very irregular and 10 plots will not give an adequate sampling, 20 plots can be selected. Fewer than 10 plots can be used if data are to be used for planning or application work with landowners, but the data should not be entered in the Ecological Site Information System.

Step 4. Adapt size and shape of plots to the kind of plant cover 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 relatively short and plot markers can be easily placed, 1.92-, 2.40-, 4.80-, and 9.60-square foot plots are well suited to use in determining production in pounds per acre. The 9.6-square foot plot is generally used in areas where vegetation density and production are relatively light. The smaller plots, especially the 1.92-square foot plot, are satisfactory in areas of homogeneous, relatively dense vegetation like that occurring in meadows and throughout the plains and prairie regions. Plots larger than 9.6 square feet should be used where vegetation is very sparse and heterogeneous.

If the vegetation 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 of 0.1 acre is suitable. If vegetation is unevenly spaced, a more accurate sample can be obtained by using a 0.1-acre plot, 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.

Plots with area expressed in square meters are used if production is to be determined in kilograms per hectare. If the plots are nested, production from both plots must be recorded in the same units of measure. For example, a plot 20 meters by 20 meters (or other dimensions that equal 400 meters) can be used for measuring the tree and shrub vegetation and a 1-meter plot nested in a designated corner can be used for measuring the low-growing plants. Determine the production from both in grams and convert the grams to kilograms per hectare. Plots of 0.25, 1, 10, 100, and 400 square meters are commonly used.

After plots are selected, estimate and record the weight of each species in each plot using the weight-unit method. When estimating or harvesting plants, include all parts of plants whose stems originate in the plot, including all aboveground parts that extend beyond a plot boundary. Exclude all parts of herbaceous plants and shrubs whose stems originate outside a plot, even though their foliage may overlap into the plot.

After weights have been estimated on all plots, select the plots to be harvested. The plots selected should include all or most of the species in the estimated plots. If an important species occurs on some of the estimated plots, but not on the harvested plots, it can be clipped individually on one or more plots. The number of plots harvested depends on the number estimated. To adequately correct the estimates, research indicates at least one plot should be harvested for each seven estimated. At least 2 plots are to be harvested if 10 are estimated, and 3 are to be harvested if 20 are estimated.

Harvest, weigh, and record the weight of each species in the plots selected for harvesting. Harvest all herbaceous plants originating in the plot at ground level. Harvest all current leaf, twig, and fruit production of woody plants originating in the plots. If harvesting forage production only, then harvest to a height of 4.5 feet above the ground on forest land sites.

Correct estimated weights by dividing the harvested weight of each species by the estimated weight for the corresponding species on the harvested plots. This factor is used to correct the estimates for that species in each plot. 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.

After plots are estimated and harvested and correction factors for estimates computed, air-dry percentages are determined by air-drying the harvested materials or by selecting the appropriate factor from an air-dry percentage table (see exhibit 4–2). Values for each species are then corrected to air-dry pounds per acre or kilograms per hectare for all plots. Average weight and percentage composition can then be computed for the sample area.

(3) Harvesting

This method is similar to 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 or kilograms per hectare are performed according to the procedures described for double sampling.

(4) Units of production and conversion factors

All production data are to be expressed as air-dry weight in pounds per acre (lb/a) or in kilograms per hectare (kg/ha). The field weight must be converted to air-dry weight. This may require drying or the use of locally developed conversion tables.

(i) Converting weight to pounds per acre or kilograms per hectare—The weight of vegetation on plots measured in square feet or in acres can be estimated and harvested in grams or in pounds, but weight is generally expressed in grams. To convert grams per plot to pounds per acre, use the following conversions:

1.92-square foot plots—multiply grams by 50

2.40-square foot plots—multiply grams by 40

4.80-square foot plots—multiply grams by 20

9.60-square foot plots—multiply grams by 10

96.0-square foot plots—multiply grams by 1

In the metric system, a square-meter plot (or multiple thereof) is used. Weight on these plots is estimated or harvested in grams and converted to kilograms per hectare. A hectare equals 10,000 square meters. A kilogram equals 1,000 grams. To convert grams per plot to kilograms per hectare, use the following conversions:

0.25-square meter plots—multiply grams by 40

1-square meter plots—multiply grams by 10

10-square meter plots—multiply grams by 1

100-square meter plots—multiply grams by 0.10

400-square meter plots—multiply grams by 0.025

When assisting landowners and operators in determining approximate production, express data in pounds per acre. Use the following factors to convert from one system to another:

To convert	To	Multiply by
Metric units:		
Kilograms 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

(ii) Converting green weight to air-dry weight—If exact production figures are needed or if air-dry weight percentage figures have not been previously determined and included in tables, retain and dry enough samples or harvested material to determine air-dry weight percentages. The percentage of total weight that is air-dry weight for various types of plants at different stages of growth is provided in exhibit 4–2. These percentages are based on currently available data and are intended for interim use. As additional data from research and field evaluations become available, these figures will be revised. Air-dry weight percentages listed in the exhibit can be used for other species having growth characteristics similar to those of the species listed in the exhibit. States that have prepared their own tables of air-dry percentages on the basis of actual field experience can substitute them for the tables in exhibit 4–2. 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.

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.

(d) Methods for determining production and composition for specific situations

The intended use of the data being collected determines the method, or variation thereof, that is selected. Unless specifically stated otherwise, composition is always determined by computing the percent from the weight, either estimated or weighed. Several activities require knowledge of production, but in varying degrees of detail. The methods or variations that apply to several of these situations are described in this section.

(1) Collecting production and composition data for documentation

Data to be used for preparing rangeland ecological site descriptions grouping soils into rangeland ecological sites, and other guides, and processing in the Ecological Site Information System are to be obtained by the double-sampling procedure. All documentary production and composition data are to be recorded on form NRCS–RANGE–417. Production determinations are made as follows:

- Tabulate production data by estimating and harvesting plots of the potential plant community for one or more soil taxonomic units associated with the site or group.
- 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. Give due consideration to species that mature early in the growing season. 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 NRCS–RANGE–417 used for the first determination.
  - — At the second determination, harvest the plots having numbers corresponding to those harvested at the first determination. For example, if plots number two and four were harvested the first time, plots number two and four are harvested the second time. Correction of sampling errors, as well as moisture data can then be made. Any species not included in these plots can be harvested individually.
  - — If two determinations are made, record the date of the second determination in the Remarks space of form NRCS–RANGE–417.
- Repeat production determinations in different years to reflect year-to-year variations.
- Analyze production data from soil taxonomic units to determine the soils that should be tentatively grouped into specific rangeland ecological sites or other interpretive groupings and also to obtain data for inclusion in published soil surveys. Soils are not grouped based on production alone. The species composition by weight is also used.

The procedures discussed above are also to be used in obtaining data for the various status ratings for rangeland ecological sites and for different forage value ratings on those sites. To accomplish this, collect data from areas that represent specific similarity index or forage value ratings for the rangeland ecological site in a single production year. This procedure will be used for all kinds and uses of grazing lands.

(2) Estimating production and composition of an area

Use the following procedure to estimate similarity index of a rangeland ecological site, areas of different similarity indices within a rangeland ecological site, and forage value rating of a forestland ecological site or a native pasture group:

- Estimate production, in pounds per acre or kilograms per hectare, of individual species in the area.

- Compute composition, by weight, of the area from estimated production data. Sample the production on a series of random plots.
- Compute average production of the plots in terms of pounds per acre or kilograms per hectare, to further check these estimates for the area as a whole, harvest or double sample.
- Using these average figures, compute average composition. Although by using this procedure some species of minor importance may be missed, the procedure provides a useful check on estimates.
- Repeat this procedure until proficiency is attained. To gain proficiency, double sample within a range of similarity indices in several rangeland ecological sites each year.

(3) Inventorying composition for conservation planning

During conservation planning, it is often necessary to determine plant composition when plant growth is not ideal for making such determinations. Some grazing units are grazed at the time of planning. In places, estimates must be made at different stages of plant growth or when plant vigor varies from grazing unit to grazing unit. In some years production is obviously much higher or much lower than normal because of weather extremes. In making production estimates, therefore, it is often necessary to mentally reconstruct plant growth as it would most likely appear if undisturbed at the end of an average growing season. Adjustments or reconstruction must be made for percent of growth made during the year, percent of growth grazed or otherwise lost, and for air dry percentages.

(4) Determining production of tree or large shrub vegetation on rangeland

Rangeland ecological site descriptions are to include composition, by weight, of trees that are part of the climax plant community. 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 are devising methods for calculating current production of some species on the basis of measurements of such factors as crown width or height and basal area.

These data are to be used in estimating the annual production of trees and large shrubs. Range management specialists, pasture specialists, and foresters work together to prepare production guides for various kinds of understory and tree stands for use by field office personnel. Range management specialists are to use the following procedures in preparing guides for rangeland:

- Select a few sample trees for each species. Samples should reflect variations in tree size, form, and spacing.
- Determine current production of sample trees.
- 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 exhibit 4–1). Determinations from sample trees should include all components of current production except bark and wood of other than current twigs. Current leaf and twig production can be easily identified for some species. For these species, current leaf growth can be collected. 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 example, Utah research shows that current production of balsam fir and Utah juniper is about 30 percent of the total foliage. Current production of these two species can be calculated by determining the total foliage present, then multiplying by 0.30 and adding to this figure the current fruit (cone) production. For species requiring 2 years for fruit maturity, half the weight of mature fruit represents the current production of fruit.
- Expand estimates to plots 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. If this happens exclude the first hit tree and include the second hit and so on or vice versa. Also describe the appearance and aspect of the plot. List component species, tree size, growth forms, number of trees, and density of the canopy.
- Repeat this process for stands of various kinds of trees or large shrubs. On the basis of data

thus collected, prepare guides that list the approximate annual production of stands of various kinds of trees or large shrubs (see exhibit 4–4).

(e) Methods for determining utilization of key species

The main purpose for determining utilization is to consider whether adjustments are needed in grazing management or stocking rate. Determining the actual use of key grazing areas is only one of the factors considered in assessing the status of plant communities. Other factors, such as trend, similarity index, and the status of rangeland health attributes, must be considered. The degree of use of one or more plant species in a key grazing area does not measure the total amount of forage that grazing animals can consume. If the key species and key grazing areas are correctly selected, it is an index of the degree of grazing use for the total plant community. Use the following methods to determine forage utilization.

(1) Weight comparisons of grazed versus ungrazed plants

Ungrazed plants of the key species occurring within movable enclosures, located in key grazing areas at the beginning of the grazing season, are cut and weighed. The weight of these plants is then compared with that of grazed plants of the key species clipped near the enclosures. As an alternative, the clipped weight of grazed plants can be compared with that of ungrazed plants of the key species selected at random in the key grazing area. If ungrazed plants of the species are not available, ungrazed plants from the nearest comparable location can be used.

(2) Determining percentage of grazed versus ungrazed plants

This method applies where evaluations relating the percentage of grazed versus ungrazed plants of a species to the percentage removal by weight have been determined locally. After the percentage of grazed versus ungrazed plants of the key species in the key grazing area is determined, the percentage removal is determined using charts and graphs prepared during previous evaluations.

(3) Use of grazed-class photo guides

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. Such 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.

(4) 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 grazing units.

(5) Determining utilization of browse plants

Even though the degree of utilization of current growth of browse plants is an important factor, it does not provide all the information needed for properly planning and managing rangeland for use by wildlife or livestock. Moreover, it is impractical to make current utilization estimates at such times as during the early part of the growing season or before current use has taken place on seasonal range. In addition to the degree of utilization of current growth, several other indicators are 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. Also, they can be observed and interpreted at any time of the year. These indicators include:

- **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, but at least several age classes should be represented in a healthy stand. Animals usually prefer seedlings and young plants; consequently, a degree of use that may be proper for mature plants often results in overutilization of younger plants.

- **Evidence of hedging of the key plant species**—The degree of hedging reflects past use and also 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.
- **Use of plant growth more than 1 year old**—Generally, 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.
- **Evidence of browse lines**—If a browse line is readily 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.
- **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.
- **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.
- **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.
- **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.
- **Condition of animals**—The physical condition and reproductive ability of game animals 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, as long as succulent growth is available. Also, supplemental feeding of livestock often masks the effect of inadequate natural forage supplies.

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 game animals using the range.

The Browse Resource Evaluation worksheet (see exhibit 4–5) can be used for judging composition, trend, and utilization of the browse plant resource. Examples 4–1 and 4–2 illustrate how to use the worksheet. Example 4–1 records the determination of trend in June 1994 and records utilization during the next three fall and winter seasons. Example 4–2 illustrates the same location in July 1997 following a prescribed burn. The change in trend is recorded, and utilization will be recorded at the appropriate time.

Example 4–1 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

- X Good
- Fair
- Poor

Browse trend

- Upward
- Stable or not apparent
- X Downward

Note: Goats removed Dec. 94; Deer only in 95; Presburn Feb. 96; Goats in summer 96.

Utilization of current year's growth

			Actual use percent							
	Season of use	Planned use percent	Years							
Key species			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					
			12-4	10-9	11-6					
			Date observed							

Example 4–2 Completed Browse Resource Evaluation worksheet showing change in trend at same site as used in example 4–1

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

X	Good
	Fair
	Poor

Browse trend

X	Upward
	Stable or not apparent
	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							

Many other factors should be considered in determining utilization of rangeland. Following are some that should be considered when working with the landowner:

- Although the degree of use or the lack of use of each plant species in a grazing unit is of interest and affects the nature of plant communities in the grazing unit, determining the use of each species is neither practical nor essential.

    — Averaging the degree of use of many species having widely different degrees of use and grazing preference values does not provide a meaningful answer to utilization or to the impact of such utilization on the plant community.

    — Nonuse or light use of a species of negligible grazing preference does not compensate for heavy use of a species having high grazing preference.

    — To determine the use status of a grazing unit, the acreage that is properly used and overused must be determined. The intent of grazing management is to prevent excessive use of grazing areas, or at least to reduce the excessively used acreage to a reasonable minimum. Most grazing units have small areas of natural livestock concentration, such as those immediately adjacent to water. These areas often are excessively used even when the entire grazing unit is properly grazed. If areas of excessive use do not exceed 3 to 5 percent of the grazing unit, the grazing unit may be considered properly used.

- To determine the degree of grazing use of key species, make the determination at or near the end of the planned grazing period.

    — For grazing units grazed on a continuous yearlong basis, make the final determination shortly before the beginning of a new growing season.

    — For grazing units grazed early every spring, rested in summer, and grazed again in fall, determine the degree of use at or near the end of each grazing period.

    — For grazing units in some type of planned grazing rotation, determine use near or at the end of the planned grazing period of each grazing unit. If grazing units are grazed more than once during the year, make the determination near the end of the last grazing period preceding the beginning of a new growth season.

- A determination of degree of use at or near the end of the grazing period serves to indicate the final utilization of grazing units. This is too late, however, to permit needed adjustments in grazing during the current season and is, in effect, a postmortem determination.

Conservationists should help cooperators make forage production and utilization determinations and trend observations well before the end of the scheduled grazing period, preferably before two-thirds of the period has passed. If determinations are made this early, enough time remains to adjust animal numbers or the length of the grazing period to avoid overuse of plants during years of poor production or to take advantage of extra forage in more favorable years.

600.0402 Evaluating and rating ecological sites

Ecological sites are evaluated with the landowner during the inventory 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 landowner. The inventory process and evaluations of ecological sites provide the opportunity to work with the landowner to identify resource problems and concerns, as well as opportunities to maintain or improve the resource, and increase the knowledge level of the landowner.

An ecological site may be evaluated in at least three distinct, but associated ways. Although these three methods are associated, they are not interchangeable. These evaluations and ratings cannot be extrapolated from one to the other.

The first method of rating is **trend**. Trend determines the direction of change occurring on a site. It provides information necessary for an operational level of management to ensure the direction of change will enhance the site and meet the manager's objectives.

Similarity index is another method to evaluate an ecological site. This method compares the present plant community to the historic climax plant community for that site or to a desired plant community that is one of the site's potential vegetation states. The similarity index to the historic climax plant community is the percentage, by weight, of historic climax vegetation present on the site. Likewise, a similarity index to a desired plant community is the percentage, by weight, of the desired plant community present on the site. As the name implies, this method assesses the similarity of the plant community to the historic climax or desired plant community. This can provide an indication of past disturbances, as well as future management or treatment, or both, needed to achieve the client's objectives.

Rangeland health provides a third way to assess ecological sites. Qualitative assessments of rangeland health provide land managers and technical specialist with a good communication tool for evaluating ecological processes and can assist to identify potential areas at risk of degradation.

Conservation planning assistance to rangeland owners and managers includes the following:

- Trend assessments (rangeland trend or planned trend) will be made, provided the appropriate plant communities are known and described in the ecological site descriptions, on the predominant rangeland ecological sites and key areas within their operating unit.
- Similarity index to the historic climax plant community or desired plant community will be determined.
- If appropriate, rangeland health ecological attributes evaluations will also be made.
- Professional judgment, based on experience and knowledge of the rangeland ecosystems, will be required to decide which rating techniques should be used on an individual rangeland unit.

(a) Trend

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 historic climax plant community or some other desired plant community or vegetation state (rangeland trend or planned trend). At times, it can be difficult to determine the direction of change.

The kind of trend (rangeland trend or planned trend) being evaluated must be determined. 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.

Trend is an important and required part of a rangeland resource inventory in the NRCS planning process. It is significant when planning the use, management, and treatment needed to maintain or improve the resource. The trend should be considered when making adjustments in grazing management.

(1) Rangeland trend

Rangeland trend is defined as the direction of change in an existing plant community relative to the historic climax plant community. **It is only applicable on rangelands that have ecological site descriptions identifying the historic climax 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 is monitored on all rangeland ecological sites. It is described as:

Toward—moving towards the historic climax plant community

Not apparent—no change detectable

Away from—moving away from the historic climax plant community

(2) Planned trend

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 and to protecting the soil, water, air, plant, and animal resources (SWAPA). It is described as:

Positive—moving towards the desired plant community or objective.

Not apparent—change not detectable.

Negative—moving away from the desired plant community or objective.

Planned trend provides feedback to the manager and grazing land specialist about how well the management plan and prescribed grazing are working on a site-by-site basis. It can provide an early opportunity to make adjustments to the grazing duration and stocking levels in the conservation plan. **Planned trend is monitored on all native and naturalized grazing land plant communities. It may be determined on any ecological site where a plant community other than the historic climax plant community is the desired objective.**

(3) Attributes for determining trend

Exhibit 4–6 is a worksheet for determining range and planned trend. The relative importance of the trend factors described 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.

(i) Composition changes—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. Disturbances, such as continued close grazing by livestock, severe or prolonged drought, abnormally high precipitation, exotic species invasion, or unnatural burning frequencies, can cause major changes in plant communities.

If the plant community is changing as a result of prolonged grazing, the perennial species 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 has occurred 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.

When disturbances that caused a decline in plant community are removed, the present plant community may react in one of several ways. It may appear to remain in a steady or static state while it moves along one of several transition pathways leading to one of several identifiable plant communities including the historic climax plant community.

Original species that have declined in amount because of past misuse will often increase over time. For this to occur, seed or vegetative parts must still be available, growing conditions be similar (soil profile, hydrologic characteristics, microclimate), and space for re-establishment must be available and must not have been displaced by other species, for example, exotic annual and perennial grasses, forbs, shrubs, or trees.

Once established, certain woody and some 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 if the decision-maker desires to remove them.

The invasion of plants on the site indicates a major change in the present plant community. Some invaders, particularly annuals, may flourish temporarily in favorable years, even when existing plant community is 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 general trend is toward objectives.

Changes in plant 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 uses often can be predicted. These successional changes in plant composition are generally not linear and vary because of localized climatic history and past use patterns.

(ii) Abundance of seedlings and young plants—Changes in a plant community depend mainly on successful reproduction of the individual species within the community. This reproduction is evidenced 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 use to which the plant is subjected. 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. Variations in seedling recruitment resulting from abnormal weather patterns should be recognized.

(iii) Plant residue—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 community, 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 that 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 historic climax plant community is exceeded, such accumulations of residue are not necessarily an indication of an improving plant community.

(iv) Plant vigor—Plant vigor 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; 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 their current plant community.

Cryptogams develop new growth during growing periods that adds to the total structure and biomass of the plant. When considerable amounts of live cryptogamic material are destroyed, several years may be required for these plants to fully replace lost tissue.

(v) Condition of the soil surface—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.

Compaction and crusting impede water intake, inhibit seedling establishment and vegetation propagation, and induce higher 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.

These soil indicators, however, are sometimes misleading. They can occur naturally under certain circumstances. For example, plant hummocking is natural—on silty soil sites that are subject to frost heaving.

Other sites do not support a complete plant cover. Bare ground crusting, stones on the soil surface, and localized soil movement may be completely natural. Even when induced by misuse, the soil surface trend indicators are not nearly as sensitive as those changes in the plant cover.

(b) Similarity index

The present plant community on an ecological site can be compared to the various common vegetation states that can exist on the site. To make the comparison, these vegetation states or plant communities must be described in sufficient detail in the ecological site description. This comparison can be expressed through a similarity index, which is the present state of vegetation on an ecological site in relation to the kinds, proportions, and amounts of plants in another vegetation state possible on the site. A similarity index is expressed as the percentage of a vegetation state plant community that is presently on the site. When determining a similarity index, the vegetation state or plant community that the present plant community is being compared to must be identified as the reference plant community.

Similarity index to historic climax plant community is defined as the present state of vegetation on an ecological site in relation to the historic climax plant community for the site. It is expressed as the percentage, by weight, of the historic climax plant community present on the site. The similarity index to historic climax provides a measurement of change that has taken place on a site. The similarity index to historic climax is the result of how climate and management activities have affected the plant community on a site.

(1) Purpose for determining similarity index

The purpose for determining similarity index to historic climax is to provide a basis for describing the extent and direction of changes that have taken place and predicting those that can take place in the plant community because of a specific treatment or management. The ecological site description indicates the historic climax plant community for the site; similarity index to historic climax represents the percent of the historic climax plant community present on the site. These evaluations provide the manager with the starting point for establishing objectives and developing management goals. These goals can result in a change in the present plant community toward a community desired by the decisionmaker that meets the needs of the soil, water, air, plant, and animal resources, as well as those of the manager.

As ecological site descriptions are revised and further developed, they are to include descriptions of other common vegetation states that can exist on the site. A similarity index to each of these or any of these will also indicate the present state of the site.

(2) Determining similarity index to historic climax plant community

The similarity index to historic climax plant community for areas within an ecological site is determined by comparing the present plant community with that of the historic climax plant community, as indicated by the ecological site description.

The existing plant community must be inventoried by recording the actual weight, in pounds, of each species present. The production of each species must be reconstructed to reflect total annual production. See exhibit 4–7 for reconstruction procedure. The reconstructed total production by species of the existing plant community is compared to the production of individual species in the historic climax plant community. For the similarity index determination, the allowable production of a species in the existing plant community cannot exceed the production of the species in the historic climax plant community. If plant groups are used, the present reconstructed production of a group cannot exceed the production of the group in the historic climax plant community. All allowable production is then added together. This total weight represents the amount of the historic climax plant community present on the site.

The relative similarity index to the historic climax plant community is calculated by dividing this total weight of allowable production by the total annual production in historic climax shown in the site description for the normal year. This evaluation expresses the percentage of the historic climax plant community present on the site.

Example 4–3 Determination of similarity index of historic climax

Example - Determination of similarity index to historic climax

Cooperator Rockin' Raindrop Ranch
Ecological Site Loamy Upland 12-16 PZ
Reference Plant Community Native midgrass (HCPC)
Conservationist Someone's name
Location Center of Horse Pasture
Date 8/30/96

A	BC	C	D	E
Plant group	Species name	Pounds/acre in reference plant community (from ecological site description)	Annual production in lb/a (Actual or reconstructed)	Pounds allowable
1	Sideoats grama and			
	others from Group 1	450	25	25
2	Blue grama and			
	others from Group 2	200	25	25
3	Threeawn species	75	40	40
4	Bush muhley and	75	25	25
	others from Group 4			
5	Curly mesquite and			
	others from Group 5	30	20	20
6	Fall witchgrass and			
	others from Group 6	30	30	30
7	Six weeks threeawn &			
	others from Group 7	30	15	15
8	Wild daisy and others			
	from Group 8	125	5	5
9	Tansy mustard and			
	others from Group 9	10	5	5
10	Range ratany and			
	others from Group 10	75	50	50
11	Jumping cholla and			
	others from Group 11	30	160	30
12	Mesquite and others			
	from Group 12	15	600	15
TOTALS		1,145	1,000	285

SIMILARITY INDEX to Mesquite-Short Grass Community = 25 %
(Total of E divided by total of C)

Example 4–3 illustrates how the similarity index to historic climax is determined on a loamy upland 12–16 PZ ecological site. (Refer to chapter 3, exhibit 3–3 for the site description.) Note: This example shows only one plant from each group of plants described in the ecological site description. This is for illustrative purposes to show the calculation of the similarity index. In actual practice, it is desirable to list each plant found in the sample transect. This example assumes the current plant community has been reconstructed to actual annual production. (See exhibit 4–7 for this procedure.) Some areas of the United States have plant communities where, because of landscape position and climatic factors, vegetative composition is greatly influenced by episodic events. For example, in desert areas of the Southwest, many watersheds are composed of very shallow soils or very little soil and considerable exposed bedrock. Intense summer thunderstorm events create high volume catastrophic runoff that flows in confined drainage ways through low-lying landscapes. Although these rainfall events may occur relatively infrequently, these high intensity, concentrated flows can and do totally remove all vegetation occurring within drainage ways and cause severe disruption of the normal plant community dynamics. In these situations, ratings of similarity index to historic climax generally are not appropriate. Secondary succession is constantly in progress with a stable plant community seldom being obtained because of the episodic nature of catastrophic events.

Similarity index to historic climax is not appropriate on sites that have been planted to single species forage plants.

(3) Determining similarity index to other vegetation states or desired plant community

In the inventory phase, determining the similarity index to one or more of the possible vegetation states in the site description may be desirable. After the landowner has identified goals, a particular vegetation state may be identified as the desired plant community.

Once a desired plant community has been identified, it is appropriate to determine the similarity index to the desired plant community during follow-up monitoring.

To determine the present plant community's similarity index to a specific plant community, the specific plant community must be adequately described as a common vegetation state in the ecological site description. It must be described by species and the expected production by weight of species or by groups of species, as well as the expected normal total annual production.

The similarity index to other vegetation states for areas within an ecological site is determined by comparing the present plant community with that of the other vegetation state plant community, as indicated in the ecological site description.

The existing plant community must be inventoried by recording the actual weight, in pounds, of each species present. The production of each species must be reconstructed to reflect total annual production. The reconstructed annual production by species of the existing plant community is compared to the production of individual species in the specific vegetation state plant community. For the similarity index determination, the allowable production of a species in the existing plant community cannot exceed the production of the species in the specific vegetation state plant community. If plant groups are used, the existing production of a group cannot exceed the production of the group in the specific vegetation state plant community. All allowable production is then added together. This total weight represents the amount of the specific vegetation state plant community present on the site.

The relative similarity index to the specific vegetation state plant community is calculated by dividing this total weight of allowable production by the total annual production in vegetation state shown in the site description for the type year (above average, average, below average). This evaluation expresses the percentage of the vegetation state plant community present on the site.

Examples 4–4, 4–5, and 4–6 show similarity index determinations to some of the other vegetation states described in the loamy upland 12 –16 PZ. These determinations use the same transect data used in example 4–3. (Refer to chapter 3, exhibit 3–3, for the site description.) **Note:** This example shows only one plant from each group of plants described in the ecological site description. This is for illustrative purposes to show the calculation of the similarity index. In actual practice, it is desirable to list each plant found in the sample transect. This example assumes the current plant community has been reconstructed to actual annual production. (See exhibit 4–7 for this procedure.)

Example 4–4 Determination of similarity index to the mesquite-short grass vegetation state

Example - Determination of similarity index to the mesquite-short grass vegetation state on loamy upland 12-16 PZ site

Cooperator Rockin' Raindrop Ranch
Ecological Site Loamy Upland 12-16 PZ
Reference Plant Community Mesquite-Short Grass
Conservationist Someone's name
Location Center of Horse Pasture
Date 8/30/96

A	BC	C	D	E
Plant group	Species name	Pounds/acre in reference plant community (from ecological site description)	Annual production in lb/a (Actual or reconstructed)	Pounds allowable
1	Sideoats grama and			
	others from Group 1	35	25	25
2	Blue grama and			
	others from Group 2	350	25	25
3	Threeawn species	35	40	35
4	Bush muhley and	0	25	0
	others from Group 4			
5	Curly mesquite and			
	others from Group 5	75	20	20
6	Fall witchgrass and			
	others from Group 6	0	30	0
7	Six weeks threeawn &			
	others from Group 7	0	15	0
8	Wild daisy and others			
	from Group 8	35	5	5
9	Tansy mustard and			
	others from Group 9	0	5	0
10	Range ratany and			
	others from Group 10	35	50	35
11	Jumping cholla and			
	others from Group 11	0	160	0
12	Mesquite and others			
	from Group 12	100	600	100
TOTALS		665	1,000	245

SIMILARITY INDEX to Mesquite-Short Grass Community = 37 %
(Total of E divided by total of C)

Example 4–5 Determination of similarity index to native-short grass vegetation state

Example - Determination of similarity index to the native-short grass vegetation state on loamy upland 12-16 PZ site

Cooperator Rockin' Raindrop Ranch
Ecological Site Loamy Upland 12-16 PZ
Reference Plant Community Native-Short Grass
Conservationist Someone's name
Location Center of Horse Pasture
Date 8/30/96

A Plant group	BC Species name	C Pounds/acre in reference plant community (from ecological site description)	D Annual production in lb/a (Actual or reconstructed)	E Pounds allowable
1	Sideoats grama and			
	others from Group 1	35	25	25
2	Blue grama and			
	others from Group 2	350	25	25
3	Threeawn species	35	40	35
4	Bush muhley and	0	25	0
	others from Group 4			
5	Curly mesquite and			
	others from Group 5	100	20	20
6	Fall witchgrass and			
	others from Group 6	0	30	0
7	Six weeks threeawn &			
	others from Group 7	0	15	0
8	Wild daisy and others			
	from Group 8	35	5	5
9	Tansy mustard and			
	others from Group 9	0	5	0
10	Range ratany and			
	others from Group 10	75	50	50
11	Jumping cholla and			
	others from Group 11	trace	160	0
12	Mesquite and others			
	from Group 12	trace	600	0
TOTALS		630	1,000	160

SIMILARITY INDEX to Native-Short Grass Community = 25 %
(Total of E divided by total of C)

Example 4–6 Determination of similarity index to dense mesquite vegetation state

Example - Determination of similarity index to the dense mesquite vegetation state on loamy upland 12-16 PZ site

Cooperator Rockin' Raindrop Ranch
Ecological Site Loamy Upland 12-16 PZ
Reference Plant Community Dense Mesquite
Conservationist Someone's name
Location Center of Horse Pasture
Date 8/30/96

A	BC	C	D	E
Plant group	Species name	Pounds/acre in reference plant community (from ecological site description)	Annual production in lb/a (Actual or reconstructed)	Pounds allowable
1	Sideoats grama and			
	others from Group 1	0	25	0
2	Blue grama and			
	others from Group 2	0	25	0
3	Threeawn species	35	40	35
4	Bush muhley and	35	25	25
	others from Group 4			
5	Curly mesquite and			
	others from Group 5	0	20	0
6	Fall witchgrass and			
	others from Group 6	0	30	0
7	Six weeks threeawn &			
	others from Group 7	0	15	0
8	Wild daisy and others			
	from Group 8	0	5	0
9	Tansy mustard and			
	others from Group 9	0	5	0
10	Range ratany and			
	others from Group 10	0	50	0
11	Jumping cholla and			
	others from Group 11	0	160	0
12	Mesquite and others			
	from Group 12	550	600	550
TOTALS		620	1,000	610

SIMILARITY INDEX to Dense Mesquite Community = 98 %
(Total of E divided by total of C)

(4) Reconstructing the present plant community

The existing plant community at the time of evaluation must be reconstructed to the total normal annual air-dry production before it can be compared with the reference vegetation state plant community. The reconstruction must consider physical, physiological, and climatological factors that affect the amount of biomass measured (weighed or estimated) for a species at a specific point in time. The present plant community is reconstructed by multiplying the measured weight of each species by a reconstruction factor. The reconstruction factor formula is :

$$\text{Reconstruction factor} = \frac{C}{(D)(E)(F)}$$

where:
C = percent of air-dry weight
D = percent of plant biomass of each species that has not been removed
E = percent of growth of each species that has occurred for the current growing season
F = percent of growth of each species that has occurred relative to normal growing conditions

Use the worksheet shown as exhibit 4–7 in the exhibits section to determine this factor.

(5) Worksheet for use in determining similarity index

Exhibit 4–7 is an example of a similarity index worksheet. Conservationists should determine similarity index of a site with the decisionmaker. If this is not possible, conservationists should review the similarity index inventory with the decisionmaker in enough detail to assure that it is fully understood. A worksheet for this purpose helps the decisionmaker to evaluate the plant communities and also serves as a record. Completed copies can be left with the decisionmaker or placed in his or her conservation plan folder. Completed worksheets are of value in monitoring changes or evaluating the effectiveness of management practices during subsequent evaluations of the same area.

(c) Rangeland health

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.*

(1) Purpose

Rangeland health assessment is designed to:

- be used only by knowledgeable, experienced people
- provide a preliminary evaluation of soil/site stability, hydrologic function, and integrity of the biotic community (at the ecological site level)
- help landowners identify areas that are potentially at risk of degradation
- provide early warnings of potential problems and opportunities
- be used to communicate fundamental ecological concepts to a wide variety of audiences in the field
- improve communication among interested groups by focusing discussion on critical ecosystem properties and processes
- select monitoring sites in the development of monitoring programs
- help understand and communicate rangeland health issues

Rangeland health assessment is not to be used to:

- identify the cause(s) of resource problems
- make grazing and other management decisions
- monitor land or determine trend
- independently generate national or regional assessments of rangeland health

The rangeland health assessment procedure was developed for use by experienced, knowledgeable rangeland professionals. It is not intended that this assessment procedure be used by individuals that do not have experience or knowledge of the rangeland ecological sites they are evaluating. This procedure requires a good understanding of ecological processes, vegetation, and soils for each of the sites to which it is applied. It relies on the use of a qualitative (nonmeasurement) procedure to assess the functional status of each indicator.

This current information incorporates concepts and materials from previous monitoring and inventory procedures, as well as from the National Research Council's book on Rangeland Health, and the Society for Range Management's Task Group on Unity in Concepts and Terminology (1995). Earlier versions of this procedure were developed concurrently by an interagency technical team led by the Bureau of Land Management and the Natural Resources Conservation Service as published in the National Range and Pasture Handbook (USDA 1997). An interagency team melded these concepts and protocols with the results from numerous field tests and numerous other comments to arrive at the process described herein. Along the way, this procedure has been termed rapid assessment, qualitative assessment of rangeland health, and visualization of rangeland health. The current version will be revised in the future as science and experience provides additional information on indicators of rangeland health and their assessment.

Relationship to similarity index and trend—The similarity index and trend studies have long been used to assess the conditions of rangeland. The similarity index is an index of where the current plant community is in relation to the historic climax plant community, or to a desired plant community that is one of the site's potential vegetation states. Trend is a determination of the direction of change in the current plant community and associated soils in relation to the historic climax plant community or some other desired plant community.

The rangeland health assessment is an attempt to look at how the ecological processes on a site are functioning. These three assessment tools (similarity index, trend, and rangeland health assessment) evaluate the rangeland site from different perspectives and are not necessarily correlated.

(2) Evaluating rangeland health ecological attributes

Ecological processes include the **water cycle** (the capture, storage, and safe release of precipitation), **energy flow** (conversion of sunlight to plant then animal matter), and **nutrient cycle** (the cycle of nutrients, such as nitrogen and carbon through the physical and biotic components of the environment).

Ecological processes functioning within a normal range of variation will support specific plant and animal communities. Direct measures of site integrity and status of ecological processes are difficult or expensive to measure because of the complexity of the processes and their interrelationships. Therefore, biological and physical attributes are often used as indicators of the functional status of ecological processes and site integrity.

The product of this qualitative assessment is not a single rating of rangeland health, but an assessment of three components, called attributes (table 4–1).

Definitions of the three interrelated attributes are:

Soil/Site Stability—The capacity of the site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function—The capacity of the site 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.

Integrity of the Biotic Community—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

Table 4–1 The three attributes of rangeland health and the rating categories for each attribute

Soil/Site Stability	Hydrologic Function	Integrity of the Biotic Community

Attribute ratings are based upon departure from ecological site description in these categories:

Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight

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.

Based upon a *preponderance of evidence* approach for the applicable indicators, each of the three attributes of rangeland health are summarized at the end of the Rangeland Health Evaluation Sheet (exhibit 4–9). To reiterate, the process described here will produce three ratings, one for each attribute.

(3) Indicators

Unfortunately, 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 (rangeland health attribute) that is too difficult, inconvenient, or expensive to measure. 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 soil/site stability, hydrologic function, and biotic integrity. For each indicator, five descriptors are developed which reflect the range of departure from what is expected for the site: None to Slight, Slight to Moderate, Moderate, Moderate to Extreme, and Extreme to Total.

Indicators have historically been used in rangeland resource inventories. These indicators focused on vegetation (production, composition, density, and other such characteristics) or soil stability as indicators of rangeland condition or livestock carrying capacity. Such single indicator assessments are inadequate to determine rangeland health because they do not reflect nor assess the complexity of the ecological processes. There is no one indicator of ecosystem health; instead, a suite of key indicators should be used for an assessment.

Rangeland health evaluations provide information on the functioning of the ecological site. This evaluation provides information that is not available with other methods of evaluation. It gives an indication of the status of the three attributes chosen to represent the health of the area of interest (the area where the evaluation of the rangeland health attributes takes place). This interest may be due to concern about current condition, lack of information on condition, or public perceptions on the condition of the area of interest.

Evaluation area—The rangeland health evaluation is site specific using the rangeland ecological site description 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. Upon arrival at the location, the evaluator(s) should identify the boundaries of the area of interest and walk 1 to 2 acres of the ecological site. This enables the evaluator(s) to become familiar with the plant species, soil surface features, and the variability of the area of interest.

Surrounding features that may affect ecological processes within the area should also be noted. The topographic position, adjacent roads, trails, watering points, gullies, timber harvests, and other disturbances can all affect onsite processes. The topographic position should be carefully described with documentation of off-site influences. There is significant variability in the potential of different sites associated with relatively minor differences in landscape position and soils (differences in aspect or location at the top vs. bottom of a slope).

Development of the ecological site reference sheet—The reference sheet describes the status of each indicator for the reference state (exhibit 4 –8). It serves as the primary reference for the evaluation. The reference sheet describes a range for each indicator based on expected spatial and temporal variability within each ecological site. The reference sheet becomes the standard for the evaluation of each of the indicators. The development of the reference sheet is an important process that must be accomplished prior to any rangeland health assessments. Reference sheet are being included in the ecological site description format and development. It is not possible to conduct a rangeland health assessment without a reference sheet. The development of the reference sheet requires at least as much expertise as the assessment process and is a five-step process:

Step 1. Assemble a diverse group of experts with extensive knowledge of the ecological site. Individuals should include those who have long-term knowledge of the variability and dynamics of the site, in addition to rangeland professionals who understand soil-climate-vegetation relationships.

Step 2. Provide group with all available sources of information. Sources of information include relevant scientific literature and ecological site descriptions. Data obtained in support of the development of site descriptions and monitoring and inventory data from the ecological site.

Step 3. Define functional and structural groups on the site. The discussion of the functional and structural groups on the site provides an opportunity to discuss the functioning of the site from an ecological process standpoint and gets all involved in the same mindset. Functional and structural groups are defined by such attributes (but not limited to) as the photosynthetic pathways, lifeform, nitrogen fixation ability, rooting structure, above ground structure.

Step 4. Visit reference areas and other examples of the variability of the ecological site.

Step 5. Describe the status of each indicator in the reference state for the ecological site. This description should be quantitative where possible and include ranges based on the natural range of variability for the reference state of the ecological site.

Review/modify descriptors of indicators for the rangeland ecological site—Ideally, each ecological site will have a unique set of descriptors (narrative under the five categories) for each indicator. In lieu of this, a set of standard or generic descriptors (called default descriptors) has been developed for each indicator, and each descriptor is listed in the Rangeland Health Evaluation Matrix (exhibit 4–10). These descriptors are used in the evaluation if they fit the observations on the indicators on the Rangeland Ecological Site Description. If the default descriptor does not fit an indicator, the evaluator(s) should modify the descriptor in the revised descriptor space that is below the default descriptor.

This Rangeland Health Evaluation Matrix with the revised descriptors should be used on subsequent evaluations on that same rangeland ecological site. Therefore, it is important to fill out the site documentation information at the top of this matrix if any of the descriptors are revised.

These modifications in the descriptors will aid in the ongoing development of rangeland ecological site specific indicators and descriptors. Copies of the Rangeland Health Evaluation Matrix with the modified descriptors should be forwarded to the person responsible for maintaining rangeland ecological site descriptions in the state (usually the NRCS state rangeland management specialist) for approval Rangeland Health Evaluation Matrix will be developed for each rangeland ecological site and any modification must be approved by the NRCS state rangeland management specialist or other designated individual.

Soil/site stability indicators are more likely to require these changes because of the inherently higher erosion potential on certain ecological sites. Example 4–7 shows changes in the descriptor narrative for the bare ground indicator.

Rate the 17 indicators—The evaluator(s) selects the category descriptor (narrative) that most closely describes the site for each indicator on the Rangeland Health Evaluation Matrix and records it on the Rangeland Health Evaluation Sheet. The rating for each indicator in the area of interest is based on that indicator's degree of departure from the rangeland ecological site description.

Narrative descriptions in the Rangeland Health Evaluation Matrix are intended to aid in the determination of the degree of departure. The narrative descriptors for each indicator form a relative scale from Extreme to Total to None to Slight. Not all indicator descriptors will match what is observed requiring a "best fit" approach in making the ratings. The rating for each indicator should be supported by comments in the space provided under each indicator rating. In some instances there may be no evidence of the indicator in the area of interest, thus it will be rated None to Slight.

The revised descriptor for an indicator is used to rate indicators if the default description on the Rangeland Health Evaluation Matrix did not adequately represent the range and status of an indicator in the ecological site description.

When making an assessment, the effects of natural disturbances (drought, fire) should be considered. For example, if a fire occurred 5 years ago in the area being assessed, reduced shrub (sagebrush) cover is not an indication of lack of biotic integrity if the natural processes alone are sufficient to allow recovery of the original plant community.

Example 4–7 Revised descriptor for the bare ground indicator

Indicator	Degree of departure from the reference state for the ecological site				
	Extreme to Total	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
4. (Revised descriptor)	Greater than 75% bare ground with entire area connected. Only occasional areas where ground cover is contiguous, mostly patchy and sparse	60–75% bare ground. Bare patches are large (>24-inch diameter) and connected. Surface disturbance areas becoming connected to one another. Connectivity of bare ground broken occasionally by continuous ground cover	40–60% bare ground with much connectivity especially associated with surface disturbance. Individual bare spaces are large and dominate the area	30–45% bare ground; bare spaces greater than 12-inch diameter and rarely connected. Bare areas associated with surface disturbance are larger (>15 inch) and may be connected to other bare areas	20–30% bare ground; bare patches should be less than 8 to 10-inches in diameter and not be connected; occasional 12 inches patches associated w/ shrubs. Larger bare patches also associated with ant mounds and small mammal disturbances
4. Bare ground (default description)	Much higher than expected for the site. Bare areas are large and generally connected	Moderately higher than expected for the site. Bare areas are large and occasionally connected	Moderately to slightly higher than expected for the site. Bare areas are of moderate size and sporadically connected	Slightly higher than expected for the site. Bare areas are small and rarely connected	Amount and size of bare areas matches that expected for the site

1. Rills—Rills are small, erosional rivulets that are generally linear and do not necessarily follow the microtopography as flow patterns do. They are formed through complex interactions between raindrops, overland flow, and the characteristics of the soil surface. The potential for rills increases as the degree of disturbance (loss of cover) and slope increases. Some soils have a greater potential for rill formation than others do. Therefore, the degree of natural versus accelerated rill formation should be established by interpretations made from the soil survey, the rangeland ecological site description and the reference sheet for the area. Generally, concentrated flow erosional processes are accelerated when the distance between rills decreases and depth and width of rills increase.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
1. Rills	Rill formation is severe and well defined throughout most of the area	Rill formation is moderately active and well defined throughout most of the area	Active rill formation is slight at infrequent intervals, mostly in exposed areas	No recent formation of rills; old rills have blunted or muted features	Current or past formation of rills as expected for the site

2. Water flow patterns—Flow patterns are the path that water takes (accumulates) as it moves across the soil surface during overland flow. Overland flow occurs during rainstorms or snowmelt when a surface crust impedes water infiltration, or the infiltration capacity is exceeded. These patterns are generally evidenced by litter, soil or gravel redistribution, or pedestalling of vegetation or stones that break the flow of water. Interrill erosion caused by overland flow has been identified as the dominant sediment transport mechanism on rangelands. Water flow patterns are controlled in length and coverage by the number and kinds of obstructions to water flow provided by basal intercepts of living or dead plants, biological crust, persistent litter, or rocks. They are rarely continuous, and appear and disappear as the slope and microtopography of the slope changes. Shorter flow patterns facilitate infiltration by helping to pond water in depressional areas, thus increasing the time for water to soak into the soil. Generally, as slope increases and ground cover decreases, flow patterns increase. Soils with inherently low infiltration capacity may have a large number of natural flow patterns.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
2. Water flow patterns	Extensive and numerous; unstable with active erosion; usually connected	More numerous than expected; deposition and cut areas common; occasionally connected	Nearly matches what is expected for the site; erosion is minor with some instability and deposition	Matches what is expected for the site; some evidence of minor erosion. Flow patterns are stable and short	Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion

3. Pedestals and/or terracettes—Pedestals and terracettes are important indicators of the movement of soil by water and by wind (pedestals only). Pedestals are rocks or plants that appear elevated because of soil loss by wind or water erosion.

Pedestals can also be caused by nonerosional processes, such as frost heaving or through soil or litter deposition on and around plants. Because of this, it is important to distinguish and not include this type of pedestalling as an indication of erosional processes.

Terracettes are benches of soil deposition behind obstacles caused by water movement (not wind). As the degree of soil movement by water increases, terracettes become higher and more numerous and the area of soil deposition becomes larger. Terracettes caused by livestock or wildlife movements on hillsides are not considered erosional terracettes, thus they are not assessed in this protocol. However, these terracettes can increase erosion by concentrating water flow and/or reducing infiltration. These effects are recorded with the appropriate indicators (waterflow patterns, compaction layer, and soil surface loss and degradation).

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
3. Pedestals and/or terracettes (wind and water)	Abundant active-pedestalling and numerous terracettes. Many rocks and plants are pedestalled; exposed plant roots are common	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestalled with occasional exposed roots	Slight active pedestalling; most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in water flow patterns and on exposed slopes	Current or past evidence of pedestalled plants or rocks as expected for the site. Terracettes absent or uncommon

4. Bare ground—Bare ground is exposed mineral or organic soil that is available for raindrop splash erosion, the initial form of most water-related erosion. It is the remaining ground cover after accounting for ground surface covered by vegetation (basal and canopy (foliar)), litter, standing dead vegetation, gravel/rock, and visible biological crust (lichen, mosses, algae). The amount and distribution of bare ground is one of the most important contributors to site stability relative to the site potential; therefore, it is a direct indication of site susceptibility to accelerated wind or water erosion. In general, a site with bare soil present in a few large patches is less stable than a site with the same ground cover percentage in which the bare soil is distributed in many small patches, especially if these patches are unconnected. The determination of adequacy of ground cover is made by comparing the expected ground cover for a site as determined by the rangeland ecological site description. The amount of bare ground can vary seasonally depending on impacts on vegetation canopy cover (herbivore utilization) and litter amount (trampling loss), and annually relative to weather (drought, above average precipitation). Current and past climate must be considered in determining the adequacy of current cover in protecting the site against the potential for accelerated erosion.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
4. Bare ground	Much higher than expected for the site. Bare areas are large and generally connected	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected	Slight to moderately higher than expected for the site. Bare areas are small and rarely connected	Amount and size of bare areas match that expected for the site

5. Gullies —A gully is a channel that has been cut into the soil by moving water. Gullies generally follow the natural drainages and are caused by accelerated water flow and the resulting downcutting of soil. Gullies are a natural feature of some landscapes while on others management actions (excessive grazing, recreation vehicles, or road drainages) may cause gullies to form or expand. In gullies, water flow is concentrated but intermittent. Gullies can be caused by resource problems offsite (document this on the Rangeland Health Evaluation Sheet), but still affect the site function on the evaluation area.

Gullies may be assessed by observing the numbers of gullies in an area and/or assessing the severity of erosion on individual gullies. Generally, signs of active erosion; that is, incised sides along a gully, are indicative of a current erosional problem while a healing gully is characterized by rounded banks, vegetation growing in the bottom and on the sides, and a reduction in gully depth. Active headcuts may be a sign of accelerated erosion in a gully even if the rest of the gully is showing signs of healing.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
5. Gullies	Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active	Moderate to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent	Moderately in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present	Uncommon with vegetation stabilizing in bed and slopes; no signs of active headcuts, nickpoints, or bed erosion	Drainages are represented as natural stable channels, no signs of erosion with vegetation common

6. Wind-scoured, blowout, and/or depositional areas—Accelerated wind erosion on an otherwise stable soil increases as the surface crust, either physical, chemical, or biological crust, is worn by disturbance or abrasion. Physical crusts are extremely important in protecting the soil surface from wind erosion on many rangelands with low canopy (foliar) cover. The exposed soil beneath the crust is often weakly consolidated and vulnerable to movement via wind. As wind velocity increases, soil particles begin bouncing against each other in the saltation process. This abrasion leads to suspension of fine particles into the windstream where they may be transported off the site. Wind erosion is reflected by wind-scoured or blowout areas where the finer particles of the top soil have blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface. They are generally found in interspace areas with a close correlation between soil cover/bare patch size, soil texture, and degree of accelerated erosion. Deposition of suspended soil particles is often associated with vegetation that provides roughness to slow the wind velocity and allows soil particles to settle from the wind stream. The taller the vegetation, the greater the deposition rate, thus shrubs and trees in rangeland ecosystems are likely sinks for deposition (mesquite dunes). The soil removed from wind-scoured depressions is redistributed to accumulation areas (eolian deposits) that increase in size and area of coverage as the degree of wind erosion increases.

Like water erosion, wind-deposited soil particles can originate from offsite, but affect the function of the site by modifying soil surface texture. The changes in texture influence the site's hydrologic function. Even when soil particles originate from offsite, they can have detrimental effects on plants at the depositional site.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
6. Wind-scoured, blowout, and/or depositional areas	Extensive	Common	Occasionally present	Infrequent and few	Current or past evidence of pedestalled plants or rocks as expected for the site. Terracettes absent or uncommon

7. Litter movement—The degree and amount of litter (dead plant material that is in contact with the soil surface) movement (redistribution) is an indicator of the degree of wind and/or water erosion. The redistribution of litter within a small area on a site is indicative of less erosion, whereas the movement of litter off-site by wind or water is indicative of more severe erosion. In a study in the Edwards Plateau in Texas, litter accumulation was shown to be the variable most closely correlated with interrill erosion. The same study showed that litter of bunchgrasses represented significant obstructions to runoff, thereby causing sediment transport capacity to be reduced and a portion of the sediment to be deposited.

The inherent capacity for litter movement on a soil is a function of its slope and geomorphic stability. For example, alluvial fans and flood plains are active surfaces over which water and sediment are moved in response to major storm events. The amount of litter movement varies from large to small depending on the amount of bare space typical of the plant community and the intensity of the storm.

The size of litter moved by wind or water is also an indicator of degree of litter redistribution. In general, the greater distance that litter is moved from its point of origin and the larger the size and/or amount of litter moved, the more the site is being influenced by erosional processes.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
7. Litter movement (wind or water)	Extreme; concentrated around obstructions. Most size classes of litter have been displaced	Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced	Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions	Slightly to moderately more than expected for the site with on small size classes of litter being displaced	Matches that expected for the size with a fairly uniform distribution of litter

8. Soil surface resistance to erosion—This indicator assesses the resistance of the surface of the soil to erosion. The stability of the soil surface is key to this indicator. The soil surface may be stabilized by soil organic matter that has been fully incorporated into aggregates at the soil surface, adhesion of decomposing organic matter to the soil surface, and biological crusts. The presence of one or more of these factors is a good indicator of soil surface resistance to erosion. Where soil surface resistance is high, soil erosion may be minimal even under rainfall intensities of over 5 inches per hour generating high runoff rates on plots from which all cover has been removed. Conversely, the presence of highly erodible materials at the soil surface can dramatically increase soil erosion by water even when there is high vegetative cover and by wind when vegetative cover is removed.

Another good indicator is the resistance of soil surface fragments to breakdown when placed in water. For a simple test, remove several small (1/4-in diameter by 1/8-in deep) fragments from the soil surface and place them in a bottle cap filled with water. Fragments with low stability appear to lose their structure or melt within 30 seconds. Fragments with extremely low stability melt immediately upon contact with the water and the water becomes cloudy as the soil particles disperse. Fragments with moderate stability appear to retain their integrity until the water in the bottle cap is agitated or gently swirled. Highly stable aggregates retain their shape, even when agitated indefinitely. This indicator is most highly correlated with water erosion. Susceptibility to wind erosion also declines with increases in soil organic matter.

Biological crusts consist of microorganisms (lichens, algae, cyanobacteria, microfungi) and nonvascular plants (mosses, lichens) that grow on or just below the soil surface. Soil physical and chemical characteristics, along with seasonal precipitation patterns, largely determine the dominant organisms comprising the crust. Biological crusts are primarily important as cover and in stabilizing the soil surface. In some areas, depending on soil characteristics, they may increase or reduce the infiltration of water through the soil surface or enhance the retention of soil water (acting as living mulch). In general, the relative importance of biological crusts increases as annual precipitation and potential vascular plant cover decreases.

Physical crusts are thin surface layers induced by the impact of raindrops on bare soil causing the soil surface to seal and absorb less water. Physical and chemical crusts tend to have very low organic matter content or have only relatively inert organic matter that is associated with relatively little biological activity. As this physical crust becomes more extensive, infiltration rates are reduced and overland water flow increases. Also, water can pond in flat crusted areas and is more likely to evaporate than infiltrate into the soil. Physical soil crusts are identified by lifting the soil surface with a pen or other sharp object and looking for cohesive layers at the soil surface which are not perforated by pores or fissures and in which there is no apparent binding by strands of organic material, such as cyanobacteria. Physical crusts are more common on silty, clayey, and loamy soils and relatively thin if at all present in sandy soils.

Chemical crusts rarely form in rangelands except on soils formed from particular parent materials; that is, salt desert shrub communities and in abandoned irrigated agricultural fields. Where they do occur, 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. Physical crusts also include vesicular crusts that have numerous small air pockets or spaces similar to a sponge, but resistant to infiltration.

Special cases: erosion pavement and open water. This indicator is not applicable to areas in which no soil is present at the surface because of the presence of an extensive erosion pavement (nearly 100% surface cover by stones) or where there is continuous open water (marshes in the Southeast). In this case the rating should be None to Slight.

Indicator	Degree of departure from the reference state for the ecological site				
	Extreme to Total	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
8. Soil surface resistance to erosion*	Resistance of soil surface to erosion extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent	Resistance of soil surface to erosion significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches	Resistance of soil surface to erosion significantly reduced in at least half of the plant canopy interspaces, or moderately reduced throughout the site	Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected	Resistance of soil surface to erosion matches that expected for the site. Surface soil is stabilized by organic matter decomposition products or a biological crust

* Stability can also be assessed by placing a small (0.24 in) soil surface fragment in water. Relatively stable fragments maintain their shape, and the water remains clear, while unstable soils appear to melt. Very stable fragments maintain their shape even after being agitated. Extremely unstable fragments disperse immediately upon insertion into the water, making it cloudy.

9. Soil surface loss or degradation—The loss or degradation of part or all of the soil surface layer or horizon is an indicator of a loss in site potential. In most sites, the soil at and near the surface has the highest organic matter and nutrient content. This generally controls the maximum rate of water infiltration into the soil and is essential for successful seedling establishment. As erosion increases, the potential for loss of soil surface organic matter increases, resulting in further degradation of soil structure. Historic soil erosion may result in complete loss of this layer. In areas with limited slope where wind erosion does not occur, the soil may remain in place, but all characteristics that distinguish the surface from the subsurface layers are lost. Except in soils with a clearly defined horizon immediately below the surface (argillic), it is often difficult to distinguish between the loss and degradation of the soil surface. For the purposes of this indicator, this distinction is unnecessary—the objective is to determine to what extent the functional characteristics of the surface layer have been degraded. Note also that visible soil erosion is covered in description of indicator 3, pedestals and terracettes, and subsurface degradation in Indicator 11, Compaction layer.

The two primary indicators used to make this evaluation are the organic matter content and structure of the surface layer or horizon. Soil organic matter content is frequently reflected in a darker color of the soil, although high amounts of oxidized iron (common in humid climates) can obscure the organic matter. In arid soils where organic matter content is low, this accumulation can be quite faint. The use of a mister to wet the soil profile can help make these layers more visible. Soil structural degradation is reflected in the loss of clearly defined structural units or aggregates at one or more scales from less than an eighth inch to 3 to 4 inches. In soils with good structure, pores of various sizes are visible within the aggregates. Structural degradation is reflected in a more massive, homogeneous surface horizon and is associated with a reduction in infiltration rates. Comparisons to intact soil profiles at reference sites can also be used although in cases of severe degradation, the removal of part or all of the A horizon or of one or more textural components may make identification of appropriate reference areas difficult.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
9. Soil surface loss or degradation	Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content	Soil loss or degradation severe throughout site. Minimal difference in soil organic matter content and structure of surface and subsurface layers	Moderate soil loss or degradation in interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter content is significantly reduced	Some soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces	Soil surface horizon intact. Soil structure and organic matter content match that expected for site

10. Plant community composition and distribution relative to infiltration and runoff—Vegetation growth form is an important determinant of infiltration rate and interrill erosion.

Vegetation is the primary factor influencing the spatial and temporal variability of surface soil processes controlling infiltration and interrill erosion rates on semiarid rangelands. The distribution of the amount and type of vegetation is an important factor controlling spatial and temporal variations in infiltration and interrill erosion rates on rangelands in Nevada, Idaho, and Texas.

Changes in plant community composition and the distribution of species can influence (positive or negative) the ability of a site to capture and store precipitation. Plant rooting patterns, litter production and associated decomposition processes, basal area, and spatial distribution can all affect infiltration, runoff, or both. In the Edwards Plateau in Texas, shifts in plant composition between bunchgrass and short grasses over time have the greatest potential to influence infiltration and soil erosion. An example of a composition change that reduces infiltration and increases water runoff is the conversion of desert grasslands to shrub dominated communities. However, infiltration and runoff are also affected when sagebrush steppe rangeland is converted to a monoculture of annual grasses. These annual grasses provide excellent watershed protection although they adversely affect the ecological processes in many other ways.

Care must be exercised in interpreting this indicator in different ecosystems, as the same species may have different effects.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
10. Plant community composition and distribution relative to infiltration and runoff	Infiltration is severely decreased due to adverse changes in plant community composition and/or distribution. Adverse plant cover changes have occurred	Infiltration is greatly decreased due to adverse changes in plant community composition and/or distribution. Detrimental plant cover changes have occurred	Infiltration is moderately reduced due to adverse changes in plant community composition and/or distribution. Plant cover changes negatively affect infiltration	Infiltration is slightly to moderately affected by minor changes in plant community composition and/or distribution. Plant cover changes have only a minor effect on infiltration	Infiltration and runoff are equal to that expected for the site. Plant cover (distribution and amount) adequate for site protection

11. Compaction layer—A compaction layer is a near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. Compaction becomes a problem when it begins to limit plant growth, water infiltration, or nutrient cycling processes. Farm machinery, herbivore trampling, recreational and military vehicles, foot traffic, or any other activity that repeatedly causes an impact on the soil surface can cause a compaction layer. Moist soil is more easily compacted than dry or saturated soil. Recovery processes, such as earthworm activity and frost heaving, are generally sufficient to limit compaction by livestock in many upland systems.

A compaction layer is a structural change, not a textural change as described in a soil survey. Compacted layers in rangelands are generally less than 6 inches below the soil surface. They are detected by digging a small hole (generally less than 1 foot deep) with the determination of a compaction layer (a soil structure change) done by a person with soils experience. These layers may be detected in some soils with the use of a penetrometer or by simply probing the soil with a sharp rod or shovel and "feeling" for the compaction layer. However, any potential compaction layer should be confirmed using multiple indicators, including direct observation of physical features. Those physical features include such things as platy or blocky, dense soil structure over less dense soil layers and horizontal root growth, and increased density (measured by weighing a known volume of oven-dry soil). Increased resistance to a probe can be simply due to lower soil moisture or higher clay content.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
11. Compaction layer (below soil surface	Extensive; severely restricts water movement and root penetration	Widespread; greatly restricts water movement and root penetration	Moderately widespread, moderately restricts water movement and root penetration	Rarely present or is thin and weakly restrictive to water movement and root penetration	None to minimal, not restrictive to water movement and root penetration

12. Functional/structural groups—Functional/structural groups are a suite of species that are grouped together, on an ecological site basis, because of similar shoot (height and volume) or root (fiberous versus tap) structure, photosynthetic pathways, nitrogen fixing ability, or life cycle. Functional composition and functional diversity are the principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. The study by Tilman, et al. (1997) showed that functional composition has a large impact on ecosystem processes. This and related studies have demonstrated that factors that change ecosystem composition, such as invasion by novel organisms, nitrogen deposition, disturbance frequency, fragmentation, predator decimation, species removal, and alternative management practices, can have a strong affect on ecosystem processes.

Relative dominance is based upon the relative annual production, or biomass that each functional group collectively contributes to the total. The recommended protocol to use for grouping species is composition by annual production. If the evaluator(s) doesn't have experience in estimating composition by annual production, then composition by cover may be used if appropriate reference data are available. The potential for Functional/Structural groups is derived by placing species into the appropriate groups from information found in the Reference Sheet. The list and ranking of functional/structural groups should reflect all of the plant (including biological crust) communities in the reference state, under the natural disturbance regime, and in the context of normal climax variability. The comparison should be to communities in the reference state (in the state and transition model for the ecological site).

The number of species in each functional group is also considered when selecting the appropriate rating category on the Rangeland Health Evaluation Sheet. If the number of species in many of the functional/structural plant groups has been greatly reduced, this may indicate loss of biotic integrity. Both the presence of functional groups and the number of species within the groups significantly affect on ecosystem processes. Example 4–8 shows functional/structural groups for a prairie ecological site, and example 4–9 shows them from a Great Basin desert site. Nonvascular plants (biological crusts) are included in example 4–9 because they are an important component of this Great Basin ecological site. Biological crusts are components of many ecosystems and should be included in this evaluation when appropriate.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
12. Functional/ structural groups (F/S groups)	Number of F/S groups greatly reduced and/or Relative dominance of F/S groups has been dramatically altered and/or Number of species within F/S groups significantly reduced	Number of F/S groups reduced and/or One dominant group and/or One or more subdominant group replaced by F/S groups not expected for the site and/or Number of species within F/S groups significantly reduced	Number of F/S groups moderately reduced and/or One or more subdominant F/S groups replaced by F/S groups not expected for the site and/or Number of species with F/S groups moderately reduced	Number of F/S groups slightly reduced and/or Relative dominance of F/S groups has been modified from that expected for the site and/or Number of species within F/S slightly reduced	F/S groups and number of species in each group closely match that expected for the site

Example 4–8 Functional/structural groups for a prairie ecological site

Warm-season tall grasses	Warm-season midgrasses	Cool-season midgrasses	Warm-season shortgrass	Perennial forbs	Leguminous shrubs
Big bluestem	Sideoats grama	Western wheatgrass	Buffalograss	Dotted gayfeather	Leadplant
Indiangrass	Little bluestem	Green needlegrass	Blue grama	Prairie coneflower	

Example 4–9 Functional/structural groups from a Great Basin desert site

Tall shrubs (deep rooted)	Half shrub	Warm-season bunchgrass	Cool-season short bunch-grass	Cool-season mid bunch-grass	Perennial forbs, N fixers	Perennial forbs, not N fixers	Biological crust
Wyoming big sagebrush	Broom snakeweed	Sand drop-seed	Sandberg bluegrass	Squirreltail	Astragalus	Phlox	Moss
Bitterbrush		Red three-awn		Thurbers needlegrass	Lupine	Arrowleaf balsamroot	Lichens
				Indian Ricegrass		Biscuitroot	

13. Plant mortality/decadence—The proportion of dead or decadent (moribund, dying) to young or mature plants in the community relative to that expected for the site, under normal disturbance regimes, is an indicator of the population dynamics of the stand. If recruitment is not occurring and existing plants are either dying or dead, the integrity of the stand would be expected to decline and other undesirable plants (weeds or invasives) may increase. A healthy range has a mixture of many age classes of plants relative to site potential and climatic conditions.

Only plants native to the site (or seeded plants if in a seeding) are assessed for plant mortality. Plant mortality may vary considerably on the landscape depending on disturbance events (fire, drought, insect infestation, and disease).

Indicator	Degree of departure from the reference state for the ecological site				
	Extreme to Total	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
13. Plant mortality/ decadence	Dead and/or decadent plants are common	Dead plants and/or decadent plants are somewhat common	Some dead and/or decadent plants are present	Slight plant mortality and/or decadence	Plant mortality and decadence match those expected for the site

14. Litter amount—Litter is any dead plant material (from both native and exotic plants) that is detached from the base of the plant. The portion of the litter that is in contact with the soil surface (as opposed to standing dead vegetation) provides a source of soil organic material and the raw material for onsite nutrient cycling. All litter helps to moderate the soil microclimate and provides food for microorganisms. The amount of litter present can play a role in enhancing the ability of the site to resist erosion. Litter helps to dissipate the energy of raindrops and overland flow, thereby reducing the potential detachment and transport of soil. Litter biomass represents a significant obstruction to runoff.

The amount of litter (herbaceous and woody) is compared to the amount that would be expected for the same type of growing conditions in the reference state per the Reference Sheet. Litter is directly related to weather and to the degree of utilization of biomass each year. Therefore, climatic influences (drought, wet years) must be carefully considered in determining the rating for the amount of litter. Do not confuse standing-dead plants with litter during this evaluation.

Some plant communities have increased litter quantities relative to the site potential and current weather conditions. An example is the increased accumulation of litter in exotic grass communities (cheatgrass) compared to native shrub steppe plant communities. In this case, litter amount above what is expected results in a downgraded rating for the site. Note in the comments section on the evaluation sheet for this indicator if the litter is undergoing decomposition (darker color) or oxidation (whitish color which may also be an indication of fungal growth). In addition to amount, litter size may also be important because larger litter tends to decompose slower and is more resistant to runoff. If litter size is considered as a part of an indicator, it should be noted in the reference sheet.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
14. Litter amount	Largely absent or dominant relative to site potential and weather	Greatly reduced or increased relative to site potential and weather	Moderately more or less relative to site potential and weather	Slightly more or less relative to site potential and weather	Amount is what is expected for the site potential and weather

15. Annual production—Annual production, as used in this document, is the net quantity of aboveground vascular plant material produced within a year. It is an indicator of the energy captured by plants and its availability for secondary consumers in an ecosystem given current weather conditions. Production potential will change with communities or ecological sites, biological diversity, and with latitude. Annual production of the evaluation area is compared to the site potential (total annual production) as described in the reference sheet.

Comparisons to the reference sheet are based on peak aboveground standing crop, no matter when the site is assessed. If utilization of vegetation has occurred or plants are in early stages of growth, the evaluator(s) is required to estimate the annual production removed or expected and include this amount when making the total site biomass estimate. Do not include standing dead vegetation or live tissue (woody stems) not produced in the current year as annual production.

All species (native, seeded, and weeds) alive (annual production only) are included in the determination of total aboveground site biomass. Therefore, the type of vegetation (native or introduced) is not the issue. For example, Rickard and Vaughan (1988) found that conversion of a sagebrush steppe plant community to an exotic annual grassland greatly affected vegetation structure and function, but not aboveground biomass production.

As with the other indicators, it is important to consider all other local and landscape level explanations for differences in production (runoff/run-on because of landscape position, weather, regional location, or different soils within an ecological site) before attributing production differences to differences in other site characteristics.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
15. Annual production	Less than 20% of potential production	20–40% of potential production	40–60% of potential production	60–80% of potential production	Exceeds 80% of potential production

16. Invasive plants—Invasive plants are plants that are not part of (if exotic), or are a minor component of (if native), the original plant community or communities that 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 (short-term response to drought or wildfire) are not invasive plants. This indicator deals with plants that are invasive to the evaluation area. These plants may or may not be noxious and may or may not be exotic.

Invasives can include noxious plants (plants listed by a state because of their unfavorable economic or ecological impacts), non-native plants, and native plants. Native invasive plants (pinyon pine or juniper into sagebrush steppe) must be assessed by comparing current status with potential status described in the Reference Sheet. Historical accounts and photographs also provide information on the historical distribution of invasive native plants.

Invasive plants may impact an ecosystem's type and abundance of species, their interrelationship, and the processes which energy and nutrients move through the ecosystem. These impacts can influence both biological organisms and physical properties of the site. The impacts may range from slight to catastrophic depending on the species involved and their degree of dominance. Invasive species may adversely affect a site by increased water usage (salt cedar (tamarish) in riparian areas) or rapid nutrient depletion (high nitrogen use by cheatgrass).

Some invasive plants (knapweeds) are capable of invading undisturbed, climax bunchgrass communities, further emphasizing their use as an indicator of a new ecosystem stress. Even highly diverse, species rich plant communities are susceptible to exotic species invasion.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
16. Invasive plants	Dominate the site	Common throughout the site	Scattered throughout the site	Occasionally present on the site	Rarely present on the site

17. Reproductive capability of perennial plants— Adequate seed production is essential to maintain populations of plants when sexual reproduction is the primary mechanism of individual plant replacement at a site. However, annual seed production of perennial plants is highly variable. Since reproductive growth occurs in a modular fashion similar to the remainder of the plant, inflorescence production (seedstalks) becomes a basic measure of reproductive potential for sexually reproducing plants and clonal production (tillers) for vegetatively reproducing plants. Since reproductive capability of perennial plants is greatly influenced by weather, it is important to determine departure from the expected value in the reference sheet by evaluating management effects on this indicator.

Seed production can be assessed by comparing the number of seedstalks and/or number of seeds per seedstalk of native or seeded plants (not including invasives) in the evaluation area with what is expected as documented on the Reference Sheet. Mueggler (1975) recommended comparison of seedstalk numbers/culm length on grazed and ungrazed bluebunch wheatgrass plants as a measure of plant recruitment potential. Seed production is related to plant vigor since healthy plants are better able to produce adequate quantities of viable seed than are plants that are stressed or decadent.

For plants that reproduce vegetatively, the number and distribution of tillers or rhizomes is assessed relative to the expected production of these reproductive structures as documented in the reference sheet.

Recruitment is not assessed as a part of this indicator because plant recruitment from seed is an episodic event in many rangeland ecological sites. Therefore, evidence of recruitment (seedlings or vegetative spread) of perennial, native, or seeded plants is recorded in the comment section of the Evaluation Sheet, but is not considered in rating the reproductive capabilities of perennial plants.

This indicator considers only perennial plants. Evaluation areas that have no perennial plants would be rated Extreme to Total for this indicator because they no longer have the capacity to reproduce perennial plants.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
17. Reproductive capability of perennial plants (native or seeded)	Capability to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is somewhat limited relative to recent climatic conditions	Capability to produce seed or vegetative tillers is only slightly limited relative to recent climatic conditions	Capability to produce seed or vegetative tillers is not limited relative to recent climatic conditions

18. Optional indicators—The 17 indicators described previously represent the baseline indicators that must be assessed on all sites. Other indicators and descriptors may be developed to meet local needs. The only restriction on the development of optional indicators and their use is that they must be ecologically, not management, related. They should also significantly increase the quality of the evaluation. For example, an indicator of suitability for livestock, wildlife, or special status species are not appropriate indicators to determine the health of a land unit. They may be important in the allotment or ranch evaluation, but are not included in the determination of the status of soil/site stability, hydrologic function, or biotic integrity.

An example of optional indicators and descriptors for Biological Crusts and Vertical Vegetation follows:

Both are partially addressed by indicator 12 (functional/structural groups); however, many users find that this indicator often becomes heavily focused on plant community composition. Both optional indicators are also partially reflected by indicator 4 (bare ground). Soil stabilized by visible biological crust (lichens, mosses, and algae) is not considered bare ground. Because the bare ground indicator includes the special distribution of bare areas, it also provides some indication of the horizontal vegetation distribution.

The biological crust indicator might be applied where these crust play particularly important biological or physical role (for nitrogen fixation or soil stabilization). The vegetation structure indicator is useful where variability in vertical vegetation structure within functional/structural groups affects wind erosion or the integrity of animal populations. This variability may be due to species differences within functional/structural groups, in the age class distribution, or to disturbances such as fire and grazing that affect growth form.

The indicators included in these sheets are not intended to be all inclusive for all rangelands. Additional indicators may be added to the sheets to improve sensitivity in detecting changes in soil/site stability, hydrologic function, and biotic integrity. As with the modification of the descriptor narratives, any additional indicators will be site specific and need approval from the state rangeland management specialist or another person responsible for maintaining the quality of the ecological site descriptions.

	Degree of departure from the reference state for the ecological site				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
Biological crusts	Found only in protected areas, very limited suite of functional groups	Largely absent, occurring mostly in protected areas	In protected areas and with a minor component in interspaces	Evident throughout the site, but continuity is broken	Largely intact and nearly matches site capability
Vertical vegetation structure	Number of height classes greatly reduced and/or most height classes lost and/or dramatic increase in number of height classes expected for site and/or dramatic reduction in the number or density of individuals across several height classes	Number of height classes significantly reduced and/or more than one height class lost and/or addition of more than one height class not expected for site and/or significant reduction in the number or density of individuals across several height classes	Number of height classes moderately reduced and/or one height class lost and/or addition of height class not expected for site and/or moderate reduction in the number or density of individuals across several height classes	Number of height classes slightly reduced and/or slight reduction in the number or density of individuals across several height classes	Number and type of height classes and the number and density of individuals in each height class closely match that expected for the site

(4) Determining the functional status of the three rangeland health attributes

The interpretation process is the critical link between observations of indicators and determining the degree of departure from the reference sheet for each health attribute in an evaluation area. The interpretation of the indicators and the selection of the degree of departure of the rangeland health attributes (soil/site stability, hydrologic function, and biotic integrity) are made at the bottom of page 2 of the evaluation sheet. (exhibit 4–9). Table 4–2 is the grouping of indicators into the three attributes of rangeland health.

The summary rating is made by reviewing the indicator ratings and comments to arrive at a single degree of departure from the Reference Sheet for each attribute.

A preponderance of evidence approach is used to select the appropriate departure category for each attribute. This decision is based, in part, on where the majority of the indicators for each attribute fall under the five categories. For example, if four of the soil/site stability indicators are in the Moderate and six are in the Slight to Moderate departure from the ecological site description, the Soil/Site Stability attribute departure would be rated as Slight to Moderate assuming that the evaluator(s) interpretation of other information and local ecological knowledge supported this rating. However, if one of the four indicators in the Moderate category is particularly important for the site (bare ground), a rating of Moderate can be supported.

Once an evaluation is made for each attribute, managers may use the attribute evaluation to identify where more information (monitoring and/or inventory data) is required. This information should be reviewed if available, or if not available, the information should be collected. Therefore, these areas (moderate departure) are often ideal for the implementation of monitoring studies since they should be the most responsive to management activities. However, additional monitoring may be useful regardless of the departure rating, dependant upon future change in uses or management of the area.

This procedure relies upon the collective experience and knowledge of the evaluator(s) to classify each indicator and then to interpret the collective rating for the indicators into one summary rating of departure for each attribute. The rating of each indicator and the interpretation into a collective rating for each attribute are not apprentice-level work. This procedure has been developed for use by experienced, knowledgeable evaluator(s). It is not intended that this assessment procedure be used by new and/or inexperienced employees, without training and assistance by more experienced and knowledgeable employees.

(d) Communicating ratings of ecological sites

Communicating ratings of ecological sites on rangeland is important to decisionmakers, users, rangeland management professionals, other agency personnel, and the general public. Ratings on ecological sites can be reported in the three ways described in the preceding paragraphs: trend (rangeland trend or planned trend), similarity index, and rangeland health. Many times all three methods of evaluation may be useful and needed to fully inventory and describe the ratings of ecological sites on the land.

(e) Evaluating rangelands occupied by naturalized plant communities

As stated in chapter 3, ecological site descriptions are to be developed for all identified ecological sites on rangeland. These site descriptions are to identify and describe the historic climax plant community along with other vegetation states commonly found on the site. In some locations the historic climax plant community has been destroyed, and the plant community cannot be reconstructed with any degree of reliability. In these areas site descriptions will be developed using naturalized plant communities for the site instead of the historic climax plant community. The use of this option for ecological site descriptions is for areas where the historic climax plant community is unknown and cannot be reconstructed with any degree of reliability. An example of the areas within the United States where this may be used is the State of Hawaii, the Caribbean Area, and the annual grasslands of California. Approval to describe ecological sites in this manner in other regions must be obtained from the national program leader for range and pasture. Evaluation of these sites may include rangeland health, planned trend, and similarity index to a desired plant community. It will not include similarity index to historic climax because there is no way to know the historic climax plant community for these sites.

Table 4–2 Grouping of the indicators of rangeland health into ecological attributes

Indicator/attribute	Soil/site stability	Hydrologic function	Biotic integrity
1. Rills	X	X	
2. Water flow patterns	X	X	
3. Pedestals and/or terracettes	X	X	
4. Bare ground	X	X	
5. Gullies	X	X	
6. Wind-scoured, blowout, and/or deposition areas	X		
7. Litter movement	X		
8. Soil surface resistance to erosion	X	X	X
9. Soil surface loss or degradation	X	X	X
10. Plant community composition and distribution relative to infiltration and runoff		X	
11. Compaction layer	X	X	X
12. Plant functional/structural groups			X
13. Plant mortality/decadence			X
14. Litter amount		X	X
15. Annual production			X
16. Invasive plants			X
17. Reproductive capability of perennial plants			X

600.0403 Evaluating grazed forest lands

Grazed forest lands will be evaluated by utilizing planned trend and forage value ratings.

(a) Planned trend

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 and to protecting the soil, water, air, plant, and animal resources. Planned trend is described as:

Positive—Moving towards the desired plant community

Not apparent—Change not detectable

Negative—Moving away from the desired plant community

Planned trend provides feedback to the manager and grazing land specialist about how well the management plan and prescribed grazing are working on a grazing unit by grazing unit basis. It can provide an early opportunity to make adjustments to the grazing duration and stocking levels in the conservation plan. Planned trend is monitored on all native and naturalized grazing land plant communities.

(b) Forage value rating

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. Five forage value categories are recognized.

Preferred plants—These plants are abundant and furnish useful forage for a reasonably long grazing period. They are preferred by grazing animals. Preferred plants are generally more sensitive to grazing misuse than other plants, and they decline under continued heavy grazing.

Desirable plants—These plants are useful forage plants, although not highly preferred by grazing animals. They either provide forage for a relatively short period, or they are not generally abundant in the stand. Some of these plants increase, at least in percentage, if the more highly preferred plants decline.

Undesirable plants—These plants are relatively unpalatable to grazing animals, or they are available for only a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.

Nonconsumed plants—These 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 removed.

Toxic plants—These plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. Toxic plants may become abundant if unpalatable and the more highly preferred species are removed.

600.0404 Vegetation sampling techniques

Vegetation sampling techniques are used in inventory and trend monitoring transects to assess utilization, cover, density, and frequency. In all cases techniques specific to the type of data needed should be used. Biomass data should be generated by clipping plots, not by trying to convert density or frequency data to weight. Frequency data should be generated from frequency techniques, not from biomass data. Photo points should be included in all monitoring programs to provide a visual record.

(a) Selecting techniques

Sampling Vegetation Attributes, an interagency technical reference released in 1996, is a good reference to use when evaluating sampling techniques. It includes examples of methods and data sheets, and can be used to plan, design, and layout for monitoring.

The technique or techniques used in monitoring depends on the vegetation attribute being monitored. For instance, a utilization technique should be used to monitor utilization to the needed level of precision within cost constraints. Because repeated clipping at a permanent monitoring location can reduce productivity, biomass is not recommended as a monitoring technique.

Indicators of environmental change, such as frequency or cover of certain species, may be the best variables to measure. For long-term monitoring, cover may be the best variable to measure. Basal cover of perennial grasses and canopy cover of woody plants typically change slowly over time. These attributes are not strongly affected by co-variates, such as climatic variation, yet they would be expected to change under different types of management. Permanent line transects established at random locations with photo points down the line are an excellent technique for monitoring environmental change.

(1) Monitoring scheme example

Range management specialists in Arizona, as well as other states, are monitoring trend using techniques similar to those described in this chapter. The following example scheme, from southern Arizona, involves a pace frequency monitoring technique to sample plant frequency and cover for overall trend.

Monitoring sites are established in key areas. Key areas are within the predominant site in the grazing unit that has potential for improvement under management and that has an adequate representation of key species. Four transects are established within the key area and marked so they can be relocated. Along each transect, 50 quadrates, 40-centimeter by 40-centimeter frequency, are read at one pace intervals. A single point on the quadrate is read for ground cover. Grasses and forbs rooted within the quadrate are recorded for presence (frequency), and trees or shrubs rooted within or overhanging the plot are recorded for presence. The data are tabulated and summarized on a summary sheet for use in discussions of trend by the rancher and range management specialist. Ancillary data noted or collected include the direction of the transect (consistent yearly), similarity index rating to a specific plant community, number of animals, season of use, utilization, production, and precipitation.

(b) Studies of treatment effects

The literature related to methods used in research, inventory, and monitoring is extensive. In many cases the conservationist will be well advised to seek advice from other professionals who may have more experience with a particular type of data need. The process of selecting an appropriate technique involves several simple questions:

Is this information really needed or is it already known? If the information has already been documented then data collection is probably not needed. However, if the information is not documented or the results in the literature are contrary to what has been observed, then data collection is needed.

Is the information needed related to a specific vegetation attribute, such as biomass, cover, density, frequency, or utilization or some combination? This is often the most difficult question to answer. If the answer is not known, biomass and cover data are the best data to collect. For example, if a difference in use has been noted between sites for a particular grass species, then the first thought might be a utilization study. A utilization study would provide the data needed to show a difference in use, but would not indicate why there is a difference in use. A chemical analysis of randomly selected plants from both sites might indicate a difference in palatability. A frequency study would indicate the presence of a more palatable plant on the site where the species is not used. A biomass study with selected materials from both sites put through a chemical analysis would also provide the needed information.

Which technique or combination of techniques will quantify the observed phenomenon? The best technique or combination of techniques will obtain the information within time and cost constraints and at the needed level of precision or will provide the best tradeoff of time and precision. An initial plot size and shape study provides this information.

Once these questions are answered, the study can be designed and completed with some likelihood of determining differences.

Exhibits

Exhibit 4–1 Examples of weight units

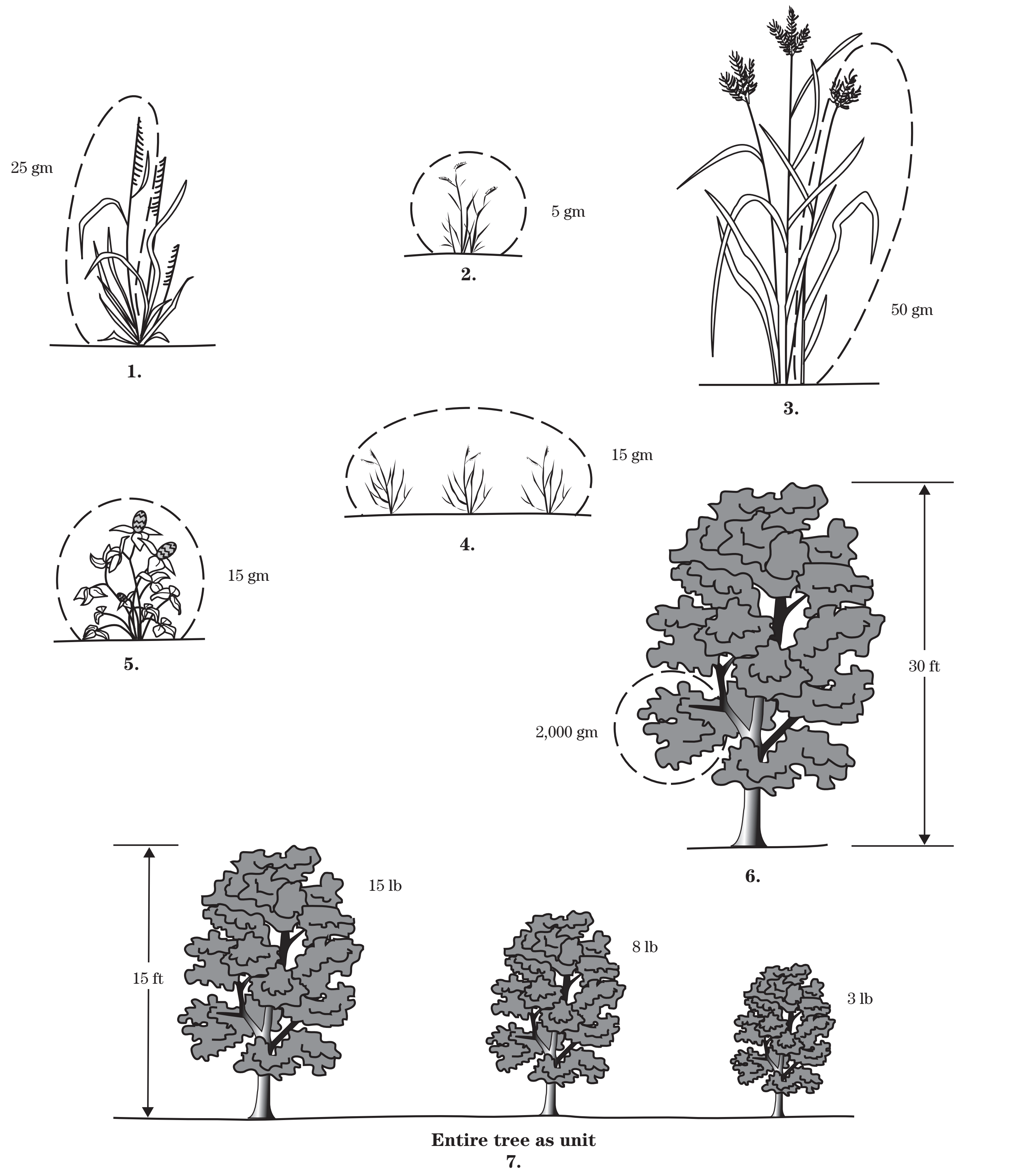


Exhibit 4–2 Percentage of air-dry matter in harvested plant material at various stages of growth

Grasses	Before heading; 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 perennial bromes bluegrasses prairie junegrass	35	45	60	85	95
Warm-season tall grasses bluestems indiangrass switchgrass	30	45	60	85	95
Midgrasses sideoats grama tobosa galleta	40	55	65	90	95
Short grasses blue grama buffalograss short three-awns	45	60	80	90	95

Trees	New leaf and twig growth until leaves	Older and full-size green leaves (%)	Green fruit (%)	Dry fruit (%)
Evergreen coniferous ponderosa pine, slash pine-longleaf pine Utah juniper Rocky Mountain juniper spruce	45	55	35	85
Live oak	40	55	40	80
Deciduous blackjack oak post oak hickory	40	50	35	85

Exhibit 4–2 Percentage of air-dry matter in harvested plant material at various stages of growth—Continued

Shrubs	New leaf and twig growth until leaves are full size (%)	Older and full-size green leaves (%)	Green fruit (%)	Dry fruit (%)
Evergreen big sagebrush bitterbrush ephedra algerita gallberry	55	65	35	85
Deciduous snowberry rabbitbrush snakeweed Gambel oak mesquite	35	50	30	85
Yucca and yucca-like plants yucca sotol saw-palmetto	55	65	35	85

Forbs	Initial growth to flowering (%)	Flowering to seed maturity (%)	Seed ripe; leaf tips dry (%)	Leaves dry; stems drying (%)	Dry (%)
Succulent violet waterleaf buttercup bluebells onion, lilies	15	35	60	90	100
Leafy lupine lespedeza compassplant balsamroot tickclover	20	40	60	90	100
Fibrous leaves or mat phlox mat eriogonum pussytoes	30	50	75	90	100

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+

Exhibit 4–3 NRCS RANGE 414, Proper grazing use

Proper Grazing Use

Cooperator________________________________

							Actual percent or pounds remaining				
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)	19___	19___	19___	19___	19___
						Initials of Conservationist Assisting with Application					
						Dates of Application Checks					

Conservationist Assisting with Planning

____

Name and Date

Proper Grazing Use

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.

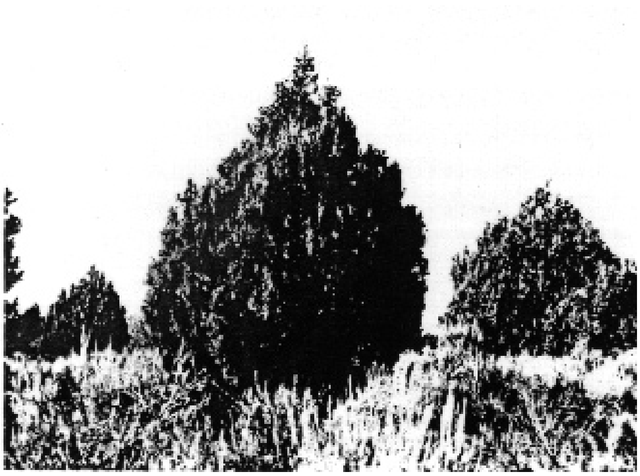
Key Plant(s) for Judging Proper Grazing Use: Enter in this column the species by common name on which you and the cooperator decide proper grazing use will be judged. There may be occasion when you will select two species, in this case enter the name of both species.

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.

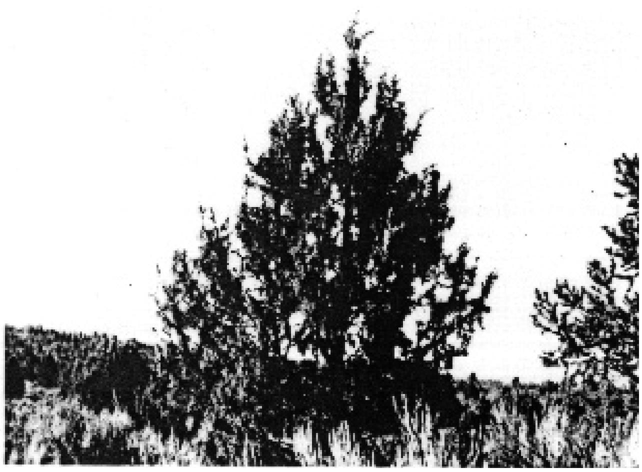
Actual Percent or Pounds Remaining: Enter in this column, by calendar year, the percent, by by weight, or pounds remaining of the selected key species in the grazing unit. This measurement should be based on the key species on the key grazing area, at or near the end of the grazing call for use in percent 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.

Exhibit 4–4 Foliage denseness classes

Dense



Medium



Sparse

Instructions for use of exhibit 4–4 tables:

Determine yields of juniper and pinyon pine by:

1. On 1/10- or 1/100-acre plots selected by random, tally crown diameter per tree and foliage denseness (sparse, medium, and dense) on each tree. From the tables, 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 1/10-acre plots and by 100 on 1/100-acre plots. This figure is pounds per acre annual yield.
2. On 1/10- or 1/100-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 1/10-acre plots and by 100 on the 1/100-acre plots to get yield per acre.

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				

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

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									
Non-preferred species									

Browse composition

Judge composition and trend based on majority of evidence

- (dotted) Good
- (white) Fair
- (gray) Poor

Browse trend

- (dotted) Upward
- (white) Stable or not apparent
- (gray) 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.

Exhibit 4–6 Trend determinations worksheet

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**

Worksheet For Determining Similarity Index

Client ______________________ **Ecological site** ______________________

Location ______________________ **Reference vegetation state** ______________________

Date ______________________ **Completed by** ______________________

A	B	C	D	E	F	G	H	I	J
Species name	Green wt. pounds	% dry weight 1/	% current growth ungrazed 1/	% growth curve comple-ted 1/	% of normal produc-tion 1/	Recon-struction factor C / (D)(E)(F)	Recon-structed present weight	Pounds in reference state	Pounds allow-able
K. Total normal annual production in reference vegetation state (from ecological site description).									
L. Total pounds of allowable present (total of pounds in column J).									
M. Similarity index (L divided by K x 100 = M).									

1/ Express all percents as decimal values (Example: 60%=.6)

Instructions for Worksheet for Determining Similarity Index

A. Species name	Enter the common or scientific name of the plant species.
B. Green wt. pounds	Enter the fresh clipped weight of each species.
C. Percent dry weight	Enter the percent air dry weight or oven dry weight as a decimal value.
D. Percent current growth ungrazed	Enter the estimated percent (as a decimal value) of the current growth that has not been removed by grazing or harvest.
E. Percent growth curve completed	Enter the percent (as a decimal value) of the current years growth for each species that should normally have occurred by the date of this determination.
F. Percent of normal production	Enter an estimation of the current years forage growth in comparison to normal expressed as a percent (as a decimal value) of normal. Example: .9 means the year's production is 90% of normal or 10% below normal. 1.1 is 110% of normal or 10% above normal.
G. Reconstruction factor	This factor is calculated by dividing (C) Percent dry weight by the product obtained by multiplying (D) Percent current growth ungrazed times (E) Percent growth curve completed times (F) Percent of normal production. (C / D x E x F = G)
H. Reconstructed present weight	This value is calculated by multiplying (B) Green weight in pounds by (G) the Reconstruction factor. (B x G = H)
I. Pounds in reference vegetation state	Enter the pounds for each plant species as shown in the appropriate reference vegetation state in the ecological site description.
J. Pounds allowable	Enter the lesser of (H) Reconstructed present weight or (I) pounds. No more than the pounds in the reference vegetation state plant community may be counted in determining similarity index.
K. Total normal annual production in reference vegetation state	This is the total normal product of all plants shown in the appropriate reference vegetation state plant community description of the ecological site description.
L. Total pounds of allowable present	This is the total of all weight shown in column (J). It is all the weight that is allowed to count toward determining similarity index.
M. Similarity index	This is calculated by dividing (L) Total pounds of allowable present by (K) total Normal annual production and multiplying by 100 to express it as a percent. (L / K x 100 = M)

Reference Sheet

Author(s)/participants ____

Contract for lead author ____

Date ___________ **MLRA** ______________________**Ecological site**_________________________ 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 ☐ Annual production ☐ Foliar cover ☐ 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:

2. Presence of water flow patterns:

3. Number and height of erosional pedestals or terracettes:

4. Bare ground from ecological site description or other studies (rock, litter, lichen, moss, plant canopy are **not** bare ground):

5. Number of gullies and erosion associated with gullies:

6. Extent of wind scoured, blowouts, and/or depositional areas:

7. Amount of litter movement (describe size and distance expected to travel):

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

9. Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):

10. Effect of plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:

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

12. Functional/structural groups (list in order of descending dominance by above-ground production or live foliar cover (specify) using symbols: >>, >, = to indicate much greater than, greater than, and equal to; place dominants, subdominants and "others" on separate lines):
    Dominants:
    Subdominants:
    Other:

13. Amount of plant mortality and decadence (include which functional groups are expected to show morality or decadence):

14. Average percent litter cover (_______%) and depth (_______ inches)

15. Expected annual production (this is TOTAL above-ground production, not just forage production):
    _________ - _________ lbs/acre or kg/ha (choose one)

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 codominant 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 what is NOT expected in the reference state for the ecological site:

17. Perennial plant reproductive capability:

Reference Sheet (standard example)

Author(s)/participants *Winnemucca class participants (May 12-15, 2005)*

Contract for lead author ____________________

Date *5-1-05* **MLRA** *024* **Ecological site** *Loamy 8-10" PZ 024XY005NV* 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 ☑ Annual production ☐ Foliar cover ☐ 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:
   Minimal on slopes less than 10% and increasing slightly as slopes increase up to 50%. Rills spaced 15-20 feet apart when present on slopes of 10-50%. After wildfires, high levels of natural herbivory or extended drought, or combinations of these disturbances, rills may double in numbers on slopes from 10-50% after high intensity summer thunderstorms.

2. Presence of water flow patterns:
   Generally up to 20 feet apart and short (less than 10 feet long) with numerous obstructions that alter the water flow path. On slopes of 10-50%, flow patterns increase in number and length. Flow pattern length and numbers may double after wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances if high intensity summer thunderstorms occur.

3. Number and height of erosional pedestals or terracettes:
   Plant or rock pedestals and terracettes are almost always in flow patterns. Wind caused pedestals are rare and only would be on the site after wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances. Pedestals of Sandberg bluegrass on pedestals outside water flow patterns are generally caused by frost heaving, not erosion. Pedestals and terracettes would be particularly apparent on 10-50% slpoes, especially immediately after high intensity summer thunderstorms.

4. Bare ground from ecological site description or other studies (rock, litter, lichen, moss, plant canopy are **not** bare ground):
   10-20% or less bare ground with bare patches less than 10% of the evaluation area occurring as intercanopy patches larger than 2 feet in diameter (intercanopy patches can include areas that are not bare ground). Most large patches can include areas that are not bare ground. Within this range, lower slopes are expected to have less bare ground than steeper slopes. Upper end of precip range (10") will also have less bare ground. Canopy gaps generallyless than 12 inches in diameter in the intervals between natural disturbance events. Bare ground would be expected to increase to 80% or more the first year following wildfire but to decrease to prefire levels with 2-5 years depending on climate and other disturbances. Multi-year droughts can also cause bare ground to increase to 30%.

5. Number of gullies and erosion associated with gullies:
   Gullies are rare and would only be present when a high intensity summer thunderstorm occurs after wildfires, with high levels of natural herbivory, extended drought, or combinations of these disturbances.

6. Extent of wind scoured, blowouts, and/or depositional areas:
   Wind erosion is minimal. Moderate wind erosion can occur when disturbances such as severe wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances. After rain events, exposed soil surfaces form a physical crust that tends to reduce wind erosion.

7. Amount of litter movement (describe size and distance expected to travel):
   Litter movement consists primarily of redistribution of fine litter (herbaceous plant material) in flow patterns for distances of 1-3 feet on 2-15% slopes, 4-6 feet on 15-30% slopes and 7-10 feet on 30-50% slopes. After wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances, size of litter and distance litter moves can increase with coarse woody litter and fine litter moving up to 10' (2-15% slope); 25' (15-30% slope) 100' (30-50% slope).

8. Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):
   Values of 4.5-5.5 under canopies and in intercanopy spaces.

9. Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):
   Surface layer is light brown and 6-7 inches thick with moderate granular structure. Loss of several millimeters of soil may occur immediately after a high intensity wildfire, high levels of natural herbivory, extended drought, or cominations of these disturbances.

Reference Sheet (standard example cont.)

10. Effect of plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:

Perennial plants and especially sagebrush capture snow, increasing soil water availability in the spring. High bunchgrass density increases infiltration by improving soil structure and slowing runoff. Loss of sagebrush after a high intensity wildfire reduces snow accumulation in the winter, reducing the depth of soil water recharge negatively affecting growth and production of deep rooted forbs and perennial grasses. This reduced soil water recharge is part of the site dynamics if exotics or other management actions don't delay the succession back to a sagebrush-grass plant community.

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

Compaction layers should not be present. There are soil profile features in the top 8 inches of the soil profile that would be mistaken for a management induced soil compaction layer. Silica accumulations can cause denser horizons, however these horizons can be distinguished from compaction by their brittleness and "shiny" material in the horizon. These silica accumulations will increase the hardness of the soil, but compaction can still occur and be detected as degradation of soil structure and loss of macropores.

12. Functional/structural groups (list in order of descending dominance by above-ground production or live foliar cover (specify) using symbols: >>, >, = to indicate much greater than, greater than, and equal to; place dominants, subdominants and "others" on separate lines):

Dominants: *Mid+tall grasses > non-sprouting shrubs (except following fire, when non-resprouting shrubs become rare on the site)*

Subdominants: *Shortgrasses > sprouting shrubs*

Other: *Annual forbs, perennial forbs*

Biological crust will be present with lichen + moss cover of 10-15%

After wildfires the funtional/structural dominance changes to the herbaceous components with a slow 10-20 year recovery of the non-resprouting shrubs (e.g. big sagebrush). Resprouting shrubs tend to increase until the sagebrush re-establishment and increase reduces the resprouting component. High levels of natural herbivory, extended drought, or combinations of these factors can increase shrub/functional/structural groups at the expense of the herbaceous groups and biological crust.

13. Amount of plant mortality and decadence (include which functional groups are expected to show morality or decadence):

Most of the perennial plants in this community are long lived, especially the perennial forbs and shrubs. After moderate to high intensity wildfires, all of the non-resprouting shrubs would die as would a small percentage of the herbaceous understory species. Extended droughts would tend to cause relatively high mortality in short lived species such as bottlebrush squirreltail and Sandberg bluegrass. Shrub mortality would be limited to severe, multiple year droughts. Combinations of wildfires and extended droughts would cause even more mortality for several years following the fire than either disturbance functioning by itself. Up to 20% dead branches on sagebrush following drought alone.

14. Average percent litter cover (___*20*___%) and depth (__*1 1/4*__ inches)

After wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances, litter cover and depth decreases to none immediately after the disturbance (e.g. fire) and dependent on climate and plant production increases to post-disturbance levels in one to five growing seasons.

15. Expected annual production (this is TOTAL above-ground production, not just forage production):

_________ - _________ lb/acre or kg/ha (choose one)

400 lbs/ac in low precip years. 600 lb/ac in average precip years and 800 lb/ac in above average precip years #/acre. After wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances, can cause production to be significantly reduced (100 -200 lb per ac. the first growing season following a wildfire) and recover slowly under below average precipitation regimes.

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 codominant 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 what is NOT expected in the reference state for the ecological site:

Cheatgrass is the greatest threat to dominate this site after disturbance (primarily wildfires but disturbances also include high levels of natural herbivory and/or extended drought). Exotic mustards and Russian thistle may dominate soon after disturbance but are eventually replaced as dominants by cheatgrass. Hoary cress, Russian knapweed, bur buttercup and tall whitetop may meet the definition of an invasive species for this site in the future, but do not currently meet the criteria of being a threat to dominate the site after the disturbance.

17. Perennial plant reproductive capability:

Only limitations to reproductive capability are weather-related and natural disease or herbivory that reduces reproductive capability.

Evaluation Sheet (front)

Aerial photo ____

Management unit ____________ State _____ Office __________ Range/ecol. site code ____________
(Allotment or pasture)

Ecological site name ______________ Soil map unit/component name ____________________

Observers ____ Date ____________

Location (description) ______________________________________

T. _____ R. _____ or ___________N. lat. or UTM E ___________m Position by GPS? Y / N
UTM zone _____ Datum _____
Sec. _____, ______ ___________W. long. or N ___________m Photos taken? Y / N

Size of evaluation area ______________________________________

Composition (indicators 10 and 12) based on: ☐ Annual production ☐ Cover produced during current year or ☐ Biomass

Soil/ site verification:

Range/ecol. site descr., soil surv., and /or ecol.ref. area:
Surface texture__________________
Depth: ☐ very shallow ☐ shallow ☐ moderate ☐ deep
Type and depth of diagnostic horizons:
1. ____________ 3. ____________
2. ____________ 4. ____________
Surf. efferv.:
☐ none ☐ v. slight ☐ slight ☐ strong ☐ violent
Parent material ______Slope _____ % Elevation _____ ft.
Average annual precipation _____ inches

Evaluation area:
Surface texture__________________
Depth: ☐ very shallow ☐ shallow ☐ moderate ☐ deep
Type and depth of diagnostic horizons:
1. ____________ 3. ____________
2. ____________ 4. ____________
Surf. efferv.:
☐ none ☐ v. slight ☐ slight ☐ strong ☐ violent
Topographic position __________ Aspect ______
Seasonal distribution ________________

Recent weather (last 2 years) ☐ (1) drought ☐ (2) normal ☐ (3) wet

Wildlife use, livestock use (intensity and season of allotted use), and recent disturbances:
____
____
____
____
____

Off-site influences on evaluation area:
____
____
____
____
____

Criteria used to select this particular evaluation area as REPRESENTATIVE (specific info. and factors considered; degree of “representiveness”)
____
____
____
____
____

Other remarks (contiune on back if necessary):
____
____
____
____
____

Reference: (1) Reference sheet: __________ Author ____________________ Creation date ________
or (2) other (e.g., name and date of ecological site description; locations of ecological reference area(s) ____________
____

Evaluation Sheet (back)

Departure from expected	Code	Instructions for evaluation sheet, page 2
None to Slight	N-S	(1) Assign 17 indicator ratings. If indicator not present, rate None to Slight.
Slight to Moderate	S-M	(2) In the three grids below, write the indicator number in the appropriate column for each indicator that is applicable to the attribute.
Moderate	M	(3) Assign over rating for each attribute based on preponderance of evidence.
Moderate to Extreme	M-E	(4) Justify 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. Bar ground _______%	S H	
5. Gullies	S H	
6. Wind-scoured, blowouts, and/or deposition areas	S	
7. Litter movement	S	
8. Soil surface resistance to erosion	S H B	
9. Soil surface loss or degradation	S H B	
10. Plant community composition and distribution relative to infiltration	H	
11. Compaction layer	S H B	
12. Functional/structional groups	B	
13. Plant mortality/decadence	B	
14. Litter amount	H B	
15. Annual production	B	
16. Invasive plants	B	
17. Reproductive capability of perennial plants	B	

E-T	M-E	M	S-M	N-S

Attribute rating justification
Soil & Site Stability:______

S (10 indicators):
Soil & Site Stability
rating:______________

E-T	M-E	M	S-M	N-S

Attribute rating justification
Hydrologic Function:

H (10 indicators):
Hydrologic Function
Rating:______________

E-T	M-E	M	S-M	N-S

Attribute rating justification
Biotic Integrity:

B (9 indicators):
Biotic Integrity
rating:______________

Evaluation Sheet (front)

Aerial photo ______

Management unit *Allotment 1, pasture 1* (Allotment or pasture) State *NM* Office *Las Cruces* Range/ecol. site code *042XB999NM*

Ecological site name *Limy* Soil map unit/component name *Nickel gravelly fine sandy loam*

Observers *Joe Smith, Jose Garcia, and Thaddeus Jones* Date *June 10, 2002*

Location (description) *Limy site two miles north of windmill in S.E. pasture*

T. *11S* R. *23W* or ______N. lat. or UTM E ______m Position by GPS? Y / (N)
UTM zone ____ Datum _____
Sec. *12* , *NE 1/4* ______W. long. or N ______m Photos taken? (Y) / N

Size of evaluation area *Evaluation area is approximately 3 acres and represents entire ecological site in this pasture*

Composition (indicators 10 and 12) based on: ☐ Annual production ☑ Cover produced during current year or ☐ Biomass

---

Soil/ site verification:

Range/ecol. site descr., soil surv., and /or ecol.ref. area:
Surface texture *grfsl, grlfs, gl*
Depth: ☐ very shallow ☐ shallow ☐ moderate ☑ deep
Type and depth of diagnostic horizons:
1. *Calcic horizon w/in 20"* 3. ______
2. ______ 4. ______
Surf. efferv.:
☐ none ☐ v. slight ☐ slight ☑ strong ☐ violent
Parent material *Alluv* Slope *0-5* % Elevation *4,100* ft.
Average annual precipation *8-12* inches

Evaluation area:
Surface texture *gfsl*
Depth: ☐ very shallow ☐ shallow ☐ moderate ☑ deep
Type and depth of diagnostic horizons:
1. *Calcic horizon at 15"* 3. ______
2. ______ 4. ______
Surf. efferv.:
☐ none ☐ v. slight ☐ slight ☑ strong ☐ violent
Topographic position *Toeslope* Aspect *South*
Seasonal distribution *Summer thunderstorms dominate*

Recent weather (last 2 years) ☐ (1) drought ☑ (2) normal ☐ (3) wet

Wildlife use, livestock use (intensity and season of allotted use), and recent disturbances:
Wildlife use is dominated by pronghorn antelope in the winter. Livestock use was extremely heavy year long during 1900-1930.
Last 50 years livestock use has been cow/calf moderate year long use.

Off-site influences on evaluation area:
None

Criteria used to select this particular evaluation area as REPRESENTATIVE (specific info. and factors considered; degree of "representiveness")
Area is located near a pasture key area. It is located in the center of the ecological site and represents the typical amount of livestock, wildlife, and recreational uses on this area. This ecological site dominates this pasture. The area is 3/4 of mile from the closest water source.

Other remarks (contiune on back if necessary):

Reference: (1) Reference sheet: *Limy SD-42B* Author *J. Christensen* Creation date *3-23-2002*
or (2) other (e.g., name and date of ecological site description; locations of ecological reference area(s) *Limy ecological site 042XB999NM, June 2001*

Evaluation Sheet (back)

Departure from expected	Code	Instructions for evaluation sheet, page 2
None to Slight	N-S	(1) Assign 17 indicator ratings. If indicator not present, rate None to Slight.
Slight to Moderate	S-M	(2) In the three grids below, write the indicator number in the appropriate column for each indicator that is applicable to the attribute.
Moderate	M	(3) Assign over rating for each attribute based on preponderance of evidence.
Moderate to Extreme	M-E	(4) Justify each attribute rating in writing.
Extreme to Total	E-T	

Indicator	Rating	Comments
1. Rills	S H *M*	*Active rill formation evident at infrequent intervals*
2. Water-flow patterns	S H *M-E*	*Flow patterns show cutting and deposition and some connectivity*
3. Pedestals and/or terracettes	S H *S-M*	*Pedestalling in flow patterns only not common*
4. Bar ground _______%	S H *M*	*Bare ground rarely connected*
5. Gullies	S H *N-S*	
6. Wind-scoured, blowouts, and/or deposition areas	S *N-S*	
7. Litter movement	S *M*	*Small litter shows sign of moderate movement, larger litter - slight movement*
8. Soil surface resistance to erosion	S H B *M-E*	*Stability values average from 3-4 on surfaces under vegetation canopy and 1-2 in interspaces*
9. Soil surface loss or degradation	S H B *M*	*Severe past erosion has left much of the site without much surface horizon*
10. Plant community composition and distribution relative to infiltration	H *M-E*	*Change from grass dominated to shrub dominated has decreased infiltration and bare ground has increased run-off*
11. Compaction layer	S H B *N-S*	
12. Functional/structional groups	B *M*	*Subdominate group basically gone (warm-season stoloniferous grass and subdominate group (warm-season narrow leaf bunchgrass) and minor group (evergreen subshrub) have*
13. Plant mortality/decadence	B *S-M*	
14. Litter amount	H B *M-E*	*Very little litter is on the site from the time of year and rainfall for the year*
15. Annual production	B *S-M*	*Production is about 70 % of expected*
16. Invasive plants	B *N-S*	
17. Reproductive capability of perennial plants	B *S-M*	*Plants show some signs of stress that will reduce seed production and stolon production this year*

E-T	M-E	M	S-M	N-S
		9		
		7		*11*
	8	*4*		*6*
	2	*1*	*3*	*5*

Attribute rating justification
Soil & Site Stability:
Although there is some active erosion in flow patterns, most is old and healing. Lots of water leaving the site, but not much erosion. All erosion occurring as concentrated flow.

S (10 indicators):
Soil & Site Stability
rating: *M*

E-T	M-E	M	S-M	N-S
	14			
	10	*9*		
	8	*4*		*11*
	2	*1*	*3*	*5*

Attribute rating justification
Hydrologic function:
Lots of water leaving the site. Runoff is increasing and all litter is being washed away.

H (10 indicators):
Hydrologic Function
Rating: *M-E*

E-T	M-E	M	S-M	N-S
			17	
	14	*12*	*15*	*16*
	8	*9*	*13*	*11*

Attribute rating justification
Biotic Integrity:
Shift in functional structural groups is significant, justifying moderate rating.

B (9 indicators):
Biotic Integrity
rating: *M*

Evaluation Matrix

State __________ **Office**____________________ **Ecological site**___________________________________**Site ID**_________________

Authors ____ **Revision date**____________________

Departure from Reference State of the Ecological Site

Indicator*	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
1. Rills					Reference Sheet:_____
Generic descriptor	Rill formation is severe and well defined throughout most of the site	Rill formation is moderately active and well defined throughout most of the site	Active rill formation is slight at infrequent intervals; mostly in exposed areas	No recent formation of rills; old rills have blunted or muted features	Current or past formation of rills as expected for the site
2. Water flow patterns					Reference Sheet:_____
Generic descriptor	Water flow patterns extensive and numerous; unstable with active erosion; usually connected	Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected	Number and length of water flow patterns nearly match what is expected for the site; erosion is minor with some instability and deposition	Number and length of water flow patterns match what is expected for the site; some evidence of minor erosion. flow patterns are stable and short	Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion
3. Pedestals and/or terracettes					Reference Sheet:_____
Generic descriptor	Abundant active pedestalling and numerous terracettes. Many rocks and plants are pedestaled; exposed plant roots are common	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed roots	Slight active pedestalling; most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in water flow patterns on exposed slopes	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes absent or uncommon

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

Evaluation Matrix cont.

Departure from Reference State of the Ecological Site

Indicator*	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
4. Bare ground					Reference Sheet:_____
Generic descriptor	Much higher than expected for the site. Bare areas are large and generally connected	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected	Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected	Amount and size of bare areas match that expected for the site
8. Gullies					Reference Sheet:_____
Generic descriptor	Common with indications active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active	Moderate in number to common with indications of active erosion; vegetation is inermittent on slopes an/or bed. Headcuts are active; downcutting is not apparent	Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or be. Occasional headcuts may be present	Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion	Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion
6. Wind scoured, blowout, and/or depositional areas					Reference Sheet:_____
Generic descriptor	Extensive	Common	Occasionally present	Infrequent and few	Match what is expected for the site

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

Evaluation Matrix cont.

Departure from Reference State of the Ecological Site

Indicator*	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
7. Litter movement (wind or water) ______	______	______	______	______	Reference Sheet:______
Generic descriptor	Extreme; concentrated around obstructions. Most size classes of litter have been displaced	Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced	Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions	Slightly to moderately more than expected for the site with only small size classes of litter being displaced	Matches that expected for the site with a fairly uniform distribution of litter
8. Soil surface resistance to erosion	______	______	______	______	Reference Sheet:______
Generic descriptor	Extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent	Significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches	Significantly reduced in at least half of the plant canopy interspaces, or moderately reduced throughout the site	Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected	Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or a biological crust
9. Soil surface loss of degradation	______	______	______	______	Reference Sheet:______
Generic descriptor	Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content	Soil loss or degradation severe throughout site. Minimal differences in soil organic matter content and structure of surface and subsurface layers	Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter content is significantly reduced	Some soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces	Soil surface horizon intact. Soil structure and organic matter content match that expected for site

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

Evaluation Matrix cont.

Indicator*	Departure from Reference State of the Ecological Site: Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
10. Plant community composition and distribution relative to infiltration and runoff ___	___	___	___	___	Reference Sheet:_____
Generic descriptor	Infiltration is severely decreased due to adverse changes in plant community composition and/or distribution. Adverse plant cover changes have occurred	Infiltration is greatly decreased due to adverse changes in plant community composition and/or distribution. Detrimental plant cover changes have occurred	Infiltration is moderately reduced due to adverse changes in plant community composition and/or distribution. Plant cover changes negatively affect infiltration	Infiltration is slightly to moderately affected by minor changes in plant community composition and/or distribution. Plant cover changes have only a minor effect on infiltration	Infiltration and runoff are not affected by any changes in plant community composition and distribution. Any changes in infiltration and runoff can be attributed to other factors (e.g. compaction)
11. Compaction layer (below soil surface)___	___	___	___	___	Reference Sheet:_____
Generic descriptor	Extensive; severely restricts water movement and roof penetration	Widespread; greatly restricts water movement and root penetration	Moderately wide-spread, moderately restricts water movement and root penetration	Rarely present or is thin and weakly restrictive to water movement and root penetration	Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

Evaluation Matrix cont.

Indicator*	Departure from Reference State of the Ecological Site Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
12. Functional/ structural groups (F/S groups) see functional/structural groups worksheet					Reference Sheet:_____
Generic descriptor	Number of F/S groups greatly reduced and/or relative dominance of F/S groups has been dramatically altered and/or Number of species within F/S groups dramatically reduced	Number of F/S groups reduced and/or one dominant group and/or one or more sub-dominate group replaced by F/S groups not expected for the site and/or number of species within F/S groups significantly reduced	Number of F/S groups moderately reduced and/or one or more sub-dominant F/S groups replaced by F/S groups not expected for the site and/or number of species within F/S groups moderately reduced	Number of F/S groups slightly reduced and/or relative dominance of F/S groups has been modified from that expected for the site and/or number of species within F/S slightly reduced	F/S groups and number of species in each group closely match that expected for the site
13. Plant mortality Decadence					Reference Sheet:_____
Generic descriptor	Dead and/or decadent plants are common	Dead plants and/or decadent plants are somewhat common	Some dead and/or decadent plants are present	Slight plant mortality and/or decadence	Plant mortality and decadence match that expected for the site
14. Litter amount					Reference Sheet:_____
Generic descriptor	Largely absent or dominant relative to site potential and weather	Greatly reduced or increased relative to site potential and weather	Moderately more or less relative to site potential and weather	Slightly more or less relative to site potential and weather	Amount is what is expected for the potential and weather

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

Evaluation Matrix cont.

Departure from Reference State of the Ecological Site

Indicator*	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
15. Annual production					Reference Sheet:______
Generic descriptor	Less than 20% of potential production for the site based on recent weather	20-40% of potential production for the site based on recent weather	40-60% of potential production for the site based on recent weather	60-80% of potential production for the site based on recent weather	Exceeds 80% of potential production for the site based on recent weather
16. Invasive plants					Reference Sheet:______
Generic descriptor	Dominate the site	Common throughout the site	Scattered throughout the site	Present primarily in disturbed areas within the site	If present, composition of invasive species, matches that expected for the site
17. Reproductive Capability of Perennial plants (native or seeded					Reference Sheet:______
Generic descriptor	Capability to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is moderately reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is slightly reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is not reduced relative to recent climatic conditions

* Descriptions for each indicator should be more specific than those listed in the generic descriptors, if possible, and refer to the criteria included in the none to slight description, which is based on the reference sheet (app. 1).

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 5 Management of Grazing Lands

Chapter 5 Management of Grazing Lands

This chapter primarily contains guidance for planning grazing management on the various kinds of grazing lands. The chapter is divided into three major sections. Section 1, Managing Native Grazing Lands, gives guidance on managing rangelands, grazed forest lands, and native and naturalized pasture. Section 2 is Managing Forage Crops and Pasturelands. Section 3, Procedures and Worksheets for Planning Grazing Management, is procedures and worksheets for forage inventory, livestock inventory and forage balance, determining forage composition and value ratings, stocking rate and forage value rating, and prescribed grazing schedule.

Chapter 5 Management of Grazing Lands

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Chapter 5 Management of Grazing Lands

Section 1 Managing Native Grazing Lands

Chapter 5 Management of Grazing Lands

Section 1 Managing Native Grazing Lands

Contents:

Example

The management of plant communities depends on an understanding of the ecological processes and the ecology of the communities to managed. Some processes of change are so universal as to be considered general ecological principles. Others may be less widely applicable (regional) and more closely related to particular communities or individual characteristics of a species.

600.0500 Managing rangelands

(a) Dynamics of ecological sites

The natural plant communities for an ecological site are dynamic. They respond to changes in 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; others may be long lasting. Changes may cross a threshold and cause a permanent change in the ecological site potential.

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 when grazed by livestock or wildlife. Most plants are sensitive to stress during some stage of growth. They may be severely affected by improper use or stress during critical growth periods, but tolerant at other times.

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 the plant next to it thrives following a fire. The same weather conditions may be favorable for the growth of one species in a plant community while unfavorable for another species in the same community. A growing season in which frequent light rainfall occurs may be ideal for some species. Other species may depend upon deep soil moisture, making frequent light rainfall ineffective for that species even though the total rainfall may be above average. Thus many complex factors contribute to changes in the composition, function, and trend of plant communities. Not all changes are related to grazing by livestock. Many changes may be caused by climatic fluctuations, fire, and extreme episodic events.

To develop alternatives with the decisionmaker for management of rangeland, NRCS employees must understand how an ecological site or association of sites responds to disturbance or other treatment. It is necessary to identify the ecological site and understand the description for that site. The ecological site description has the information necessary to interpret the findings of inventories to determine the rating of an ecological site.

(b) Establishing management objectives

Management objectives are developed and determined with the landowner during the planning process. All inventory and other necessary information for the development of objectives and the application of the grazing management are gathered during the planning process. The objectives of the landowner and those of the NRCS do not need to be the same, but they must be compatible. The management objective must meet the needs of the landowner, the resources, and the grazing animals.

(c) Determining treatment alternatives

For most management units, there are several management alternatives. These alternatives must provide the kind of plant community that provides for and maintains a healthy ecosystem, meets resource quality criteria in the local field office technical guide, produces adequate, available amounts of quality forage for the grazing animals, and meets the needs of the grazing land enterprise(s) and the desires of the landowner. The plant community that meets these criteria is the desired plant community.

After the cooperator has set goals for the site based upon the intended use, the NRCS conservationist provides information and analysis to assist the cooperator in selecting the appropriate plant community to meet these goals. This plant community becomes the desired plant community (DPC). The trend is determined (see chapter 4), and the appropriate plans are made by the cooperator to either maintain the existing plant community (if it is the DPC) or plan the appropriate transition from the present plant community to the desired plant community. This decision sets the stage for the selection of the appropriate conservation practices and resource management systems for the cooperator's conservation plan.

The NRCS conservationist will use information from the ecological site description, trend determinations, similarity index determinations, rangeland health determinations, and other information to assist the land manager. This assistance will provide alternatives that would most likely lead toward the desired plant community.

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 the desired plant community that meets the land manager's goals and the resource needs.
- Determine what changes may be occurring (determine trend).
- Compute similarity index of present community to the desired plant community.
- Determine how the ecological processes of the site are functioning (rangeland health determinations).
- Determine what conservation practice alternatives and resulting resource management system will achieve or maintain the desired plant community.
- Provide followup assistance to land manager in plan implementation.
- Provide assistance to monitor trend.

Conservation practices applied on grazing lands are grouped into three categories to reflect their major purposes: vegetation management, facilitating, and accelerating practices.

Vegetation management practices—Practices that are directly concerned with the use and growth of the vegetation. Example are prescribed grazing and prescribed burning.

Facilitating practices—Practices that facilitate the application of the vegetation management practices. Examples are water development, stock trails, fencing, and prescribed burning.

Accelerating practices—Practices that supplement vegetation management. These practices help to achieve desired changes in the plant community more rapidly than is possible through prescribed grazing management alone. In some instances, the practices may be required to achieve desired change. Examples are brush management, range planting, and prescribed burning.

This list of conservation practices is not complete. Definitions and standards for each conservation practice are provided in the National Handbook of Conservation Practices. The local Field Office Technical Guide provides detailed information applicable to the conservation practices discussed, and others available to be considered in development of alternatives with the landowner.

(d) Planning grazing management

The Natural Resources Conservation Service provides assistance to cooperators who wish to apply grazing management. The primary conservation practice used is prescribed grazing. Prescribed 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. This practice has been developed to incorporate all the methods and concepts of grazing management. Prescribed grazing is the controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective.

The objectives developed with the landowner during the planning process determines the level of planning and detail necessary for the application of prescribed grazing. The minimum level of planning for the prescribed grazing practice includes enough inventory information for the landowner to know the proper amount of harvest to maintain enough cover to protect the soil and maintain or improve the quality and quantity of desired vegetation. The available forage and the number of grazing and browsing animals must be in balance for effective management of grazing lands. This is done by developing a feed, forage, livestock 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 3 of this chapter (exhibits 5–1, 5–2, 5–3, 5–4, 5–5, and 5–6).

Grazing is one of the major forces in defining what plant species will dominate a site. Different grazing pressures by different grazing and browsing animals favor different plant species. If the grazing is severe, undesirable plants are generally favored.

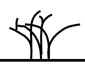
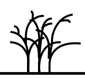
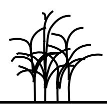
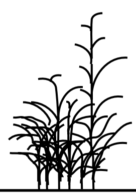
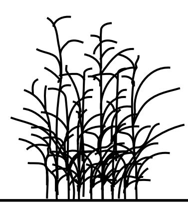
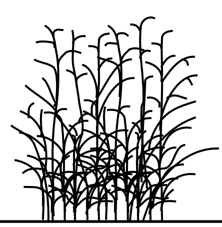
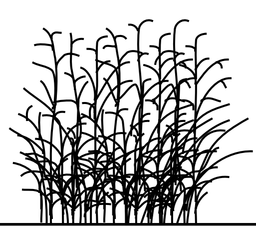
Grazing management can be planned and applied that favors a particular plant community or species. This can be done to meet the objectives of the landowner and the needs of the resource. Grazing management has been successfully planned and applied that has favored the re-establishment and increase in woody plants along riparian areas while still providing quality forage for the grazing animal.

Alleviation of grazing pressures that have induced composition changes in a community does not immediately and by itself terminate or reverse the change that such pressures induced. Many plants, desirable and undesirable to grazing, are long lived. If increase of undesirables is related to only the suppression of the desirable species, a change in grazing pressure and management sometimes permits 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. Although plants of the original community are invigorated by the reduction of grazing pressure and may suppress the successor species, the seedlings of the original species can become established in competition with the undesirable species only under favorable conditions.

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 axillary buds to initiate new tillers. 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 5–1 illustrates the relationship between grazing and root growth. Healthy plant roots are essential for soil stability and erosion control, especially in riparian systems.

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 meet the needs of the land, based on the NRCS Field Office Technical Guide quality criteria, the landowner, and the livestock. Meeting these needs is essential to the success of all grazing management.

Figure 5–1 Relationship between grazing and root growth (Crider 1955)

	Top reduction	**Single clipping**
	90%	No root growth for 17 days. 60 percent of root growth on 33rd day.
	80%	No root growth for 12 days. 96 percent of root growth on 33rd day.
	70%	Approximately 48 percent of root growth after 17 days. 159 percent root growth on 33rd day.
	60%	Approximately 55 percent of root growth after 5 days. 192 percent root growth on 33rd day.
	50%	Averaged a 3 percent root growth stoppage for 14 days. 223 percent root growth on 33rd day.
	30%	117 percent root growth on 3rd day. 250 percent root growth on 33rd day.
	0%	129 percent root growth on 3rd day. 338 percent root growth on 33rd day.

(1) Key grazing areas and key species

The grazing enclosure is the management unit for grazing land. Every 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 (frequency and severity 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 enclosures of a farm or ranch. Determining the key grazing area(s) in each enclosure 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 is properly grazed, the unit as a whole will not be 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.

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, to attempt to attain 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 entire plant community will not be excessively used.

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 areas remote from water or of limited accessibility. However, 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. From the landowner's perspective, properly managed riparian areas will be key in retaining flexibility and control of the property. Table 5–1 is an example of how and when to consider using a riparian area as a key grazing area.
- Generally consists of a single ecological site or part thereof.
- Areas of special concern can also be designated as key areas. Areas of special concern could include habitat for threatened or endangered species, cultural or archeological resources, water quality impaired waterbodies, and critically eroding areas.
- Is usually limited to one per grazing enclosure. More than one key grazing area may be needed for an unusually large enclosure, enclosures with riparian areas, enclosures that have very rough topography or widely spaced water where animals tend to locate, when different kinds of animals graze the enclosure, or when the enclosure is grazed at different seasons. The entire acreage of small enclosures can be considered the key grazing area.

Key grazing areas should be

- Selected only after careful evaluation of the current pattern of grazing use in the enclosure.
- Selected to meet the objectives and needs of the resources, livestock, and landowner. Objectives and needs must meet the FOTG quality criteria.
- Changed when the pattern of grazing use is significantly modified because of changes in season of use, kinds or classes of grazing animals, enclosure size, water supplies, or other factors that affect grazing distribution.

Characteristics of key species:

- 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; e.g., riparian areas.)

- 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 or if it is critical to the needs of grazing animals. A species producing less than 15 percent of the forage may also be selected if necessary to meet the FOTG quality criteria, the needs of the resource, or the landowner's objective. 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 reduction in the stocking rate, and additional measures may be needed to hasten 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 climax state, the key species should be one that is a major component of the historic climax plant community.
- 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.

Key species should be selected only after the decisionmaker

- Chooses the key grazing area and evaluates the present plant community.

Table 5–1 Decision support for consideration of riparian areas as key grazing area*

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.

* Select column based on preponderance of characteristics or a critical characteristic as determined by landowner.

- Determines the kind of plant community that will be the goal of management.
- Gives due consideration to kinds and classes of grazing animals and the season of use.
- Thoroughly evaluates the factors affecting grazing distribution. If only one species of animal grazes the unit, a single plant species generally will suffice as the key species.

(2) 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 decisionmaker. The trend, similarity index, and/or rangeland health of the rangeland ecological site are the major concern. 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 merely a planning tool and guideline or reference point by which the welfare 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 native plant 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 native 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 subject.
- If a grazing unit is grazed mainly during the dormant season, use may be significantly greater than during the growing season.
- The planned or allowable degree of use for browse species differs from grass species. The degree of use applies 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 annual twig growth only.
- A significantly greater percentage of annual growth can be safely removed from many native plants if grazing units are grazed at a 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 and key grazing areas need to be changed when the grazing season and grazing periods are altered within the grazing prescription.
- 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 to be 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 the use on annual ranges of the Mediterranean-type climatic zone can be expressed in pounds of current growth left as residue.
- For certain perennial plant communities, the appropriate degree of use can also be expressed in pounds per acre of annual growth 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 to the functioning of the plant within its community. During an unfavorable growing season, a weakened plant may be severely damaged by use that would not adversely affect it during a normal or favorable growing season. Under the conditions listed the residue procedure can be fairly easily 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. Until a workable procedure is developed, grazing use specifications are to indicate the percentage of annual growth that can be removed from the key plant species in key grazing areas.
- Monitoring Percent Use of Grazing Species form (exhibit 4–3 in chapter 4) 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 chapter 4, 600.0401(e).

(e) Degree of grazing use as related to stocking rates

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 attainment of a specific degree of use. If the specified degree of use is to be attained and trend satisfactorily maintained, stocking rates must be adjusted as the amount of available forage fluctuates.

When determining initial stocking rates, grazing distribution characteristics of the individual grazing unit must be considered. For example, a Stony Hills Range Site that has steep areas adjacent to a relatively level Loamy Upland Range Site generally receives less grazing use by cattle than the Loamy Upland Range Site. The Stony Hills Range Site may produce enough forage to permit a stocking rate of 2 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.

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. The Multi Species Stocking Calculator in the Grazing Lands Application (GLA) software is one method for determining stocking rates, especially when the area is grazed or browsed by more than one kind of animal. See also Stocking Rate and Forage Value Rating Worksheet in chapter 5, section 3, (exhibit 5–3).

(f) Prescribed grazing schedule

A prescribed grazing schedule is a system in which two or more grazing units are alternately deferred or rested and grazed in a planned sequence over a period of years. 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 function. Grazing management is a tool to balance the capture of energy by the plants, the harvest of that energy by animals, and the conversion of that energy into a product that is marketable. 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 on all grazing units.
- Improve efficiency of grazing through uniform use of all 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.

Many grazing systems are used in various places. Prescribed grazing is designed to fit the individual operating unit and to meet the operator's objectives and the practice specifications. Exhibit 5–6, Prescribed Grazing Schedule Worksheet (chapter 5, section 3) may be used in conservation planning. Other formats that contain the necessary information may also be used. The basic types of grazing management systems follow. Many others can be developed to fit specific objectives on specific lands.

- Deferred rotation
- Rest rotation
- High intensity—Low frequency
- Short duration

(1) Deferred rotation grazing

Deferred rotation grazing generally consists of multi-pasture, multiherd systems designed to maintain or improve forage productivity. Stock density is moderate, and the length of the grazing period is longer than the deferment period. An example of a deferred grazing system would be the four pasture, three herd Mer-rill 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 4 months. In this way the same grazing unit is not grazed the same time each year. This type of system will repeat itself every 4 years. Figure 5–2 is a conceptual model of a deferred rotation system.

Figure 5–2 Deferred rotation system model

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

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 5–2 assumes equal size (in terms of forage supply) for the four grazing units in the system.

(2) Rest rotation grazing

Rest rotation grazing consists of either multipasture - multiherd or multipasture - single herd systems. Grazing units are rested or deferred: (1) to restore plant vigor, (2) to allow for seed development and ripening, and (3) to 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 5–3 is a model of one example of five grazing treatments in which growing season begins 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 part of growing season to further enhance seedling establishment and then the unit is grazed the remainder of the growing season.

Figure 5–3 Rest rotation system model

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									

Figure 5–3 Rest rotation system model—Continued

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									

(3) High intensity – low frequency grazing

High intensity - low frequency (HILF) systems are multipasture - single herd systems. Stock density is high to extremely high. 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 5–4 is a conceptual 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 5–4 HILF grazing system model

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			

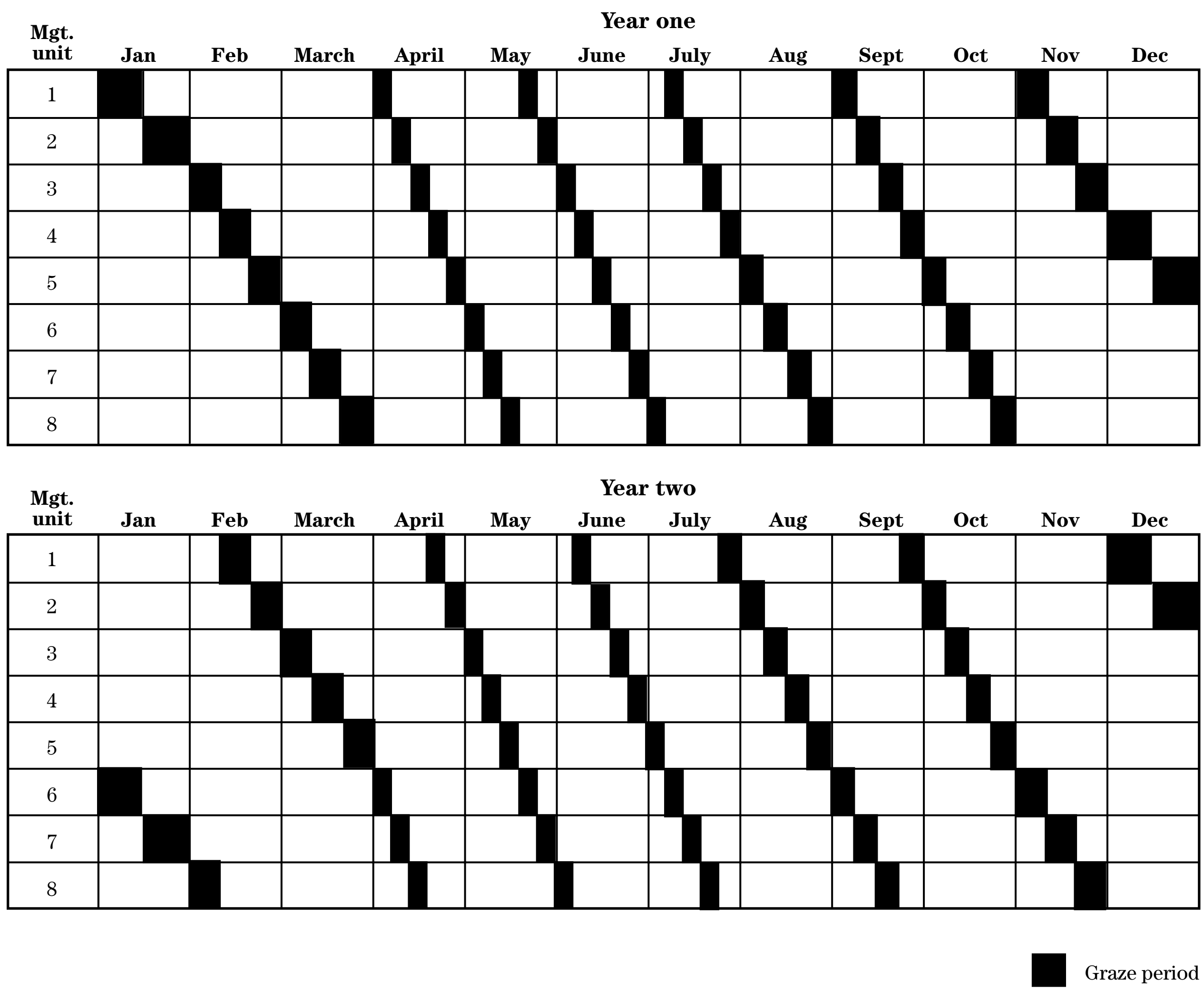
(4) Short duration grazing

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. Utilization, therefore, is less during any given grazing period. Stock densities are high. Figure 5–5 is a conceptual model of a short duration grazing system.

In the short duration model, the pattern may never repeat itself. 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.

In many parts of the United States, livestock cannot be grazing on the land the entire year. Where snow or other related conditions prevent yearlong grazing, the concepts of the grazing systems still apply. Figure 5–6 is an example of a deferred rotation grazing scheme where the livestock can only be on the grazing land from April through October.

Figure 5–5 Short duration grazing system model



Conservation planning and application on grazing lands are detailed in chapter 11. How each type of grazing management system works and the advantages and disadvantages of each type must be understood. A landowner 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 is increased. All of these factors must be discussed with and understood by the landowner.

Figure 5–6 Deferred 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						

600.0501 Managing grazed forest lands

(a) Principles of forest grazing

Managing a forest to produce forage for livestock, desired wildlife habitat, quality water, quality fisheries, timber production, and many other desired forest products requires an understanding of the forest ecosystem and how it responds to the manager's decisions.

Some forest ecosystems managed for timber production have limited capabilities for livestock grazing. Livestock grazing can cause detrimental effects, such as reduced regeneration of desired woody species, adverse soil compaction, or soil erosion on steep, highly erodible sites. A decision must be made to determine if the forest ecosystem will support livestock grazing that is designed and managed to meet the needs of the cooperator and the forest ecosystem. Many forests can be grazed where grazing management is designed to meet the needs of the soil, water, air, plants, and animals.

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. This causes a filtering or reduction of solar energy as it penetrates to the next layer of vegetation, whether it is a 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 production is, in a large part, accomplished by managing the plant populations in the different stories (overstory, midstory, and understory) to provide the most efficient use of solar energy by the desired plants. Managing forest for forage and timber production requires the Timber Management Plan and the Prescribed Grazing Plan be coordinated to produce the desired effects on the plant community and all of the ecological components.

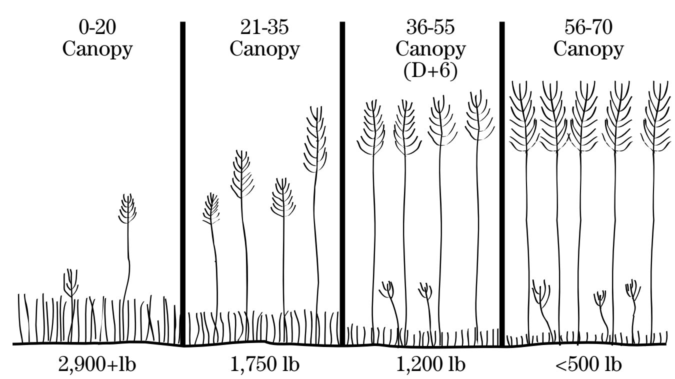
(b) Management of the overstory

The ecological site descriptions for forest land are in Section II of the Field Office Technical Guide (FOTG). They provide information for each forest land ecological site in the field office area. Each forest land ecological site contains a description of the overstory canopy 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.

As canopy closes from totally open to totally closed (fig. 5–7, a southeast forest site), the understory species almost completely change from warm-season to cool-season plants. Forage production will be reduced significantly as a result of the species composition change and the near elimination of sunlight penetration to the ground level.

Management of the overstory canopy with timber management practices is essential to the desired production of forage and understory species. The midcanopy densities (21 to 35 and 36 to 55 percent) produce a mixture of the warm- and cool-season plants and in many instances can be managed to maximize timber production.

Figure 5–7 Canopy classes in a southeast forest site



For example, in some southern pine forests the practice of periodic thinning on a 5- to 6-year rotation maintains the desired basal area and canopy of trees for maximum timber production. This canopy allows substantial forage production for livestock and for grazing and browsing wildlife (fig. 5–8) This periodic thinning is continued until the forest matures. At that time, the forest is clearcut and allowed to regenerate, or it is replanted to the desired tree species. The forage and browse production is excellent until the canopy of the regenerated or planted trees closes at about 10 years. Very little understory will be produced for about 5 years. At about the 15th year of the new forest, the first thinning cut will be made. This will again start the maintenance of the 35 to 55 percent overstory canopy that maximizes timber production and allows substantial understory forage production.

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 (fig. 5–9). Pulp wood rotations, where plantings are made and not thinned until they are fully harvested, are examples of this type management. Many privately owned forests are not managed because of a lack of understanding of timber management, grazing management, or other factors. This causes a canopy closure with the same results.

(c) Management of the midstory

Many forests develop a midstory canopy that can completely shade the ground level understory (fig. 5–10). 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 was closed. The understory species composition is changed to those that are shade tolerant, and forage production is reduced severely.

In this case, if understory production is desired, the manager must reduce the midstory. In many cases prescribed burning can be used to control the midstory species. In others forest improvement should be planned to manage the midstory to the desired canopy.

(d) Management of the understory

The understory is made up of grasses, forbs, legumes, sedges, vines, and shrubs. When the overstory and the midstory are managed to permit the desired amount of light to reach the forest floor, a plant community develops that is adapted and supported by the amount of light, water, and nutrients available on the site.

Figure 5–8 Forage production clearcut for natural regeneration with periodic thinning

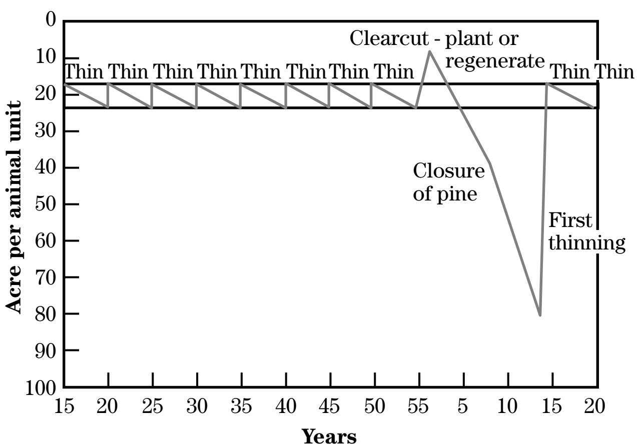
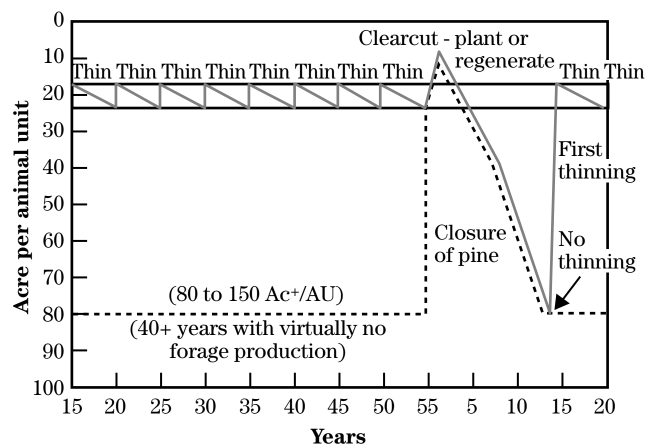


Figure 5–9 Forage production clearcut or natural regeneration with periodic thinning (compared to clearcut or natural regeneration with no thinning)



Livestock and wildlife grazing and browsing on this site select their preferred species. If they are stocked too heavily and for too long a time, they overgraze the desired species. These species are weakened and reduced in percentage composition, 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 (fig. 5–11 and 5–12).

To correct this grazing management problem, prescribed grazing must be applied along with the needed facilitating practices, such as firebreaks, fences, ponds, wells, pipelines, and troughs. Other practices, such as trails, walkways, and roads, may be needed. Range planting may be needed to provide a seed source of the desired species.

Each conservation plan must be tailored to meet the needs of the soil, water, air, plants and animals, as well as the needs and objectives of the landowner.

Figure 5–10 Forage production clearcut or natural regeneration with periodic thinning (effects of hardwood midstory)

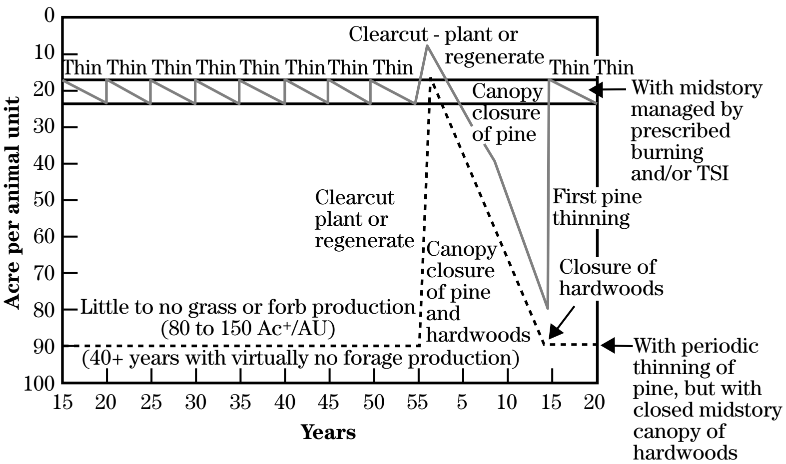


Figure 5–11 Plant community response to grazing management (36 to 55% canopy)

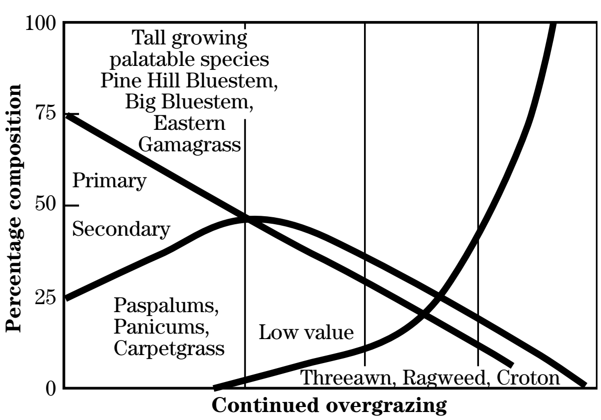


Figure 5–12 Forage production clearcut or natural regeneration with periodic thinning (very high forage value rating vs. low forage value rating)

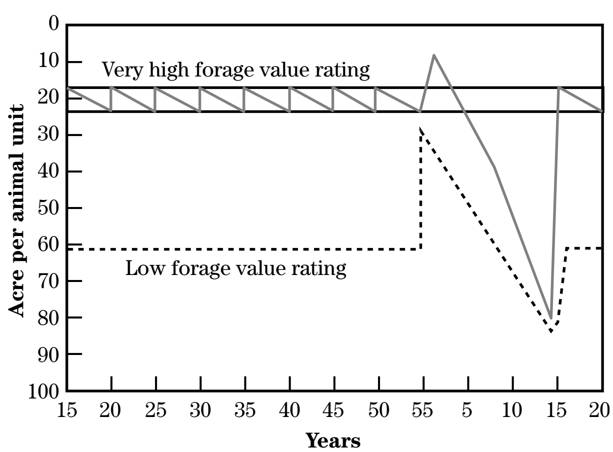
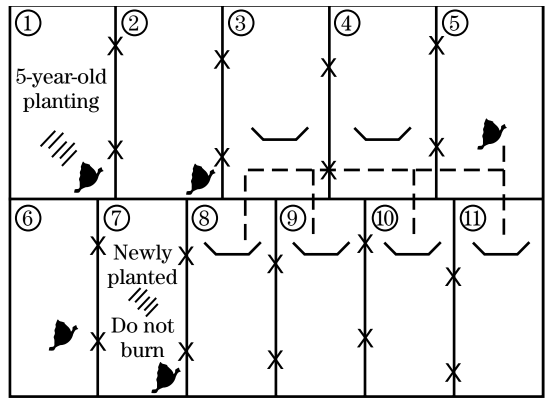


Figure 5–13 is an example of how a plan can be developed in a southern pine forest to meet the needs of a 50-year timber rotation, livestock production, and improved wildlife habitat. Example 5–1 describes a plan for southern pine forest.

Figure 5–13 Clearcut or natural regeneration using a 55-year cutting cycle



Every 5th year thin all pastures as needed; in one pasture (1/11) clearcut and plant or harvest to seed trees.

Example 5–1 Plan for southern pine forest (refer to figure 5–13)

1. Divide into 11 equal units. Eleven units allow the 50-year production 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 timber and livestock and for harvesting timber, 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 timber each 5 years in all units except those recently planted. First thinning will be at year 15.
6. Clearcut and plant, or harvest to seed trees, one unit each 5 years. Rest new plantings as needed. Seed to native grasses, legumes and forbs if a seed source is needed for establishment. (Severely overgrazed 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 grazable units in a manner that meets the needs of the pine, forage plants, wildlife, and livestock.

(e) Western native forest lands

Many western forests have naturally open or savanna-like aspect with highly productive understory plant communities. Others naturally develop dense canopies that at maturity will eliminate nearly all understory vegetation.

Savanna forest land overstories are typically managed by selectively removing mature trees for lumber, on a periodic basis, while managing the understory community for wildlife habitat and forage.

Dense forest lands only develop significant understory vegetation after stand removing fire or clearcutting of the site occurs. During this open canopy period, forest reseeding or natural regeneration causes the community to transition back to dense forest. This transition period normally lasts from 10 to 20 years, and, while open, these areas can provide an important forage source for livestock and wildlife. Forest management generally adds new clearcuts to the landscape on a periodic basis while open forest lands transition back to closed canopies on a planned schedule. This ensures that a stable transitory forage resource is always available at some locations on the operation for wildlife and livestock use.

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.

(1) Managing grazed forest lands for multiple benefits

Many native forest lands in the Western United States produce multiple forest products including timber, grazing for wildlife and livestock, habitat for many species of wildlife, sustained summer streamflows, and pure water. Careful resource management is required to ensure that proper balance is achieved and that multiple resource values are sustained.

These 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.

A typical grazed forest land ecosystem in the Western United States would be a ponderosa pine, bitterbrush, Idaho fescue ecological site. This site typically is dominated by an overstory of ponderosa pine. Site indices (SI) can range from a low of less than 40 to more than 120. Wood products are harvested using uneven-aged management techniques. Mature and overmature trees are selectively removed from the stand on a scheduled basis. They are naturally replaced in the stand by younger trees that are released to grow more rapidly once the older competition is removed.

Fire played an important role in this community by periodically thinning out part of the younger trees while causing little damage to the older ones because of their insulated, fire resistant bark. This created an open, savanna-like aspect to the communities, 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 canopy.

Even though fire played an important role and is a natural part of these communities, people have aggressively removed fire, causing major changes in the structure and health of many of these forest communities. Dog-hair thickets of young ponderosa pine now occupy the middle canopy layer, effectively shading out the understory vegetation while creating the potential for catastrophic, stand removing crown fire.

Management of these communities requires a knowledge of both the forest resource and the understory grazing resource. Forest products, such as logs, fence posts, and firewood, can be harvested periodically while routinely harvesting the forage for the production of food and fiber.

The first step in managing the forest resource on a site is to complete an inventory of the various timber stands on a site and by determining the growth potential or 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 merchantable products as part of this thinning when feasible.
SI 80 to 100	Thin trees to a D+5 to D+8 spacing. Remove merchantable products as part of this thinning when feasible.
SI < 80	Thin trees to a D+6 to D+9 spacing. Remove merchantable products as part of this thinning when feasible.

For optimum grazing in these stands, add 1 or 2 feet to the spacing.

The D+ spacing is determined by measuring the diameter at breast height of each leave tree converting this number to feet and then adding the + factor to establish to total spacing for that individual tree for optimum growth. Select the next leave tree at the perimeter of this thinned area and repeat the process. As timber 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. Prescribed grazing is the National Conservation Practice Standard 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 must also consider existing and planned tree plantations to provide protection during periods when seedlings could be damaged by grazing animals.

(f) Inventorying grazed forest

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, often regardless of grazing use. Some such 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. Significant changes do result from grazing use, however, and the understory can often be extensively modified through the manipulation of grazing animals.

For these reasons the forage value rating of grazable forest is not an ecological evaluation of the understory. It is a utilitarian rating of the existing forage value of a specific tract of grazable 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.

(1) 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 (exhibit 5–4) in section 3 of this chapter.

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.

600.0502 Managing naturalized or native pasture

Naturalized pasture is land that was forest land in historic climax, but is being managed primarily for the production of forage rather than the production of wood products. It is managed for forage production 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.

Because naturalized pasture was forest in its natural state, it will naturally evolve back to a forest dominated plant community. For the site to be maintained as naturalized pasture, a form of brush management is normally planned to suppress the tree and shrub component of the site. Prescribed burning, mechanical, herbicides, or biological control need to be planned, designed, and applied to create the desired plant community to meet the resource criteria.

Prescribed grazing is planned to meet the needs of the plant community and the livestock and wildlife of concern. The grazing management principles applicable to grazed range and pasture are applicable to naturalized pasture. The prescribed grazing plan must address solving all of the resource problems and concerns identified in the inventory and problem identification process where either livestock or wildlife is a contributor to the cause of the problem.

Range planting may be needed to establish the desired plant community when a seed source of the desired species is not evident. Facilitating practices, such as firebreaks, fences, and livestock water development practices are planned as needed.

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. The Forest Ecological Site Description is 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.

Forage value ratings should be determined 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.

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600.0503 General

Efficient use of forage crop and pasture lands requires understanding two basic components of forage growth:

- Each forage's physiological and morphological attributes must be understood.
- How the forage responds to competing plants, climate, soil, machine harvest timing and frequency, human determined inputs, and grazing timing, duration, pressure, and frequency must be known.

Agronomic inputs into forage crop production and improved pastures are seeding mixtures used, selection of adapted cultivars resistant to local diseases or insects, fertilizer, pasture clipping, planting procedures used, soil amendments, pest control, drainage, irrigation, and other crops, if any, used in rotation with forage crop. Animal nutrition variables are off-farm feed supplements, producer production goals, and the kind, number, and class of livestock being fed.

The growth habit characteristics, soil chemical and physical preferences, and palatability characteristics among agronomic forage crops vary widely. This creates a myriad of shifts in plant species composition on forage crop and pasture lands even in so-called monoculture fields. Depending on which species is favored based on climatic and soil conditions and the management the forage stand receives, some species live on and others die out. The shift in forage species composition is swift even under the survival of the fittest scenario. However, a farmer with a plow or sprayer and a planter can cause one crop to disappear and another crop appear in a few days. The same producer can also cause radical changes for good or harm with a herd or flock of livestock.

All management decisions, whether they be agronomic, economic, or animal nutrition driven, must be done within the constraints imposed by the management unit ecosystem at any given moment. If the constraints are ignored, the improvement practice ultimately fails. No conservation or improvement practice should be applied without analyzing what drives the system.

On pastured lands, once climate and soil factors affecting forage growth and production are accounted for, the system is driven by the grazing management regime applied. If producers are unwilling to change their customary approach to grazing management, agronomic solutions to forage growth enhancement will only be as effective as that grazing management regime allows. If the forages are overgrazed, agronomic attempts to improve forage production are likely to fail, or the improvement is only marginal. The accompanying environmental problems resulting from the weakened plant community will be affected little as well.

On cropped (machine harvested) lands, once climate and soil factors affecting forage growth and production are accounted for, the system is driven by planting and harvesting regimes (by grazing animal or machine). If either is done poorly because of improper timing or technique, all the other agronomic inputs add more to the cost of production, but little to improved forage or livestock production. In the meantime environmental problems created by this mismanagement continue to mount.

600.0504 Managing improved pasture

Pasture is harvested principally by the grazing animal; therefore, it must be managed differently than hayland and cropland that are harvested primarily by machine. Seasonal availability or distribution of forage growth is vital to allocating enough feed to the grazing animal without wasting it or overgrazing it. A growing forage is a perishable commodity. As it matures, it lowers in value nutritionally. This is especially true after seed-head emergence on grasses or initial flowering of legumes and forbs.

Stored forages (roughages) are a more nutritionally stable commodity if stored properly. However, they generally are of lower nutritional value because they are harvested at a later stage of maturity than are the more timely grazed pastures. When an animal eats standing forage, there is no loss of leaves and no loss of vitamins and dry matter. The forage is directly ingested rather than curing in a field or barn or fermenting in a silo or forage bag, and they can select the choicest forage available. Therefore, pasture management must recognize that ups and downs occur in forage quality and quantity. Pasture must be stocked in concert with growth and availability of forages. If this is done, forage quality will be consistently near its optimum for the time of the year.

Pastured land also differs from cropland and hayland in the way plant material is removed. The grazing animal tends to graze from the top down, but it does this over a period of time. They take a bite, move on, take a bite off another area, and proceed across the pasture selecting what appeals to them. Depending on how much control the producer exerts, the livestock may have free rein to explore the whole management unit or a very small part of it. They may be able to return to the same spot continually throughout the grazing season or be allowed to return only within a few hours and then be off for several days or weeks. In any case, more residual material is always left behind than where forage crops are harvested mechanically unless heavily overstocked or stocked for prolonged periods.

After initial green-up pasture forages generally are less dependent on stored food reserves to continue growth than are machine harvested forages. They still have photosynthetic area to continue producing simple sugars that are synthesized into plant food. Machine harvested forages are dependent on food reserves and basal growing points or axillary buds held below the cutting bar to generate new growth. After machine harvest few or no green leaves are left to carry on photosynthetic activity.

The distribution of plant tissue removal is also quite variable on pasture unless severely overgrazed or rationed tightly under a multiple paddock system. The latter mimics machine harvest in uniformity of removal if managed well. With machine harvest all forage is removed from the management unit uniformly. This variation in plant removal by grazing results from a number of factors:

- Selectivity of the grazing animal
- Differences in palatability among the plant species present
- Differences in maturity and palatability as a result of the previous selective grazing
- Steepness of the terrain
- Presence of barriers that affect livestock movement or behavior
- Distance to water
- Distance to shade when present

Another way pastured lands differ from cropland and hayland is that nutrients are recycled within their boundaries. Most of the nutrients consumed are used to maintain the animal and are excreted. They may not be distributed evenly, but they are continually returned as long as the pasture is occupied by livestock. On hayland and cropland, all nutrients in the harvested crop leave the field. They may or may not be replaced by manure or fertilizer nutrients.

Nutrient removal from pasture as animal products is relatively low. A thousand pounds of milk removes only 6 pounds of nitrogen; 2 pounds each of phosphorus, potassium, and calcium; and negligible amounts of other minerals. A thousand pounds of beef removes 27 pounds of nitrogen, 8 pounds of phosphorus, 2 pounds of potassium, and 13 pounds of calcium. Even under the best conditions, 1,000 pounds of stocker beef is all that can be produced per acre per year. More commonly, gains per acre on good pasture can range from 250 pounds per acre to 750 pounds per acre. If the livestock are fed any supplemental feed or minerals at all while on pasture, no net loss occurs in fertility level and a gain in the less mobile nutrients can occur. High producing dairy cattle on pasture typically are fed stored forages and concentrates to balance their diet for optimum milk production. Import of nutrients from these supplements tend to match or exceed export of nutrients as milk production. See accelerating practice, nutrient management.

(a) Seasonal distribution of growth or availability of pasture

Pasture, in the broader sense of the word, occurs on all three land uses that make up forage crop and pasture lands. Therefore, when allocating standing forage to grazing livestock, more than just when the forage is growing and at what rate must be considered. Often the forage's growth curve does not dictate the forage's grazing availability, a management decision does. For example, forages can be stockpiled. They are allowed to grow and accumulate mass and then grazed at a later date even after the growing season has ended. Forages that retain their leaves and nutritional value are preferred for stockpiling.

Crop residue can also be grazed. Again, a seasonal growth curve is of no value in developing a livestock feed budget that uses crop residue. Instead, what is important is: When is it available? Cornstalk residue, for instance, becomes available after harvest and has a useful life of about 60 to 90 days before weathering or trampling diminishes its usefulness as a feedstuff (table 5–2). This is, of course, dependent on rainfall and temperature. Low rainfall coupled with very cold temperatures prolongs its nutritional quality. Decomposition is arrested or slowed, and no mud is available to be trampled onto the residue.

A basic tool needed to manage pasture and allocate it to livestock is the seasonal distribution of growth or availability table or family of curves that are developed for your climatic area. Three examples of seasonal distribution of growth or availability curves are shown for the Gulf Coast, Upper South, and Upper Midwest in figures 5–14, 5–15, and 5–16. Note change in species as latitude changes. Also note for a crop like alfalfa how the growing season length changes with latitude, short in the north and long in the south.

Seasonal distribution of growth or availability curves should not only be identified by species, but by growing season length as well. Other important factors are the beginning and end dates of the growing season and the distribution of rainfall and growing degree days during the growing season. Two areas of the country with the same growing season length can have different distribution of growth responses due to differences in rainfall patterns and how fast it warms up after the growing season begins. A mid-continent climate is slower to warm up than one along the Atlantic seacoast where the Gulf Stream can quickly warm the region. When the same growing season length region has different beginning and ending dates as it crosses the continent, changes in day length response also take place where long or short day plants are important forages. Long day plants tend to grow faster to make up for lost time where the growing season starts later in the spring. For all these reasons, it is best to use seasonal distribution of growth and availability curves developed in your region. Do not use distribution tables from regions that have greatly differing seasonal rainfall and cumulative growing degree day patterns.

Note in figures 5–14, 5–15, and 5–16 how the different forages are available for grazing during different parts of the year. Warm-season grasses, such as bermudagrass, bahiagrass, pearl millet, big bluestem, switchgrass, and sorghum/sudan, produce during warm weather. Cool-season grasses and legumes produce most of their growth in the cool weather of spring and fall. Cool-season winter annuals actually produce grazable forage in the Gulf Coast States and as far north as Maryland and Kansas during the winter months. Year-round grazing is possible over much of the United States using a combination of these forages by taking advantage of their different availability periods. Cool-season forages can be relied on during the early and late parts of the year. When they go dormant or grow slowly during the middle of the year, warm-season forages can be relied on to fill in the grazable forage gap.

Crop residue, such as cornstalks, can be grazed after the crop is harvested. The proportion of the acreage devoted to either warm- or cool-season forages, or an interseeding of warm- and cool-season forages, depends of the livestock demand fluctuations of the land unit being planned and the ratio of warm-to-cool weather of the climate in which the land unit is located. Crop residue can also be grazed where available and where perimeter fences exist around the management unit. Another alternative is to stockpile forages that keep their quality well and withhold from livestock until a livestock demand as the season progresses. This is typical of a stocker or cow-calf operation where animals are growing. As they gain, animal units mount up.

Table 5–2 Estimated monthly availability of forage for grazing [1/]

Type of pasture	Percentage available, by month							
	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Kentucky bluegrass-white clover, unimproved	25	30	10	5	10	10	5	—
Kentucky bluegrass-white clover + N, P	35	35	8	5	10	4	3	—
Renovated (continuous grazing)								
Birdsfoot trefoil-grass	10	25	25	20	10 [2/]	5 [2/]	5	—
Birdsfoot trefoil -grass, deferred for midsummer grazing	—	15	35	25	15 [2/]	5 [2/]	5	—
Tall grasses + N [3/]	30	30	10	5	10	10	5	—
Tall grasses + N, deferred for fall grazing [3/]	30	30	—	—	—	25	15	—
Renovated (rotational grazing)								
Alfalfa with smooth bromegrass or orchardgrass	20	25	25	15	5	5 [2/]	5 [2/]	—
Supplemental								
Sudangrass or sorghum-sudan hybrids	—	—	40	40	15	— [4/]	5	—
Sudangrass or sorghum-sudan hybrids, deferred for fall and winter grazing	—	—	—	—	—	100 [5/]		
Winter rye	50	20	—	—	5	15	10	—
Miscellaneous								
Meadow aftermath-following one cutting	—	20	30	25	5 [2/]	15 [2/]	5	—
Meadow aftermath-following one cutting, to be plowed	—	20	30	10	20	20	—	—
Meadow aftermath-following two cuttings	—	—	10	35	25 [2/]	25 [2/]	5	—
Meadow aftermath-following two cuttings, to be plowed	—	—	10	25	35	30	—	—
Cornstalks	—	—	—	—	—	100	—	—

1/ Source: Schaller (1967). Compiled originally by W.F. Wedin, Agronomy Department, Iowa State University.
2/ Allowances have been made for winter hardening of legume from about September 15 to October 15.
3/ Smooth bromegrass, orchardgrass, tall fescue, reed canarygrass, or combinations.
4/ Grazing must be avoided between first frost and definite killing frosts because of prussic acid content in regrowth shoots.
5/ All forage becomes immediately available, but may be gazed for up to 3 months if quality and supply are sufficient.

Figure 5–14 Gulf Coast seasonal distribution of growth and availability of pasture (from Ball, et al. 1991)

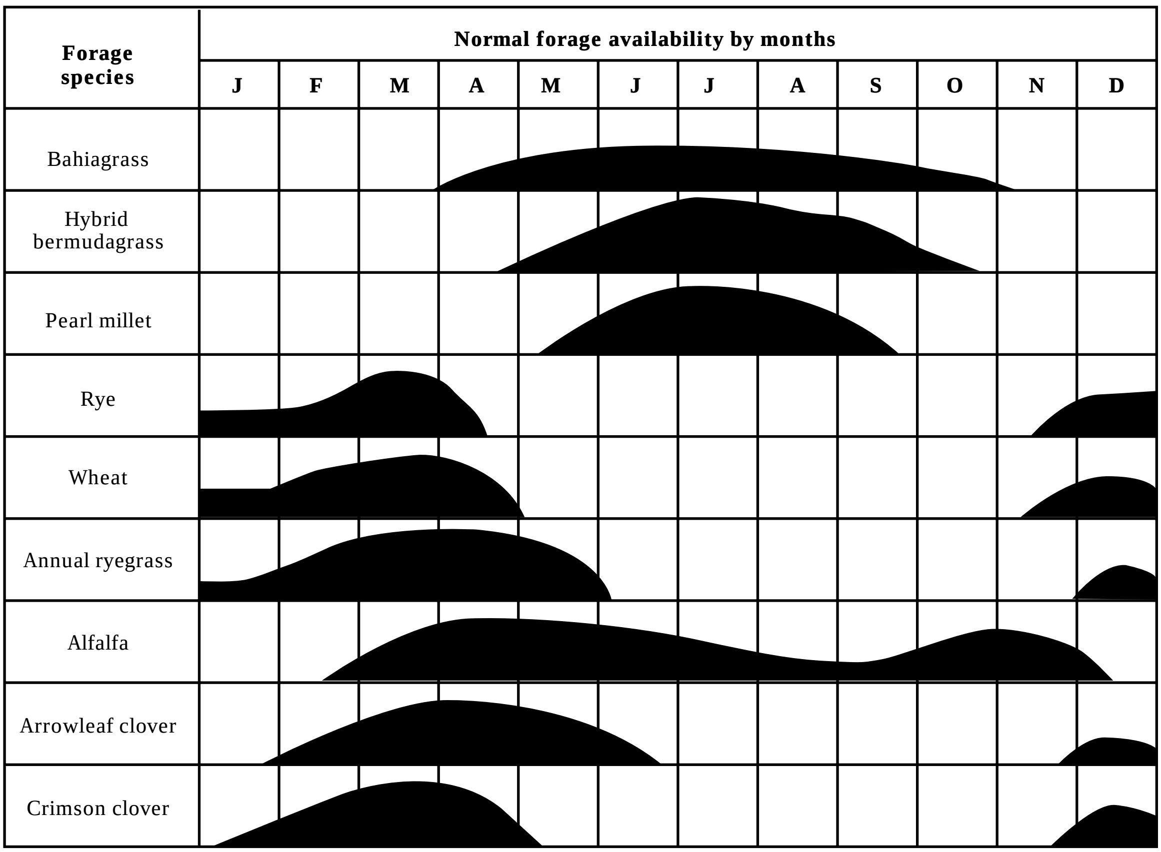


Figure 5–15 Upper South seasonal distribution of growth and availability of pasture (from Ball, et al. 1991)

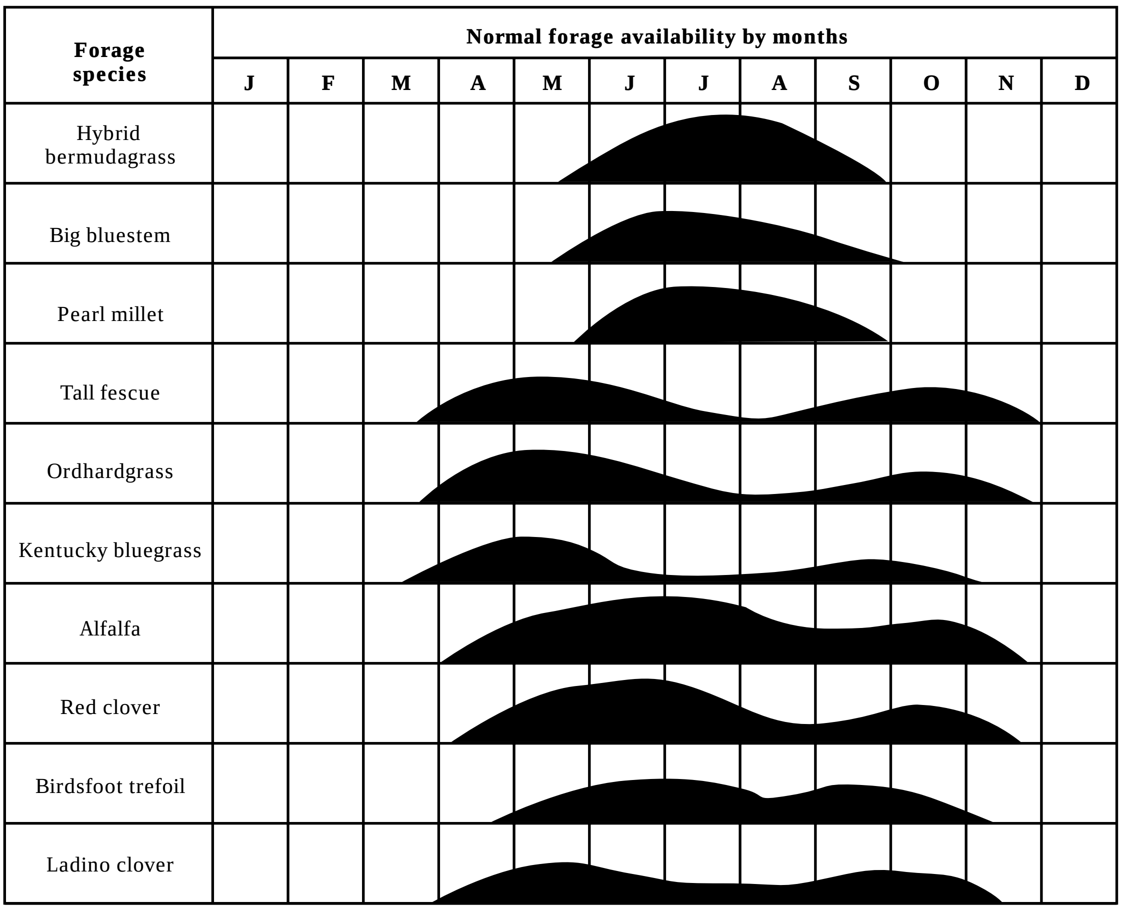


Figure 5–16 Upper Midwest seasonal distribution of growth and availability of pasture (adapted from Undersander, et al. 1991)

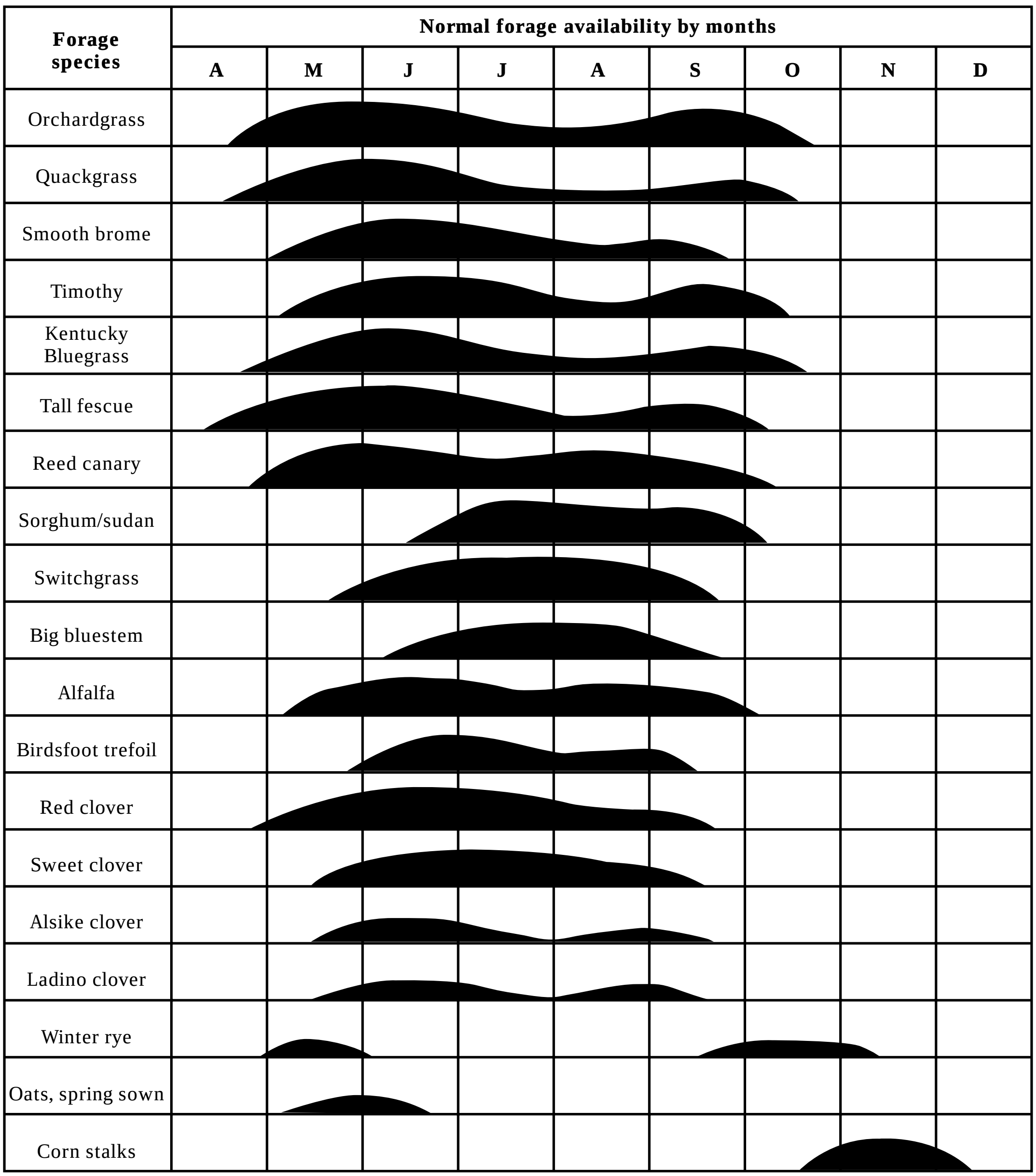
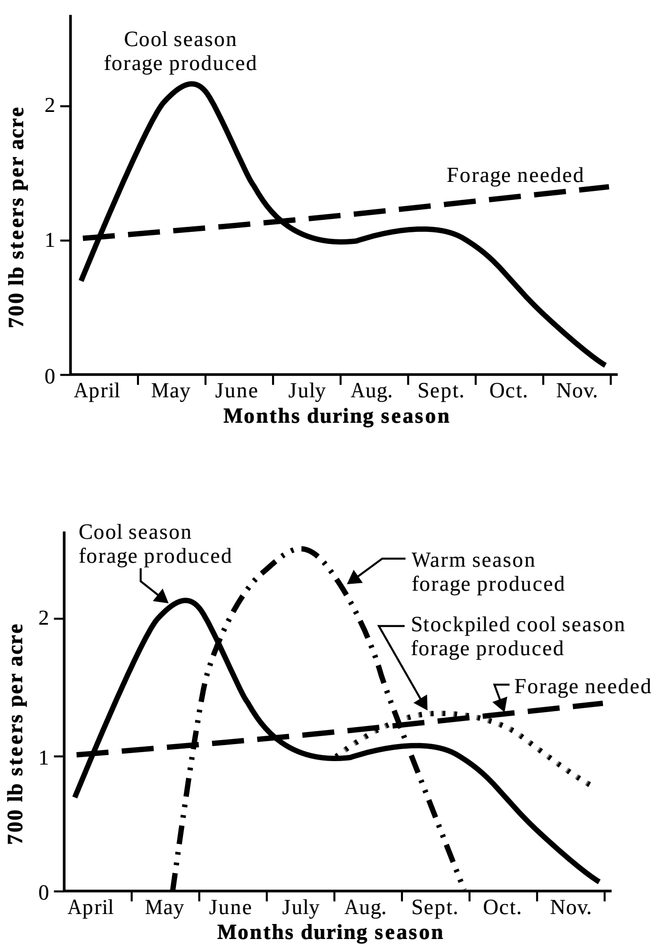


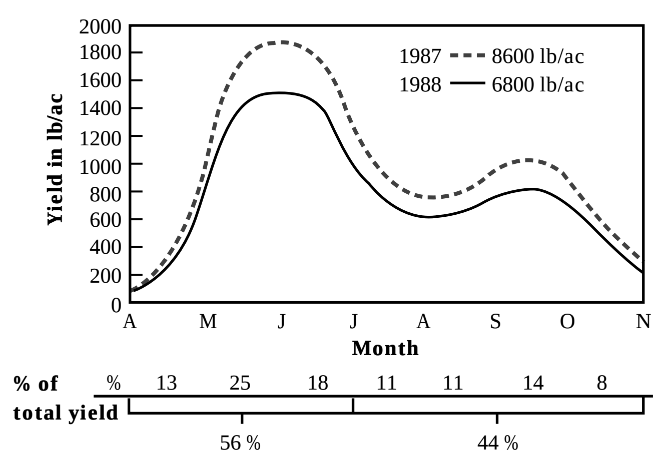
Figure 5–17 illustrates that a cool-season forage pasture produces too much forage early-on, and, as the summer heat arrives, begins to produce too little to meet livestock demand. The use of different forages either in the same pasture or in separate pastures allows the livestock producer to maintain enough forage on-offer to his livestock throughout the grazing season. Using stockpiled forages or growing winter annuals can extend the grazing season past that of the perennial cool- and warm-season forages' growing seasons illustrated in figure 5–17. If grazed rotationally, the warm-season grass could also be stockpiled (not shown) and grazed later in the fall as a standing cured forage if not weathered too badly. The figure also shows that with both the cool-season and warm-season in the pasture system, surplus pasture is available in mid-summer. The excess could be harvested as hay or stockpiled for grazing, depending on operator preference. Meanwhile, at the end of the grazing season, the stockpiled cool-season forage would need to be supplemented with some stored forage if the warm-season grass was not stockpiled for use in November. This is just one example of how the distribution of growth or availability graphs can be used to help formulate a pasture system for a livestock operator.

Figure 5–17 Livestock demand versus forage growth and availability during the grazing season where livestock were placed on pasture April 1 (adapted from Barnes, et al. 1995)



A drawback of the graphs or growth curves is their lack of specific numbers. They are useful because they quickly point out peaks and troughs of growth or availability. Tables are more useful in doing detailed pasture budgeting. They use units, such as monthly percentage of total annual production, tons of dry matter per acre per month, animal unit months per acre per month, or acres needed per animal unit per month. Table 5–2 illustrates the use of monthly percentage of total annual production. It is the most useful form because the other three assume a fixed annual production value. In regions where soil variability, climate variability, past crop management history, or a combination of these vary widely from farm to farm or field to field, annual forage yields can range widely from one site to the next and from one season to the next. This is illustrated in figure 5–18.

Figure 5–18 Seasonal distribution of growth of cool-season pasture and total production for 1987 and 1988 in southern New York (from Emmick and Fox 1993)



Note that the distribution of forage production remained constant, but forage on-offer was quite different between years as was total annual production. The factors listed do impact the percentage distribution throughout the season as well, but less so. Given the year to year variability inherent with a living system, think of the percentages as being averaged, somewhat inexact constants for doing pasture budgets. Some are constructed from long-term averages. Others come from limited short-term research studies. Therefore, expect some variation from year to year.

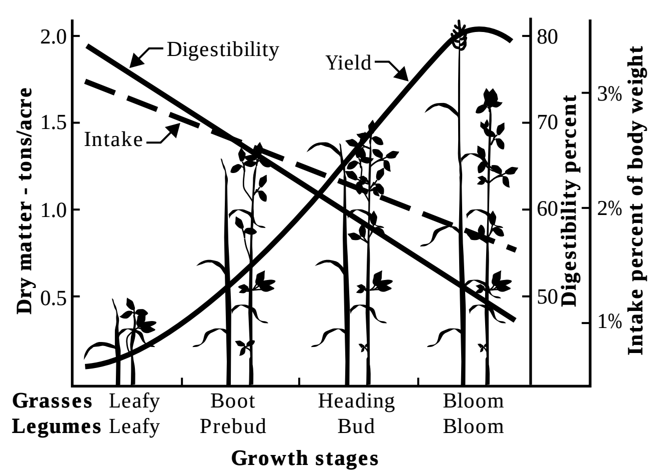
The monthly percentage of total annual production when multiplied times the estimated total annual production indicates the amount of forage grown or available during that month. If forage demand by grazing livestock for that month is known or can be estimated, the acres of pasture needed to feed the livestock that month will be known. This is the essence of a pasture budget. It allocates enough pasture forage to meet forage demand for the livestock being pastured. Therefore, seasonal distribution of growth and availability information is a crucial tool in doing a pasture budget and an overall livestock feed budget for the year. The livestock feed budget is necessary to do whole farm planning of a livestock producing management unit. It dictates ratio of pasture to cropland and hayland and the choice and balance of crops in crop rotations planned on cropland. For instance, an operator may decide to plant a summer annual on cropland to meet a deficit in forage production on the permanent pasture acres. The planner and farmer need to work that crop into the rest of the crop rotation. If not, then another alternative, such as grazing some hay crop acres after first cut, needs exploring.

(b) Forage growth response to the grazing animal

No matter what stocking method is used to allocate forage to grazing livestock, the goal should be to keep pasture forage in a vegetative growth stage. This is when the forage is at its best nutritionally and photosynthetically most active. Cool-season forages lose some of their digestibility especially when allowed to go to head or flower (fig. 5–19). They produce more dry matter, but livestock intake is depressed. In fact, this is why mature forage areas are avoided by livestock in fields that have been spot grazed. They go to the choice spots where growth is still highly vegetative, preflower for tap-rooted legumes or pre-boot stage for grasses.

Warm-season grass loss of digestibility is much lower. However, many are lower in digestibility than cool-season forages to start with, so the warm-season grasses must be harvested even more timely. In comparing pasture to stored forage production, it is critical that the planner not become hung up on total dry matter production. Pasture may produce less total dry matter than machine harvested forage acres. However, it produces a higher quality feed than machine harvested forage acres and similar total digestible dry matter if livestock demand and seasonal forage production are closely matched. Most stored forages are cut after grass heading and initial legume flowering.

Figure 5–19 Growth stages of grasses and legumes and their effect on intake, digestibility, and dry matter production (from Blaser, et al. 1986)



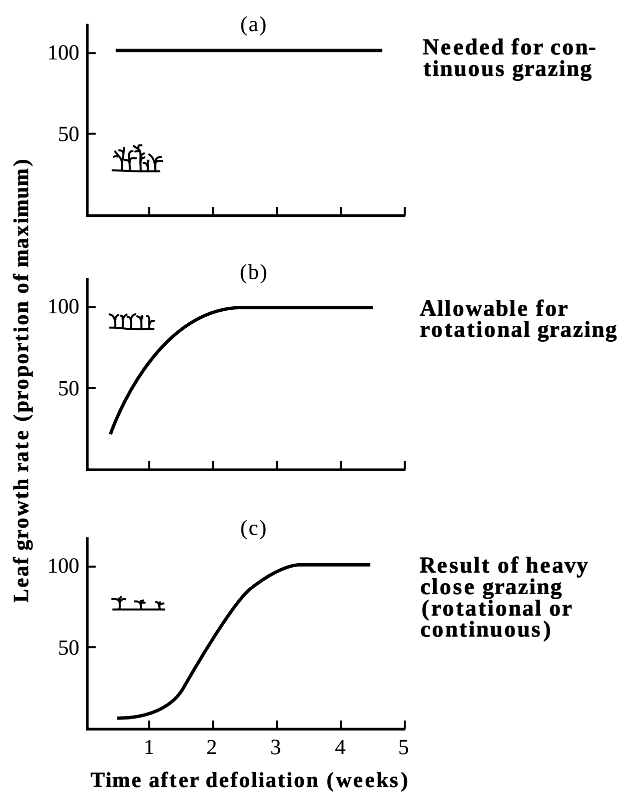
Forages grazed too close lose green leaf area below that needed to optimally capture sunlight. This delays regrowth and uses stored food reserves. The growth curves are shown in figure 5–20. If grazed too close repeatedly, the forage plant becomes weaker as food reserves run low. Death can result if other stresses or physical damage from hoof action occurs. Forages differ greatly in their ability to withstand close grazing. Forages that have growing points and some leaf area below the grazing height can withstand close grazing (fig. 5–21). Examples of these are Kentucky bluegrass, bahiagrass, bermudagrass, white clover, and tall fescue. Forages that have rhizomes and/or stolons just below and above the ground surface respectively, also have a greater chance of surviving close grazing. Both prostrate stems store food reserves and can initiate new shoots and roots at nodes from those reserves. Close grazed pastures where these forages are climatically adapted will be dominated by these species if introduced there initially. They simply have the competitive advantage in that situation.

Grazing height is therefore the critical parameter in pasture management where regrowth is possible and desired. Different forage species require different residual heights to maintain adequate leaf area to intercept full sunlight. For most forages a leaf area index (LAI, leaf area to ground surface ratio) of 3 to 4 will intercept enough sunlight to maintain maximum photosynthetic activity. The height at which this is attained varies from species to species. White clover and bermudagrass can attain this at a height of only 1 inch. Meanwhile, orchardgrass and tall fescue would need from 1.5 to 2 inches. Table 5–3 lists suggested residual grazing heights for major pasture species.

If grazed to the minimum height required to maintain full light interception and maximum growth rate at all times, as shown in figure 5–20(a), the grazed stubble is higher (schematic inset). Plant or stem density tends to be higher as a result as well. This is necessary where pastures are to be stocked continuously. Because cattle are there continuously, there is no recovery period to allow forages to increase leaf area before they may be grazed again.

Where pastures are rotationally stocked, forages can be grazed closer, as shown in figure 5–20(b). However, enough residual leaf area must be left behind to keep plants in a vigorous, fast growth state. Note in this example the recovery period to the maximum growth rate is about 16 days. A few more days then would be needed to allow forages to grow to the desired available forage mass needed for the class of livestock being fed. Do not interpret figure 5–20 to be graphs showing mass accumulation.

Figure 5–20 Leaf growth rate changes based on residual leaf area left as result of grazing height (from Hodgson 1990)



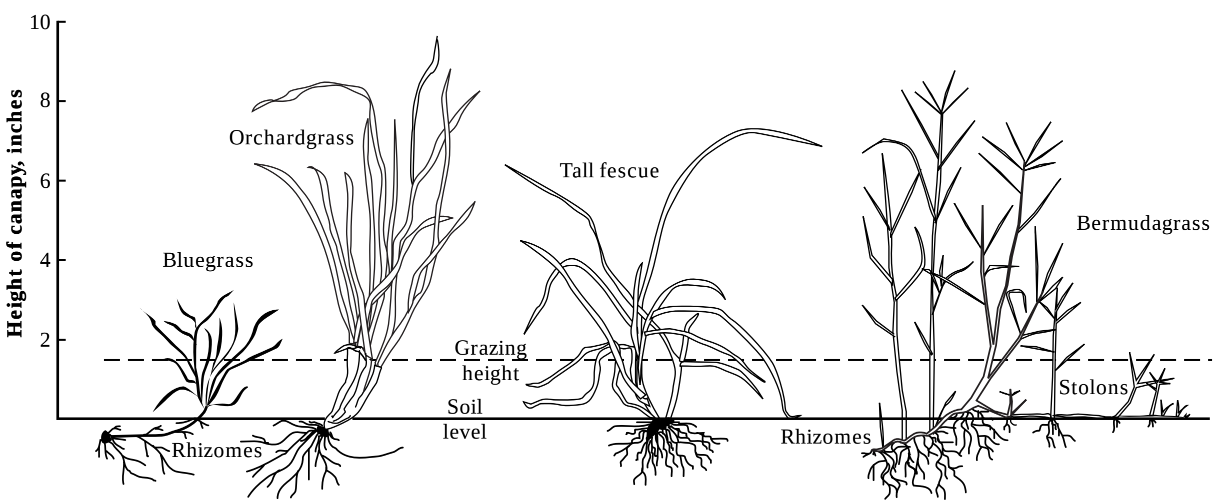
When forages are grazed close so that little to no leaf area remains, it may take a week or more for dormant growing points to initiate growth or active growing points to reactivate leaf growth, as shown in figure 5–20(c). In this example it takes 24 days before plants are growing at their maximum rate. Note the schematic of grasses in in this graph shows a thinned stand that is also low in stature. If forage plants are repeatedly grazed closer than they ought to be, plant and stem counts dwindle. This leads to lower production, bare ground, and a chance for less desirable plants (weeds) to invade the pasture. This situation is not good for either rotational or continuously stocked pastures.

Grazing height in relation to where the growing points are held on the plant is important as well. Legumes that require regrowth from leaf axillary buds, such as birdsfoot trefoil and sweetclover, need to be grazed higher than those that initiate regrowth from crown buds or stolon nodes, such as alfalfa and white clover.

Grasses whose growing points enter the grazing zone must rely primarily on basal or rhizome buds to produce new leaves. Grasses that typically send their growing points on vegetative tillers into the grazing zone are called jointed (culmed) grasses. They have elongating internodes along all their stems. The growing point is pushed up into the grazing zone as each internode starting from the base of the plant elongates. A leaf arises at each node. If the growing point is removed from the stem, a dormant bud initiates growth along the stem, along stolons or rhizomes, or from the plant base.

These jointed grasses rely heavily on stored food reserve for regrowth. They must have a recovery period to produce new leaves and restore food reserves before being defoliated again. Typical jointed grasses used for pasture are barley, bermudagrass, big bluestem, corn, Johnsongrass, oats, reed canarygrass, smooth bromegrass, sorghum, sudangrass, switchgrass, timothy, and wheat.

Figure 5–21 Differences in forage plant morphology from one species to the next change their response to grazing height (from Blaser 1986)*



* Bermudagrass and Kentucky bluegrass can withstand close grazing since they hold some leaf area close to the ground and have food reserves stored in prostrate stems, rhizomes, or stolons. Orchardgrass and tall fescue have less leaf area after close grazing. They also contain most of their food reserves in the stem bases. If the stem bases are damaged, they are slow to recover.

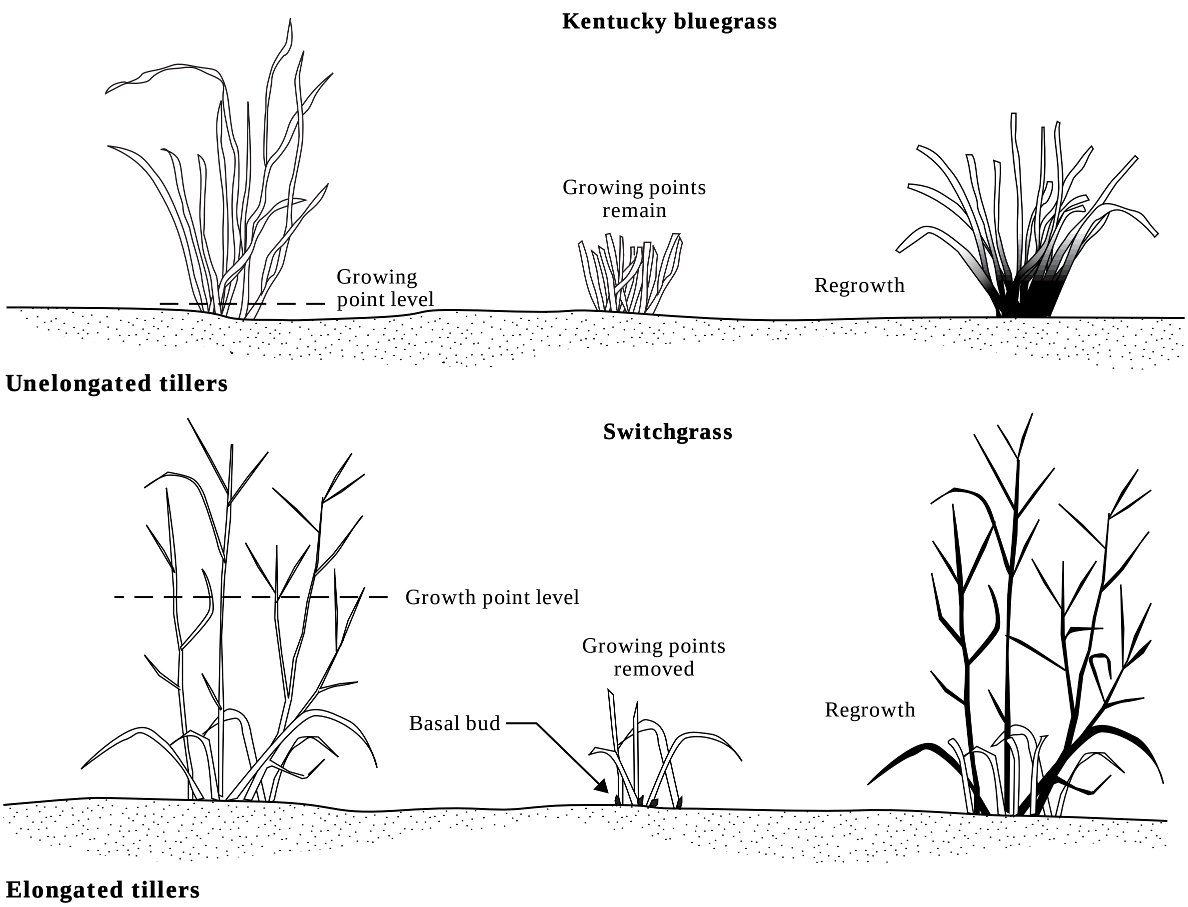
Table 5–3 Suggested residual grazing heights for major pasture forage species [1/] (from Ball, et al. 1991; Barnes, et al 1995; Blazer 1986; Chessmore 1979; Hayes 1966; Serotkin 1994)

Pasture type	Continuously stocked, average height of pasture (in)	Rotationally stocked, minimum height at removal (in)
Predominately grass		
Bahiagrass	1.5 to 3	2
Bahiagrass-legume	1 to 3	1
Common bermudagrass	1.5 to 3	1
Bermudagrass-white clover	1 to 3	1
Hybrid bermudagrass	3 to 6	2
Kentucky bluegrass	2 to 3	1 to 2
K. bluegrass-white clover	2 to 3	1
Bromegrass, smooth [2/]	4 to 5	2 to 3
Orchardgrass	4 to 5	2 to 3
Orchardgrass-Ladino clover	2 to 4	2
Reed canarygrass [2/], [3/]	——	2 to 3 [4/]
Ryegrass	2 to 3	1 to 2
Ryegrass-white or Ladino clover	1.5 to 3	1 to 2
Switchgrass [3/]	——	6 to 8 [4/]
Tall fescue	4 to 5	2 to 3
Tall fescue-Ladino clover	2.5 to 4	1.5
Winter small grains	3 to 6	3
Predominately legume		
Alfalfa [3/]	——	1 to 3 [5/]
Arrowleaf clover	2 to 4	2
Berseem clover [3/]	——	3 to 4
Birdsfoot trefoil, prostrate type [3/]	——	1 to 2
Birdsfoot trefoil, upright type [3/]	——	2 to 3
Crimson clover	2 to 4	2
Ladino or white clover	1 to 4	2
Lespedeza [3/]	——	3
Red clover [3/]	——	2
Rose clover	2 to 4	2
Subterranean clover	1 to 3	1

1/ Heights given are those to maintain stand vigor and longevity. Greater heights may be needed to maintain proper intake for certain livestock types and classes.
2/ Must be grazed before jointing occurs or allowed to mature for hay and aftermath grazed.
3/ Not recommended for continuous stocked pasture use; includes grazing type alfalfa.
4/ Stubble height largely dictated by stiff stems discouraging lower defoliation.
5/ Stubble height of 3 inches for overwinter protection. Grazing type benefits more from residual stubble height during the growing season than does a hay type.

Nonjointed (culmless) grasses maintain their growing points on vegetative tillers below or at ground level most of the year. They send up reproductive jointed stem stalks once per season. These grasses are resistant to close grazing and not very dependent on stored food reserves except at green-up. This is mainly because when grazed, their actively growing leaves continue to elongate. The active meristematic tissue is pushing them up from below and creating fresh new photosynthetic area. These grasses can be continuously grazed provided enough leaf area is left to produce maximum photosynthetic activity. Typical nonjointed pasture grasses are bahiagrass, bentgrass, Dallisgrass, Kentucky bluegrass, little bluestem, orchardgrass, redtop, ryegrass, and tall fescue. Figure 5–22 is a visual comparison between jointed and nonjointed grasses.

Figure 5–22 Response of a nonjointed grass like Kentucky bluegrass compared to a jointed grass like switchgrass* (from Waller, et al. 1985)



* Same leaves continue to grow on bluegrass. Switchgrass starts tillers from basal buds. Older stems die.

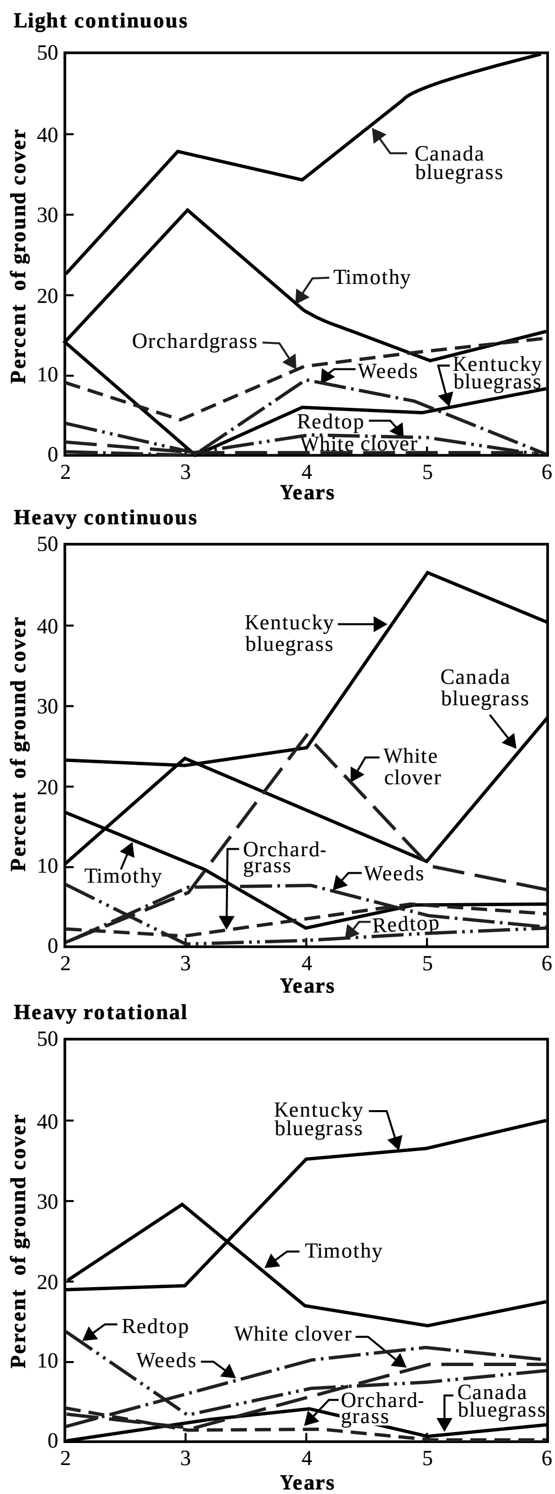
Shifts in plant species composition often occur unintentionally under different grazing regimes (fig. 5–23). In the 6 years of applying three different types of stocking management to three sections of a pasture seeded to a uniform mixture of pasture forages, species composition shifts occurred swiftly. Figure 5–23 starts with year two. The top graph shows the shift in pasture species where stocking was light, but continuous. Spot grazing occurred, leaving high stubble heights in ungrazed areas. The taller upright grasses were favored over Kentucky bluegrass. Canada bluegrass being less palatable proliferated. Timothy decreased after an initial increase resulting from drought in the fourth year. It reached an equilibrium point in years five and six. White clover never gained any ground because stubble heights were too high for sunlight to reach it.

The middle graph in figure 5–23 shows the result of heavy, continuous stocking. Grazed close, this promoted Kentucky bluegrass at nearly the expense of everything else. White clover was initially favored, but decreased in the final two years because of the dry weather. Timothy almost disappeared from the stand as a result of repeated drawdown of food reserves. Canada bluegrass recovery in the final year resulted from a weakened Kentucky bluegrass stand from drought.

The third graph in figure 5–23 shows the effect of heavy grazing rotationally. Kentucky bluegrass and white clover were favored because the grazing height was close. Most taller grasses nearly vanished. Timothy was not grazed during stem elongation while heading out. It was allowed to restore food reserves and remained fairly constant in ground cover. A less palatable grass, such as Canada bluegrass, is eaten where livestock are restricted to a smaller grazing unit. It appears from the rate of gain data in the published report (not shown) that they were not given enough forage on-offer and were forced to eat everything provided.

Grazing height can also be used to intentionally manipulate species composition in pastures. White clover persistence and percentage of the stand, for instance, are readily improved by grazing a pasture to a low grazing height. Under rotational stocking, this temporarily removes the grass canopy grown in association with white clover and allows light to penetrate down to the stolons. This activates growth of new leaves

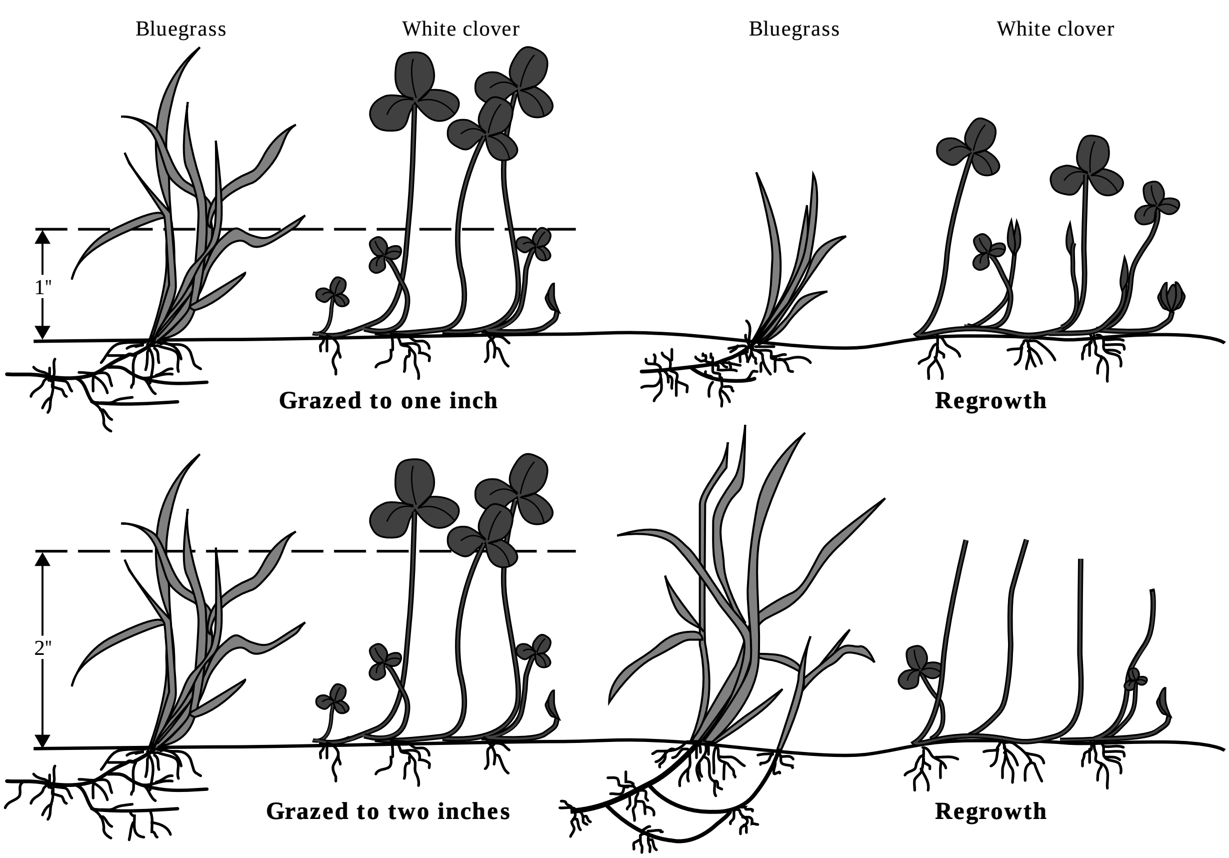
Figure 5–23 Changes in species composition over a 5-year period under different stocking regimes (from Smith 1975)



from nodes (fig. 5–24). The white clover then is able use this light energy to produce food for continued stolon growth and spreads laterally. Yet, if a tall grass, such as switchgrass, is the forage to be retained, maintaining high stubble heights and perhaps taking the first growth off as hay shade out competing cool-season forages.

On humid northern pastures, cool-season grasses, such as bluegrass, are likely to invade warm-season grass pastures if stubble heights and plant densities of the warm-season grass are not kept high. In this case the two grasses are incompatible and, over the long haul,one will win out over the other depending on the grazing height achieved. In the South where cool-season winter annual forage growth and warm-season grass growth do not interfere with each other, it may mean only to graze the warm-season grass close at the end of its growth cycle in the fall. This promotes the onset of growth of an interseeded cool-season grass or legume. The cool-season winter annual grass or legume normally dies back before or shortly after the onset of the warm-season grass growth the following season. An example of this is the combination of bermudagrass and interseeded annual ryegrass or legume, such as arrowleaf clover. A nearly continuous supply of pasture year-around in the same field is possible.

Figure 5–24 Differences in regrowth of white clover as result of grazing height; removal of the grass canopy favors the growth of white clover (from Blaser 1986)



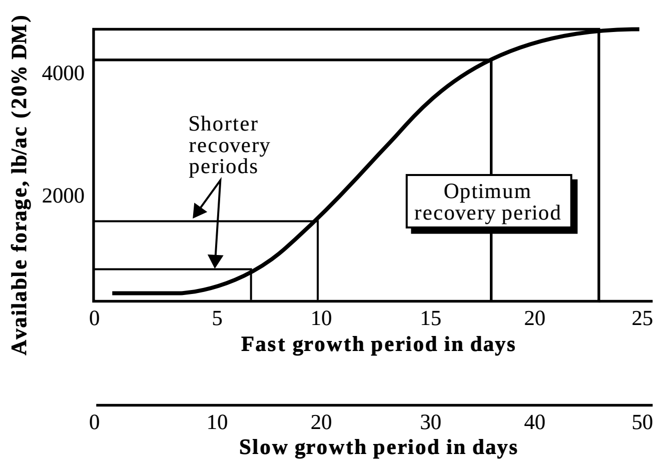
If the photosynthetic area is reduced below an LAI of 3 or the apical growing point is removed because it is elevated into the grazing zone, a recovery period for the forage crop is needed. This is often referred to by other authors as a rest period, which is a misnomer. The plant has undergone major surgery by the grazing animal. It is not resting. It is recovering. Initially, it is using stored food reserves to grow new leaf area. It needs time to restore enough leaf area to intercept as much sunlight as possible. It may also need time to build up the food reserves depleted in initiating dormant bud growth. If the surgery was too radical or food reserves were too low, it may not have enough active meristematic tissue to recover. This can be particularly true if other stress vectors, such as drought, cold, disease, or insects, occur. When this happens the plant population thins. Plants with few active meristems become shaded out by plants that have more actively growing leaves and nondormant buds.

Different forages have different recovery period requirements. Forages with widely fluctuating growth rates throughout their growing season need variable recovery periods. They grow quickly at one time of the year and very slowly at other times. Recovery periods may be as short as 10 days and as long as 60 days or more. Pasture species falling into this category are bluegrass, reed canarygrass, orchardgrass, perennial ryegrass, tall fescue, and white clover. To a large extent, the return of livestock to the pasture is determined by available forage target the operator is willing to accept (fig. 5–25).

Other pasture forages respond better to a fixed recovery period. The legumes in this group when faced with dry, hot weather will go to physiological maturity regardless of stature and vegetative growth will cease. Extending the recovery period only hurts quality and produces no additional forage. The grasses, if grazed too late, go to physiological maturity, and many leaves are lost to senescence. This reduces the quality and quantity of forage ingested. If either of the legumes or grasses of this group are grazed too early, food reserves or leaf area are not restored sufficiently. This can lead to a steady decline in plant, stem, or tiller counts. Pasture species in this category are bahiagrass, bermudagrass, big bluestem, Dallisgrass, alfalfa, red clover, smooth bromegrass, switchgrass, and timothy. A generalized fixed time interval cannot be given because it does vary by species and climate. Recovery times deemed sufficient for long-term forage survival are even debated for some species. Alfalfa, for instance, was stated as being somewhere between 28 to 35 days. With the newer pasture-type alfalfas, some agronomists recommend only a 21-day recovery period. However, this is based on leaving enough stubble with leaves to carry on some photosynthesis.

Forage crops that are going into a winter dormancy period require a special recovery period near the end of their growing season. This allows them to develop enough food reserves to make them cold hardy as well as store energy for next year's green-up period. Normally, a 4- to 6-week recovery period is needed. Under rotational stocking, this can often be accommodated in the regular rotation. Under continuous stocking, some way of reducing stocking density by opening up other grazing areas, such as fields with grazable crop residue, or temporarily removing livestock from the pasture is helpful.

Figure 5–25 Variable recovery period* (from Murphy 1988)



* During fast growth periods, days for recovery are half that of slow recovery period in this example. During prolonged periods of moisture stress, recovery periods can be much longer before available forage target is reached for class of livestock being pastured. Note shorter recovery periods fail to make much use of fast accumulation rate portion of growth curve (typical of continuously over-stocked pasture).

(c) Selective (spot) grazing of pastures

As mentioned earlier, a characteristic of pasture setting it apart from hayland and cropland is that it can be harvested (grazed) unevenly. Several factors contribute to this. However, the primary factor that sets this into motion is the forage supply exceeds livestock demand, either seasonally or season long. Here again, this shows the importance of forage growth curves. If flush periods of growth are not accounted for, forage production gets ahead of the herd's or flock's ability to eat it. The animals tend to go back to previously grazed areas where the less mature (vegetative) plants are because these forages are more palatable. Once patches of mature (reproductive tillers present) forage plants establish from grazing preference patterns, they persist the whole grazing season, or possibly several seasons, unless mowed (clipped). This can lead to severely overgrazed spots and underutilized spots in the same pasture. This does not occur on overstocked pastures nor on rotational pastures that have stock densities in keeping with the amount of forage on-offer. In fact, on severely overgrazed pastures, zones of repugnance (avoidance of livestock eating near their own waste) do not exist around urine and feces spots. Even that does not contribute to selective grazing when animals are underfed. These pastures are grazed uniformly closer than most lawn mowers can cut except for an occasional distinctly unpalatable plant. Forage utilization is high, but production is very low.

(1) Factors involved in selective grazing

The main factors involved in selective grazing are:

- Forage supply exceeds livestock demand
- Plant palatability differences from species to species
- Plant palatability differences within species due to maturity differences or level of anti-quality chemicals
- Plant palatability differences due to terrain and soil conditions
- Avoidance of plants soiled by dung and urine

Palatability differences among pasture species revolve around two main factors: morphological and chemical. Morphological differences are differences in leaf coarseness and stem to leaf ratios. Chemical differences are anti-quality metabolites that impart off-odors or flavors or that induce illness. Other factors, such as succulence and fiber content, affect intake by livestock using other grazing areas, but the differences among pasture species are relatively small.

Pasture species that are quite different in palatability should not be planted together in a mixture. The least desirable species will be shunned. If they can spread by seed or vegetatively, they will. Over time, they will increase in areal extent. The more palatable species will be overgrazed and lost from the stand. This argues against using shotgun seeding mixtures. It is hard to get more than two or three species together without getting a significantly less palatable species added to the mixture.

Some responses by livestock come from what they are conditioned to eating. Often reed canarygrass is avoided by livestock if they are not initially raised on it. This can be for two reasons. One is that it has a large coarse leaf and with age becomes stemmy, a stiff stem at that. The other is that some ecotypes are laced with an alkaloid that causes digestive problems in animals not conditioned to eating it. If it is grown in association with other grasses, it will be left untouched and will eventually cover the grazing unit. If it is rhizomatous and tall, it spreads and shades everything else out.

Tall fescue is similarly rejected if grown in association with other grasses. It tends to have leaves that are coarser and tougher than other species. It also has an alkaloid in it caused by the endophytic fungus, *Acremonium coenophialum*. This is toxic to animals causing a number of symptoms: fescue foot, bovine fat necrosis, and fescue toxicosis. The first two conditions can be worsened by high nitrogen fertilizer rates from commercial fertilizer or manures, such as chicken litter.

Within species selective grazing is most often caused by succulence differences. As the plants mature, they become less succulent and more fibrous. Mature seedheads also make the areas less inviting to grazing. Areas that are initially grazed are repeatedly regrazed when animals have the chance to graze more forage on-offer than they can eat completely. The forages in these areas are younger and therefore more succulent. If given a wide latitude, livestock are very selective.

Chemical differences are less important except where endophyte infested tall fescue pastures are renovated and planted to endophyte-free tall fescue. In this case the chances of having a few infected plants survive or germinate from the soil seed bank are quite high. With time these plants may capture more and more ground area as they are rejected and allowed to proliferate over the more palatable and less hardy endophyte-free fescue. The alkaloids that are produced in response to the endophyte make those plants bitter and cause digestive and metabolic problems in livestock.

Terrain and soil differences can cause spot grazing to occur. Shallow, low fertility, and low water holding capacity soils often produce more succulent plants than deep, high water holding capacity soils. These poorer soils produce plants with finer leaves, more leaves, and higher sugar content than plants on the better soils. Because these sites are more fragile to begin with, their attractiveness as food fare only worsens their ecological condition. They will be the first site to show the effects of overgrazing even if other areas of the pasture are not. These areas often occur on knolls and ridge points that have south and west aspects. Often low, poorly drained sites are said to produce washy plants. These plants have coarser leaves, lower sugar content, and become stemmy quickly. Consequently, livestock reject the forage in these areas or use them only as a last resort.

Steep sloped areas will be avoided or underused by livestock if more level terrain is available with adequate forage reserves. This is particularly so in mountainous terrain where distance to water may also be great. Limited water sources tend to cause areas of pasture nearest the water to be overgrazed while areas farther away are underutilized if used at all. Bare areas may encircle the water source, and trailing to and from the water source may become excessive. If the pattern is allowed to occur for several years, ecological succession can begin to progress in areas remote to the water source. Woody vegetation can invade making the fringe pasture areas from the water source become even less desirable to graze.

Shady areas that exist along fencelines or in the pasture itself often influence grazing patterns as well. These areas cause a grazing pattern similar to that around water sources. Close grazing occurs near shady areas, and utilization decreases with distance outward. Because of heavy treading pressure under trees, vegetation may often be lost entirely in the shaded area.

Barriers, such as fencelines, rock outcrops, cliffs, and high walled streams, often disrupt grazing access. The areas made difficult to reach are so infrequently grazed that they become overmature. Once they reach maturity, they are less desirable and perpetuate their status as a little used foraging area. If cattle find them hard to get to, these areas will be left unmanaged by the land unit manager. They may eventually revert to woody vegetation.

The remaining effect causing selective grazing is the **avoidance of grazing near dung or urine spots.** This is less of a problem with sheep and horses than it is with cows. Cattle may reject forage in an area surrounding the dung pat 5 to 12 times the size of the pat. Depending on the controls of forage on-offer and forage species being grazed, the amount of pasture area rejected may be none under an overstocked scenario to as high as 70 percent found in a study conducted on a continuously grazed coastal bermudagrass site after 98 days of grazing.

Commonly, 20 percent of the available forage can be wasted because cattle avoid dung spots. Fresh urine spots are avoided. Older urine spots, on the other hand, may attract grazers especially during drier months. The grasses there tend to be more succulent because of the effect of high soil nitrogen concentrations on the growth of the grass. Plants with adequate to excessive levels of nitrogen remain greener longer under drought stress than other plants in the pasture having less nitrogen available to them.

600.0505 Conservation practices for pasture

(a) Harvest management practice—Prescribed grazing

The prescribed grazing conservation practice is used to provide adequate nutrition to animals while maintaining or achieving the desired vegetative community on the grazed site. The principal agent for vegetative manipulation is the grazing animal. If the controlled stocking of grazing animals cannot effectively change the vegetation toward the desired level of production or forage species composition in the time frame desired, then accelerating conservation practices are employed. These practices are described later in detail.

(1) Principles of allocating forage to livestock—pasture budgeting

The two main goals of the prescribed grazing practice on pasture are:

- To achieve acceptable livestock production on either a per land unit basis or per animal basis.
- To maintain a healthy forage base on the pasture acres.

The decision to do either one or a combination of the two is up to the landowner or operator. Circumstances dictate which one of these is most desirable or if striking a balance between the two is best.

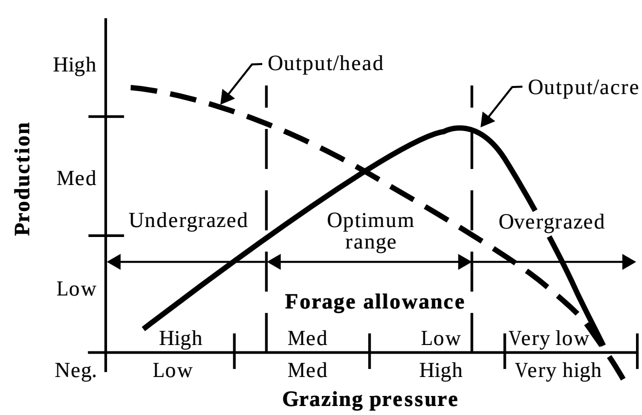
(i) Achieve acceptable livestock production—Seedstock producers stake their reputation on providing superior performing animals. Therefore, it is appropriate that they seek maximum performance per animal.

Commercial operators, on the other hand, may wish to optimize production on a per acre basis. This is particularly important where land prices and property taxes are high. High costs of land ownership or renting dictate being efficient on a per acre basis. However, these same commercial operators may not want to lose too much animal performance if it means a smaller net profit, or deferred sales resulting from slower gains on meat animals. The latter means possible cash flow problems, increased interest costs, and foregoing the time value of money. These operators may want to strike a balance between output per head and output per acre.

NRCS needs to work with landowners and managers to avoid the extremes shown in figure 5–26, especially the overstocked situation. In the overstocked situation, forage production declines because of overharvest. There is an increase in grazing pressure even though animal units may stay constant. There is just less forage growing to be eaten. As a result, in highly overstocked cases there may be actually a loss in weight by the grazing animal because their maintenance needs are not being met. In these cases all five natural resources (soil, water, air, plant, and animal) are in jeopardy. Plants are lost. As a result, animals have too little to eat. The soil with too little cover erodes by wind, water, or both. This in turn impacts air and water quality.

On the other end of the graph, the pasture may be understocked. There is more forage than the livestock are able to consume. This leads to spot grazing. The animals do well individually because they return to graze previously grazed material that is younger and higher in quality. However, the number of animals is low in relation to the potential forage available. Production of animal products per acre suffers. Over time, pasture quality and production decline if far in excess of livestock needs. Much of the forage production will

Figure 5–26 Relationship of output per head versus output per acre based on grazing pressure (animal units per # DM) or its reciprocal, forage allowance (# DM per animal unit) (adapted from Barnes, et al. 1995)



senesce. This senesced residue shades the ground and causes plant thinning unless the pasture is clipped repeatedly.

Going from a high forage allowance to a lower forage availability status is possible without increasing livestock numbers. As forage plant numbers decline, a less vigorous sod allows weeds and woody vegetation to invade. With low livestock numbers, these plants survive and eventually dominate areas of the pasture. This can impact the five natural resources as well. The biggest impact is felt by the plant and animal resources. The plant community transitions into something less desirable as a forage resource. Browsers may be favored over grazers if succession back towards forest occurs. In advanced stages, areas of overgrazing will co-exist with undergrazed.

Both situations can be reversed back toward the middle of the graph. There the forage allowance given per animal unit is somewhat short of maximum rate of gain per head, but allows for a higher utilization rate of the forage and a much higher output per acre. Therefore, it is critical to know first what the forage requirement is per animal unit. General rules of thumb have been 2.6 percent of body weight for most ruminants and 3.0 percent of body weight for lactating dairy cows. However, these should not be considered absolutes.

Intake is affected by forage quality, temperature, amount of forage on-offer, and animal condition. A normal range of values is 1.5 to 4 percent of body weight. The optimum forage allowance is this required forage ration plus some additional forage mass to cover losses by rejection, trampling, and soiling as well as to make it easy for animals to get a full bite each time. This optimum is expressed where the output per head and output per acre lines cross in figure 5–26. If the actual forage allowance deviates from this optimum, the results are shown in figure 5–26 and were described earlier. If stored feed is fed in addition to pasture forage, this dry matter contribution should be subtracted from the ration.

***(ii) Maintain healthy forage base*—**The second main goal of prescribed grazing is maintaining a healthy forage base on the pasture acres. Forages are a renewable resource when harvested with their needs in mind. This means stocking livestock commensurate with the amount of available forage throughout the grazing season. When overgrazed or undergrazed, forage stands continue to renew themselves, but at lower and lower levels of production. Over time, the stand thins in plant and stem numbers. Invasion by less desirable plants occurs.

For those forages tolerant of continuous grazing and managed that way, it means leaving enough residual stubble 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 seedheads. This stimulates those plants to produce new vegetative growth.

For those forages better suited to rotational stocking 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 stocking schedules can do harm to the forage stand as well as cause distortions in feed quality and quantity. Delays can develop because of faster forage growth than expected or the grazing period is extended to use pasture subunits or paddocks better. When this occurs some of the paddocks nearing seedhead emergence or bud flowering should be cut for stored feed unless they can be stockpiled for grazing later. If return interval starts to speed up as a result of grazing periods being cut short for lack of enough available forage, supplement pasture with stored feed or, if available, bring in additional grazable acres.

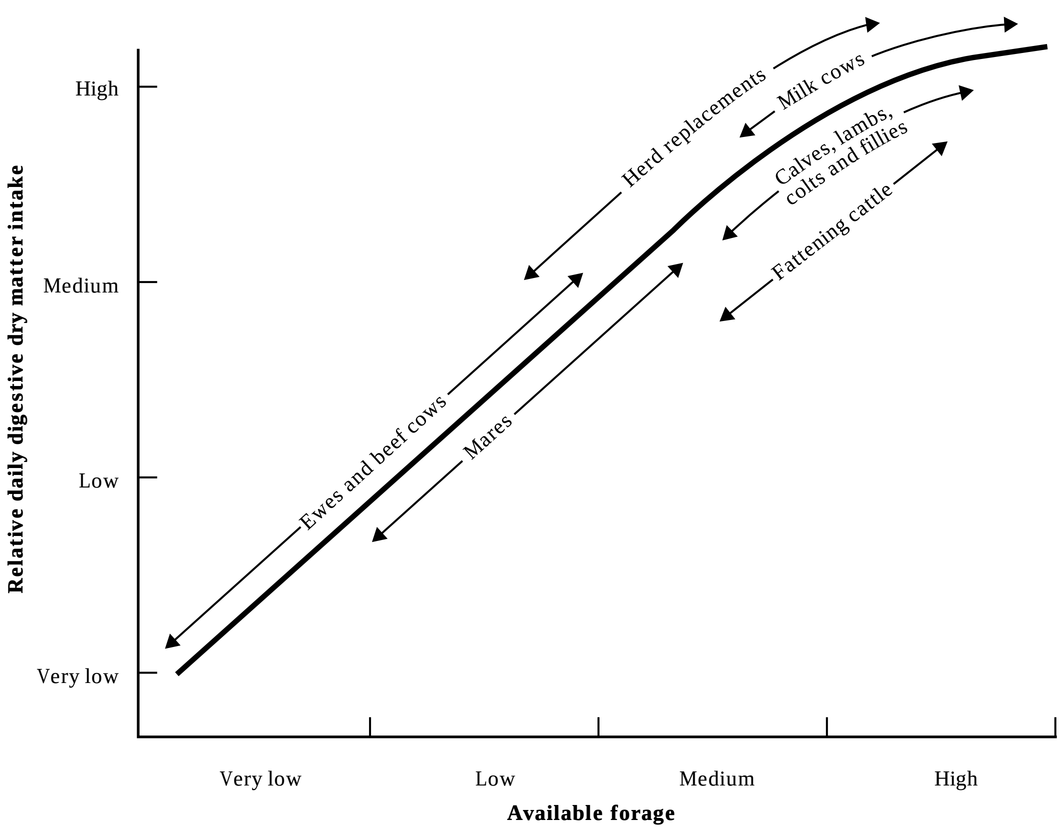
Paddock forage growth should be measured well in advance of the herd. All paddocks should be monitored once per week. If measured and charted, the rate of growth for each paddock can be determined. Considering the rate of growth and any trends observed (declining, flat or rising growth rate), the operator can project when each paddock will be ready to graze based on available forage target. If the projection shows available forage target is exceeded well before livestock will occupy a paddock and several paddocks will be in this condition, either adjust stocking rates upward or machine harvest the number of paddocks required to get to a paddock that meets available forage target. If some paddocks are slower to recover while others are faster, the operator should adjust the sequence of paddock grazing to accommodate the variance in growth rate. These differences are caused by forage species composition, soil type, aspect, or grazing residual height variability associated with the site and season.

Available forage is a critical term needed regardless of grazing method. As applied to pasture, it should be defined as the consumable forage in pounds of digestible dry matter per acre between the allowable minimum stubble height for the preferred forage species being grazed and the plant height achieved before or during grazing. It should not be to the height to which the grazing animal can graze it down. This fails to recognize the harm done to the forage crop when grazed too close, the resource that the animal and producer depend upon for their livelihood. It may be available to the animal, but it is not indiscriminately available if forage persistence and vigor are desired. As it was defined here, it is sometimes called usable forage.

Another key to the definition is that available forage is constantly changing unless forage is dormant or dead. Available forage is changing before grazing. It increases as the forage grows ungrazed. Available forage declines once grazing is initiated in rotational grazing methods. It declines until the animals are removed. It fluctuates up or down under continuous grazing methods depending on how finely tuned grazing pressure is applied and the variability in forage growth rates in relation to livestock stocking rates (animal units per acre). The importance of this moving target is that it must meet each class of livestock's requirements at all times.

Figure 5–27 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 it falls below the minimum required. If rationed too tightly, the animals are not able to maintain intake. In some instances, some classes of livestock, such as milk cows, have a fall-off in production before grazing to the minimum stubble height needed to maintain plant vigor. High producing

Figure 5–27 Available forage requirements for different classes and ages of livestock (from Blaser 1986)



milk cows simply need more available forage or a high forage allowance to maintain a high level of intake. They need to move to pastures that have sufficient available forage or be fed stored feed. Dry matter intake by high producing milk cows falls off rapidly as available forage declines below 1,000 pounds per acre. Other classes that only need to maintain body weight may graze below the minimum stubble height needed for the health of the preferred forage community if lax grazing management is applied. Where too much available forage is presented, spot grazing can occur and animals may be overconditioned (too fat). The latter can lead to livestock reproductive and health problems too and waste a valuable forage resource. Methods for monitoring available forage are described in chapter 5.

The other key to the definition of available forage is the term, **digestible dry matter**. This accounts not only for the quantity of forage available for consumption, but its quality as well. As stated earlier, pasture forage kept in a vegetative state has a higher digestible dry matter content than it does typically when harvested as stored forage. Much of this is related to its stage of maturity, but it is also a reflection of losses suffered by stored roughage during harvest operations and storage. Pasture forage should therefore be allocated based on its quality as well as quantity, or utilization will be less than predicted. A forage allowance based only on total dry matter will be too generous on high quality pastures.

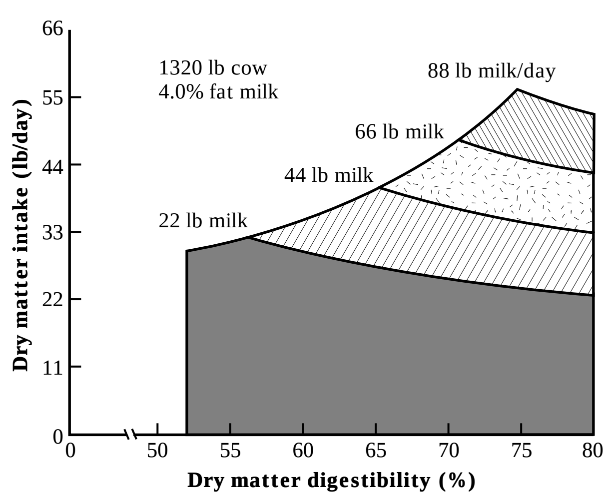
Pastures that run above 65 percent digestible dry matter dampen dry matter intake for many classes of livestock depending upon their energy requirements. For example, see figure 5–28. This illustration depicts dry matter intake versus dry matter digestibility for dairy cows at different milk production levels. The intake of a low producing milk cow drops off starting at 56 percent digestible dry matter. While that of a high producing cow does not drop off until forage digestible dry matter exceeds 75 percent. High producers only get this much digestible dry matter by being fed concentrates along with pasture forage. Pasture forage may be 75 to 80 percent water and will fill the gut before the percent digestible dry matter factor can influence intake.

Forage utilization is the percent of available forage actually consumed by the grazing animal based on net forage accumulation that occurs before and while they occupy the pasture unit. The amount of available forage presented times the acreage of the pasture unit (forage on-offer) must equal the forage allowance required to feed the herd or flock for the period they will occupy the pasture unit unless supplemental feed is fed. In other words, if 15 animals were to occupy a 1-acre pasture unit for 3 days and had a forage requirement of 25 pounds of digestible dry matter per animal unit per day, 1,500 pounds of available forage would be needed on that acre if the utilization rate was 75 percent (1,500 lb/ac x 0.75 x 1 acre = 1,125 lb = 25 lb/au/day x 3 days x 15 au).

A 100 percent efficient enterprise is impossible without unacceptable livestock performance. As livestock move about grazing, some forage is rejected, some trampled, and other soiled as the animals selectively graze the choicest plants and plant parts first. The larger the area and more days on the pasture, the more forage lost to initial rejection, trampling, and soiling.

Table 5–4 gives 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 (fig. 5–29). If the 80 percent

Figure 5–28 Dry matter intake of dairy cows based on dry matter digestibility and daily milk production (from National Research Council 1989)



ceiling is surpassed, then animal production per acre declines quickly. At the same time some forage areas within the pasture unit will be grazed to stubble heights lower than ideal for persistence and vigor. If 40 percent or less of the available forage is used, individual animal performance is high, but the pasture is undergrazed.

Forage availability or allowance 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 5–27 may need to be followed on rotational pastures with a less demanding herd of livestock. For instance, 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. Their mothers once past peak lactation 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.

To summarize, livestock must be given a forage allowance (pounds of dry matter per animal unit) that covers their forage requirement plus some wastage. The practical limit is 20 percent wastage (80 percent utilization) before intake suffers in a big way and animal production per acre starts to decline. Individual animal performance has already declined at this point. At the 40 percent utilization rate, individual animal performance has peaked, but available forage utilization is low.

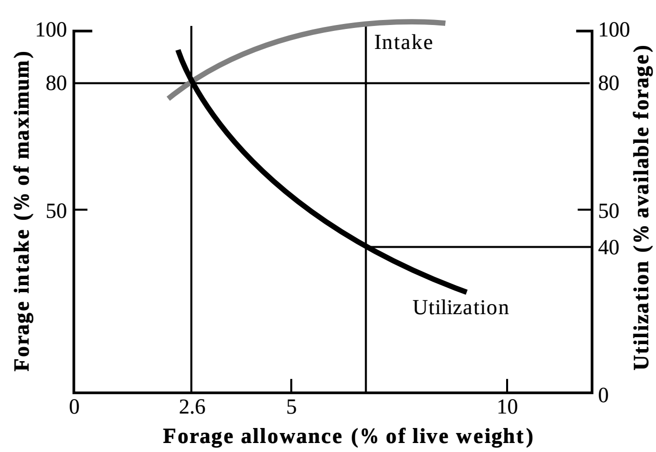
To get the right forage allowance in front of the animal requires a few critical items that are all interrelated and form the basis of a pasture budget. These items include:

- How much forage in pounds of digestible dry matter (DDM) per acre is available?
- The number, kind, and class of animal units to be placed on the pasture.
- Will these animals be fed stored feed while on pasture? If so, how much? This establishes their true requirement for pasture forage.
- Establish length of stay in the pasture unit. This determines the final available forage amount based on its status at the start of the grazing period and the growth rate during the grazing period. It also establishes the grazing period forage requirement for the animal units being pastured, daily forage requirement per animal unit times animal units times number of days of grazing period.

Table 5–4 Rotational pasture estimated utilization rates (from Penn State University, Agronomy Guide 1994)

Grazing period (days)	Pasture utilization (%)
0.5 – 1	80
2	75
3	75
4	70
5	65
6 – 30	60

Figure 5–29 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.

- Estimate a utilization percentage. This is the least precise input, but the practical range is between 40 and 80 percent.

This information helps in determining the forage allowance needed for the whole herd, grazing period forage requirement divided by utilization ratio (step 6). The size of the pasture unit can then be determined t(step 7) by taking the grazing period forage allowance for the herd and dividing it by available forage during the grazing period (lb DDM / lb DDM/acre = acres). This is pasture forage budgeting. The process is simple. Gathering reliable data is the hard part. Note that stocking rate, the number of animal units per acre per specified time period, was never relevant. It is an outcome of the process once livestock demand and forage supply issues have been resolved. It becomes relevant when animals are stocked with little regard to supply-demand issues.

For pastures that have forages with widely fluctuating seasonal growth rates and long grazing periods, such as with season-long continuous stocking, calculate monthly forage production during the high and the low forage growth rate month. This determines the number of animals that can be supported or the number of acres of pasture needed during those two disparate time periods in forage growth. This must be done for rotational stocking as well to determine differences in total pasture acreage needed at these two different periods in forage availability. If more than one forage community is pastured or pastures vary markedly in their productivity, then these same calculations need to be done for each pasture being used.

Herd requirements for forage change with time as well. They gain weight. Some are sold. Milk production during the lactation cycle for dairy cows fluctuates greatly and therefore so does their need for energy. This is especially important in figuring demand for seasonal dairying herds where all the cows are in the same part of the lactation cycle. Therefore, as simple as the forage budget process is, it is necessary to reiterate it as often as needed depending on the complexity of the pasture system being planned and used.

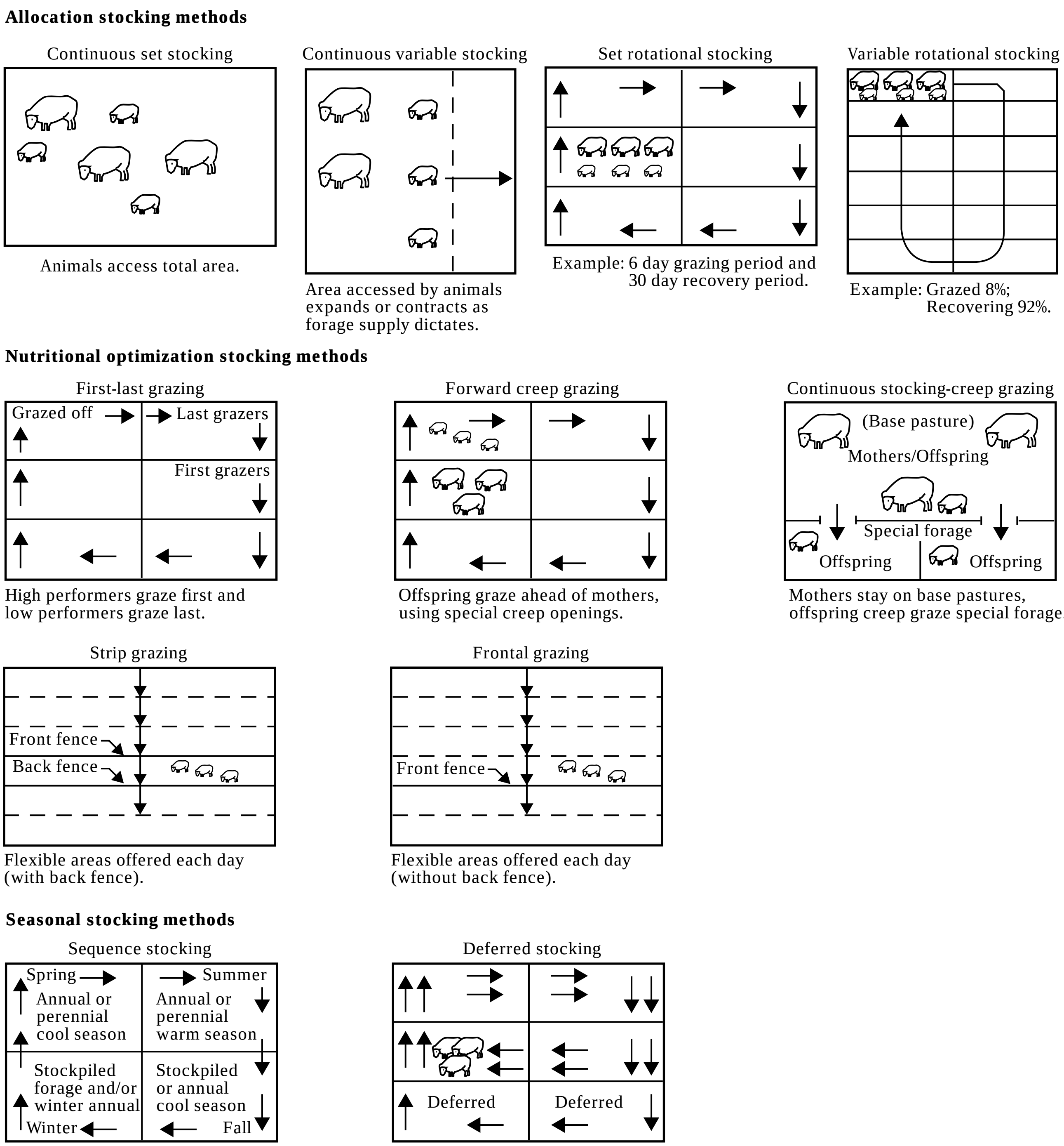
Care must be taken in developing forage budgets. Some budgets ignore forage quality. Others ignore utilization, and some overcompensate for it. Other budget formats ignore both quality and utilization. On high quality pasture this creates compensating errors, and the end result is a remarkably good answer for middle of the road performing livestock. The dry matter forage requirement, 2.5 to 2.6 percent of body weight, assumes a level of digestibility considerably lower than that available from high quality pasture. Because this assumed digestibility is 70 to 80 percent of that available on high quality pasture, the forage requirement already has the forage allowance covered if the utilization rate is in the 70 to 80 percent range.

In figure 5–29 see the forage allowance required at the 80 percent utilization rate. It equals 2.6 percent of body weight, but it assumed only 80 percent utilization of that 2.6 percent of body weight forage allowance. Only 2.1 percent of body weight was actually consumed, and intake was only 80 percent of maximum. Remember this maximizes production per acre and sacrifices some animal performance. The margin is razor thin. After that, animal intake drops precipitously. The curve has to go to zero intake in a narrow range of forage allowance. In other situations, such as low quality forage or maintaining a high availability for high performance livestock, less detailed forage budgets would not work out so well.

(2) Stocking methods

(i) Allocation stocking methods—The four basic allocation stocking methods used throughout the country are continuous set stocking, continuous variable stocking, set rotational stocking, and variable rotational stocking. Herbivores graze, but livestock producers stock them on pasture. Hence, the use of the term **stocking** is preferred over the term **grazing**. Within the four basic methods, applications can vary based on livestock responses desired, climatic considerations, soil and terrain conditions, forage crops being grazed, and management preferences of the producer. The scope of this section is not to cover all the various applications, but it will cover the more common ones. Figure 5–30 is a diagrammatic illustration of each.

Figure 5–30 Three classes of stocking methods and their associated stocking method* (adapted from Barnes, et al. 1995; Hodgson 1990)



* Each method is diagrammed to show how the livestock are deployed about the pastures.

Continuous set stocking method—Continuous set stocking of livestock either season-long or year-long is a common method of pasturing them. Continuous set stocking means the same numbers of animals are on one pasture unit for the whole grazing period. This is a misnomer because although the animal numbers remain constant, animal unit demand for forage often does not. Meat animals gaining weight, and lactating animals have variable forage demands during the grazing period. If set stocking is to be used, an average forage allowance for the grazing period must be calculated. If there is a recovery period, it is at the beginning or end of the grazing period (= season). If the forage being grazed has a very nonuniform distribution of growth, forage utilization will be low. Periods will occur when forage growth gets ahead of livestock and times when it is too slow. During slow growth periods, livestock are forced to consume less palatable and lower quality forage that has collected in ungrazed or less grazed areas of the field. This reduces intake and also lowers utilization. Low utilization at the beginning of the year perpetuates low utilization. First there is too much to eat. Some forage matures. When the season progresses, there is more low quality, high fiber forage than succulent. This reduces intake. Spot grazing is high under this circumstance.

This method is appropriate, however, where both forage growth and animal unit demand are relatively evenly matched throughout the grazing period. Another situation where it can work well is where the forage has made all or most of its growth and it will be grazed until it is gone. This works well on seasonal annual forages and on stockpiled forages. Regrowth is generally of little or no concern. With stockpiled perennial forages, a minimum stubble height should be observed to allow it to go through its dormant period without stand loss. For annual forages leave enough stubble to protect the soil from erosion and allow ones that can naturally reseed themselves time to produce seed, as needed, to get a good stand next season.

This stocking method has been equated with poor grazing management. The method itself is appropriate under the right forage growth circumstances and when managed to provide the proper forage allowance to the class of livestock being fed. Unfortunately, this method is applied all too often with none of that in mind.

Continuous variable stocking method—Continuous variable stocking is a stocking method alternative that adjusts land area or livestock numbers as forage availability changes throughout the grazing period. On commercial operations, this method starts out with a core pasture that is grazed during the high growth rate period of the forage. As forage growth rate declines, this method attempts to add more acreage and available forage to the livestock ration. The additional acreage is often harvested for stored roughage first. It is allowed to regrow. Then, it is opened up to livestock grazing as the core pasture forage growth rate starts to fall behind the livestock removal rate, or the available forage is nearing the desired maximum percent utilization rate. The decision to open up additional pasture is based on forage stubble height, changes in spot grazing behavior, animal performance, or a combination of these. With a milking herd, when milk production tails off and can be correlated to pasture condition, this signals a need to increase forage intake by increasing pasture size. The other alternative for this method is to keep the pasture the same size and vary livestock numbers. This is done in an experimental plot setting, but is not common on commercial operations. The procedure is called put and take. Livestock numbers are varied as forage growth conditions warrant.

Some pasture forages are not well adapted to continuous grazing. They are alfalfa, big bluestem, Indiangrass, Johnsongrass, red clover, sericea lespedeza, smooth bromegrass, switchgrass, and timothy. Many of these forages disappear completely under continuous grazing while the others persist, but at low levels of production. If managed under a rotational system, some forages respond and increase in percentage of total forage production and ground cover. These forages depend on a cycle that allows them to rebuild food reserves while they reach physiological maturity. Continuous grazing never allows that to occur.

Other forages, such as birdsfoot trefoil, Coastal bermudagrass, orchardgrass, perennial peanut, and tall fescue, are adapted to continuous grazing as long as they are not grazed too closely. If grazed close, they will persist, but in fewer plant numbers and at a much reduced growth rate. Bahiagrass, common bermudagrass, Dallisgrass, Kentucky bluegrass, ryegrass, white clover, and many annual clovers are adapted to close continuous grazing. They hold much of their leaf area and their growing points below the grazing zone. Bahiagrass and common bermudagrass often increase when present in a mixed stand with Coastal bermudagrass.

Set rotational stocking method—Set rotational stocking is a stocking method that falls under several different names depending on what region of the country it is used in. This method is useful on pastures where forage growth rates vary little or physiological maturity is going to occur regardless of forage height and growth rate. These forage crops respond to a recovery period because they need time to build food reserves while gaining in leaf area.

This general method has a set grazing cycle period. A set grazing period and a set recovery period make a complete set time cycle before the livestock return to the same pasture paddock or subunit. It is obvious from table 5–4 that higher utilization rates occur if the grazing period is short. It is rather important to most pasture forage species with elevated growing points that the grazing period not extend beyond a week. Otherwise, regrowth begins that may be grazed off when livestock are stocked at high densities. This can drawdown food reserves and make recovery slow as more growing points must break dormancy and grow to replace the newly initiated, but grazed off points. The recovery period is set based on the recovery period needed by the forage crop. The recovery period time and the grazing period time determine the number of paddocks needed. The recovery period time divided by the grazing period time plus one equals the number of paddocks required. For instance, alfalfa may require from 21 to 28 days to recover depending on the cultivar being grazed, pasture-type versus hay-type, and growing degree days for the region. If a pasture-type is grazed for 1 day and recovers for 21 days, 22 paddocks are needed. If the grazing period is extended to 7 days, only 4 (21/7 + 1), but much larger, pasture subunits are required.

A weakness in the set rotational stocking method is the variability that can occur with available forage in a pasture subunit from one cycle to the next. If it truly is set, it cannot account for changes in forage growth rates well. Alfalfa, for instance, will go to physiological maturity under drought conditions and flower even though it may be several inches shorter than it was when water was plentiful. A paddock that was sized right for optimal moisture conditions is going to be too small under drought conditions. Some fine tuning of paddock size may be warranted. This can be done with portable fences. Another option is to oversize paddocks to strike a balance between projected highs and lows in production. The other option is allow some flexibility in the grazing period seasonally and incorporate another field during low forage accumulation periods. Keep paddocks the same size, but reduce occupancy time to match available forage with forage allowance needed for the herd. Recovery periods remain set, but now more paddocks are grazed during the recovery period than when forage growth rates were high.

Pasture forage crops that respond best to a set grazing cycle period are alfalfa, big bluestem, birdsfoot trefoil (upright), Coastal bermudagrass, indiangrass, Johnsongrass, perennial peanut, red clover, smooth bromegrass, switchgrass, and timothy.

Variable rotational stocking method—Variable rotational stocking is a stocking method that adjusts the recovery period to the variable growth rate of forage species being grazed. The grazing period is generally set. In practice, it often is not. If the grazing period is not set, it tends to only defer problems of too much or too little forage within the area set aside for rotational pasture. The grazing period for high performance animals (intensive or short duration rotational stocking), such as lactating dairy cows, fattening cattle, and youngstock, should be no longer than 3 days, preferably not more than 1 day. For other livestock classes the grazing period can extend up to 7 days, but preferably not more than 4 days to prevent grazing of new leaf growth.

If a first-last stocking method is used, the combined total period of occupancy should not exceed 7 days (3 days for intensive rotational stocking). The grazing period length must be determined by animal performance, forage availability, and target residual stubble height or mass of forage to get rapid regrowth during the recovery period. This is initially determined using the pasture budgeting technique described earlier. If one or more of the estimates used to determine paddock size is off, the decision to deviate from the planned grazing period must be based on available forage and stubble height left at time of viewing.

This method is similar to the continuous variable stocking method in one respect. It relies upon expanding or contracting the area being actively grazed during the grazing season. During periods of high forage growth rates, the number of paddocks and pasture area is least. During periods of slow or arrested forage growth, the number of paddocks and pasture area expand to provide an adequate forage allowance for the herd in each paddock throughout the grazing cycle period. This additional pasture acreage typically is machine harvested until needed for grazing use. Grazing is initiated when enough forage has accumulated in each paddock to meet the herd's forage allowance (available forage x area x utilization rate = livestock demand).

This rotational system can have a high degree of flexibility. Paddocks can be stocked out of sequence when forage growth is variable from paddock to paddock because of landscape position, differing soil fertility and water holding capacity status, forage species composition differences, or past grazing pressure. When forage supply is much higher than expected, fewer paddocks than usual are stocked per grazing cycle and more are machine harvested. If the forage supply is low, additional paddocks are brought into the grazing cycle. In severe shortages the machine harvested forage made earlier when forage was in excess of livestock demand is available for feeding. This becomes critical if pasturing must cease to prevent forage stand loss or prolonged delay in forage recovery after the stress period has passed. Recovery periods range considerably, from 10 days to more than 60 days.

Pasture forages that respond best to this stocking method are ball clover, bentgrass, berseem clover, birdsfoot trefoil (prostrate), Kentucky bluegrass, orchardgrass, perennial ryegrass, redtop, reed canarygrass, tall fescue, and white clover.

(ii) Nutrition optimization stocking methods— These stocking methods are used to selectively feed livestock. They can be associated with either continuous or rotational stocking methods. They are **first-last grazing and strip grazing**. Creep grazing, where young stock graze ahead of their mothers, is generally considered a separate category, but in effect is just a form of first-last grazing on rotational pastures. On rotational pasture, it is called forward creep grazing. On continuous pasture, creep grazing requires a separate pasture of high quality forage which the mothers may never gain access to. Therefore, it becomes its own separate category in that situation. Strip grazing also has a variation to it called frontal grazing. Strip grazing requires a back fence to keep livestock off the previously grazed area. Frontal grazing provides animals with a fresh strip of forage too, but has no back fence. Animals have access to the land previously grazed as well as the new forage being offered. Both major selective methods and their variations are enhanced attempts of offering the appropriate plane of nutrition to the classes of livestock being pastured.

Creep grazing—Creep grazing allows young stock to graze forage their mothers cannot get to. It is used with meat type animals to get higher weaning weights. In either continuous pasture setting or rotational pasture, a gate with an opening just large enough to allow young stock to pass through is placed in the fence between the shared pasture area and the creep pasture. On rotational pastures, the mothers follow the young stock onto the forward paddock after the young stock have had first choice of the available forage. In this instance, it is a first-last grazing method. On continuous pasture the young stock have access to a separate field of high quality forage. The mothers may only get to clean it up near the end of the growing season or never gain access to it. In lieu of creep grazing, creep feeders may be placed in pastures so that only the young stock have access to high energy feeds for faster weight gains.

Another common first-last grazing scenario places lactating dairy cows ahead of heifers and dry cows on rotational pasture. High production lactating dairy cows require a high forage allowance to keep intake from falling off near the end of the grazing period that they are in a paddock. After they are removed, considerable available forage is still left. Heifers and dry cows having lower intake requirement can use forage left behind by the milkers.

Other first-last grazing combinations are rapidly growing weaned youngstock being placed ahead of the brood stock. Because high daily gains are desired of the meat animal, they are removed before intake starts to fall off and the quality of forage ingested declines. Care must be exercised to keep the total occupancy period no longer than 6 to 7 days on rotational pasture when grazing forages with regrowth potential.

Strip grazing—Strip grazing in its ultimate usage is trying to maximize utilization of standing forage by limiting the amount of fresh forage at any one time to the grazing herd. This tends to increase intake because the herd responds to fresh forage on-offer by grazing as soon as it becomes available to them. If intake increases, this will increase milk flow or weight gain. Thus, it is best utilized with high performance livestock. Generally it occurs on fields that are also machine harvested. The interior fences subdividing the field are portable and are removed once the field is readied for machine harvest again. Thus, no barriers are present to impede equipment traffic. Strip grazing may break forage allocation down to units small enough to be grazed off in one to four hours. The forward and back fences are picked up and moved to new positions based on completeness of forage removal. The same purpose and concept is used with frontal grazing except no back fence is provided. The forward fence gets moved as new forage is needed.

Under more lax grazing management, strip grazing may occur where the grazing period is similar to that of an intensive rotational stocking method where the livestock are moved on a half day to daily basis. Single strand electrified fence is used that is portable and can be removed if need be to facilitate machine harvest. This is useful on the fields that are brought into the rotational system during the low forage growth rate period. When not needed for pasture, they are cropped. In fact, the field strip grazed may be a crop field with grazable crop residues, or one seeded to an annual forage crop. Strip grazing serves a useful transitioning tool between cropping and grazing a field in this instance, but does nothing to further enhance animal nutrition beyond what the basic rotational method does.

Frontal grazing—Frontal grazing is a form of continuous variable stocking. As available forage disappears, more area is opened up for grazing. Again, as with strip grazing in variable rotational stocking, frontal grazing is most useful to incorporate a new field into the area being grazed when forage production is low. Instead of stocking the whole field at once and sustaining high trampling and rejection losses, the new field is rationed piece by piece. Forage utilization is higher, and higher intake rates can be sustained until the field is entirely opened up. This method is also more appropriate where the forage being grazed either has little or no regrowth potential. Crop residue, some brassicas, small grains grown for forage use only, and other short-lived annuals are examples. Perennial forages being grazed in this manner should be tolerant of continuous grazing.

When budgeting forage with strip or frontal grazing, care must be taken to not set aside more forage than can be consumed without a significant decline in forage quality when the last is made available for grazing. Entry into the field should begin slightly ahead of full forage growth potential to avoid having to stock animals on overmature forage near the end of the occupancy period.

(iii) Seasonal stocking methods—Another class of stocking methods seek to time access to fields to lengthen the grazing season or avoid harming the pasture area. The two main methods are deferred stocking and sequence stocking. They too can be used to varying degrees either in continuous or rotational stocked pastures.

Deferred stocking method—Deferred stocking can be done to stockpile forages or to keep livestock out of pasture areas needing seasonal protection for a variety of reasons. When the grazing season can be extended by stockpiling forages (i.e., tall fescue) that maintain their quality well, some pasture area is deferred from further grazing to allow the forage growing there to accumulate. Later on, this area is reopened for grazing when the other pasture areas are no longer producing grazable forage or need a recovery period.

Another form of deferred grazing is delaying the stocking of a pasture because it is too wet. Other pasture areas are selected that are drier to avoid damaging the sod and destroying soil structure. Soils when wet can compact severely. It is reversible only with mechanical treatment. On saturated soils, hoof prints are left behind that trap water and keep the site wetter longer than normal. The act of leaving these deep hoof imprints is called either poaching or pugging.

Deferred stocking may be used to protect riparian areas from grazing at critical times of the year. Another use might be to protect ground nesting bird habitat from disturbance until brood leaves the nest. Deferred stocking is also used where part of the pasture area is not needed for grazing until forage production slows down. This land typically is machine harvested to conserve the early growth and then stocked once sufficient forage is available for grazing. Deferred stocking may also occur on paddocks that are slow to recover for a number of reasons. They may be skipped over during a rotational cycle or two. A typical site would be a droughty soil paddock.

Sequence stocking method—Sequence stocking takes advantage of the seasonality of forage production. It integrates forages with differing seasonal availability into a diverse group of pastures. All fill a seasonal niche to supply enough forage to meet demand by the grazing herd. Review figures 5–14 through 5–16 and Table 5–2. Sequence stocking attempts to lengthen the grazing season or fill forage production shortfalls during the grazing season. Winter small grains might be grazed in late winter and spring, then early maturing cool-season perennial pastures next, followed by a later maturing cool-season perennial pasture, followed by a warm-season perennial or annual pasture, sequencing back to a cool-season pasture, and following up with a post harvest crop residue field and, where winters are mild, a winter annual pasture. Depending where the farm or ranch is situated in the country, all or part of these seasonal pastures and others not mentioned can be integrated into the forage production system. This stocking method attempts to reduce stored feed production and consumption to an absolute minimum.

(b) Accelerating practice—Nutrient management

Nutrient management on pasture differs from forage crop production nutrient management in two respects. First, most nutrients are recycled within a pasture's boundaries (fig. 5–31). Few of the nutrients brought onto the pasture as feed supplements, manures, atmospheric deposition, or commercial fertilizer leave its boundaries as animal products.

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. For instance, rates of nitrogen (N) application at urine spots can range from 200 to 900 pounds per acre. Sometimes the rate is so high as to cause plant burning.

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. From 15 to 18 percent of the total N can be lost within 2 days of urination. The drying of the surface causes the urea to hydrolyze to ammonium. This raises the soil pH in a localized area that causes the ammonium to break down into ammonia, a gas, and a hydrogen ion. Windy conditions speed the process of ammonia volatilization. Surface runoff may also carry nitrogen and phosphorus (P) to receiving water if concentrated livestock areas are near open water and soil infiltration is low as a result of low vegetal cover or tight, compacted soils.

Phosphorus and potassium (K) levels are rather stable in pasture soils. Pastures should be soil tested every 4 to 5 years for these two elements. Plant available P and K should be built to the optimum levels for the soil series sampled. If the soil is already at the optimum level for these two nutrients, no further response in forage yield will occur with the addition of manure or commercial fertilizer containing these elements (fig. 5–32). Normal recycling of the P and K through random placement of dung and urine should maintain levels. If much supplemental feeding of hay, grain, or minerals occurs, soil P and K levels tend to slowly build in the pasture soil. Legumes are heavy users, but inefficient gatherers of phosphorus and potassium. If a legume component is desired in a pasture, P and K levels in the soil should be in the optimum to high range so they can compete successfully with the grasses.

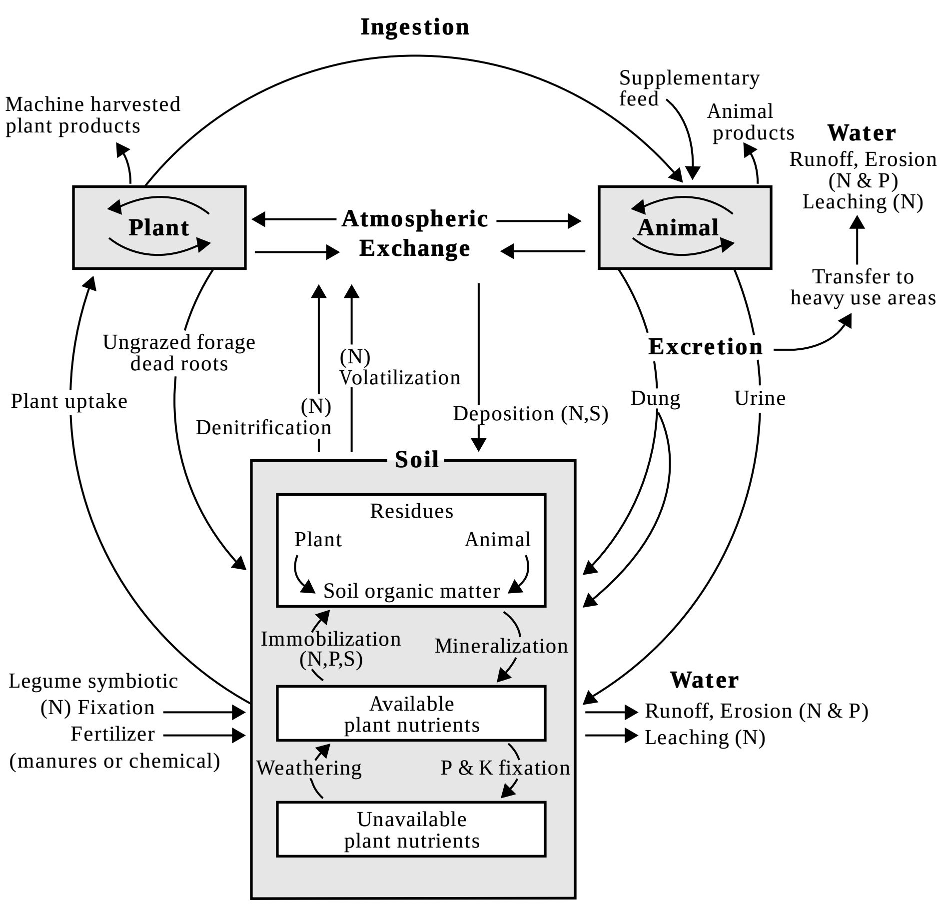
Soil reaction, or pH level, should also be noted when the soil test results return. Keep the soil reaction within the range of acceptable forage production. Most legumes grow best in a slightly acid to neutral soil. Where aluminum toxicity can inhibit forage growth, maintain soil pH at 5.5 or higher. *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.

Nitrogen is generally the major limiting nutrient in pastures. As mentioned before, it can leave by three pathways: volatilize, leach, or run off. The distribution of dung and urine under even the best of circumstances 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.

Intensive rotational stocked pastures tend to have a more even distribution of manure than do continuous set stocked pastures. However, it is extremely important that water, feeding areas, salt and mineral boxes, and shade are evenly distributed on a rotational pasture. If not, dung and urine spots can be distributed just as poorly. Poorly laid out paddocks and single source water, feeding, salt and mineral, and shade areas cause livestock to camp at these sites just as they do on continuous set stocked pastures. Long laneways to these attractive areas can receive much of the excreta as livestock traverse back and forth from grazing area to camp site.

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

Figure 5–31 Nutrient cycling in a pasture ecosystem (adapted from Barnes, et al. 1995)



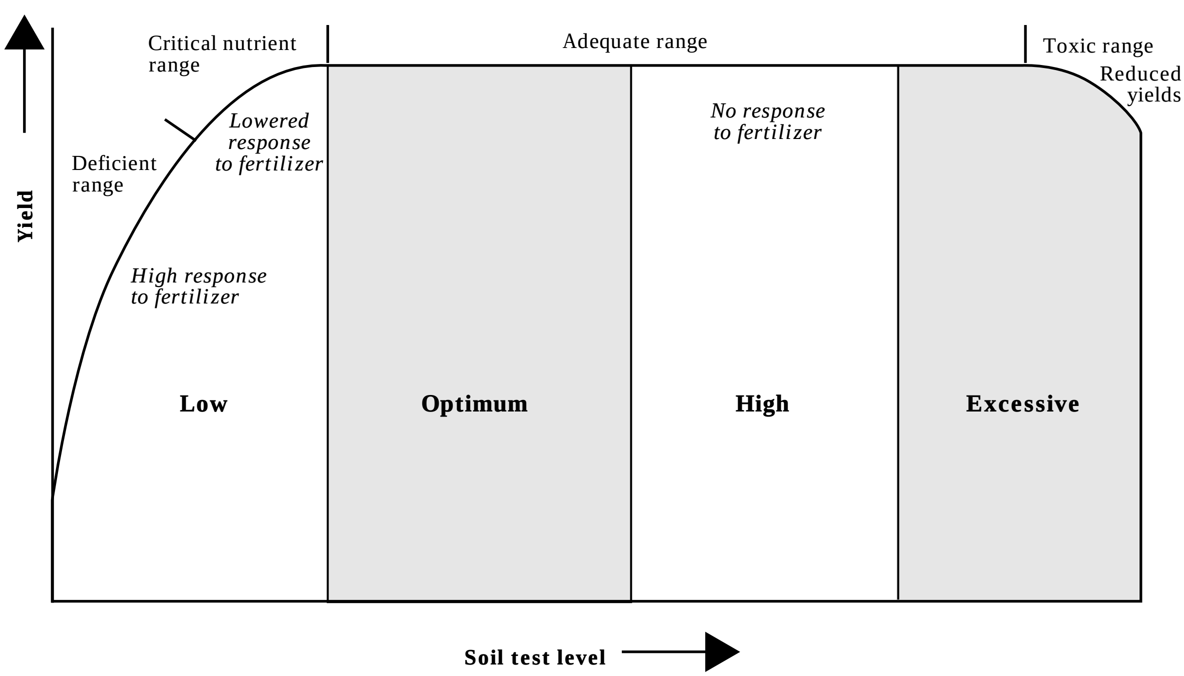
where grass tetany is know to be a problem to livestock. If a legume component is desired to improve animal intake and nutrition, N fertilizer rates and timing should also avoid giving the grasses a competitive advantage over the legumes.

Legumes can fix atmospheric nitrogen by acting as a host to *Rhizobium* bacteria. See table 5–5, Seasonal total of nitrogen fixation by forage legumes and legume-grass mixtures. During the first year of legume growth, no nitrogen is transferred to the grass component of a pasture sward. Thereafter, nitrogen is transferred from the legume to the grass in substantial amounts, providing up to 50 percent of the N requirement of some grasses. Depending on the legume species and its distribution and percent of stand, N transfer to cool-season grasses ranges from just a few percentage points to 50 percent. Stand life average N transfer to grasses from the legumes accounts for no more than 25 to 30 percent of cool-season grass needs.

It appears with some warm-season grasses that compatible legumes grown with them may be able to supply perhaps all their N needs. Ideally, to be effective in transferring fixed N to grasses, the legume should make up at least a third of the stand and be well dispersed. Maintaining the legume component in the stand requires good grazing and nutrient management. Even then, diseases and insects can still take out the legume component. Maintaining legumes in a pasture takes a concerted effort to reintroduce them by overseeding or renovating the pasture from time to time.

Nitrogen fertilizer additions, whether from fertilizers or N fixing legumes, induce long-term soil acidification in the topsoil and subsoil. 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. Soil acidification results in the loss of exchangeable cations, of

Figure 5–32 Yield response curve to indicated range of plant available nutrients from soil test results* (from Serotkin 1994)



* Note once optimum level for a plant nutrient is reached, no further yield response occurs.

particular importance, calcium (Ca) and magnesium (Mg). Soil acidification is heightened in the surface layer (0 to 2 inches) of the soil of permanent pastures in particular. The N fertilizers are generally surface applied and no, or infrequent, tillage takes place to mix any lime from deeper in the soil profile with the surface soil.

Sulfur (S) is a secondary nutrient of critical importance to forage growth. It is a component of chlorophyll and proteins. Sulfur is similar to N in some respects in that it can be an atmospheric contaminant that is deposited on the soil and can also be immobilized by microbial breakdown of soil organic matter. With the advent of high analysis fertilizers, little or no sulfur is added to the soil when commercial fertilizers are applied unless they are specifically formulated to contain sulfur. Sulfate had been used widely as a carrier for nitrogen and potassium fertilizers. Also, as acid deposition is brought under control, less sulfur is being deposited on the soils from the atmosphere. As a result, sulfur deficiency symptoms are beginning to reappear, especially in legumes. For optimum plant growth, the N:S ratio in plant tissue should range from 14:1 to 16:1 when N content of the plant is adequate.

Calcium and **Mg** are important secondary nutrients for plant and animal nutrition. On calcareous soils, both generally are adequate. On acid soils these nutrients can be in low supply unless the soils are limed regularly. Magnesium is particularly important to pastured cattle and sheep. Areas deficient in magnesium or areas that are overfertilized with K, N, or heavy applications of manures containing N and K can cause seasonally low dietary levels of Mg in the forage ingested by livestock. This causes low blood plasma levels of Mg (hypomagnesemia or grass tetany) in livestock, especially freshening females. Death can result if not treated quickly or prevented by agronomic or feeding practices. Agronomic practices to avoid hypomagnesemia are liming soils with dolomitic limestone (calcium and magnesium carbonates) and splitting N and K fertilizer applications. If poultry litter is used as a nutrient source, prudent rates must be applied and preferably after high grass growth rate periods. Magnesium supplements can also be fed to livestock prior to calving or lambing and before flush grass growth periods.

Table 5–5 Seasonal total of nitrogen fixation by forage legumes and legume-grass mixtures 1/

Legume or legume-grass	Total N_2 fixation (lb/acre) 2/
Alfalfa	70 – 300
Alfalfa - orchardgrass	13 – 121
Alfalfa - reed canarygrass	73 – 226
Alsike clover	119
Berseem clover	55 – 210
Birdsfoot trefoil	44 – 100
Birdsfoot trefoil - reed canarygrass	27 – 116
Crimson clover	94
Hairy vetch	100
Ladino clover	100 – 179
Lespedeza (annual)	85
Red clover	20 – 200
Red clover - reed canarygrass	5 – 136
Subterranean clover	52 – 163
Subterranean clover - soft chess	19 – 92
Sweet clover	119
White clover	103 – 114
White clover - bahiagrass	> 270
White clover - bermudagrass	135
White clover - Dallisgrass	143
White clover - tall fescue	187

1/ Sources: Ball, D.M., et al. 1991, Southern Forages; Barnes, R.F., et al., 1995, Forages; Chessmore, R.A., 1979, Profitable Pasture Management; and Graffis, D.W., et al., 1985, Approved Practices in Pasture Management.
2/ Ranges given where available. Single values are probable maximums or the averaged result of one experiment. Highly variable. Do not use as absolutes.

Use of pastures as sites for manure disposal must be done with some prudence for other reasons. 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 since Cu salts are fed as wormers to both livestock types. High rates of poultry litter applied to endophyte infected tall fescue pastures can also intensify bovine fat necrosis outbreaks. Ideally, no more than 4 tons per acre of poultry litter should be spread on tall fescue pastures. It also is important not to overload pasture soils with P and K either. As mentioned before, these nutrients are slow to leave the pasture as animal products. Long-term accumulations of these nutrients can induce deficiencies of other essential nutrients in plants and animals. Recently, high levels of K in pasture grasses have been implicated in cases of milk fever in freshening dairy cows grazing them.

Two trace elements of critical importance to livestock production are **copper** and **selenium** (Se). Both are essential for livestock health, but have a narrow range of acceptable concentration in feedstuffs. Induced copper deficiency in livestock can occur in areas where soils contain elevated levels of molybdenum and sulfur. Selenium deficiencies occur in the Pacific Northwest and the Eastern third of the United States. In semi-arid parts of the U.S., selenium may be present in forage in toxic amounts. Soils deficient in these two elements cannot be safely supplemented with either Cu or Se fertilizers. Overfertilization with either is easily done. Feed rations must be balanced through supplementation where Cu and Se deficiencies occur or through dilution when forages containing toxic amounts of Cu and Se are produced.

The trace element **cobalt** (Co) can be safely applied as a fertilizer. It is required in energy metabolism in ruminants and for the health of *Rhizobia* in legume root nodules. Pastures deficient in cobalt can be fertilized with low rates of cobalt sulfate (1.5 to 3 ounces per acre of Co).

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.

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 is possible with the setting involved. Multiple watering sites no greater than a quarter mile away from each other is a start. If the water is not close to the grass, livestock once at the watering site will tend to camp there. Grass will be underused away from the watering site and receive little manure. Meanwhile, the grass close to the watering site will be overgrazed and receive all the manure. In multiple paddock layouts, water must be at each paddock. Ideally, water is placed towards the middle of the paddock if the length of the paddock exceeds a quarter mile. If water is not available at each paddock, the laneway serving the paddocks will end up with a disproportionate amount of the excreta.

Salt and mineral blocks should not be placed close to other attractive areas. This encourages livestock movement and dispersion of excreta. Shade and hay feeding areas are best kept on higher ground away from streams. Ideally they should be positioned on knolls or hilltops. Manure and urine will be concentrated there, but runoff events tend to wash some of it back down the slope.

(c) Accelerating practice—Pasture planting

At times, grazing management cannot provide the desired species mix or quantity and quality of forage on a pasture in a timely fashion. Also the seedbank may not store enough seed of the desired species missing from the stand. When confronted with these problems, planting seeds or sprigs is necessary to achieve pasture production objectives. Several good reasons to resort to pasture planting include:

- Reintroduce legumes into the stand.
- Replace low producing common varieties of grasses with improved varieties.
- Replace grasses with low palatability or high alkaloid content with improved varieties of the same species or altogether different species.
- Replace disease or insect prone grasses or legumes with new resistant varieties.
- Plant forage species on land being brought back into pasture use as part of a crop rotation cycle or as a land use change.
- In lieu of other corrective measures to change the site conditions of a field, replace poorly suited forage species presently growing on the field with forages better suited to soil and climate.
- Replace some existing forage stands on part of the land unit to better match livestock forage demand throughout the year by providing sequential stocking areas of high forage availability. (For instance, reintroducing some warm-season grasses on a part of a land unit currently without any warm-season pastures to provide summer pasture when cool-season grasses are dormant.)
- Plant annual forage crops to extend the pasture season into a dormant period for the perennial species growing on the site or provide emergency or supplemental feed when other pasturage is low in quality, quantity, or both.

Keep pasture forage mixtures simple, not more than four species. In permanent pastures the soil seedbank provides several adapted alternative forage species anyway. Therefore, it is not real critical to achieve instant diversity and run the risk of planting a mixture that really does not persist as formulated anyway. Select species that have similar maturity dates and palatability, compatible growth characteristics, and are adapted to the same soil and climatic conditions. Use certified seed to get superior cultivars of known resistance to pests common to the production area and high seed quality of known purity and germination percentage. On soils with variable drainage, planting several forage species with differing adaptability to the drainage conditions on the site might be warranted. However, much of the seed sown will end up in places where the particular species will not thrive or perhaps survive. Therefore, do this only on sites where random variability of drainage is too complex to seed areas separately with different seeding mixtures.

Pasture plantings should be accompanied by good nutrient management practices. Soil tests should be taken to ensure the nutrient status of the soil is adequate for the species being planted. When the soil sample is sent in for nutrient analysis, it should state the species to be planted and the yield goal desired. If soil amendments of lime or gypsum may be required, take soil samples at least a year in advance of the planting time. Soil amendments should be applied at least 6 months ahead of planting to have sufficient time to react with the soil. On soils that tend to fix phosphorus, fertilizer should be band applied at planting rather than broadcast over the field.

Pasture plantings should also be accompanied by good pest management practices. Weed control before and after planting is critical. Many of the forage species are slow to germinate and establish themselves. Weeds that survived seedbed preparation or that germinate after planting can quickly shade and smother out young forage seedlings. Late season seedings of cool-season forages can avoid the heaviest weed pressure. Undesirable stoloniferous or rhizomatous grasses and broadleaf weeds should be killed with an herbicide several weeks in advance of tillage. No amount of tillage effectively controls them. Damping-off of seedlings can be controlled with fungicides labeled for use. Insecticides should be used as needed to control insect feeding. Severe plant thinning to total loss of stands can occur if insect pressure is high while seedlings are young and tender. This can also occur if slug feeding is high.

If pastures are to be tilled prior to planting, they should be grazed closely the year before planting to reduce the amount of organic residue incorporated. Otherwise, getting a seedbed that is firm, smooth, and not too trashy is difficult. This leads to overworking the soil to get it firm, smooth, and free of large amounts of residue. Overworked soils can crust over and dry quickly. This can jeopardize seedling germination and emergence. Tillage for forage establishment should only be used on fields with little or no erosion potential.

Once fields have been tilled to incorporate soil amendments and fertilizers and to produce a firm, smooth, granular seedbed, several implements are available to choose from to apply seed. Drills, cultipacker seeders, broadcast seeders, and band drills are the primary types. Band drills put down a band of fertilizer between rows of drilled seeds. Drills without press wheels and broadcast seeders should be followed with a culti-packer to get better seed-to-soil contact. Otherwise, these two seeding implements need to be followed by a soaking rain to get good seed-to-soil contact.

Forage seedings may be seeded clear (forage seed only) or with a companion crop. Clear seedings get a fast start, but weed growth generally needs suppression. Mowing or top grazing weeds off above forage seedlings is one method. Applying herbicides is another. However, there are no herbicide products that can be used on mixed grass and legume seedings. Straight grass mixtures can be treated with broadleaf herbicides labeled for use. Straight legume seedings can be treated with either broadleaf or grass herbicides labeled for the legume being protected. Companion crop seedings are not generally recommended south of the 39th parallel.

Bermudagrass may also be established by using sprigs, the stolons and rhizomes of the grass. Tillage should commence in the fall to kill existing sod where the bermudagrass is to be planted. It is left rough to cut down on soil erosion. Sprigs are dug with a sprig digger or spike tooth harrow from a nursery of a known cultivar. They are windrowed with a side delivery rake and can be baled to improve handling ease. Sprigs are planted either with a sprigger or broadcast, disked in, and the ground rolled to improve sprig-to-soil contact. To avoid weed competition, herbicides should be applied immediately after sprigging to control competing grasses and broadleaves.

Timing of plantings is regionally dictated. General strategies are to plant when moisture and temperature conditions are most favorable for the species being planted, enough growing season is left to ensure maturity or overwinter survival, and weed, disease, and insect pressures are best avoided. For instance, late summer to fall seedings of legumes can avoid major weed competition and damping-off diseases in some areas. However, in other areas, they may succumb to late season disease problems, such as Sclerotinia crown and stem rot.

Sod seedings (no-till) have become a more popular way of seeding pastures since improved no-till drill designs have become available. Sod seedings can be used on sites susceptible to high erosion rates and on soils that tend to dry out quickly or crust if tilled. To start, suppress or kill existing vegetation. The decision to suppress or kill depends on the value of the forage species remaining on the site and their abundance. If enough desirable forage plants cover the site, the suppression option can be chosen. Vegetation may be suppressed by grazing close for several weeks before planting. Ideally, seeding should come later in the growing season when it is unlikely that the suppressed vegetation will come back strong. This is very useful when planting cool-season annuals in warm-season grass pastures, such as bermudagrass.

Suppression can also be done using a burndown herbicide, one that burns back the green growth of perennials, but does not kill the crown or roots. This herbicide can either be broadcast or banded. Band spraying to leave alternate strips of green and burned back vegetation allows for an early return to grazing when spring sod seeding a legume into a grass pasture. Weed suppression is also greater. There is less need for herbicide as well. If the present pasture has little forage of any value and aggressive spreading low quality forages and better cultivars of existing forages are desired, then the existing stand should be killed. Ideally, this should be done towards the end of the previous growing season for an early seeding the following year. This is particularly needed if unwanted rhizomatous or stoloniferous vegetation is present. It gives time to react to less than a 100 percent kill and treat the area again.

A low technology method of sod seeding is frost crack seeding. This is used in areas of the United States where late winter alternate freeze and thaw cycles causes the soil to honeycomb at the surface. Successful clover seedings can be done in this manner by broadcasting the seed over the existing sod. These seedings eventually come in good contact with the soil during the freeze and thaw cycles to germinate when the soil warms enough to trigger germination. Further seed-to-soil contact can be promoted by allowing livestock to tread the seed in when the soil is firm enough not to become poached badly. They must be removed before germination.

Seed depth is critical for small seeded forages. Most require a shallow depth (0.25 to 0.50 inch) to get good emergence and survival. In drier regions, depths may need to extend further in the ground (up to 1 inch) to get adequate moisture for germination. Even in the same MLRA, seed depth must vary according to soil type. Greater seed depth is required in sandy soil than in silt or clay loams. Seed depth recommendations for various forages should be based on their specific requirements, surface soil moisture conditions as affected by soil texture, and time of year of seeding.

Seeding rates should be based on pure live seed, the percentage of pure seed that will germinate from the seed lot being planted. Seeding rates should be adjusted for soil textural differences. Sandy soils can be seeded at lower rates than heavy clay soils since emergence is less inhibited by soil crusting. Soils with low water holding capacity should be seeded at lower rates because they cannot support as many plants as soils with high water holding capacity. Seeding rates should be adjusted based on seeding equipment and method used. If seed is broadcasted or drilled without press wheels or trailing culti-packer, seed rates need to increase by 25 percent. Seedling mortality will be high because of the hit or miss soil coverage of the seeds. If clear seeding, adjust seeding rates upward to crowd out weeds and maximize first year forage production.

Mortality is high with forage seedings. Commonly only a third of the seeds become emerged seedlings. Of that, only 20 to 50 percent survive at the end of the establishment year. Oversown fields, where seed is spun on and lightly harrowed or frost crack seeded, have very high seedling mortality; 10 percent survival is typical. This is why seeding rates are as high as they are. For instance, where alfalfa is seeded at the rate of 15 pounds PLS per acre, there are 77 seeds per square foot. At the end of establishment year, 20 to 50 alfalfa plants per square foot is considered optimal. If 50 percent of the seed survived to be plants at the end of the establishment year, the number per square foot would be 38. If only a third survived, then 26 alfalfa plants per square foot remain.

Given the cost of seed and the expense of preparing the ground to plant it, it is wise to take care in planting it. If the planter used cannot by itself ensure good seed-to-soil contact, then a pass with a culti-packer or shallow set harrow is worth the time spent. Fungicides and insecticides can also be effective in reducing seedling mortality. Livestock should not return too soon to new seedings. Treading damage and ripping of plants out of the ground during grazing can result.

All legume seed should be inoculated with the proper strain of *Rhizobium*. Most of the alfalfa and clover seed sold today is preinoculated. When the seed is preinoculated, it must be sown before the inoculant expiration date on the seed tag. Otherwise, it must be retreated with inoculant. For untreated seed or expired treated seed, apply the humus based inoculant to the seed with a sticking agent just before sowing.

(d) Accelerating practice—Prescribed burning

General rule of thumb: Burn warm-season grasses as needed. Never burn cool-season pasture forages.

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 indiangrass, 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.

Burning of cool-season forages is not recommended. In fact, it is a control measure to get them out of warm-season grass stands. Despite an early green-up when dead residue from previous years is burned off, experimental results have shown substantial decreases in forage yield for the season after a burn. An exception to this rule might be where previously abandoned/unused forage stands have large amounts of dead, low quality residue and invading brush and weeds on them. In this case a prescribed burn would hasten the return to good forage production and kill the brush. First year production would have been low anyway because forage plant densities had declined as a result of long-term shading from mature plant material and competing vegetation.

Burns should be fast and done when the soil is moist to protect roots and crowns from damage and under low wind conditions. They should be done by qualified people in accordance to local statutes and the NRCS Prescribed Burning conservation practice standard.

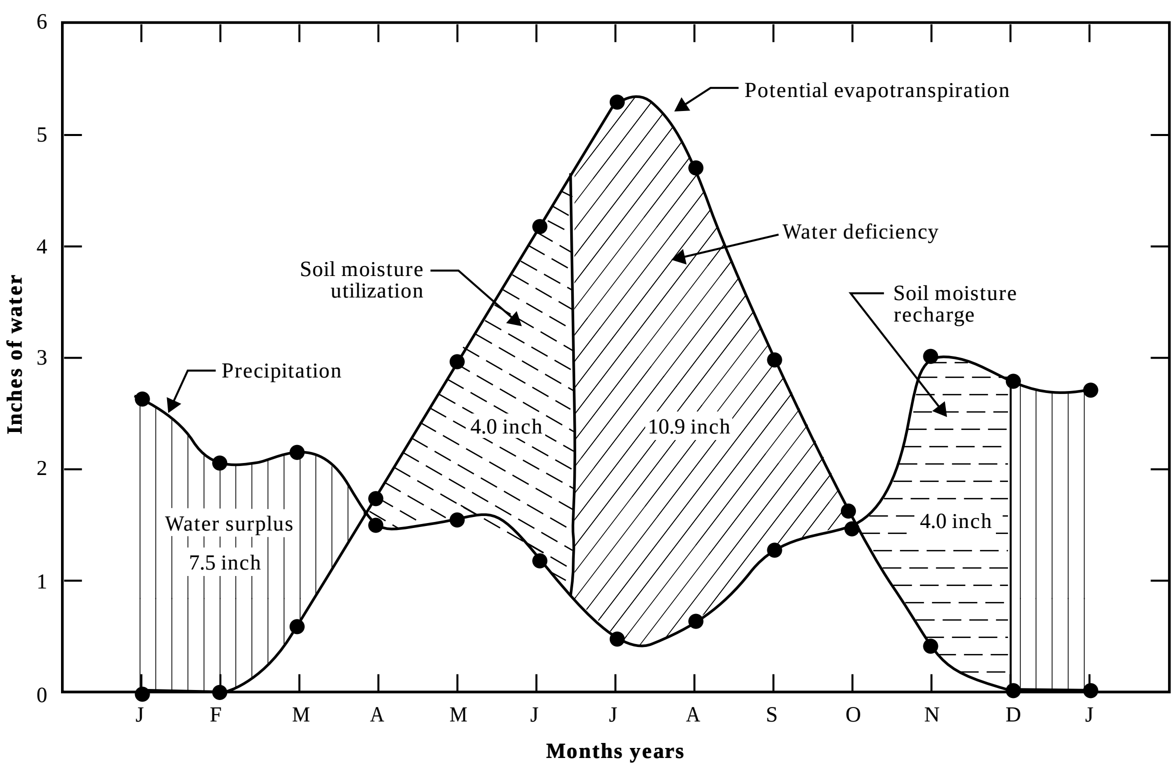
(e) Accelerating practice—Irrigation water management

Irrigated pastures are commonly used to complement rangeland and other types of permanent pasture. They can provide dependable pasture when other pastures are dormant. These pastures can also be used to achieve higher average daily gains on calves and stocker cattle. This results in more pounds of beef for sale at the end of the grazing period when the cattle are moved to the feedlot. Similar production gains can be had with other livestock types.

Irrigation of pasture is put to best use in areas where precipitation and stored soil moisture fall well short of potential evapotranspiration needs of the pasture. Water ends up being the limiting nutrient during the seasonal height of pasture growth. Figure 5–33 shows a typical yearly water budget. In the example displayed in this figure, nearly 11 inches of water is needed to meet the pasture's need for water during the summer months. Plant available soil moisture for this particular soil and forage species is 4 inches. This water is used up during the spring months since plant uptake requirements exceed precipitation by mid-March. After plant growth begins to slow down in the fall, precipitation exceeds plant uptake. Soil moisture begins to be restored. Once plant available water is restored, the rest entering the soil becomes surplus and leaches below the root zone. Rainfall exceeding the soil's infiltration rate will runoff as well.

Irrigation water management described here focuses on management only as it specifically relates to pasture. A more in-depth description is in the section, Forage crops.

Figure 5–33 Typical water budget showing where the seasonal need to irrigate occurs and the magnitude of that need (from Baver 1961)



Many of the forages grown for pasture have relatively shallow root systems or at least have 70 to 80 percent of their root mass in the first 4 to 6 inches of the soil. This limits the amount of water that can be stored in the effective root zone for these forages. Irrigation applications need to be more frequent and at relatively low rates to be certain the water is used by the forages and not percolating by their roots. Deep percolation is sometimes necessary to leach salts and sodium from saline and sodic soils. On these soils heavier application rates are necessary to keep the salts from accumulating in the root zone and burning the forages. When irrigating forage mixtures, the species having the shallowest root system generally controls the irrigation schedule. It will suffer the most if irrigation is delayed.

Flood and sprinkler irrigation are the most commonly used pasture irrigation methods. When flood irrigation is used, large heads are required to get quick coverage and uniform distribution of water over the flooded area. This is because pasture sods reduce overland flow velocities quickly and create an absorbent soil surface. The distance between head ditches that are used to flood the pasture must be close spaced because of these vegetal retardance and soil porosity factors. If not, some areas of the pasture receives all or most of the water while others remain too dry for top yields. When feasible, land smoothing should be done to remove high and low spots in the pasture.

Sprinkler irrigation gives a more uniform water application especially on rolling topography and highly permeable soils.

Rotation grazing of irrigated pasture facilitates the scheduling of irrigation after a grazing event. This avoids having livestock on wet soil where poaching damage can occur to the sod. Having the pasture divided into two or more subdivisions, allows the manager to graze one subunit while irrigating another immediately after the livestock are removed. Livestock should remain off the irrigated subunit long enough for the ground to firm up and permit enough regrowth to meet available forage requirements. Set minimum allowable grazed stubble heights on irrigated pasture to achieve rapid regrowth recovery of the preferred species. Maintenance clipping of irrigated pastures minimizes selective grazing, enhances forage quality by setting all plants back to early vegetative state, and thereby increases utilization rates by livestock.

In arid regions, irrigated pasture soils generally are low in nitrogen and phosphorus. Legume-grass mixtures can overcome the nitrogen deficiency. Fertilizing with superphosphate fertilizers promotes excellent growth of these forages. Soil nitrogen tends to build with time as long as legumes remain a component.

Irrigated pasture can be used in rotation with other crops to improve soil tilth through increasing soil organic matter content and soil particle aggregation. Being under a crop rotation also allows the pasture to be renovated on a scheduled basis to maximize forage production when it is in pasture.

Annual forage crops grown on irrigated pasture benefit by being irrigated just before or immediately after planting. Germination and initial growth proceed quickly and produce grazable forage faster and more predictably than rain-fed crops. Irrigated pasture also enhances cool-season forage growth during the midsummer slump period. The lack of moisture is more critical than the high temperatures in suppressing their growth

(f) Facilitating practice—Water development

To get maximum use of available forage, water must be within a quarter mile of the forage producing site on level to undulating topography. Where slopes exceed 25 percent, watering sites should be no more than 600 feet away, 1,200 feet between watering sites. When distances get greater than this under the slope conditions mentioned, forage past those distances are lightly grazed if at all. At greater distances to water especially with fence barriers blocking movement, pastures become overgrazed near the watering site and undergrazed at more remote locations.

Water development can take many different forms. Several forms are described in this section.

(1) Pipelines

Most farmsteads and ranch headquarters have wells. Where distances are short to pastures, it may be easier and cheaper to extend pipelines from the well to water troughs. Many pipelines using polyethylene tubing are laid across the ground surface or buried. Hydrants with connecting valves are located at convenient intervals to temporarily attach water hoses that lead to a water control valve in a water trough. Polyethylene tubing is preferable to other materials because of its resistance to corrosion, resiliency, and lower friction resistance to water flow. In locales where water freezes in the winter, exposed pipelines need to be drained of water or have sufficient water flow-through to remain unfrozen. Buried pipelines need to be placed below the frost line, or drained during the winter months if rock limits depth of excavation. The decision to bury or let the pipelines lie on the surface depends on the permanency of the pasture layout, amount of vegetal cover present to shade the pipe, and ultimate temperature of the water at the trough. Water temperature above 75 degrees Fahrenheit decreases water intake and milk production in dairy cows. Lactating dairy cows produce the most milk when drinking water is between 50 and 65 degrees Fahrenheit.

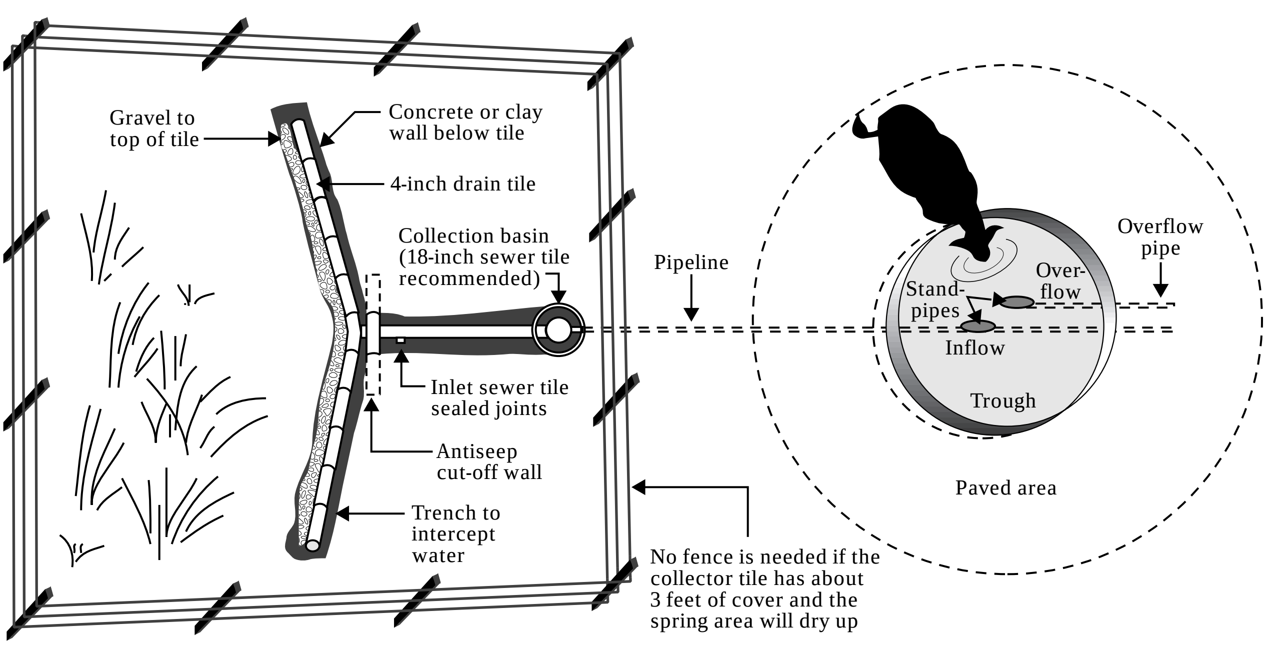
(2) Springs or seep areas

Springs or seep areas often occur in pastures at elevations above creek and river bottoms. These areas are useful as water sources for livestock on pastures remote or isolated from headquarters or farmstead wells. Livestock normally use these water sources as they naturally exist. However, this can lead to degradation of the seep or spring area. Eroding banks, water fouled with excrement and mud, poaching of the wet soils around the fringe of the open water, and damage to riparian vegetation are the most apparent problems. Weaker seeps and springs can be so badly disturbed that they become unreliable watering sites except during high flow periods. Spring developments are used to provide a reliable source of high quality water to livestock, exclude livestock from the riparian area of its source, and convey the overflow back to an adequate outlet with a minimum of contamination and warming. Figure 5–34 shows a typical installation. It has three major components: a collection system, pipeline, and trough.

(3) Ponds and streams

Ponds and streams are often used as water sources. In a pasture setting, limiting access to these water sources helps to prevent contamination of the water by excreta. Coliform bacteria counts can often be quite high in these situations. Blue-green algae blooms can occur during hot weather in nutrient rich ponds. Livestock deaths have resulted from blue-green alga blooms when the concentration of toxins was high at the water surface. Basically, the water quality can be less than desirable for the drinkers as well as the downstream recipients. Several options are available to limit or remove livestock from open water sources altogether.

Figure 5–34 Spring development showing collection system, pipeline to and from trough, and trough



(i) Controlled access options—An option that limits access is a paved ramp or stream ford. Paved ramps can be used at the shoreline of a pond to allow cattle to drink, but not wallow around on the muddy pond bottom. Siting of these ramps is critical so as to avoid severe trailing erosion and resultant fouling of the water and burial of the pavement. The ramp should not be near the inflow point of the pond and not on the embankment or in the emergency spillway where provided. Paving material can be crushed rock, concrete, asphalt, or other durable paving material. In frost prone areas a good base is required to prevent frost heave damage to the pavement. The rest of the pond and any dam or spillway are fenced off to leave a vegetative filter of grass between the grazed area and open water. At the ramp the fence extends into the water at the sides and has a front fence that prevents wading beyond the ramp.

Stream fords are constructed in a fashion similar to paved ramps at points where livestock show an inclination to cross. Stream fords not only provide water, but allow access to pasture areas on either side of the stream. They should be sited and constructed to prevent trailing erosion sediment from flowing directly into the stream. Pavement should extend to an elevation equal to the top of upstream streambank. Paving materials should be resistant to dislodging caused by the maximum expected water velocity achieved at bankfull flow. Concrete grid pavers or confinement floor slat seconds are good choices because they are not likely to dislodge and form a cleated surface to prevent livestock from slipping on the wet surface. Stream corridor fencing ordinarily is combined with this practice to get full benefit of the stream ford. Some contamination of the water will still occur, but there is a substantial reduction in sediment loading. Paved areas can be made uncomfortable enough to make livestock move through faster than if it were a natural site that was easier on the hooves and legs. Where fences are used with this practice, flood gates of various designs are used up and down stream to flank the ford. They can be simple breakaway devices to swinging gates, or simply a one strand electrified wire with a curtain of chains or wires hanging down within a few inches of the water and stream embankment.

(ii) Pond and stream devices—Gravity feed pipelines or siphons can provide water from ponds and streams if proper elevations can be achieved in a reasonable distance within the pasture. These pipelines extend to a trough or series of troughs that either are equipped with a shutoff float or overflow stand and outlet pipe. The inlet of the pipeline must be equipped with a filter or screen to prevent sediment and algae from flowing through the pipe and fouling the water at the trough or clogging float valves.

A water ram is another device that can be used. In this case water is needed at higher elevations than that of the pond or stream. The water ram is dependent on some pressure head to pump water to higher elevations. It is convenient to use in rugged terrain where pastures have no other source of pressurized water and no high elevation sources of gravity flow water. This device requires someone experienced in its installation. It requires careful design to deliver the proper amount of water under the specific site conditions with which it must work. The placement of the inlet pipe and its intake site is also critical. If not done properly, the intake can be silted over. The ram itself must be placed in a safe area so that it is not dislodged or destroyed during a flood event. It may be piped to a storage tank or reservoir before going to a trough. The siting of a ram should be accessible to the operator on a daily basis to check for proper functioning.

A nose pump or pasture pump is another device used to pump water for livestock. They pump water using the force produced by a drinking animal when it pushes against a nose plate while drinking water from a cup positioned underneath the nose plate. When the animal quits drinking after emptying the cup of its water, the piston behind the nose plate goes back to the rest position. When it does this, water is drawn into the cup from a hose that goes to a pond or stream. The inlet must be protected from sediment. A natural pool should be selected instream that remains relatively free of bottom sediment. These pumps are appropriate for small herds that have immediate access to them. They are inappropriate where the distance is far enough to cause the herd to go en masse to drink. The dominant animals will drink and spend the rest of the time harassing the others. Figure 5–35 shows a typical pasture pump installation.

Water troughs are made of several materials: galvanized steel, reinforced concrete, polyethylene, rubber (including used tires), and wood stave. Water troughs come in all sizes. Their size depends on:

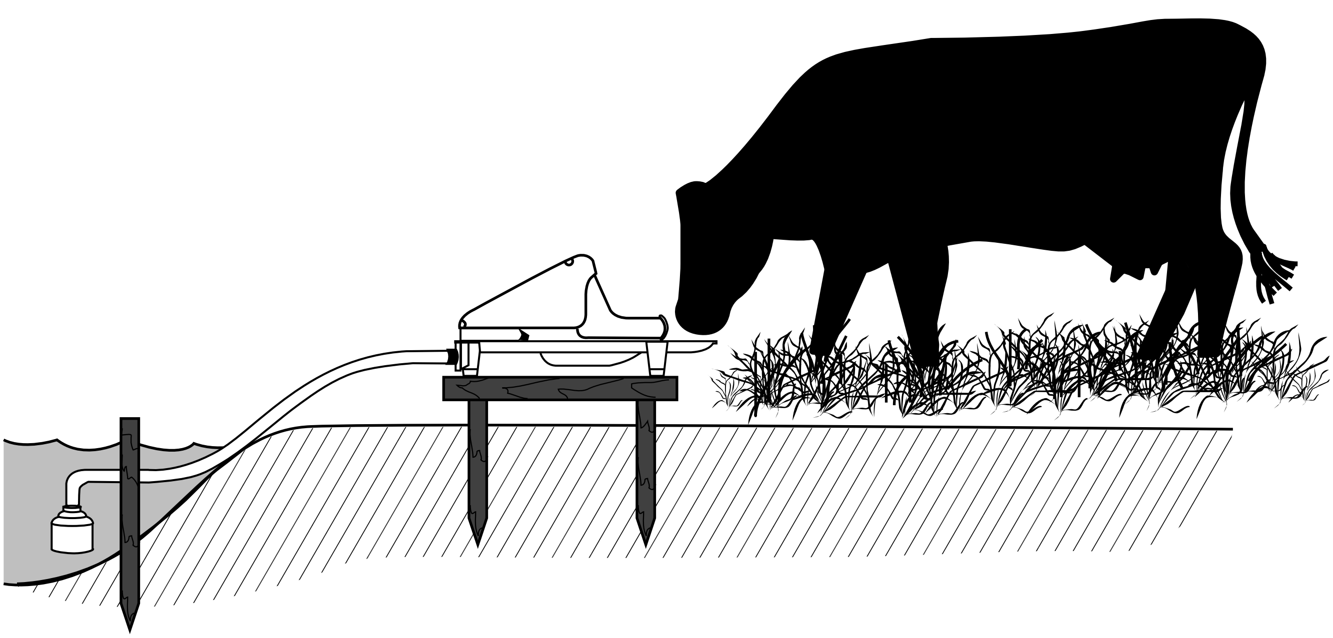
- Number of head being served, their daily or one time intake
- Number of head at the trough at any given instance
- Delivery rate of the pipe or valve delivering the water
- Whether the trough is being used as a storage reservoir as well as a watering site

If water troughs are close by the grazing resource and refill quickly, they can be small because animals come up individually or in small numbers to drink. If the trip to the water trough requires a long walk, the animals tend to herd up and make the voyage together. If the trough is being served by a low flow system (less than 3 gallons per minute), the trough should be at least large enough to handle the whole herd at one time. See table 6–7 (page 6–12) in Chapter 6, Livestock Nutrition, Husbandry, and Behavior, for water requirements for livestock given in gallons of water drank per day by various types of livestock. These daily requirements vary widely. They depend on the water, protein, and salt content of the forage and feed being eaten; quality of the water being drunk; exertion expended during daily routine; air temperature; shade availability; and humidity levels. The values in table 6–7 should not be considered absolutes; however, they can give an estimate of how much water needs to be supplied on a daily basis.

Plan to deliver enough water to handle the extremes for the area. Livestock caught short on a hot day could be disastrous to their health and the owner's wealth. Water troughs should be constructed or placed to prevent entry by livestock. This protects the animals from injury or death and keeps the water cleaner. The troughs also need to be resilient to pushing and resistant to being tipped over by livestock.

Shut-off valves of various types are needed at troughs where water overflow pipes are not practical. These valves need to be durable to prevent livestock from dislodging or breaking them. Valves with free-floating floats tend to be attractive to curious livestock. If within reach, the valves can be broken from their moorings, and water will overflow the trough. Placing them under a fence or other rigid or electrified object can protect them. Floats that are clamped to the side of a trough should be securely fastened and protected from being rubbed on and uplifted.

Figure 5–35 Pasture pump installation



(4) Water quality

Water quality is extremely important to consuming livestock. See table 6–8 (page 6–12) in Chapter 6, Livestock Nutrition, Husbandry, and Behavior, for water quality standards for livestock. New sources of water should be tested to see if they are suitable for the livestock to be watered. Important water quality parameters are nitrates, sulfates, total dissolved solids (TDS), salinity, bacteria, pH, and pesticide residue.

Nitrates can kill ruminants if ingested at high dosages. The nitrates are converted to nitrites in the rumen. These are absorbed in the blood stream. The nitrites attach themselves to the blood hemoglobin forming methemoglobin. This does not allow the blood to carry oxygen, so the animal can die of asphyxiation. Animals so affected have chocolate brown blood. Nitrates at lower concentrations can cause reproductive problems in adults and reduced gains in youngstock.

High sulfate and high TDS or saline water causes diarrhea. Dehydration may occur in severe cases. Salt water toxicity can also upset the electrolyte balance of the afflicted animal as well.

Bacteria, especially total bacteria count, can increase calf losses, cause animals to go off-feed, increase infections, and cause chronic or intermittent cases of diarrhea. Acidic water (<5.5) or alkaline water (>8.5) can cause acidosis and alkalosis, respectively. Animals become unthrifty, go off-feed, have infertility problems, and get infections easier. Although most pesticides are not directly harmful to livestock, the milk and meat produced by them may become contaminated if not broken down during digestion or eliminated.

The organophosphates are most dangerous to livestock directly. As mentioned briefly earlier, blue-green algae can kill livestock drinking from ponds contaminated with them. It happens suddenly without warning. A brief algal bloom and wind drifted accumulations at the drinking site can spell quick death. There is no way to test ahead of time, just a post-mortem. This perhaps is the best incentive not to allow livestock direct access to ponds at least during hot, dry weather. The cost of one animal lost can build several rods of fence and pay for a stock tank.

Watering site layout on improved pastures needs to provide even distribution of grazing to enhance forage utilization. Livestock can travel longer distances than what is needed to get optimum forage utilization. However, other improvements will fail to deliver if the animals do not graze areas well remote to water. With rotational pastures a trough or other watering facility should be in each paddock. Depending on layout and distances involved, two to four paddocks might be served by one watering facility strategically placed at a fenceline or the intersection of two fencelines. The watering facility must be sized correctly and positioned to avoid crowding. In continuously grazed pastures, troughs or other water sites should be evenly distributed. This avoids having underused or overused areas or corners of pasture.

(g) Facilitating practice—Stock walkways or trails

On improved pastures, stock walkways or trails are most often referred to as lanes or laneways. They facilitate livestock movement. The lanes may be paved, unpaved, or a combination of both. Dairy pastures are better served by paved laneways because the cattle need to move back and forth from pastures to the milk parlor at least twice daily. Paving is also critical where laneways must cross wet soils to provide the most efficient or the only way to get to all pasture areas.

Constructed fords, culvert crossings, or bridges need to be provided at live streams unless the streambed and approaches are firm and relatively stable. Culvert crossings or bridges should be used sparingly. They should not be used at all if the stream is prone to flooding. Maintenance of crossings and bridges is high. Debris can easily plug the entrance. Downstream cavitation at the outlet can cause bank instability and eventual undermining of the culvert or bridge abutments. Damage to downstream areas caused by successive washouts of either abutment can also be excessive. This can be avoided by providing a designed floodway channel that creates an island at the culvert or bridge during a flood. This is rarely done, however.

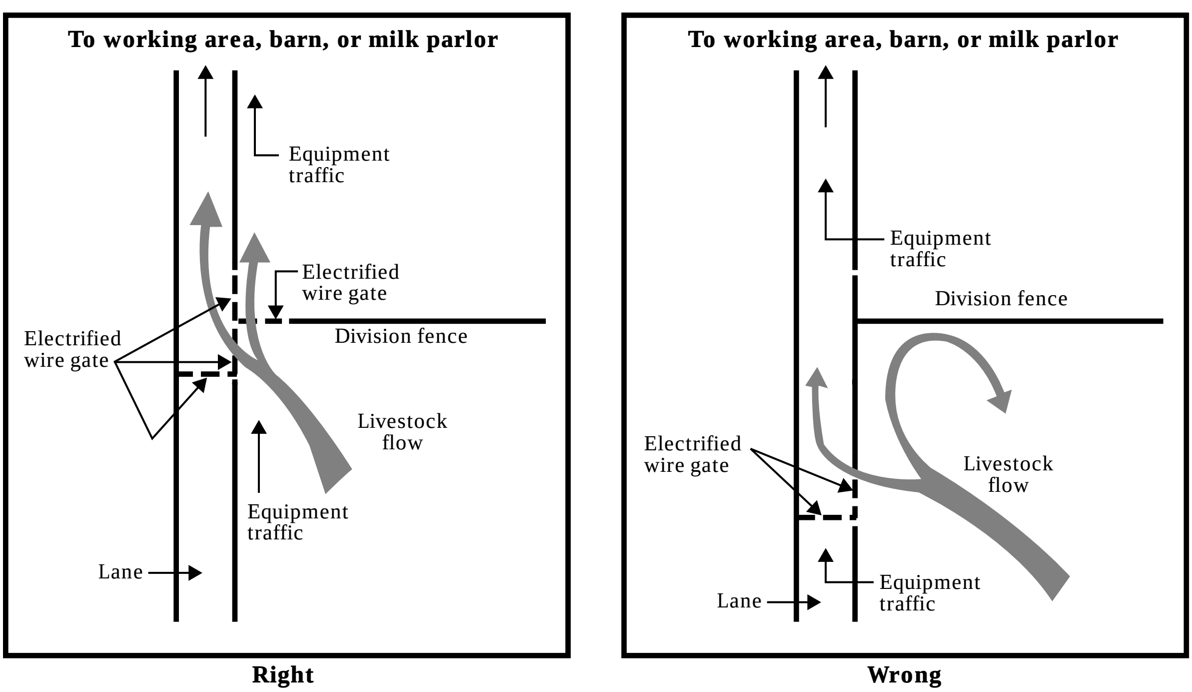
Position lanes to most directly access the fields or paddocks to be grazed, including crop or hay fields grazed temporarily from time to time. Some lanes may be temporary and be formed by two parallel single strand electrified fences. When lanes serve rotational pastures, they should be positioned to create paddocks that are as near square as possible. On very steep ground, rectangular paddocks that have their long axis across the slope may be preferable if forage utilization becomes stratified from top to bottom of the slope. Placing lanes directly up and down steep slopes should be avoided if at all possible and still get a good paddock layout. If this is not possible, the lane should be paved with an erosion resistant material, graded to have water diverters placed at regular intervals, or both. Equip any lane with long continuous gradients with water diverters to break up waterflows directed down the lane.

Width of the lanes is dependent upon the size of the livestock, herd size, and expected equipment traffic.

The operator should keep lanes as small as they and their livestock feel comfortable with. Lanes tend to become unproductive grazing areas. Building wide ones wastes the pasture resource.

Avoid driving equipment up and down unpaved lanes. Livestock use the slightest wheel rut as a preferred trail. Continual use kills out the vegetation and causes erosion to begin where water can channel and gather velocity in the trail. Some producers that need machinery access along laneways create a parallel accessway. This can be done by using a three-gate opening (fig. 5–36) where each paddock division fence intersects with the lane fence. This also cuts down on lane traffic by livestock because they can go from one paddock to the next without setting hoof in the lane. It also allows easy egress no matter which way direction of flow must be out of the paddock.

Figure 5–36 Three-gate opening*



* Always position gates along lanes in the corner nearest next move. The three-gated opening labeled **right** can facilitate a move up or down the lane shown. It also allows for equipment movement outside the cattle lane to avoid causing wheel track trailing in unpaved laneways.

(h) Facilitating practice—Fencing

Fence layout and design require forward thinking. The number of divisions and their size come from the pasture budget described in Accelerating practice—Prescribed grazing section of this chapter. This is determined by the productivity of the field being subdivided, the forage species growing there, the number of head being fed, their size and growth rate or milk flow, and the grazing period they will be on the pasture unit. Other questions to answered when planning include:

- How much of the farm will be used for grazing? Annual production of pasture must be determined. A realistic utilization rate must be set. It must match the livestock demand for forage for the grazing season. If crop and hay fields are to be used seasonally, the fence and lane layout need to provide easy access to them at points that create the least amount of trailing or poaching damage. They need secure perimeter fences, access to water, and possibly temporary interior fences to strip graze off forage.
- Will some of the pasture be machine harvested? If so, which portion is the best site for that activity? This area will be best served with interior temporary fences that can quickly be taken up to open up a large area for harvest. This increases machine harvest efficiency. These same fences will also be easily replaced once machine harvest and any topdress fertilizing are complete.

Fencing, therefore, depends upon a whole farm forage budget, which will be detailed in the section on Forage crop production management. This budget integrates and allocates all the forage and feed resources that are produced on the farm. Fencing facilitates this allocation of the forage resource to livestock. With modern, light-weight, portable fencing materials, this becomes much easier to do than in the past when fencing, once in place, was rarely moved.

Fencing materials are diverse. Woven wire, steel welded panels, barbed wire, smooth high tensile wire, polywire, polytape, polymesh, board (plank or stockade), rail, chain link, steel rail or pipe, cable, concrete, stone, and plastic are all used. Each has their place. Woven wire, barbed wire, and smooth high tensile wire are good, economical fencing material for livestock control along the perimeter of grazing areas. Smooth high tensile should be electrified for best control. Wood board, rail, chain link, concrete, stone, and plastic can be also used for perimeter fencing, but are used for decorative, screening, or security reasons as well as control. They tend to be expensive to install and maintain. Plastic fence is being used to replace wood board fences because they do not rot or require repainting. Fences in working areas where livestock are crowded and seeking ways to escape need strong materials. Heavy planking, steel rail or pipe, welded panels, and cable are often used. Stone and concrete have been used some for corrals and barnyards. When used, they must be sunk to a soil depth below the frost line.

The posts used to hang the fencing materials come in diverse materials and sizes as well. Post materials are treated wood, untreated native wood, fiberglass, plastic, steel T-posts, angle iron, or pipe and reinforced concrete. Wood and concrete posts are the most rigid and can handle high lateral loads without bending or breaking. Steel can bend under heavy loads. Plastic and fiberglass tend to get brittle with age and can break under moderate loads. Sudden impacts are more likely to shatter them than when just being leaned against.

The choice to use electric fence hinges depends on the ability to provide electricity at the site conveniently and reliably, the miles of fence to energize and maintain, the permanency of the fence, the degree of control that is needed or desired, and to a large extent, the inclination of the producer. Woven wire and barbed wire have served well for years. Their initial cost is rather high compared to most electrified fences. However, with timely maintenance their degree of control is as good and they do not rely on an electrical shock that is often hard to consistently maintain to control livestock. Some arguments have been raised about the longevity of woven and barbed wire compared to high tensile wire. However, in humid and subhumid climates, the wood posts on which the fence is suspended will rot off at ground level before or about the time the wire fails. Steel T-posts longevity is generally in the same timeframe. New steel posts can be seen in several old wire fences. Many soil types are highly corrosive to steel. Pitting of the steel occurs at the ground line within a few years and the posts eventually break.

Several guidelines should be followed to ensure that electric fences operate consistently all the time:

- Voltage must be maintained at all times for adequate livestock control. To achieve this exacting standard requires a reliable charger or energizer, first. Low impedance, high voltage energizers meet this requirement. These energizers produce a short, high energy pulse. This short burst of high energy can be sent down a long length of wire that may be partly grounded by weeds and still provide shocking power. Various sizes are available and are selected based on the amount of fence to be charged. They are rated in joules or in miles of fence. Both ratings can be misleading. The delivery of amperage that causes the shock is dependent on the pulse rate as well as the joule rating. If the pulse rate is slower, less amperage is delivered down the wire and less shock delivered as well. Miles of fence ratings assume no brush, weeds, or grass clinging to the fence, nor inadequate grounding or poor insulation of the wires.
- Good insulators must be used to suspend the wire from all wood and steel posts, or nonconducting plastic or fiberglass posts used instead.
- The fence and charger must be properly grounded.
- Lightning arrestors should be installed to protect energizer from damage.
- Vegetation growth along the fence line must be controlled. Sometimes, this is easily achieved where the livestock can graze under the lowest wire. They often preferentially graze these areas very close.
- Maintain fence integrity, check for proper tension and post damage.
- Surge protectors are important when served by power line electricity.

Energy sources for electric fences can be regular farmstead service lines or batteries, or it can be solar or wind powered units. Choice is dependent on the length of fence, degree of reliability needed, cost, accessibility, and length of service needed.

All livestock need to be trained to respect electrified wire. This can be done at infancy if raised on the farm or ranch where electric fence is used. If new animals are brought in, they should be trained in a confined area before being placed on pasture.

Regardless of whether a wire fence is electrified or not, construction principles for them remain the same. Brace assemblies at the corners, gate openings, ends, and wire stretching points must be built to handle the stress placed on it by wire tension. If these are built improperly, the end and corner (anchor) posts will slowly pull out or the bracing will collapse, or both. Whenever possible, posts should be driven on permanent fences. If not driven, they must be backfilled and tamped well to remain solidly in place. Brace assemblies should be placed at corners, at sharp breaks in slope, and at no more than 660 feet on straight runs to stretch wire (stretcher-post assemblies).

Curved fences built to follow land contours should have stretcher-post assemblies in straight sections, not in the curve itself. Curved fences, whether in the vertical or horizontal plane, require posts with great rigidity and must be set well to avoid tipping or bending. If steel T-posts are used to save time and labor, wood posts should still be used and spaced at regular intervals between steel posts to alleviate some of the strain.

Generally, posts of permanent fence brace assemblies should be a minimum of 5 inches in diameter and 8 feet long and buried at least 3.5 feet deep. In some places it may be necessary to drill into rock to get this. For light weight fences (single or double strand), short runs of permanent fence under 330 feet long, and temporary fences, an anchor post with a diagonal brace set into the ground or on a brace block in the direction of the pull is appropriate. The anchor posts can also be used in shallow soils when full post setting depth cannot be achieved easily. Backfill over-widen anchor post hole with concrete. Allow concrete to set and cure before stretching fence on the assembly.

Always place fencing materials on perimeter fences on the side where the livestock are most likely to be pushing on it. Stretch wires with wire stretchers built for the type of wire being used. There are several models. Never use vehicles or tractors to stretch wire other than as a dead anchor. Board ends should abut on posts wide enough to accommodate double nailing. Fence heights, spacing of wire or boards, and mesh opening must vary by the type and class of livestock being controlled. Type of fencing material is often dictated by animal safety concerns. Wide meshed woven wire and barbed wire can cause serious injury or death, but accidents also happen with other materials as well. Well-fed animals are less likely to test fences unless under duress.

Temporary division fences can be nothing more than electrified single or double strand wires suspended on short, hand driven posts for most types of livestock, including sheep. These fences are quite portable and have spurred renewed interest in rotational stocking. If mistakes are made in allocating forage to livestock, they can be easily corrected by repositioning the fences. These fences can either be rolled up on a spool or collapsible so that wheeled vehicles, people, or livestock can go over them when necessary. The plastic posts often used to suspend the wire on these portable fences come in many different designs. Some are downright unhandy and may cause inadvertent contact with a live wire. Others are not very durable after prolonged sun exposure. Some fiberglass rods splinter and are nasty to handle barehanded.

All fences require checking and maintenance, especially as they age. Fence wires can age more quickly if crimped by staples or fasteners at posts, abraded, or damaged by the stretcher used to string it up. Wood should be pressure treated to increase useful life. Plastic and fiberglass need an ultraviolet light (UV) protection formulation. Galvanized wire should be coated to class III specifications. Heavier gauge lasts longer than thinner gauge and has more strength. The difference in price is not worth the aggravation later.

Gates for ingress and egress also vary widely in the material used and strength. They may be simple one strand electrified wire, electrified rod swinging gates, electrified spring wire with insulated handle, barbed wire suspended on two or three poles, tubular steel, board, plastic, woven wire suspended on a steel frame, chain link suspended on a steel frame, or welded panels on a frame. Cattle guards can be used at heavily used gateways where livestock never need to walk through. Their use avoids continually opening and shutting gates. Gates need to be wide enough to pass vehicles and livestock through without damage to the fence or the by-passers. Angle of approach and turning radius need to be taken into account to achieve proper width.

Floodgates are used at points where fences must span creeks and ditches. These too can be made of different materials. They must be constructed to allow floodwater to pass through without their continual destruction, not pull down sections of fence adjacent to them, and keep cattle from leaving the field via the creek or ditch bed or bank. This is not always easy to do simultaneously. Brace assemblies at these points must be built extra strong, at least two brace posts plus the anchor post. These assemblies should be at least at top of bank and safely away from potential bank undercutting or protected with riprap. If the stream current is swift and passes a large volume of water by the floodgate, the brace assemblies for the floodgate should be a separate set from the ones used to extend the fence to the stream.

Swinging floodgates work well for nonelectrified fences. They can be suspended from cables attached to the brace assemblies. Many different styles have been designed to lessen the collection of flotsam on them. They should be buoyant so that they ride up with the rising water.

On electrified fences, a single strand of high tensile wire or cable can span the stream or ditch. Regularly spaced hot wires are suspended down to within a few inches of the water or bank to keep livestock from passing through. These are hard to take out unless the suspended wire is too low or a large branch or tree floats by and snags it.

Floodgates will break away from time to time in major storms. To a certain extent, they should be designed to do that. Cables should be attached to J-bolts that hook on to O-bolts bolted into the anchor post, not wrapped around anchor posts. When forces exceed tensile strength of the bolts they straighten out and release the cable. This avoids major repairs to adjoining fences or to the brace assemblies holding them. Inspect after every flood event to remove debris or repair as needed.

Exclusionary fences can run from single strand electrified to permanent perimeter type fences. If stream corridors are to be fenced, the simpler the fence is, the better it is in flood prone areas. From a maintenance standpoint, a single strand electrified fence kept as high as possible and yet still get adequate animal control is best. This limits debris buildup on the wire. A minimum of posts should be used to have the least number of debris collection points and still suspend the wire adequately. Setbacks from open water should provide at least a 15-foot grass vegetative filter. The filter takes out most suspended sediment and some dissolved nutrients. Fences around woodlots should not be built using the trees at the edge for posts. Hardware becomes imbedded in the logs and is the bane of loggers and millers.

(i) Accelerating and facilitating practice—Pasture clipping

This practice is a bit of both, accelerating and facilitating. It stimulates forage regrowth by cutting off reproductive stems from forages. This causes new vegetative shoots to appear. Pasture clipping can be used to get rid of competing vegetation or reduce canopy shade to favor forage growth. This makes it an accelerating practice. It also influences the movement of grazing animals by removing undesirable patches of undergrazed forages. It can be used to change the pattern of spot grazing. This makes it a facilitating practice. This practice can largely be avoided if the utilization rate is kept high. It is far better to graze fewer acres and machine harvest the rest than to graze a larger acreage and then sacrifice leftover forage by clipping.

Pasture clipping can also be used as a weed and brush control practice where the livestock mix does not control the species invading or existing on the site. Although goats and sheep often eat plants that cattle will not, mixed species grazing rarely happens on commercial farms and ranches. Clipping does not immediately control weeds or brush, but repetitive cuttings just before flowering prevents further seeding of weeds. Clipping does not eradicate or even provide very good control of rhizomatous or stoloniferous perennials. It controls annuals provided they are mown off before flowering. Some weeds not eaten by livestock when green, once cut, are eaten because as the weeds dry, their sugar content is enhanced. Clipping is appropriate on new seedings where livestock control of weeds could damage young seedlings by trampling or uprooting. Weeds should be clipped often above forage seedling height to keep amount of clipping residue down. Too much residue can smother seedlings.

Removal of seedheads and other tall vegetation may also improve livestock health. Fewer eye infections occur if the irritants and disease transmitters are removed.

Clipping can improve forage species mix if certain aggressive established species shade other species' seedlings coming up through the canopy. Clipping avoids the need of waiting for sufficient regrowth to produce a hay or silage crop. This may often take too long or be untimely, and cause shaded seedlings to die. There also may simply be too many acres to graze down to the height needed to release the seedlings.

Rotary mowers work best in pasture setting. Duty rating of mowers is important. Woody species require heavier duty mowers. Pastures can be mown while livestock are present. Almost everything mowed will be eaten. In rotational pastures, mow rejected areas after the livestock leave. This tends to make the rejected areas more acceptable next time, at least, the urine areas.

600.0506 Managing forage cropland

Hayland and cropland produce machine harvested forage primarily, but are often used as sources of supplemental, emergency, and seasonal pasture. On some farms forage crops have totally supplanted pasture as a source of feed for forage consuming livestock. These farms have gone to total confinement. The livestock may not always be in freestall barns, barnyards, or feedlots. Milk cows may also be placed in loafing areas on dairy farms. Loafing areas are adjacent to the milking parlor and barn. Farmsteads sited along creek and river bottoms often locate loafing areas in riparian areas to avoid using tillable acres. Other dairy farms only use pasture for youngstock and dry cows on any marginal land not fit to crop. These areas are not very productive and often are highly erosive.

The movement away from pasture production to forage crop production, particularly with dairy farms, was partly caused by the perception that pasture was an inferior forage production option. USDA Miscellaneous Publication 194, *A Pasture Handbook,* in 1946 stated that closely grazed pasture "produces about three-fourths as much digestible nutrients as the hay." In terms of dry matter it states, "Closely grazed pasture produces about two-thirds as much dry matter as the same plants would produce if they were allowed to grow nearly to maturity and then cut for hay." This basic set of premises has been used repeatedly in different wording for the last 50 years. The same misleading premises stay even with the different wording.

First, closely grazed continuous pastures have a poor growth rate. They are kept at the low end of sigmoid curve displayed in figures 5–20(c) and 5–25. We can agree that this is common practice and happens on many pastures. However, with better grazing management, we can keep forages growing in the rapid growth rate range. The tighter the management, the more this can be maximized. In fact, it can be more easily done on pasture than on hay cropland. Hay crops are allowed to mature and end up on the slow growth upper end of the sigmoid curve.

Then, some authors begin to talk about hay and the ideal premise is brought out, not the common practice. The same producers that are overgrazing pastures probably are not cutting their hay at peak quality either. Much hay is not harvested at the nearly to maturity stage, but at advanced maturity stages. A large percentage of it is also damaged by rain, humidity, and sun exposure. Then it sits in storage and loses dry matter. Equally well managed pasture and hay cropland will produce the same amount of digestible dry matter at the time of feeding. Both leave stubble in the field. Livestock avoid some forage above the grazing height. Preserved forage, whether it be hay or ensilage, also leaves harvestable material behind. The material includes leaf shatter, respiration losses, leaching losses if rained on, fermentation losses if ensiled, spoilage, and feeding losses. The end result, as shown in figure 5–37, is somewhere around a 20 percent loss of harvestable digestible dry matter even if the stored forage crop is handled right.

(a) Forage crop production

Forage crop production is capital, labor, and machinery intensive. It requires silage storage, dry hay storage, sometimes automated feeding systems, a full line of machinery from seedbed preparation to harvest, feeding operations, waste handling, and often livestock confinement facilities.

Forage crop production is approached in two basic ways. One avenue is used to support pasture production. In this approach to grassland farming, 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 avenue totally supplants 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. They may import varying amounts of feed to the point of being totally dependent on purchased feed.

Whichever avenue 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 convert it into a salable livestock product.

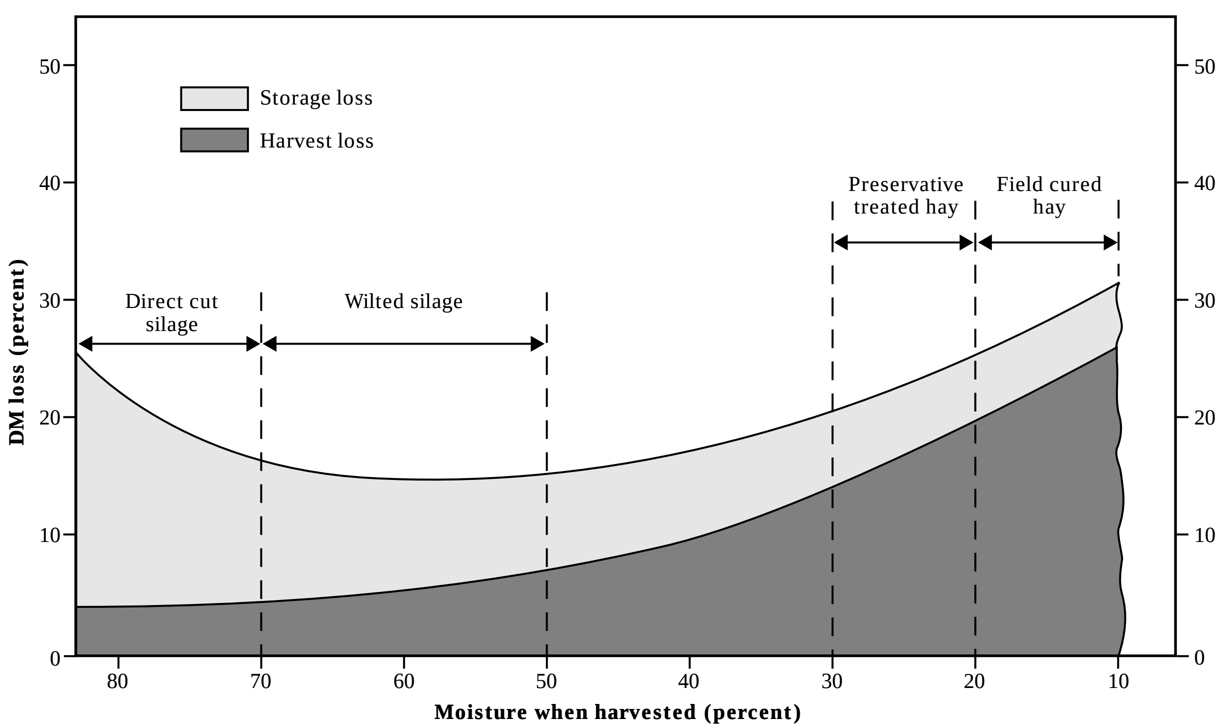
The remainder of this section focuses on the first avenue of approach to forage crop production. It requires the highest degree of integration of all grazing land resources on the farm or ranch. To integrate well requires analyzing the farm or ranch operation available resources, the tools that are available to produce forages, and how those tools can be used to best advantage on the specific site being analyzed. This thought and decisionmaking process is diagrammed in figure 5–38.

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 need to be more closely analyzed. The following questions should be answered:

- Which forages are adapted to the climate and soils on the land unit?
- What is the seasonal distribution of pasture now?
- What could it be if we selected different species from the ones currently growing on the farm?
- Can the grazing season be extended past the current one being used and not hurt the pasture resource?
- Once reasonable alternatives to feed the livestock with pasture are exhausted, what forages will meet stored feed quality and quantity requirements?
- What cultivars are appropriate for disease, insect, and soil reaction, salinity, and drainage circumstance?

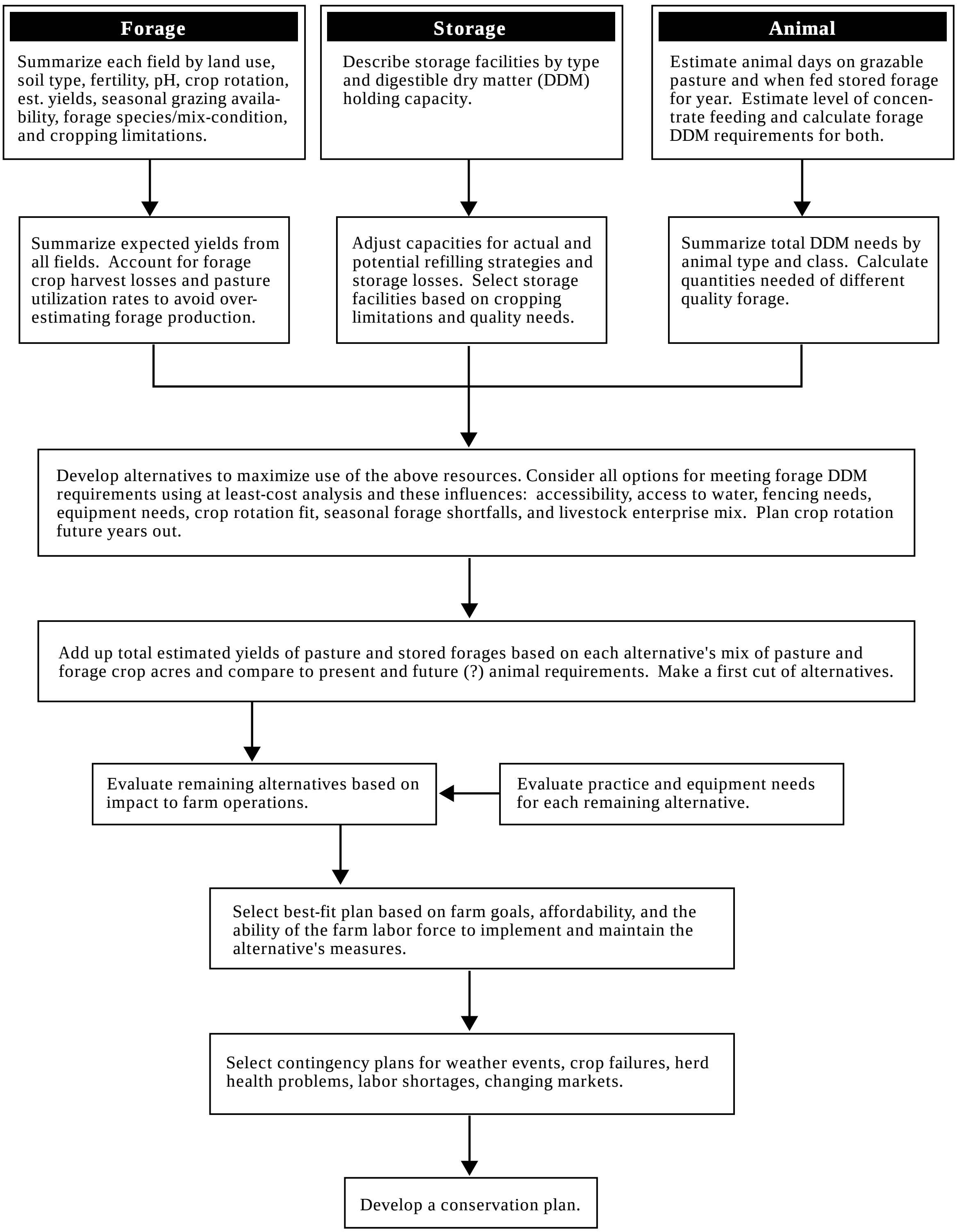
The thought process required for forage management is shown in figure 5–39. Forage management planning starts with gathering information on the site characteristics of each field. The climate and soil limitations must first be known. Forage suitability groups characterize major soil limitations and give guidance on how they can be overcome. They help site selection by

Figure 5–37 Amount of dry matter loss of harvested forages during harvest operations and storage* (from Barnes, et al. 1995)



* This is the loss of harvestable forage. It does not include stubble left below the cutter bar.

Figure 5–38 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.

pointing out which forage species are suitable for the soils on a land unit.

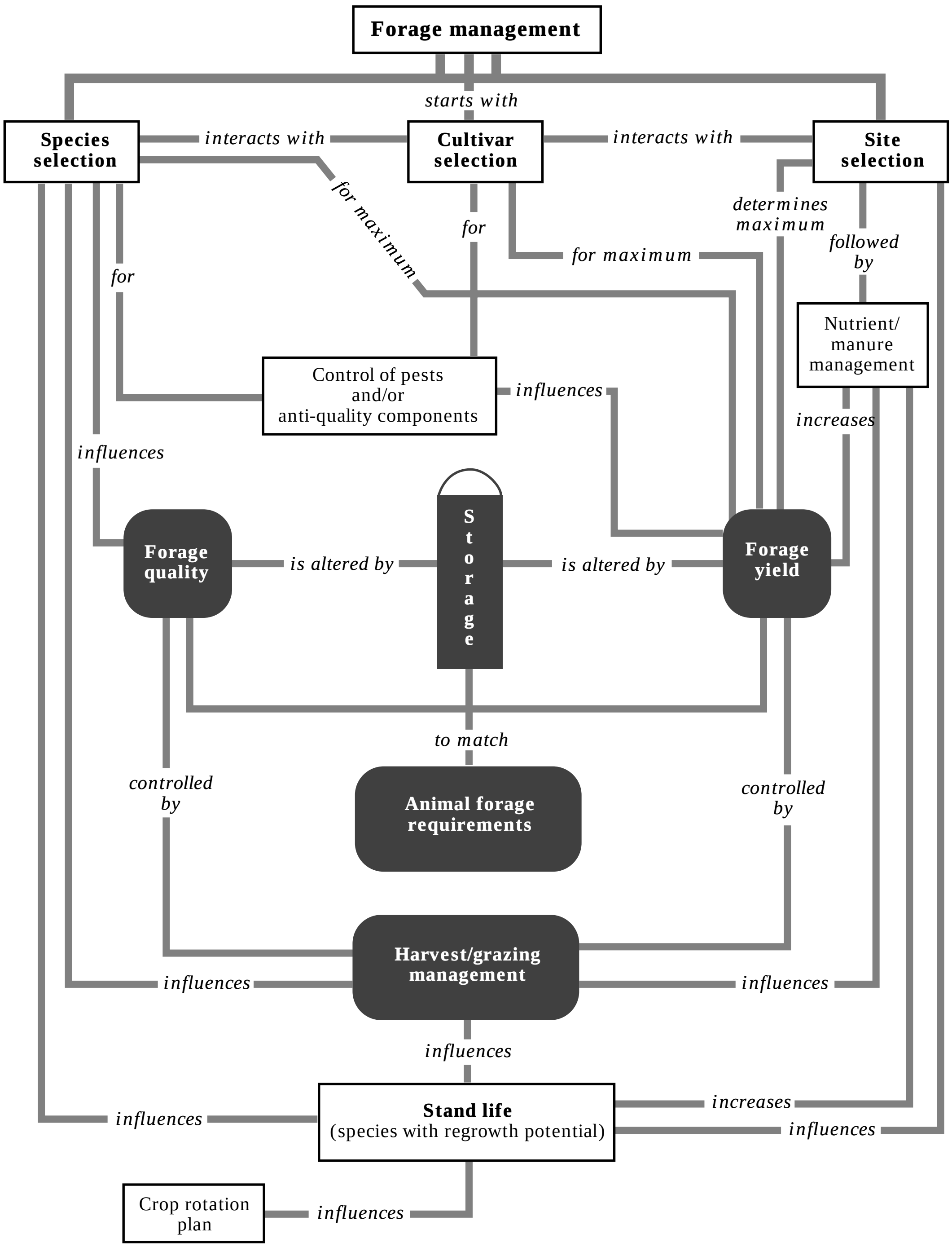
Forage species selection also involves selecting species readily consumed by the livestock type and class being raised on the land unit. They must be palatable and encourage maximum intake for high production animals. Other classes of livestock are often better served nutritionally by lower quality forage. Pasture and stored forage needs must be planned for these livestock classes too.

Within species, there may be only one or two cultivars (varieties) or several to choose from. Specific cultivars are selected for several reasons. Some are resistant to insect and disease pests. Some are bred to be lower in or free of anti-quality factors, such as alkaloids, tannins, and saponins. Tall fescue is a good example. It has several cultivars that are endophyte free. Being endophyte free allows cattle to graze it without the symptoms of fescue foot, bovine fat necrosis, and fescue toxicosis appearing. Some cultivars are just more productive. Others are bred to be leafier. Some forage species are bred to have a wide range of climate specific cultivars. Alfalfa is good example of this. It has varieties that can withstand severe winters and others that grow during the winter in warmer climates by varying the degree of fall dormancy each one exhibits. Other forages are bred to be higher in protein or lower in fiber.

Forage selection is also done to choose between distinctly pasture type forages and hay type forages. At other times forages may be selected that harvest or graze well. For example, orchardgrass and bermudagrass produce good pasture or hay. Some species, such as alfalfa and birdsfoot trefoil, have hay type cultivars and pasture type cultivars. Some grasses can be grazed, but do better as hay crops. Examples of this are timothy and smooth bromegrass. They elevate their growing points early and have basal buds that do not break dormancy until around heading time. If grazed or cut before boot stage, they are slow to recover. When mixed with alfalfa and cut early at bud stage for alfalfa, both grasses can be weakened and with successive harvests, die out prematurely.

Once the production options have been weighed and the best fit plan for the land unit is selected, it is time to implement forage crop management. This will ensure the right kind of stored forages will be available to round out the livestock feed ration.

Figure 5–39 Forage management planning elements and how they interact with one another (from Barnes, et al. 1995)



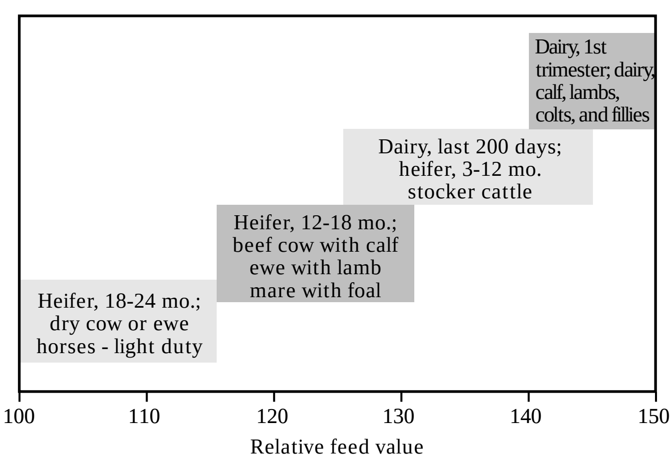
600.0507 Vegetative conservation practices for forage cropland

(a) Harvest management practice—Forage harvest management

This practice is used to provide forages of varying quality in the quantities needed for a livestock enterprise. Forages are stored to meet all or part of the forage needs of livestock. Stored forages may be fed to supplement pasture and to increase dry matter and fiber intake, especially with dairy herds. During droughts and other emergencies, stored feed may carry livestock through until there is pasture to graze again. Other times, stored forage is stockpiled to provide feed during expected loss of pastures, such as in winter.

Depending on the quantities needed of each forage quality, forage harvest can be timed to produce the proper quality for the livestock class being fed. As a forage reaches maturity, it becomes more fibrous and decreases in protein content. This lower quality forage is still appropriate for many classes of livestock. For example, in figure 5–40 relative feed value (RFV) is an index that ranks forages relative to the digestible dry matter intake of full bloom alfalfa (RFV = 100). For

Figure 5–40 Relative feed value and livestock classes (adapted from Barnes, et al. 1995)



dairy cattle, RFV equals DDM times DMI divided by 1.29. Digestible dry matter (DDM) is calculated as 88.9 minus 0.779 times percent acid detergent fiber (ADF), and dry matter intake (DMI) is calculated as 120 divided by percent neutral detergent fiber (NDF).

Forage harvest management as it pertains to perennial forages becomes more difficult. While keeping in mind the livestock needs, the land manager must also weight what is best for the forage resource, and ultimately their costs of production. For perennial forages, it becomes a compromise between yield, quality, and persistence. More harvests per season mean younger vegetation is being cut so quality is high, low fiber and high protein content. However, this can lead to stand loss and the need to replant or rotate to another crop. Fewer harvests per season will better maintain stand persistence, but forage cut will be more mature and so quality, or its digestibility, will be less. The forage will be more fibrous and lower in protein.

Most forage stage of maturity guidelines put out across the Nation are a compromise between quality and stand life. Harvesting a little earlier would improve quality, but reduce stand life if done continually. Harvesting a little later lowers quality, but builds food reserves, allows basal buds of some species to break dormancy, and increases stand life. More frequent harvests tend to decrease overall dry matter yield especially from a multiple year standpoint. This is a result of lost vigor and slowness to recover between cuttings. This leads to a progressive and quicker stand decline on a year-to-year basis.

When grasses and legumes are grown together, the legume stage of maturity is used to time the harvest except in the case of birdsfoot trefoil, Ladino clover, and white clover. Some grass species have had cultivars selected that seek to time their stage of maturity with that of alfalfa. For instance, orchardgrass varieties have been selected to slow down spring maturation. Meanwhile, timothy and smooth bromegrass varieties were selected that sped up their first cut maturation to coincide with that of alfalfa. The two white clovers and trefoil tend to maintain their quality because they are indeterminate in their growth. In the case of common white clover, it is too diminutive to make up much of the total forage taken off a mixed stand anyway. Therefore, the grass component's stage of maturity is a better target to get the forage quality desired. Common white clover is also not likely to persist in a stand managed only for hay. The grass component shades out common white clover unless it occupies areas lacking grass cover.

Annual grass forages, such as sorghum, millet, and sudangrass, that can be harvested several times in a season, should be cut at boot to early head stage. This triggers more tiller growth at their bases because they are not able to set seed. If a foliar or insect outbreak threatens stand survival or forage quality unduly, harvest prior to correct stage of maturity. This will preserve as much quality as possible and remove the host to curtail spread of the pest. For instance, mow alfalfa within 10 days of normal stage of maturity when economic threshold is exceeded for weevils, spittlebugs, or potato leafhopper. When the economic threshold is exceeded for alfalfa caterpillars, harvest forage at early bud stage. In some cases outbreaks occur too early after the previous harvest. The appropriate labeled pesticide must then be used to prevent loss of a forage cutting or the whole crop.

For annual forages that are harvested one time only, the whole focus can be on achieving the desired forage quality for livestock consumption. This may be tempered a bit on silage crops where the type of storage being used has an influence on the amount of moisture left in the forage at filling time. However, some thought about the quality of the forage needed should play a role in the type of silo built. Bunker silos, although cheaper to build per cubic foot of storage than upright silos, require more moisture in the silage to ensure good compaction. The same is true for bagged silage.

Compaction of the silage is needed to have good anaerobic fermentation of the silage. The upright silos achieve the compaction just by the sheer weight of the material stacked 50 to 80 feet high. With more moisture in the silage this can lead to leaching losses of dry matter and create a high biochemical oxygen demand (BOD) effluent. This effluent must be diluted substantially to not cause a fast drop in oxygen levels of receiving water. Effluent production generally occurs in forages that are ensiled in bunkers or bags at moisture contents over 70 percent or in tower silos atmoisture contents above 65 percent. The percent moisture values shown in table 5–6 are the recommended moisture levels for hay-crop and corn silage to ensure good fermentation and a well-preserved silage.

Corn silage chopped at the dent stage of kernel maturity coincides pretty well with the upper limit of moisture of 68 percent. If kernel maturity proceeds to the black layer stage, then the whole plant moisture level is down to the lower limit of 55 percent. Harvest should not be delayed past black layer. For bunker and conventional upright silos, harvesting at the one-third milk line is appropriate. At one-half milk line, the moisture is appropriate for oxygen-limited silos. For sorghum, chop when kernels are between soft to medium dough stage.

In many parts of the Nation wet weather and high humidity also impact when, how, and at what moisture content forage crops can be harvested. In some situations where rains come on a daily basis, hay-crops that are reaching maturity should come off as direct cut silages to preserve as much quality as possible. Effluent production will need containment. The addition of dry feedstuffs, such as ground ear corn, reduces the overall moisture content and acts to soak up the leachate produced before it becomes effluent. Proprionic acid and similar organic acids can also be used. They quickly drop the pH of the silage to avoid bad fermentation from taking place. This reduces effluent production. However, some effluent production still occurs that needs containment and treatment as part of a waste management system for the land unit. This is far better than letting a valuable forage

Table 5–6 Silage storage structure forage moisture suitability

Storage structure type	Hay-crop [1] (% moisture)	Corn [2] (% moisture)
Upright or tower, conventional	60 – 65	63 – 68
Upright or tower, oxygen – limiting	40 – 55	55 – 60
Bunker or horizontal	65 – 70	65 – 70
Bag silo (plastic tube)	50 – 60	65 – 70
Balage (plastic wrapped round bales)	50 – 60	——

1/ Coastal bermudagrass should be ensiled direct cut (65 to 75%) to get required packing.
2/ Add 5 percentage points to the range for sorghum silage.

resource be underused when it cannot be grazed off fast enough to keep up with production. It is also better than waiting for dry weather to make hay. Much of the forage will rot, and the rest is a mix of overmature and highly weathered first growth and green second growth material.

In other areas storm systems track through on a 3- to 4-day schedule. This prevents field cured hay that is not rained on at least once from being produced without preservatives. Where relative humidity levels are high as well, this becomes even harder. In these areas wilted silage or haylage can generally be taken off the fields before the next storm system arrives.

For the harvest of legumes and legume-grass mixtures, roller conditioners are used universally to crack the stems of the legumes. This speeds up drying. Flail conditioners can be used on grasses to break the waxy cuticle and their stems to speed drying. These conditioners tend to break off too many leaves on legumes. Both conditioners are generally integrated with and mounted behind a mower unit. The combined implement is called a mower-conditioner. Later on, during drier weather when rains are infrequent, cuttings can be made as dry hay. This basically is taking what the climatic conditions are allowing. For many farms, this is not a large increase in equipment. On some, it may mean having a forage harvester and a forage wagon or two as well as a baler. For others that have a forage harvester for corn silage, the purchase of windrow head for the forage harvester is all that is required. The added expense can easily be paid for in the degree of flexibility it affords to harvest more quality forage in a timely fashion.

Another option is to bale dry hay using preservatives that are sprayed on when mowed or baled. This allows the hay to be baled at higher moisture levels (between 25 and 35 percent moisture) and can reduce drying time by 1 day. Preservatives used range widely from proprionic acid and other organic acids to anhydrous ammonia to bacterial inoculants. All have their drawbacks. The acids are corrosive to farm implements. Anhydrous ammonia is an excellent preservative and provides nonprotein N for the livestock feed ration. However, it can be toxic when fed to livestock if injected at rates above 3 percent of forage weight. The bacterial inoculants seem to only improve appearance, but do little to reduce dry matter losses of stored hay.

Another harvest method that works well in wet climates is green chopping. Fresh forage is chopped daily to feed directly to livestock on a feedlot or loafing area. Traditionally, this is used in dairy country. Obviously, this eliminates the need for pasture for that group of animals, but it does not eliminate the need to preserve some forage for later use unless it is produced off the farm. Although used widely when first introduced, little green chopping is done nationwide today. It is labor and machinery intensive, although it tends to use the forage harvesting equipment to the maximum. However, a separate flail chopper is generally used instead of the conventional forage harvester. It takes a good manager to use this method well. Average management leads to a wide spread in stage of maturity of the harvested forage. Early cuttings are cut too early for maximum stand survival, and late cuttings are overmature for the best nutritional value to milk cow herds. This variation in quality and its interference with other crop harvest activities on diversified farms led to its loss of popularity. The flail chopper also causes a ragged cut that retards regrowth and lowers stand persistence. Green chopping does have a place on farms where the land base is small in relation to livestock numbers. It optimizes forage production per acre. All that is left behind is some stubble. The most common forage grown for green chop is alfalfa.

Moisture content of forages when being windrowed, tedded, or inverted should be moist enough to keep leaf loss to a minimum. In humid areas field dried hay may need to be rearranged on the field a few times to get all the forage to dry evenly. Tedders and inverters are used to expose underlying forage to the sun and wind. This is especially important where the ground is damp from previous rains. Tedders or inverters should stir or lift the forage while it is still over 40 percent moisture. The hay when raked for baler pickup should be between 30 and 40 percent moisture.

Bale field cured hay at 15 to 20 percent moisture to prevent heating and spoilage in the barn or stack. This minimizes dry matter losses and prevents spontaneous combustion from occurring. Bale hay to be forced-air dried at 20 to 35 percent moisture. This hay is generally treated with a preservative and stacked on pallets in a building with an air circulation system.

Number of cuts or harvest interval of perennial forage crops is also a compromise between yield, quality, and persistence. This is because it is tied closely to stage of maturity of the forages. However, this is not always the case in grasses. Many grasses are only reproductive once a year. Once they have produced seedheads, the rest of the tillers sent up are vegetative the rest of the growing season. Therefore, stage of maturity is meaningful only once a year. The harvest interval after that time is arbitrary, being based on harvesting convenience, the legume component's maturity, and weather delays. Some forage cultivars have been bred to take a more intense harvest schedule than others.

If high quality forage is a goal, then the number of cuts will be maximized for the climate. The crop rotation planned for such a goal must be a more rapid one. It involves a quick replacement of the forage crop with other crops in the rotation unless the forage cultivar is up to the stress. On fields in continuous perennial forage crop production, more frequent hay seedings are necessary if the forage cultivar cannot take frequent cuttings.

If maximizing the number of cuts is a goal, then it is necessary in humid climates to be able to ensile as well as make dry hay. For producers with round balers, this may require nothing more than the ability to wrap large round bales in plastic to create balage.

End of growing season harvest interval in areas where winter survival of forage crops is a concern should be at least 40 days long for legumes and at least 30 days for grasses. This allows food reserves to be replenished before going into winter. The last cut should be timed to coincide with a killing frost if the forage is needed for stored feed. On fields that can be pastured, the last cut could be 30 to 40 days before a killing frost, and then the pasture should be grazed after the killing frost to extend the grazing season. In either case a nonharvest period before a killing frost is best for long-term forage stand survival. Some evaluation of the stand condition is necessary, as well, to decide whether to harvest any of the forage produced during the fall recovery period. Leaving unharvested aftermath may increase forage stand survival significantly depending on the severity of the winter and the vigor of the stand going into the winter. The aftermath can be left to provide soil insulation and cover for wildlife. In snowfall areas, it will trap snow better than short stubble. This provides additional insulation and improves soil moisture distribution across the field in the spring. The added insulation can reduce the chances of frost heave damage as well as winter killing.

Stubble height must be based on each species' requirement for adequate residual leaf area; adequate numbers of terminal, basal, or axillary tillers or buds; insulation from extreme heat or cold; and unsevered stem bases that store food reserves needed for a full, vigorous recovery. Where mixed stands are raised, the species grown together should have similar stubble height requirements. Always go for the stubble height of the species requiring the highest stubble. This keeps the least tolerant or most sensitive forage in the stand. Some loss of yield may occur, but the quality of the forage taken off will be higher. There will be less basal stem that is mostly lignified fiber. For annual forages with regrowth potential, sufficient stubble height (6 to 8 inches) must be left behind to promote tillering. Thicker stalked cultivars need higher stubble heights than thin stalked ones to tiller well.

In special situations, stubble heights may be reduced below that generally used to promote fast regrowth and plant vigor. In the South, alfalfa should be close mown at last cutting at the end of the growing season to control alfalfa weevils. This removes their overwintering cover. Mow warm-season grasses grown in association with winter annual legumes or grasses close at last cutting to release emerging seedlings.

Contaminant effects on forage quality are as equally important to consider as the nutritive components.

Green chopping of sorghum-sudangrass and piper sudangrass must be done with care to avoid prussic acid (hydrocyanic acid) poisoning. The risk of this is reduced if sorghum-sudangrass is cut when over 30 inches tall and piper sudangrass when over 18 inches tall. Drought or frost damaged forage of these species should be avoided for at least a week after the event has ceased. Ensiling actually reduces prussic acid content during fermentation and lowers it below toxic levels (<200 ppm) sufficiently in 6 to 8 weeks. These forages, including sorghum, are poisonous to horses and are not to be fed.

Forages containing high levels of nitrates (>1,000 ppm) are also better harvested as ensilage than as hay. No loss of nitrates occurs during hay curing. Haylage as it is fermenting reduces nitrates to nitrogen dioxide, silage gas. This detoxifies the haylage, but the gas can cause severe lung damage within seconds of exposure if not vented out of the haylage stack or silo. Carbon dioxide is also formed during fermentation. It is heavier than oxygen and can displace it in the silo. People have died from suffocation not realizing soon enough that no oxygen remained in the silo. Corn or sorghum fertilized heavily with nitrogen and stressed by drought can also have high nitrate levels. Silos containing forages suspected of being high in nitrates or silo rooms attached to them should not be entered for the first time within a week of filling without being thoroughly ventilated first. Delay feeding silage for 6 to 8 weeks after filling.

High tannin forages, such as birdsfoot trefoil and sericea lespedeza, lose as much as half of the tannin during field drying. In doing so, digestibility increases significantly.

Blister beetle poisoning of horses can occur where the beetles occur in high concentrations in isolated spots of alfalfa fields that are mechanically conditioned. They contain a toxic compound called cantharidin that is released into the hay when they are crushed with the hay in the conditioner rollers. The compound is stable in hay and therefore can be harmful to horses eating the hay.

Red clover hay infected with black patch fungus contains an alkaloid, slaframine, that sickens livestock when fed shortly after storage. Long-term storage reduces the concentration.

The alkaloids produced in endophyte infected tall fescue are reduced only 20 percent in curing hay and little at all in storage. Ensiling has little effect.

Moldy hay causes colic and heaves in horses. Cattle can have mycotic abortions or contract aspergillosis from certain fungi associated with moldy hay.

Fields should be free of metal, such as wire, to prevent hardware disease in livestock.

Another forage quality issue is the length of cut of ensiled forages that are chopped. The theoretical length of cut range for hay-crop, corn, sorghum, and small grain silages is 3/8 to 3/4 inch. This is done by setting the shear-plate on the forage harvester for a 3/8 to 3/4 inch cut. This is theoretical because not all particles will be in that size range. About 20 percent actually should be longer than 1 inch to provide enough long fibers to aid rumen digestion. Chopping the forage fine aids in compaction so that good fermentation takes place. Again, some compromise must be reached. Too fine is not good for rumen digestion, but too long does not allow for good compaction.

Storage of the forage is important to maintain quality and digestible dry matter. Whenever possible, dry hay or silage should be under cover in humid climates. This can be nothing more than plastic film. Large round bales left on the ground and uncovered can lose up to 40 percent of their dry weight in humid climates over a season. Losses range from a low 0.5 percent per month in arid climates to as high as 3 percent per month in wet, warm climates. Moldy hay is often rejected by animals unless forced to eat it. Then, they can have health problems as mentioned earlier. If large round bales are made to save on labor, they must either be wrapped with plastic around their circumferences or placed on end in a barn or shed in humid areas. They can be stacked three high without anything more than a front end loader on a tractor.

Bunker silos must be covered to prevent great spoilage and leaching losses. Plastic film weighted down to prevent uplift and removal is necessary. If this is not done, leaching losses can be high as rain filters down through the material. If exposed to the air, spoilage of the top foot or two is common in humid areas. Dry matter is lost (up to 25 percent of it), and the spoiled forage will be rejected at the bunk.

When haylage or silage is bagged, care must be taken in their handling and placement not to puncture or rip the plastic. They also must be checked weekly for rodent or raccoon damage and patched. If management is lax, spoilage will start at these openings and spread farther into the bag. Silage should never be stacked except under limited and very temporary circumstances. Effluent can readily escape, contaminating shallow aquifers or adjacent streams. Dry matter losses can be high, from 15 to 30 percent of the total placed in the stack. Hay, if stacked outdoors, should be covered and placed on a well-drained pad or on pallets.

(b) Accelerating practice—Nutrient management

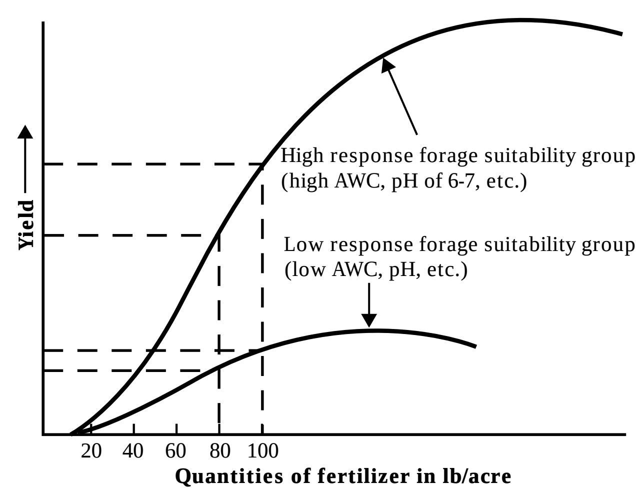
Nutrient management on forage crops differs from pasture nutrient management in that it is a put-and-take operation. When harvested all the nutrients in the forage are removed from the field. They may be replaced later, or they may not. On land units where manure is recoverable from a feedlot, barn, or barnyard, it can be returned to the field. The likelihood of it coming back with the same proportions of nutrients as left the site is nil. If fed to livestock while on pasture, there is no way to recover the nutrients economically. There is a total transfer of nutrients from the forage cropland to the pasture. Therefore, chemical fertilizers are used to provide the balance of nutrients needed to continue optimal production if so desired. Legumes can be used to provide some or all of the nitrogen (N) needed to support optimal grass production. However, the removal of phosphorus (P), potassium (K), and secondary nutrients from forage crop production lands by harvest activities must still be dealt with.

Forage crop response to fertilizer additions is dependent on the inherent productivity of the soil in which the crop is growing. Forage production in humid climates is mainly controlled by available water holding capacity (AWC). The next most important soil factor is soil reaction. In more arid climates, it is controlled primarily by rainfall or irrigation rates and salinity or sodicity. These factors set the maximum forage production limit, not fertilizer. In figure 5–38, note site selection does determine maximum yield. Each soil series has a response curve to nutrient additions. Some of them may be similar. Soil series grouped together as forage suitability groups should have the same response curve. Figure 5–41 shows two soil groups and their response curves to fertilizer. Fertilizer merely drives the soils to produce near their potential maximum when weather and pests permit.

The maximum potential yield is seldom achieved on a site. It certainly is not achieved from fertilizer additions. The economics of fertilizer additions dictates that this is not going to occur under commercial forage crop production. Before the maximum potential forage yield can be reached, each increment of fertilizer used costs more than the worth of the forage produced. This is illustrated in figure 5–42. Going from 100 pounds of fertilizer per acre to 150 pounds of fertilizer per acre produces a good crop response. The additional forage produced is worth more than the cost of the additional 50 pounds of fertilizer. However, at the 150 pounds per acre rate, the cost of the last pound of fertilizer equaled the value of the forage produced. The yield at which this occurs is called the maximum economic yield. This yield is not static, but changes with the cost of fertilizer and the value of the forage crop being produced. The maximum economic yield is going to occur at a much lower application rate of fertilizer on a low response forage suitability group soil than on a high response forage suitability group soil. Compare where the rates of fertilizer intersect the two response curves shown in figure 5–41.

Because forage crop production removes nutrients completely from the field, the primary goal of nutrient management on these lands is to return nutrients back in nearly the same proportion as were removed. This is tempered by the natural fertility of the soils being used to produce forage crops. In some parts of the Nation, native fertility can be high in P or K, or both. Long-term forage crop production may do little to reduce the natural store of these nutrients. Little or no crop response occurs when fertilizers containing these two nutrients are applied on soils where they are abundantly available. In other areas these nutrients may

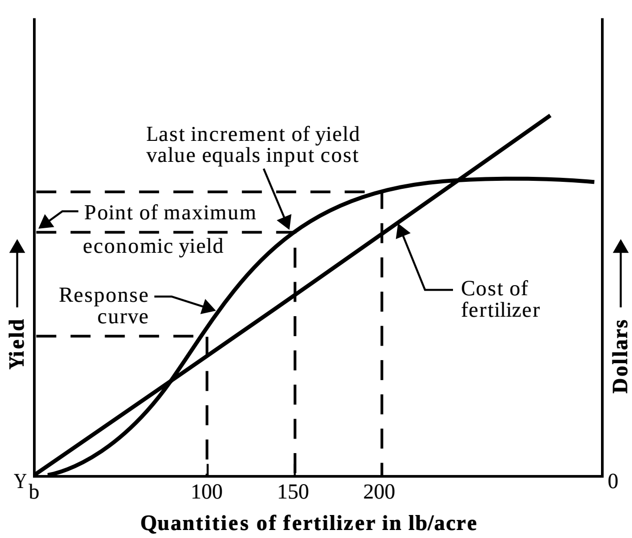
Figure 5–41 Response to fertilizer by two forage suitability groups*



* The same amount of fertilizer applied resulted in two very different forage yields. In the case of the low response forage suitability group, water was primarily the limiting nutrient.

have always been deficient or marginal. Any crop production quickly draws down the natural store of P and K. Yields quickly drop, and forage stands become weak and thin. In these areas P and K are added to replace those removed by harvest (maintenance applications). Additional P and K may be added to build the soil store of P and K. This latter amount of fertilizer is called build-up or corrective fertilizer applications. This is done so that the two nutrients do not limit production. Once a soil test indicates that they are in the optimum range, no further build-up or corrective amounts is recommended. Only maintenance amounts are recommended, generally based on a projected yield of the next crop. A more conservative approach, however, would be to replace what was taken off by the previous crop. This is truly replacement; the term used to describe this method of nutrient management. Since no response is supposed to occur when the soil is in the optimum range, being theoretically short a few pounds of P and K should not jeopardize a better harvest than the year before. Furthermore, it avoids over-applying fertilizer based on a prediction that is more likely to be missed by a wider margin than a harvested yield based on less than ideal estimates of dry matter.

Figure 5–42 Maximum economic yield* (adapted from Blackmore 1958)



Y_b=Base forage yield without fertilizer

* Maximum economic yield is the point on response curve where an additional dollar spent on fertilizer returns a dollar of additional forage produced. Beyond that point the additional fertilizer being spread on the field costs more than the additional increase in forage production is worth.

Forage crops remove large amounts of K, 30 to 50 pounds K_20 per acre for every ton of forage harvested. Grasses are better at taking up K than are legumes. Grasses have a fibrous root system with a high degree of root replacement. Legumes are primarily tap rooted, have fewer roots, and a slow root turnover rate. The grasses with their greater, ever-shifting root mass can exploit the soil better for nutrients than legumes. Some grasses, such as ryegrass, can also absorb K two to five times faster than the companion legume at the root exchange sites. Therefore, when the two are grown together, K fertilization is important to the survival of the legume. The legume needs to be able find abundant K in a small volume of soil composed of its root-to-soil interface. Fertilizing with K also helps the legumes by promoting more root branching. Fertilizing legumes with K then causes a compounding effect. Fertilizing with K on soils lacking sufficient available K will thus maintain the legume component in legume-grass mixtures.

K applications should be done at least yearly. If yearly rates call for 167 pounds per acre of actual K (200 lb/acre K_2O) or more, split the application to avoid luxury uptake of K during any one cutting. In areas where winter survival is critical to stand longevity, apply the last application of K fertilizer prior to last regrowth. Split applications are especially important on soils that have a low cation exchange capacity (< 7.0 milliequivalents per 100 grams of soil) to avoid leaching losses and nutrient imbalances on the exchange sites.

Forage crops also remove large amounts of P. They remove about 15 pounds of P_2O_5 per acre for every ton of forage harvested. Forage production responds to annual maintenance applications of P better than to infrequent heavy rate applications. This is primarily because much of the applied P is being rendered insoluble (fixed or immobilized, see fig. 5–31) in most soils and thus unavailable for plant uptake. Even in soils with optimum levels of P, forage seedings often respond to a banded starter fertilizer containing P by growing more vigorously and thicker.

Both P and K availability are enhanced by liming acid soils. P is most available when the soil pH ranges between 6.0 and 7.5. At either side of that pH range, much P can be precipitated out and rendered insoluble for plant uptake. With K, liming removes exchangeable aluminum (Al^{+3}) from the soil cation exchange sites allowing K to compete with Ca and Mg for those sites. Liming also increases the pH-dependent cation exchange capacity (CEC) significantly. This creates more CEC in the soil by creating more negatively charged particles in the soil. It is a continuous function increasing from a lowest value at a pH of 3 to a highest value at a pH 9. The higher the CEC, the more K that can be held in the soil as a plant available form.

Standard soil tests do not test for N in humid areas. Nitrogen fertilizer rates are given based on long-term field trials of forage species at research farms scattered about those states in humid areas. The nutrient is too soluble and so subject to various transformations in moist to wet soils that it is impossible to measure it accurately. The measured value also would not have any meaning over the useful life of the soil test. A nitrogen quick test produced for corn uses a soil sample taken when the corn is about 12 inches high. This snapshot in time can predict whether the corn crop needs additional N fertilizer. This, too, is just an approximation and correlates the concentration of nitrate in the soil at that stage of corn development to the amount of fertilizer needed to produce the corn yield desired. The reading itself, without the correlation data, is meaningless. It works best on ground either receiving manure or that has residual N from the previous year. It is not appropriate if highly available N fertilizers have been spread or injected just before corn planting.

Naturalized and native haylands are primarily grass based. Naturalized haylands, being primarily cool-season grasses in the North and subtropical or tropical warm-season grasses in the South, benefit by the addition of N. Legumes are either absent or a minor component (<10 percent by weight) in those grass stands (fig. 5–43). If manure is available, it can be spread at the rate to meet the N needs of the crop produced. Manures and N fertilizers should be spread before grass regrowth occurs at the beginning of the season or after a cutting. The most efficient way of applying N is to split apply yearly requirements in humid areas or on some irrigated pastures. These split applications should equal the amount needed to produce the forage growth expected for the cutting being fertilized. If applied all at once, a high percentage can be lost to leaching, runoff, denitrification, or volatilization before forage crop uptake. Grasses also take up excessive amountsof N if excessive amounts are present in the soil. This can lead to nitrate poisoning unless ensiled and stored for 6 to 8 weeks before feeding.

Native haylands, being primarily temperate warm-season grasses and growing in more arid areas where little N is leached or denitrified, may require little or no N. In humid climates N fertilizer can actually be detrimental to temperate warm-season grass stands by favoring cool-season grass invaders. Therefore, N fertilization should be avoided unless applied in small amounts late in spring at the outset of warm-season grass growth. In areas receiving 18 inches of rainfall, 50 pounds of N per acre is sufficient. In areas receiving 30 inches or more rainfall, 100 pounds of N per acre optimizes yields of warm-season grasses. The goal is to avoid leaving any significant residual N in the soil for cool-season grasses to exploit once cool weather begins again.

Naturalized or native haylands being mostly grass based do not benefit much from pH adjustments unless the soil is extremely acid (<5.0) or extremely alkaline (>8.7). So liming to reduce acidity or decreasing alkalinity through irrigation water management or acidification is rarely necessary for these haylands. Most grasses grow well within this range.

For forage crops grown in rotation with row crops, another method of fertilization may be the rotation method. This works particularly well when manures are available for disposal. Most manures, when applied at the N rate needed to produce the expected yield of the row crop, deliver higher rates of P and K to the soil than that required annually by many row crops grown in association with forages. Yet, this is the most ideal time to spread manure for the following reasons:

- Row crops can use the N to greatest economic advantage.
- Manure spreading can be done before row crop planting and after harvest so that no crop damage can occur from smothering, salt burn, or traffic injury.

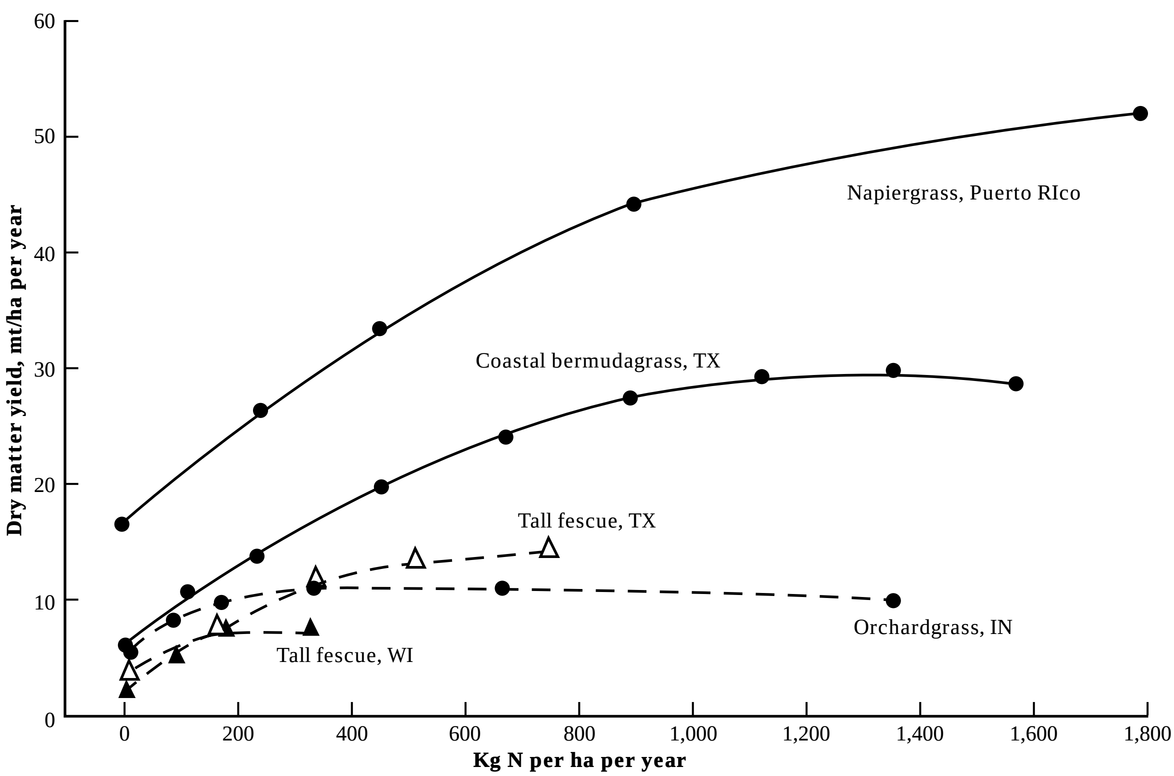
- Legume and legume-grass forage crops are not subjected to unneeded N applications that can increase planted or volunteer grass competitiveness with the legume.
- Forage crops are also not fouled by manure that could lead to livestock health problems or at least lower intake.

This method of fertilization leaves residual P and K in the soil for the forage crops that follow in the rotation. The forage crops are then left in the rotation at least long enough to draw down the P and K to balance crop removal with nutrient additions over the life of the rotation. Some supplementary P and K may be added if the forage crop's life in the rotation extends beyond that needed to balance manure nutrient inputs with crop removal.

This leads to one other method of fertilization, prescription application of nutrients. The prescription method accounts for the various possible sources of nutrients on a fully integrated livestock farm or ranch. The sources include atmospheric deposition, feed purchased, fertilizer, fixed nitrogen from previous crops, manure, and soil.

Soil test results prescribe fertilizer amounts based on the availability of soil nutrients. If soils test high, fertilizer amounts are reduced accordingly to the point of recommending no more of a particular nutrient be added. This portion of the prescription method is easy and accounted for in the soil test recommendations. The rest of the accounting procedure requires more tests and a mass nutrient balance worksheet.

Figure 5–43 Grass response to nitrogen fertilizer* (from Barnes, et al. 1995)



* Note tropical and subtropical warm-season grasses have greater response to very high rates of N than that of the cool-season grasses. Also note longer growing season increased tall fescue yield and response to N.

In areas where atmospheric deposition of N is significant, an annual deposition rate is included in the calculations. In some cases it is ignored because of offsetting N losses, such as denitrification, that are known to occur, but do so at unpredictable rates.

Manure, where applied, should be tested for nutrient value. Book values reported in the literature are averages and may have nothing in common with the manure being spread. This manure test picks up the nutrients being brought onto the farm through feed supplements. The manure analysis reflects what the livestock are eating. This is often why the onfarm manure analysis differs so widely from literature values. Another reason for the possible disparity is the way manure is stored and handled on the farm versus how it was stored as cited in the literature. Losses of N and K can be substantial if the liquid fraction of the wastes escapes collection. Ammonia N can also volatilize away during collection, storage, and application. The rate of application of manure should be calibrated so that there is a known rate of application associated with manure usage. If manures are applied, they are added to the supply ledger.

If legumes are in the crop rotation, the next crop or the legume's companion crop in the rotation will benefit from the nitrogen released from the decaying legume residue, roots, and aerial parts. Their contribution to the N supply can be estimated by using tables similar to table 5–5 developed for your area. Care must be taken not to over estimate their contribution. If the legume stand is thin or has become very grassy, little carryover of N to the next crop occurs. Once the nutrients are accounted for from these sources, they are subtracted from the amount of commercial fertilizers recommended in the soil test recommendations. Landowners or managers that have the ability to use manures and legumes in their cropping systems can save on fertilizer expenses. They also must realize that purchased feed serves a dual purpose: It feeds livestock and ultimately the crops on the farm.

From a water quality standpoint in many watersheds around the Country, N and P loadings on farms need to be closely tied to crop utilization and export of crop and livestock products. These two nutrients are causing downstream pollution and eutrophication in receiving water where uncontrolled high inputs of these nutrients occur in some watersheds. Where forage crop and pasture lands impact these watersheds, dairies, being intense livestock enterprises, tend to be major nonpoint sources of N and P. In particular they tend to be phosphorus accumulators because the importation of feed supplements and purchased fertilizer outweigh the export of P in milk and meat.

P can leach as readily as N on some sandy soils having little ability to fix or immobilize P as water insoluble compounds. Therefore, P can reach receiving water by shallow groundwater interflow as well as by surface runoff. Nitrogen can also move via these two pathways.

Dairy cattle are fed high protein diets to produce milk. If not supplemented with the right proportion of rumen degradable protein to rumen undegradable protein, much of the rumen degraded protein leaves the animal as urea in the urine rather than as protein in the milk. This elevates the nitrogen excreted either in the pasture or on the confined area. Depending on the management of the confined area, nitrogen may leave it as surface runoff or be disposed of later as manure on forage crop land. There, it may be subject to further loss by leaching or runoff. Therefore, nutrient management planning is as critical to grass based farming as is the forage-livestock balance sheet to achieve total whole farm planning.

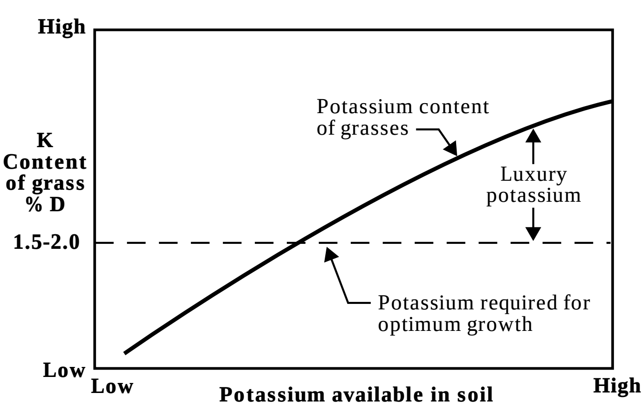
Potassium is also becoming an important factor in nutrient management. As mentioned under nutrient management on pasture, high levels of K in forages can affect animal health adversely. Dry dairy cows 2 to 3 weeks from freshening need grass forages with the lowest K concentrations available to avoid milk fever and other symptoms caused by a cation-anion imbalance in their diet. However, heavy fertilization or high feeding rates of off-farm produced feedstuffs cause soil K levels to become high or excessive on fields receiving most of the animal waste. Luxury uptake of K by grasses builds K concentrations in the grasses well in excess of 3 percent of dry weight (fig. 5–44). Late dry period cows should be fed a total ration with not more than 0.8 percent K in it. If the grass has more than 2 percent K in it, the ration becomes difficult to balance. It must involve other feedstuffs containing much less K to dilute the concentration.

Legume forage crops are sensitive to low soil levels of sulfur (S) and boron (B). When growing legumes, alone or with grass, on hayland or on cropland in rotation with other crops, specify that these two nutrients be evaluated when sending in soil samples.

On strongly acid soils, molybdenum (Mo) may also limit legume growth. It is directly responsible for N fixation by *Rhizobia* and for N assimilation and protein formation in the plants. These nutrients can be added to a blended fertilizer and spread with other required nutrients. Standard soil tests do not test for these nutrients.

Soil tests for forage crop production should be taken at least once every 4 years or per crop rotation cycle. Soil sampling in late summer or fall gets reliable K results. Soil tests should be taken at least a year before seeding back to a perennial forage crop. This is particularly important where stand longevity is critical to maintaining the correct rotation length and avoiding frequent renovation events on permanent hayland. This allows the producer to correct soil pH and micronutrient deficiencies or build soil levels of P and K before planting the perennial forage crop. The chances of establishing a thick stand and ensuring its long-term survival are greatly enhanced by having adequate soil fertility before establishment. Soil tests, to have any validity, must be taken in areas of the field that have the same soil type, topo-graphy, and cropping history. Several soil plugs or slices should be taken randomly within the area of like conditions. These are then mixed and a composite sample taken from that. Each sample must be clearly identified as to soil type, field number, and location in the field.

Figure 5–44 Influence of potassium available in the soil to potassium content in grasses (adapted from Brady 1974 and Bosworth 1995)



With precision farming, soil samples can also be collected in a grid pattern that is mapped using global positioning system (GPS) technology. This establishes a geo-referenced pattern of soil fertility over the field. Fertilizer trucks equipped with geo-referencing devices can spread fertilizer at variable rates across the field based on the soil fertility map superimposed over the field map. This avoids placing too much or too little fertilizer in areas of differing soil fertility across the field.

Soil samples also must be sent to a soil test laboratory that uses the proper extraction methods for the soil sampled and has knowledge of the soil's response to fertilizer. In some states this is easily done by sending samples to the land grant university facility. However, some land grant universities no longer have such a facility for public use. In those states private laboratories are certified by the land grant university. Much of the controversy over the validity of soil testing was because of the mistaken belief that soil testing procedures are the same nationwide. They are not and should not be. Soil chemistry varies too widely over the Nation to have one perfect extraction procedure. Soils also vary in their response to fertilizer. Laboratories without access to field trial data for the soil type listed on the soil test form cannot give accurate fertilizer recommendations. The recommendations they give will be high to avoid under estimating amount required and incurring blame for a poor crop response.

Plant tissue samples can also be taken to indicate the current status of nutrient sufficiency in the forage crop. The results are compared to reference nutrient concentrations of a "normal" forage at a specified yield level. Tissue testing can reveal any nutrient imbalances, but the soil test accompanying it helps determine the cause of the imbalance. Tissue testing alone only tells you whether or not you have a problem. It cannot tell you why it is occurring.

(c) Accelerating practice—Hay planting

This practice is used to renovate permanent hayland or reintroduce hay-crop forages on a field where a crop rotation is used. It does not include row crop plantings that might be harvested as a forage crop, such as corn silage. The full title of the practice standard in the FOTG is Pasture and Hay Planting. As with pasture plantings, hay plantings are done for several reasons:

- To reintroduce legumes back into permanent hayfields that have gotten increasingly grassy. This improves forage quality and often increases forage yields by increasing plant density and fixing atmospheric N.
- To introduce newly improved cultivars of grasses or legumes not before used by the producer. These varieties have improved disease and/or insect resistance and greater productivity.
- To introduce wholly different forage species that are better adapted to the site's climate, soils, and harvest regime.
- To introduce forage crops into a crop rotation that will balance crop removal of nutrients to those applied as manures over the life of the crop rotation.
- To introduce hay-crop legumes into a crop rotation to provide organic N to the next crops in the rotation. For instance, depending on the rate of decomposition, alfalfa may provide residual N for up to 3 years of crop production.
- The same planting techniques can be used to plant cover crops in orchards and vineyards or on cropland. On cropland, the cover crops retain soil nutrients in the root zone, provide ground cover and organic residue, and may fix additional N for the production crop's benefit. They may be tilled into the soil or burned down with herbicides before the next production crop's planting or left as a living cover crop.
- To improve soil quality by increasing soil organic matter (primarily through root mass accumulations) and soil particle aggregation. Root exudates and expansion cause soil particles to bind together by supplying a gluing agent and applying pressure.
- To provide excellent ground cover and root binding to protect the soil from erosion while they are in the crop rotation, thereby reducing overall soil erosion rates where applied.
- Where the plantings are properly sited, they provide crops that can trap wind blown soil, filter sediment and nutrients from runoff water, and intercept nutrient laden shallow interflow water with their roots. These areas may be trap strips or vegetative barriers in wind erosion prone fields. They may serve as vegetative filters along watercourses or waterbodies and at lower edges of sloping row crop fields. They may be hay-crop strips alternated with tilled strips across the hillslope or the prevailing wind direction in stripcropping layouts. On vegetative filter sites, to be truly effective in removing nutrients, the forage should be harvested as a hay-crop anyway to remove the nutrients stored in the plant tissue. Otherwise, the nutrients will eventually make their way to the watercourses targeted for protection.

(1) Hay-crop plantings

Hay-crop forage plantings generally contain only one or two species for ease of management. As the stands mature, other species of plants, desirable or undesirable, invade as openings in the canopy permit. Either a pure grass or legume stand is the easiest to manage. Weed control is easier because most herbicides presently on the market cannot kill the weeds without either killing the grass or the legume at the same time depending on their chemistry. Grasses tend to be quite competitive towards legumes having stronger root systems, a taller canopy, and faster leaf growth. Therefore, without fertility and harvest measures to favor the legumes, grass-legume mixtures eventually become grass only stands. However, most binary seeding mixtures for hay-crop seedings contain a legume and a grass. The advantages to doing that even though maintaining two different plants is difficult are:

- Legumes reduce the need for N fertilizers because they fix N.
- Legumes improve forage quality because they are more digestible and have higher protein concentrations.
- Most legumes can produce good hay cuttings during the summer when cool-season grass components produce little or nothing.
- Grass-legume mixtures tend to provide a denser canopy suppressing weeds from invading in the first place.

- Theoretically, grasses can protect legumes from frost heave damage on soils where this commonly occurs. There may be some value, but it is inconsistent and very much subject to the severity of the winter conditions that cause frost heave.
- Grass-legume mixtures tend to dry down faster as hay and ensile better than pure legume mixtures.
- Grasses alone generally have to be ensiled wetter to achieve required packing to exclude oxygen.
- A grass-legume mixture provides insurance from crop failure because if the legume dies out unexpectedly, the grass remains to provide some yield until the field can be scheduled for renovation again.
- Grasses tend to prevent legumes from lodging (laying over with no recovery after a hard rain or wind storm).
- Legumes grown with grasses reduce nitrate poisoning and grass tetany cases in livestock if the stand is 40 percent or more legume.

(2) Grass-legume mixtures

Hay-crop grass-legume mixtures should contain a legume and a grass that have similar maturity dates, are compatible in height, and adapted to the hay cutting regime of the operator. This generally goes beyond just getting compatible species together. It also requires getting varieties together that are most compatible in maturity timing and cutting interval tolerance. As mentioned before under pasture plantings, common varieties of many grasses have differing maturity dates to the legume standard, alfalfa. Some mature before the alfalfa is ready and others mature much too late for quality alfalfa hay or ensilage. Grass varieties must be selected that mature at the same time the alfalfa is entering the harvest stage of maturity that the producer likes.

The decision to renovate pure legume stands or grass-legume stands hinges on the number of legume plants left per square foot. Most legumes need only 6 to 8 plants per square foot in established stands to produce maximum yields. Alfalfa stands with less than 3 plants or 25 stems per square foot, whether or notgrass is present, are in need of renovation. Alfalfa forage yield at this point is unacceptable if it is really being counted on for its quality and production. Other crowned legumes at 4 plants per square foot produces only about 50 to 60 percent of their potential yield.

(3) Herbicide use

Hay-crop forages should not be planted immediately after other crops treated with herbicides that have carryover residual effectiveness from one crop to the next. The triazine herbicides called atrazine, metribuzin, and simazine, chloroacetamides called acetochlor and dimethenamide, imidazonlinones named imazethapyr and imazaquin, clomazone, and tank mixes or premixes containing these herbicides should not be used the year before a hay-crop planting. Reduced rates of any single chemical the year before seeding may lessen injury, but crop damage may still occur depending on soil type and rainfall amounts received between last herbicide application and hay-crop planting. A reduced rate may avoid a stand failure, but stand vigor may be unacceptably low.

If an application of lime is needed to reduce soil acidity before seeding a hay-crop, an application at least a year in advance releases any applied triazines bound to soil particles. If done just before cool-season hay-crop seedings, the triazines released may be enough to cause an establishment failure. If the soil was that acid, the liming would have actually made the triazine weed control more effective for the row crop treated. Sulfonylurea herbicides have a shorter carryover effect, but can go into the next crop year. The time interval between last application of them and hay-crop seeding must be separated sufficiently. Crop restriction periods range from 9 to 16 months for alfalfa and clovers. A summer hay-crop planting of alfalfa or clover is safer than a spring planting if sulfonylurea herbicides were used the year before. Flumetsulam has a long cropping restriction on it for clovers, 26 months and still needs to be bioassayed to see if activity is still there. It has only a 4-month restriction on it for alfalfa.

The management message is to be extremely careful in crop rotations not to apply herbicides to a previous crop that may do crop damage to the next one in the rotation. New herbicides are registered each year and others are taken off the market. Labels are subject to change and may become more restrictive. Some herbicides are registered for use in some states and not others. All herbicide users should carefully read herbicide labels and proceed with treatment only after they are sure they understand the environmental consequences of their actions. The information in the preceeding two paragraphs should not be considered a definitive source at the state level. These paragraphs were done in some detail to point out the complexity of the management issue involved.

(4) Seeding failures

Seeding failures can also occur from natural chemicals called allelopathic compounds. Sometimes considered a defense mechanism to protect the plants already growing on the site, allelopathic compounds are chemical substances that inhibit the growth of seedlings of the same species or competing species. These chemical substances are either secreted or leached from plants or are toxic degradation products from old crop residue. If the allelopathic compound interferes with the germination and development of seedlings of the same species, the effect is called autotoxicity. This latter effect has been attributed to alfalfa and clover seeding failures when new seedings are planted immediately after a preceding crop or into a thin stand of the same genera.

Autotoxicity has a name in the case of clover. It is called either clover-sick soil or clover sickness. In this case some researchers isolated some phenolic compounds that were degradation products of isoflavonoids contained in the clover herbage that inhibited germination of red, white, and alsike clover seeds. They also inhibited red clover seedling growth. Presently, it is not recommended to reseed by complete renovation or overseed alfalfa into old, thin stands of itself because of the strong evidence that it is autotoxic. If the thin stand is less than 1 year old, a no-till alfalfa seeding into the existing stand is unaffected by autotoxicity. To avoid autotoxicity problems on older stands, kill all old plants at least 6 months before the next seeding. Generally, this allows for enough decomposition and leaching of toxic compounds to dilute their effect on the new seedlings. A surer autotoxicity avoidance measure is to totally eradicate the old alfalfa and rotate to another crop for at least one year before reseeding back to alfalfa.

Tall fescue, orchardgrass, redtop, quackgrass, ryegrass, timothy, Johnsongrass, bermudagrass, bahiagrass, pangolagrass, rhodesgrass, and Dallisgrass have all been implicated in being allelopathic to various legumes and grasses seeded into them. Ball clover was most affected by the warm-season grasses followed by arrowleaf and white clovers. Crimson clover was unaffected. Tall fescue is variable in its allelopathic effect on legumes. It appears that specific genotypes are allelopathic while others are not. Birdsfoot trefoil, rape, and medium red clover germination and growth have been retarded by some tall fescue genotypes. Even large crabgrass growth was excluded in some tall fescue stands. Quackgrass toxicity has been studied extensively, but evidence is inconclusive on its being allelopathic. It may be more related to its aggressive rooting and dense canopy nature. For legume hay-crop plantings, grass eradication before seeding is best. A crop rotation than includes a year or more of crop production that uses clean tillage, herbicide treatments, or both, to kill old sods of these grasses is desirable.

Seed quality is important whether it be a pasture or hay-crop planting. Certified seed should be used whenever possible to guarantee the variety of choice is actually what is in the bag and the quality of the seeds contained in the bag. Seed tags should show species name, varietal name and/or number, lot number, the germination percentage of the forage species stated on the tag, germination date, the percentage of pure seed, the percentage of other crop seed, the percentage of weed seed, the percentage of inert material (chaff, seed coatings, soil), the percentage of noxious weed seeds, the percentage of hard seed (species dependent), total germination and hard seed, origin of the seed, and weight of the bag.

Seeding methods, depths, and rates; seed treatments; and pest management covered under the pasture management section equally apply here. Please refer to pasture planting for those management items. One notable exception is a pest management concern on alfalfa planted into sods or heavy residue. Most alfalfa seedings are done on hay-crop land, so it is covered here. Slugs can be a serious problem on spring or summer no-till alfalfa seedings in sods, heavy crop residue, or heavily manured fields. Some tillage to reduce the ground cover may be necessary to destroy the slug's habitat. Presently, there are no molluscides labeled for use on forage crops used for forage, only their seed crops. Slug damage can occur on several other forage species where cool, moist, trashy soil conditions prevail.

(5) Evaluation of forage seeding

Evaluation of the successfulness of a forage seeding establishment should occur about 5 months after the seeding or at first harvest, whichever comes first. Sometimes this can be just a visual scan across the field and deciding the stand is uniform, thick, and lush. In situations where weather conditions or other stress factors have created a questionable stand in terms of numbers and vigor, an assessment of whether to reseed or overseed or plant to another crop is needed. Stand counts based on the number of plants per square foot are taken randomly across the field. Guidelines for some common forage legumes and grasses are given in the table 5–7. These values should be viewed as guidelines only for pure stands during the establishment period.

The ultimate decision to destroy the stand and replace it with a new seeding or another crop ultimately rests with the producer. The numbers are high to suppress weed growth and optimize first year forage yield. Since perennial plants do little tillering the first year, they must be thick in numbers to form a closed canopy. The numbers can be considerably lower for perennials (6 to 8 plants) in later years and still produce maximum yields. Over time they will thin out as weaker individuals are crowded out by the more vigorous ones. Perennial plant numbers are virtually meaningless after the establishment year. Stem counts are more valid in rating stand density. Sod formers and stoloniferous plants lose their identity as individual plants. Crowned plants, if healthy, produce more stems as plant numbers decline.

If the numbers observed in the field during the establishment period are somewhat lower than those given in table 5–7, remedial measures can be taken to make the best of the situation. Weeds should be suppressed with herbicides if they threaten to overtop the forage crop. A more lenient forage harvest management can put less strain on surviving forage plants. This might include higher stubble heights, less frequent cuttings, and more advanced maturity stages for the legumes. This will build food reserves and keep canopy closed for longer periods to suppress weed competition. Some additional fertility may also be in order if leaf color and tissue analysis indicate less than optimum nutrient levels. On irrigated land, close monitoring of soil moisture can help to avoid any water stress that would harm development.

Hay-crop plantings may be clear seeded or planted with a companion crop, such as spring oats or barley. If a companion crop is seeded with the hay-crop, it must be sown at no more than 75 percent of its normal seeded alone rate. This reduces competition for water, allows for more light penetration to the lower canopy of forage seedlings, and decreases to some extent its likelihood of lodging under wet conditions. Ideally, the companion crop should be removed early as an ensilage crop. If it is allowed to mature for grain, the straw windrows left by the combine should be baled as soon as possible. Windrows left in place for prolonged periods smother the hay-crop seedlings lying beneath them.

Table 5–7 Minimum number of plants per square foot to achieve a full stand 1/ 2/

Species	Minimum number/ft^2
Alfalfa	20 3/
Alsike clover	15
Birdsfoot trefoil	15
Cicer milkvetch	7
Crimson clover	20
Crownvetch	7
Kura clover	15
Red clover	15
Sainfoin	7
Sweet clover	7
White (Ladino) clover	10
Orchardgrass	50
Reed canarygrass	50
Ryegrass	60
Smooth bromegrass	15
Tall fescue	50
Timothy	30

1/ Sources: Cornell Field Crops and Soils Handbook, 1987; Hanson, A.A., et al. Alfalfa and Alfalfa Improvement, 1988; Knight, W.E., The Effect of Thickness of Stand on Distribution of Yield and Seed Production of Crimson Clover, 1959; Piper, C.V., Forage Plants and Their Culture, 1941; Sheaffer, C.C., Forage Legumes, 1993; Sprague, M.A., Seedling Management of Grass-Legume Associations in the Northeast, 1963.

2/ For pure hay-crop stands of the species named at 5 months from planting date or first harvest, whichever comes first. Rainfed areas receiving at least 16 inches of rainfall during the growing season or irrigated lands.

3/ Alfalfa is an average value going from an arid (14 plants) to humid (26 plants) climate.

(d) Accelerating practice—Irrigation water management

This practice is used primarily in rainfall limited areas to produce high quality hay-crop forages for livestock. Eighty-one percent of all irrigated acreage occurs in the 17 contiguous Western States. Much of the acreage devoted to hay-crops is sown to alfalfa. General guidelines are given here only because of the regional differences in evapotranspiration, soils, effective rooting depth, species and cultivars used, and irrigation methods used that affect water usage. Other field specific environmental factors that influence water usage are age and vigor of the forage being irrigated and soil nutrient status.

The primary methods of irrigation are gravity and sprinkler. Under these two general methods are specific types of irrigation used for pasture or hay-crop land. Gravity irrigation types used for pasture or hay-crop land are border-strip, corrugation, flood, and wild-flooding. They benefit from land that has been leveled first. With wild-flooding, however, this is less likely because the terrain is generally too uneven to be leveled.

Sprinkler irrigation types used for pasture or hay-crop land are center pivot, portable, solid set, and traveling gun. A less common method of irrigation is called subirrigation. It requires nearly level land and a shallow water table that can be elevated and lowered with a water control structure at the ditch or tile main outlet that drains the field being subirrigated.

(1) Soil water criteria

Soil water criteria are used to determine irrigation scheduling where applicable rather than plant based criteria. By the time visual symptoms appear, yield reductions will frequently occur. Two soil water criteria are used. One is based on available water, and the other on extractable water.

(i) Available water criteria—Available water in the effective root zone is the amount of water released by the soil when the equilibrium soil water matrix potential is decreased from field capacity (0 bar) to permanent wilting (-15 bar). This is the portion of water in a soil that can be absorbed by plant roots. Using this criterion, available water is allowed to be drawn down by the crop, typically 40 to 65 percent, before irrigation commences.

(ii) Extractable water criteria—Extractable water is a lesser quantity of water than available water. It is the difference between the amount of water held by the soil at field capacity and the water remaining in the effective root zone when severe wilting of the crop occurs. In this case, however, a greater depletion percentage is allowed before irrigation commences, typically 65 to 75 percent.

The goal of either method is to prevent a decrease in plant transpiration. With a decrease in transpiration rate, there is a corresponding decrease in yield. A decrease in transpiration means the plant is undergoing water stress. Water stress decreases stem numbers and diameter, internode number and length, and leaf size. Moderate water stress lowers alfalfa yields, but produces a leafier product. Under severe water stress, however, lower leaves drop off, resulting in a stemmy, low yield cutting of alfalfa.

When soil water depletion is used as an irrigation criterion, water depletion is monitored most often in the upper 3 feet of soil rather than from the full effective root zone. However, there are instances when monitoring the lower part of root zone is of value. It provides information on potential storage of excessive rainfall that might occur after an irrigation event. This can often happen in humid and subhumid areas. This allows the storage of rain that might otherwise be lost to deep percolation if the entire root zone was at field capacity. It is also important for the control of soluble salt leaching in saline or sodic soils.

Soil water depletion can be monitored directly, indirectly, or based on evaporation pan or climatonomic models that estimate maximum daily water use or evapotranspiration (ET). Direct measurements are not used by producers because of their expense and operating difficulties. Indirect measuring devices are calibrated soil tensiometers, neutron meters, or time domain reflectometry. The procedure involving ET estimates either from pans or the Penman, Priestley-Taylor, Jensen-Haise, and Makkink formulas calibrated for the particular crop and climate situation is most often used. Crop coefficients are developed during various crop growth stages throughout the year.

Once ET estimates have been developed, irrigation can be scheduled using a water budget. This budget sums soil water depletion using one of the climatonomic estimators and deducts water inputs from precipitation or irrigation. This provides a net soil water status. This simplistic procedure can have cumulative errors introduced from erroneous ET estimates or water input assumptions. It should be verified with tensiometers or other soil water measuring devices to avoid over or under applying irrigation water.

Excessive moisture supplied by irrigation or rainfall is detrimental to alfalfa root and shoot growth and to stand persistence. In the desert irrigated regions, alfalfa can be scalded by nearly saturated, high temperature soils. These plants most often die within 3 to 4 days. Over-irrigating alfalfa immediately after cutting when little regrowth has occurred leads to severe plant stress and stand thinning. The roots are deprived of oxygen, and toxic concentrations of ethanol and other substances build up in them. Leaf loss starting at the base of the plant and death of xylem tissue results. Since growth of phytophthora root rot fungi is favored by wet soils, this infection can be a secondary cause of stand loss. In more northern or higher elevation irrigated areas, excess soil moisture during the latter part of the growing season can decrease freezing tolerance of alfalfa plants and lower winter survival.

It takes from 1 to 1.5 acre-inches of water to produce a ton of alfalfa hay per acre. Maximum daily water use or ET of alfalfa is typically 0.2 to 0.5 inch. Daily ET rates vary based on global radiation, plant growth stage, air temperature, and day length. The highest ET rates occur during full plant canopy on hot, long, windy days with low humidity. Seasonal alfalfa ET rates range from 14 inches in the Northeast or Pacific Northwest to 74 inches in the arid Southwest. Table 5–8 gives the typical seasonal ET values for alfalfa by regions in the Western United States. For a comparison with other forage crops, see table 5–9, Seasonal consumptive-use requirements of some forage crops.

Irrigating a field's soil-to-field capacity before seedbed preparation enhances germination and emergence. This avoids applying water to planted seedbeds on soils prone to washing and crusting. Irrigation should commence after emergence to increase root penetration and growth. Seedling roots are suppressed more than shoot growth by moisture stress.

Table 5–8 Total seasonal consumptive use of water by alfalfa in Western United States (from Hughes, H.A., Conservation Farming, 1980)

Location	Growing season (days)	Seasonal consumptive use (inches)
Southern coastal	300+	36
	250 – 300	30
South Pacific, coastal interior, and northern coastal	250 – 300	37
	210 – 250	32
	180 – 210	26
	150 – 180	22
Central valley, California, and valleys east side of Cascade Mountains	250 – 300	40
	210 – 250	34
	180 – 210	30
	150 – 180	26
	120 – 150	20
	90 – 120	14
Intermountain, desert, and western high plains	250 – 300	52
	210 – 250	44
	180 – 210	36
	150 – 180	30
	120 – 150	24
	90 – 120	19

Table 5–9 Seasonal consumptive-use requirements of some forage crops (from Hanson, A.A., Practical Handbook of Agricultural Science, 1990; Hughes, H.A., Conservation Farming, 1980)

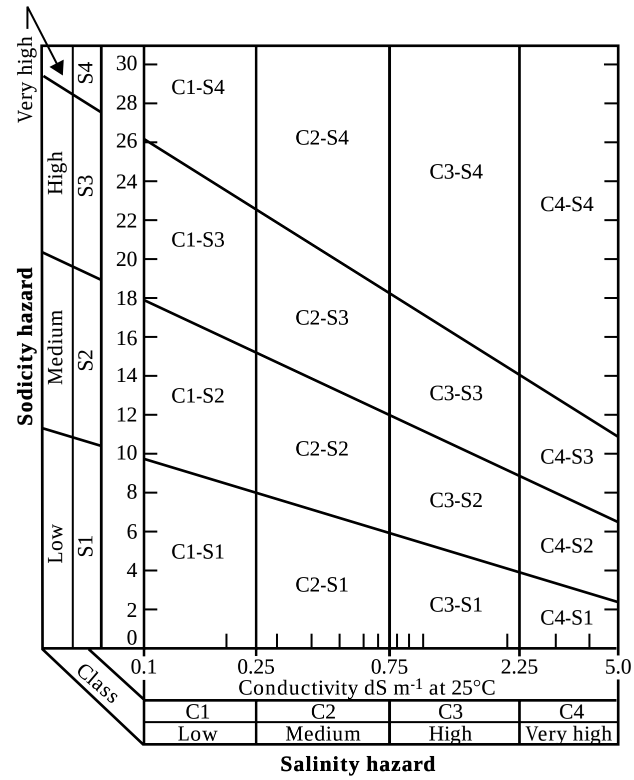
Crop	Fraction of alfalfa water requirement
Alfalfa	1.0
Bromegrass	1.16
Corn	0.65
Pasture	0.90 (variable)
Red clover	0.90

(2) Water quality requirements

Water quality requirements for irrigation water are important. Concentrations of boron, chloride, sodium, and salt must be monitored to prevent crop damage. Water is classed based on its content of boron, chloride, sodium, sulfate, and electrical conductivity. The classes for boron and chloride are rated starting with the purest water named excellent and followed with decreasing quality by good, permissible, doubtful, and unsuitable. Sensitivity to these contaminants varies with forage species. They are ranked as sensitive, semi-tolerant (medium tolerant), and tolerant. Table 5–10 gives classification of irrigation water based on boron and chloride content. Refer to table 3–6 in chapter 3 for salinity tolerance ratings of various forage crops.

Forage crops are rather tolerant of high boron concentrations in the soil. Some forages and their tolerance limits to boron are shown in table 5–11. Figure 5–45 graphically shows the USDA irrigation water classification based on water sodicity and conductivity. In sodic, nonsaline soils, Ca and Mg are often deficient for good plant growth. Sodic irrigation water may induce Ca and various micronutrient deficiencies in these soils. In sodic-saline soils, the salinity of the water becomes more important because of its osmotic effect on plant roots (burning). Sodic irrigation water can also reduce soil permeability and tilth because the sodium ion acts as a soil dispersant. It also causes the soil to crust badly as well, which impedes seedling emergence. A computerized and noncomputerized version of WATSUIT can be used to determine the suitability of irrigation water for a specific site and crop.

Figure 5–45 USDA classification of irrigation water* (from Wild 1988)



* The higher the total salt content of the irrigation water (as measured by its conductivity), the lower must be its sodium absorption ratio if the exchangeable sodium percentage of the soil is to remain below the level needed to produce adequate yields of the crop being raised.

Table 5–10 Classification of irrigation water based on boron and chloride content (from Hanson, A.A., Practical Handbook of Agricultural Science, 1990)

- - - Class of water - - -		- - Concentration (meq/L) - -		Hazard characterization
index	grade	boron	chloride	
1	Excellent	<0.5	<2.0	Generally safe for sensitive crops.
2	Good	0.5 – 1.0	2.0 – 4.0	Sensitive crops generally show slight to moderate injury.
3	Permissible	1.0 – 2.0	4.0 – 8.0	Semi-tolerant crops generally show slight to moderate injury.
4	Doubtful	2.0 – 4.0	>8.0	Slight to moderate injury for some tolerant crops.
5	Unsuitable	>4.0		Hazardous for nearly all crops.

Irrigated saline soils need to be leached on a timely basis to remain productive. Salts tend to build up in saline soils as plants extract water from the root zone and water is lost at the ground surface by evaporation between irrigation events. Evaporation and the quick drying of plant roots in the upper part of the soil enhance the potential for upward water movement. This upward water movement carries salts from deeper in the soil profile towards the surface, especially where a shallow saline water table exists. Salts must be removed by leaching to maintain the salt balance of the soil at an average salinity level compatible with the crop being raised. The fraction of total irrigation water needed to leach these salts through the root zone is called the leaching requirement (Lr). The fraction of total irrigation water that often percolates through the root zone as a result of irrigation inefficiencies is called the leaching fraction (L). Improved irrigation water management can reduce L to coincide with Lr. This can reduce downstream salinization because in concert with irrigation, drainage (open ditch or subsurface) must be provided to carry the leached salts away from the root zone. Drainage is also necessary in areas where the water table needs to be lowered to the proper depth to enable leaching and prevent upward flow of soil water into the root zone. Not only is less salt leached from the field, but less salt is applied when saline irrigation water is used because of the lower application rate. The required leaching can be achieved two ways. One way is to apply enough water at each irrigation to meet the Lr. The other is to schedule leaching irrigation that removes the salts accumulated by previous irrigations.

Table 5–11 Boron tolerance limits for some forage crops (from Stewart, B.A., and Nielsen, D.R., Irrigation of Agricultural Crops, 1990)

Forage crop	Threshold (ppm)
Sensitive	
Perennial peanut	0.75 – 1.0
Wheat	0.75 – 1.0
Moderately tolerant	
Barley	2.0 – 4.0
Bluegrass, Kentucky 1/	2.0 – 4.0
Corn	2.0 – 4.0
Oat	2.0 – 4.0
Clover, sweet 1/	2.0 – 4.0
Turnip	2.0 – 4.0
Tolerant	
Alfalfa 1/	4.0 – 6.0
Vetch, purple 1/	4.0 – 6.0
Very tolerant	
Sorghum	6.0 – 10.0

1/ Tolerance based on reductions in vegetative growth.

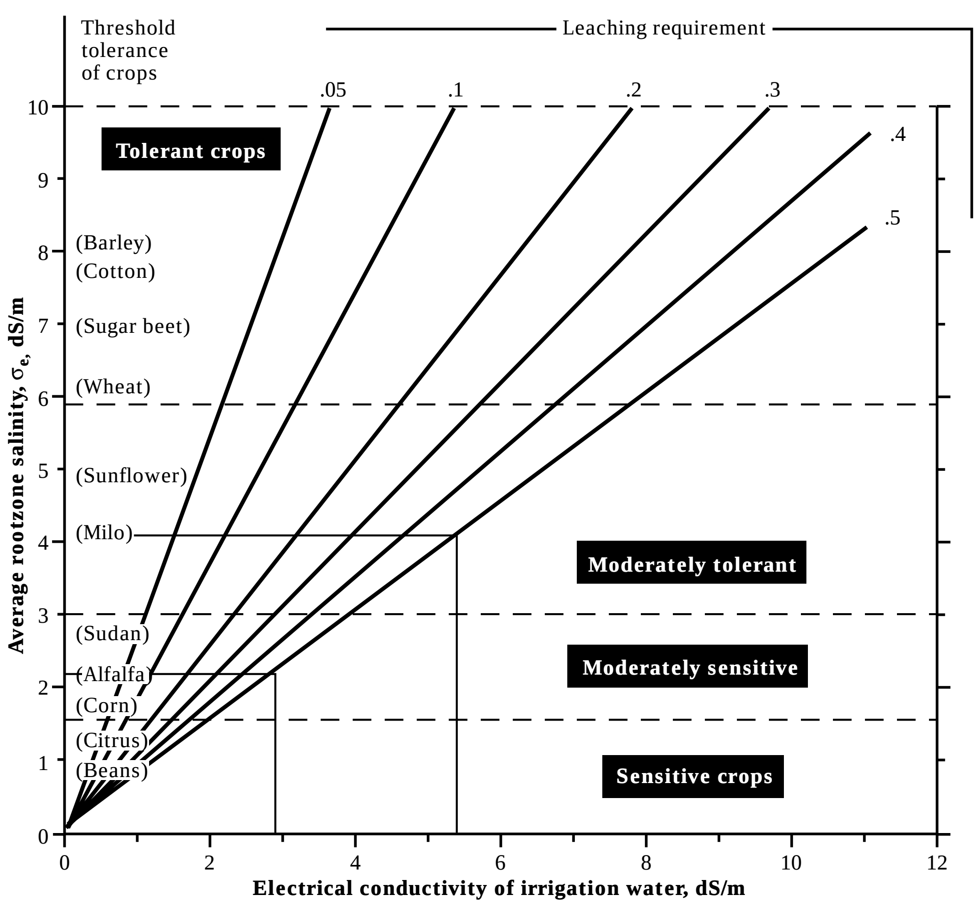
The salt balance or time-averaged root zone salinity is greater in soils that are irrigated less frequently than in soils that are irrigated more frequently, all other factors being the same. Saline soils benefit from more frequent irrigation to maintain them at a wetter condition than nonsaline soils. This keeps the soil salinity level lower. Figure 5–46 shows how the targeted average root zone salinity, based on the crop grown, is affected by the electrical conductivity of the irrigation water and the leaching fraction chosen. When the irrigation water salinity is higher than that required to achieve a no yield-loss threshold value for the preferred crop, some crop yield reduction occurs unless a more tolerant crop or a higher Lr is selected.

Sometimes excessive levels of salts in soils cannot be reduced through normal irrigation applications and crop management. Cropping is discontinued for a while and a deliberate effort to leach the salts and/or sodium is begun. In the case of sodic soils, soil amendments and leaching may both be required to reduce exchangeable sodium. When reclaiming saline soils, leaching requirements can be determined by measuring bulk soil electrical conductivity. This can be measured by soil electrode probes or electromagnetic induction instruments held by hand aboveground. The progress of salt removal is immediately measured by such devices. Boron is more difficult to leach. It takes about the twice the irrigation water to remove a given fraction of it as to remove soluble salts by continuous ponding. The act of irrigation itself tends to release more boron by hastening mineral weathering of the soil.

Irrigation water management that reduces salt uptake by forage crops prevents them from becoming too salty for animal consumption. Livestock fed high salt forage often get severe diarrhea and are dehydrated as a result. Often during reclamation forage crops are used to dry the soils some to improve salt removal efficiency. This prevents large pore bypass of water leachate that often occurs during saturated flow. These crops are best plowed under as a green manure crop. If harvested, they remove less than 5 percent of the soluble salts in the root zone. This is less than the amount normally applied back with the irrigation water. It also avoids livestock health problems while improving soil tilth. Organic matter returned to sodic soils improves soil aggregation a great deal.

Figure 5–46 is an example nomograph used to select the proper leaching fraction based on the average root zone salinity target required to grow the selected crop without yield loss and the electrical conductivity of the irrigation water available for use. Conventional irrigation commonly used for forage production allows the soil to dry between irrigations. Using the same leaching requirement fraction of 0.5, irrigation water must be much less saline (2.9 dS/m) to keep the average root zone salinity level in the soil at the proper level to grow alfalfa than it would (5.4 dS/m) to grow milo (grain sorghum). Both crops could receive irrigation water classified as C4, very high salinity hazard (from fig. 5–45) at this leaching requirement fraction. At a leaching requirement fraction of 0.3, alfalfa must receive irrigation water classified as C3 (0.75 to 2.25 dS/m) to keep the average root zone salinity at a level that would not lower alfalfa yields.

Figure 5–46 Assessing salinity hazards using conventional irriation (adapted from Stewart 1990)



(e) Accelerating practice—Soil amendment application

Soil amendments are organic and inorganic soil conditioners used to improve the chemical, physical, or both, condition of the soil. Although they may add some nutrients, their primary function is to improve soil tilth or decrease concentrations of growth inhibiting elements in the soil. However, the use of these amendments often makes soil borne plant nutrients more available or increases the soil's ability to store more applied nutrients. The most common agronomic organic soil amendments are manure, compost, green manures, and sewage sludge. Other organic amendments not included in the list just mentioned are more commonly or exclusively used for horticultural crops. The most common inorganic soil amendments are lime and gypsum. Soil acidifiers, such as sulfur, sulfuric acid, lime sulfur, ammonium thiosulfate, and ammonium polysulfide, may be used as well for agronomic crops. Other soil acidifers, such as aluminum sulfate, are generally used for horticultural crops requiring acidic soils for optimum production.

The inorganic soil amendments, lime and gypsum, basically flood the cation exchange capacity of the soil with calcium ions. Dolomitic limestone also provides magnesium ions. These ions displace exchangeable sodium ions in sodic soils and exchangeable hydroxyaluminum ions in acidic soils. Lime proceeds further to neutralize the hydrogen ions released while the hydroxyaluminum ions are being reduced to unexchangeable aluminum hydroxide. This is the exchangeable hydrogen referred to in older explanations of soil neutralization with lime. Lime also neutralizes soil acidity caused by weak organic acids and ammoniacal and urea nitrogen fertilizers.

Soil acidifiers acidify soils that either are alkaline or not acid enough for the best production of the desired crop. Soil acidifers benefit forage crop production on calcareous soils by lowering the soil pH to levels where iron, phosphorus, zinc, and manganese solubility are increased enough to not limit production. On calcareous sodic soils that have native supplies of calcium (Ca), soil acidifiers cause enough calcium to become exchangeable to drive sodium (Na) off the exchange sites as well.

Irrigation water itself is a soil amendment when it is used to leach salts and sodium from the root zone. It can be used alone on saline-sodic soils with soluble Ca in the A soil horizon. It can also be the lone amendment if deep plowing or chiseling brings up Ca carbonate or sulfate (native gypsum) from the B and C horizons of a sodic B horizon soil.

Sodic soils have poor soil tilth because Na is a soil dispersant. The soils when wet become puddled (no aggregation) having little pore space. They compact readily and form hard surface crusts. which greatly reduces their suitability as a plant growth medium. The addition of Ca to the soil acts as a soil flocculant. This causes clay sized particles to stick together to form aggregates. This increases soil permeability and aids the movement of water (irrigation or rainfall) through the soil profile to the depth Ca is incorporated or released. This flushes the exchangeable Na downward through the soil profile. Adequate artificial drainage must be in place to remove the Na irreversibly from the root zone.

The economic feasibility of treatment depends upon the value of the crops being grown and the amount of exchangeable Na in the soil. Most often treatment with soil amendments is done at smaller application rates over a period of years rather than with one large single application. The first application improves soil permeability and tilth to aid leaching of the sodium. The later yearly applications then draw down exchangeable Na slowly over several years. The soil amendments may be applied on sodic soils with the irrigation water, spread dry on the surface, or incorporated. In most situations surface applications of gypsum are more effective than incorporated applications. One exception to this is on slick spots in humid areas, where incorporation at depth and providing tile drains was the only effective technique.

Strongly sodic soils having more than 20 percent of the exchange capacity occupied by Na are expensive to treat. Calcium chloride or sulfuric acid can be used to rapidly drop the amount of exchangeable Na on the exchange sites. A combination of calcium chloride and gypsum can reduce the cost of treatment and be nearly as effective. However, forage crop production on these soils is not likely to pay for the cost of reclamation.

Particle sizes of applied gypsum and lime are important to their effectiveness short- and long-term. Gypsum should be a mix of finer and larger particle sizes with an upper limit of 2 millimeters (10 mesh). This ensures that there are fine particles to quickly increase soil permeability and large particles to sustain a continuous release of Ca over time to keep exchangeable Na percentage low in the root zone. To be most effective, lime should contain a mix of fine and larger particle sizes: Fine ones to quickly raise the soil pH, and coarse ones to have some residual value. Many states regulate the fineness of agricultural limestone. Generally, lime particles greater than 20 mesh are of little value in increasing soil pH while particles passing through a 60 mesh sieve are highly effective.

The other important factor with lime is its calcium carbonate equivalent (CCE) rating. To meet the actual rate at which the soil test recommendation specifies, the CCE percentage of the lime material being applied must be known so that it is applied at the proper rate. For instance, a soil test recommended 2 tons of lime per acre to adjust the soil pH and the lime used had only a CCE of 80 percent. Then, 2.5 tons or 5,000 pounds of that lime would be needed per acre.

Organic soil amendments are applied to increase soil organic matter. This improves soil tilth by increasing the number of water stable soil aggregates. It also improves the cation exchange capacity of the soil and creates a sink that holds nitrogen, phosphorus, and sulfur within the root zone as organic forms. As this organic matter slowly decomposes, these organic forms of plant nutrients are released for plant uptake. On sodic soils, organic matter incorporation improves soil permeability and enhances the effect of applied inorganic amendments, such as gypsum.

Many forage crops serve as green manure crops. Rather than being harvested for their feed value, they are allowed to return to the soil unharvested to increase soil organic matter. This is done to benefit production of other crops following in the crop rotation. Allowing green manure crops to fully mature is more effective in building soil organic matter than terminating them at an early vegetative growth stage. The mature growth stage has more lignified material in it and is more resistant to decomposition.

Manure and sewage sludge are the most commonly applied organic soil amendments to forage crops. Care must be taken not to smother the forages with heavy applications of these soil amendments. Excessive rates of application may also cause salt burn as well.

Both amendments should be applied at spring green-up or immediately after a harvest. This reduces the likelihood of contaminating harvested forage and renders it unfit for livestock feeding. Sewage sludges should be tested for their heavy metal concentrations. Applications of sewage sludge should be terminated once EPA or state regulated maximum soil loading rates are approached. Soil tests for regulated heavy metals should be done each year sludge is to be applied. Both of these amendments are stable organic matter sources. Soils amended with these products for several years drop in organic matter content very slowly once applications cease.

(f) Accelerating practice—Weed control

Weeds are herbaceous plants growing in places where they are not wanted and interferring with the growth of the desired crop. They sometimes reduce its harvested quality if allowed to remain. Weeds appear anywhere ground disturbance has taken place. They are pioneer species in plant ecological succession. They invade sites where competing vegetation has been destroyed. It is not a matter of: Will they show up? It is a matter of: What will show up? Every time forage crops are established, weeds will be present to compete with them unless control measures are applied. Forage crop stands that have declined will also be invaded by weeds as they thin out.

Weeds are broadly classified as grasses (includes grass-likes) and broadleaves. This is important when choosing among selective herbicides. Some selective herbicides are excellent in controlling grassy weeds, but are ineffective in controlling broadleaves. Others provide excellent control of broadleaves, but are mostly ineffective in controlling grassy weeds. Other herbicides may have broad spectrum control of several grassy and broadleaf weeds. Others are nonselective and kill every actively growing plant. Herbicide selection should be based on those labeled for use on the following:

- Forage crop being raised
- Intended end use of the crop (pasture or stored forage)
- Anticipated weed type most likely to compete with the forage crop

Weed control is not so much a single practice, but a technology area. Some of the other accelerating practices already described help control weeds. Nutrient management, liming, clipping, irrigation water management, prescribed grazing, forage harvest management, and pasture and hay planting all have an impact on forage stand health that can keep weeds suppressed. Anything that gets a forage stand off to a vigorous start and maintains a full canopy keeps weeds under control. The proper application of these conservation practices reduces the need and reliance on chemical weed control in close sown forage crops. It will not eliminate entirely the need for chemical weed control. Drought, insect and disease outbreaks, winter injury, human error, and other extreme environmental factors can often override the best efforts in management. These stresses can thin or wipe out forage stands and give rise to a weed invasion.

Another classification of weeds distinguishes between noxious and non-noxious weeds. Noxious weeds are those specified by Federal or State law as being especially undesirable, troublesome, and difficult to control. Examples would be Canada thistle, quackgrass, leafy spurge, horsenettle, Johnsongrass, and several bindweeds and mustards. Each state that has a noxious weed law should have a noxious weed list in the NRCS field office technical guide. These weeds should have picture identification and key distinguishing characteristics described for them. When giving onsite planning and application assistance to landowners, the presence of noxious weeds should be brought to their attention. Control measure options should be discussed and documented in any conservation plans prepared for the land unit.

Besides chemical weed control, biological controls are sometimes appropriate for a targeted weed species. This type of weed control is generally not available to the individual landowner. Federal laws prohibit the indiscriminate entry of exotic insects and diseases that might be hosted by a particular weed in its native habitat. Biological controls are extensively studied by governmental research agencies first and generally applied by governmental agencies. Great care must be taken not to introduce another pest that might get out of control. Biological weed control should not be considered a benign alternative to pesticides. Once a biological control is introduced to a new habitat, it cannot be easily gotten rid of if negative impacts arise.

The use of cultivating tools in controlling weeds in forage crop production is primarily limited to those that can be row cropped, such as corn or sorghum silage. Spike toothed harrows, however, can be used on established legume stands to kill annual weed seedlings without seriously hurting the legume crowns. Primary tillage tools do control weeds to some extent during seedbed preparation for both close sown and row crop forages. They kill existing weeds and newly germinated seedlings. Tillage tools may also dilute weed seed counts if the previous crop was weedy. They do this by mixing or inverting heavily seeded surface soil with soil lower in the tilled zone that has a lower seed count. Deep burial tends to prevent small seeded weeds from germinating. Large seeded weeds, however, may be little affected. If buried below the effective depth of herbicide treatment, large seeded weeds, such as giant ragweed, may escape herbicide control. Row cultivation can be used on forage row crops with over the row banded herbicides. The cultivator keeps weeds under control between the rows while the herbicide checks weed growth in the row. This cuts down on the amount of herbicide needed for control of weeds over the entire field.

Herbicide control of weeds can be done at various times. The five times when herbicides can be applied to forages are: preplant or preplant-incorporated, preemergence, postemergence, dormant, and between cuttings.

Preplant-incorporated (PPI) applications are done before planting the crop when conventional tillage equipment is used to prepare the seedbed. PPI herbicides should be mixed into the first inch of soil. Preplant herbicides are used to kill weeds and existing forages for no-till seedings.

Preemergence herbicides are sprayed on the soil surface after planting, but before seedling emergence. These herbicides are used on row crop forages, but not on close sown ones.

Postemergence herbicides are used widely on forages to suppress weed competition during establishment. They can be applied to legumes at rather early growth stages. On hay-crop grasses, postemergence applications must be delayed until the grass is at least 4 to 5 inches tall; at least 6 months for Ally.

Dormant sprays are put on when the forages are dormant, but weeds are actively growing. These herbicides are nonselective and will kill the forages if enough green leaf is available for herbicide uptake.

Spray applications between cuttings work similarly to dormant sprays. Timing is essential and must be done before significant forage regrowth occurs.

Whenever herbicides are used, crop use, field re-entry, harvest, and grazing restrictions must be adhered to strictly to prevent contamination of people, food supply, and livestock. Mixing areas should be sited and constructed to prevent surface or ground water contamination. Operators should wear appropriate protective gear when mixing or applying chemicals and afforded washing facilities at the mixing and application site to decontaminate themselves or the protective gear in case of exposure. Spray operations should be conducted when wind velocities are low to prevent drift. They should not occur within a few hours of predicted heavy rainfall that could cause washoff and herbicide entry into watercourses. Sprayer tanks should be rinsed, and the rinse water applied to the field just treated. All chemical containers should be triple rinsed, and the rinse water placed in the sprayer and used on the target field. Dispose of containers as directed on label. Strict adherence to all of this prevents contamination, illness, or death of people, non-target plants, or livestock and wildlife by needless exposure to these poisons. Always follow the product label and local and state pesticide regulations.

To prevent herbicide resistance from developing in weeds, alternate chemicals with different modes of action in disrupting weed growth from one crop season to the next. Herbicide modes of action to kill weeds are cell membrane disrupter, fatty-acid inhibitor, growth regulator, photosynthesis inhibitor, pigment inhibitor, protein biosynthesis inhibitor, and seedling growth inhibitor. Also, the potential user can minimize need for herbicides by using the other control methods mentioned.

Spray equipment should be under a preventative maintenance schedule to prevent drift, irregular spray delivery, and possible spill of herbicide. Each spray nozzle should be calibrated for correct delivery of spray. Any nozzle not delivering the proper rate should be replaced. Correct nozzle type selection for the application requirements is necessary.

(g) Accelerating practice—Disease and herbivory control

In actuality this is a dual technology area; it is being described under one title because the same principles apply to both. Chemical control, cultural control using practices already mentioned, resistance breeding, and biological control can keep diseases, insects, mites, nematodes, uninvited vertebrate herbivores, and mollusks from reducing forage production and quality and shortening stand life.

Many organisms are covered under this dual technology area. They are diseases or pathogens that include viruses, bacteria, fungi, and nematodes; arthropods that include insects and mites; mollusks that include slugs and snails; and vertebrate herbivores that include some birds and mammals, such as rodents, rabbits, and wild ruminants.

Resistance breeding has effectively reduced the severity of disease outbreaks, nematode feeding, and insect attacks on forage crops. Thus planting varieties of forages resistant to locally important diseases, nematodes, and insects is a viable cultural method to reduce the incidence of stand or yield loss.

Other cultural controls include conservation crop rotations that break up life cycles of disease and insect pests, nutrient management, forage harvest management, irrigation water management, prescribed grazing, and control of weeds that act as alternate hosts for other forage pests. Nutrient management produces forages that are more resilient to attack by disease and insects. Forage harvest management may include early harvest to halt the spread of disease inoculum or take away the food source of the unwelcome herbivores. It also includes cleaning harvesting equipment between harvests, mowing younger forage stands before older ones, maintaining a cutting schedule that keeps food reserves high for rapid recovery, and mowing after dew, rain, or irrigation water has dried on plants to prevent disease spread or outbreaks. Irrigation water management can keep soils from being over-saturated to prevent outbreaks of soil borne diseases that thrive under waterlogged soil conditions. When a new forage seeding is being planned, select forage species that are adapted to the soil and climatic conditions at the site. This reduces the risk of a disease outbreak that are favored under less favorable conditions. An example would be phytophthora root rot in alfalfa on restricted drainage soils. The timing of a forage planting can reduce slug damage. Depending on the climate, this can be either early spring plantings where adults do not overwinter or late summer plantings in warmer, drier areas when slug numbers and movement are suppressed. Residue management can also reduce slug numbers. All or a portion of the residue harboring slugs can be destroyed before planting to reduce their numbers. Exclusionary fencing, hunting, and trapping can control vertebrate herbivores to various degrees.

Biological controls have had some good success on the control of insects and other herbivores. Parasitic wasps and *Bacillus thuringensis* (Bt) are two examples. Bt has been a spray insecticide product for some time. Now the Bt gene is being spliced onto corn genetic material to control corn borer through plant breeding. The corn plant produces its own insecticide. Parasitic wasps are being used to control alfalfa weevil. Where deer predation on corn silage seedlings is high, planting forage sorghum is alternative. It is not palatable to deer. Insect pheromones are used to aid in the detection, monitor the density of, and sometimes to disrupt the mating of insects. Pheromones are chemical attractants released by female insects to attract a male. Pheromone traps are used to check insect populations. Point sources of pheromones placed about a field confuse male insects and keep them from finding female mates. This is effective only when the larvae produced by this mating cause the economic damage to the forage crop. However, this control method is expensive and not always effective, especially if it attracts more females to the field.

Chemical controls should be applied only if none of the other approaches have proven effective or timely. As with herbicides, care must be taken not to contaminate or poison nontarget species or areas with bactericides, fumigants, fungicides, insecticides, miticides, nematicides, and rodenticides. Crop use, field re-entry, harvest, and grazing restrictions must be adhered to strictly to prevent contamination of people, food supply, and livestock. Mixing areas should be sited and constructed to prevent surface or ground water contamination. Operators should wear appropriate protective gear when mixing or applying chemicals and afforded washing facilities at the mixing and application site to decontaminate themselves or the protective gear in case of exposure. The appropriateness of the protective gear is based on the toxicity of the chemical and its formulation. Follow label instructions. Formulation types are emulsifiable concentrate, solution, flowable, wettable powder, dry flowable, soluble powder, invert emulsion, dust, granule, pellet, microencapsulate, and water-soluble packet. Formulation selection is also influenced by the forage crop being protected, its proximity to water sources, human habitation, and other sensitive areas, the available application machinery suitableness to deliver it properly, and cost considerations. Spray operations should be conducted when wind velocities are low to prevent drift. They should not occur within a few hours of predicted heavy rainfall that could cause washoff and pesticide entry into watercourses. Sprayer tanks should be rinsed, and the rinse water applied to the field just treated. All chemical containers should be triple rinsed, and the rinse water placed in the sprayer and used on target field. Dispose of containers as directed on label. This prevents contamination, illness, or death of people, non-target plants and animals, or livestock by needless exposure to these poisons.

To prevent pests from developing resistance to chemical control, rotate chemicals with different modes of action. Fungicide combinations are also effective in keeping resistance from building up in the fungi being treated. The use of other control methods before resorting to chemicals also extends the useful life of chemicals.

The combination of different control methods is called integrated pest management (IPM). It attempts to find the most effective, lowest cost, and least environmentally hazardous combination of pest control methods. Key principles for IPM in forage pest management are:

- Avoid killing off beneficial species when trying to suppress a pest.
- Take advantage of natural suppression through crop management practices that favor the forage crop's health, encourages natural predators, or both.
- An ounce of preventive control is worth a pound of responsive control.
- If preventative cultural measures fail, resort to a responsive control only when the pest density reaches the economic threshold warranting the expense of the control measure.
- Pests are likely to overcome plant resistance and pesticide control measures with time through natural selection and evolution.

Components of an effective forage crop IPM program are the following:

- Recognize that most noncrop organisms in a forage crop field help maintain a favorable crop environment and should not be sacrificed to kill off the target pest.
- Correctly identify the offending pest. This has two aspects. Make sure you have the real offender and not just a symptom of underlying deeper problem. Then make sure to correctly identify the organism so that the treatment selected is effective in its control.
- Know at what stage of the pest's life cycle or what time of the year the pest will do the most damage to the forage crop.
- Use preventative measures whenever possible by anticipating which pests are most likely to be a problem. This will avoid a pest build-up in the first place.
- Scout for pests regularly to detect their presence and build-up. Early detection can result in projections on when pest damage will peak and indicate an effective, least cost treatment option.
- Evaluate past performance of pest control strategies to see if more viable control alternatives are needed. Field records are essential to this component. Timing of control measures can be evaluated with good records. The control measure itself may not be the problem, but the time or care at which it was applied is.
- Monitor new product development to employ new viable control options as they come on-line.

(h) Facilitating practice—Conservation crop rotation

This practice is mentioned last because it is greatly influenced by all the other practices mentioned previously along with the land unit's animal forage and feed requirements, resource base, and its position in a watershed. Refer back to figure 5–39. As much as is economically feasible, a conservation crop rotation plan for the land unit should strive to meet the livestock forage and feed requirements being raised there. This is a decision that only the land unit manager can make. It should be based on an economic analysis of the land unit's costs of production versus purchasing forage and concentrates from off-farm sources. The more diversified the crops are, the more farm machinery and feeding equipment generally are needed.

Because many livestock-rearing operations are sited on marginally productive lands, there may be environmental as well as good economic reasons to purchase feed or forage. Row crop forage and feed grain production may cause undue soil loss or water quality problems downstream. Even with the best conservation plan that corrects the environmental problems, it still may not be economically practical to raise only a few acres of a crop that requires a different set of machinery and storage facilities.

Conservation crop rotation is a facilitating practice on livestock-rearing operations in that it attempts to satisfy livestock forage and feed requirements for the production year. This is especially true where livestock do not have access to a dependable year-long source of grazable forage. It is also true on livestock farms or ranches where complementary pastures on cropland improve weight gain over that obtained by native rangeland or permanent pasture. This is not to say that the crop rotation plan for the farm should not dictate at least to some extent the number of livestock being raised on the land unit. However, the conservation planner must be cognizant of two things:

- The land unit manager or the financial advisor have probably established a herd size that meets a financial objective based on expected output and commodity price.
- Most land units have not reached their full productive potential so there is room for forage and feed production improvement. There are exceptions to this generalization. However, those exceptions need only limited assistance from NRCS.

Conservation crop rotation also facilitates the establishment of a more diverse set of crops, forages, or others. Generally, this is done on livestock farms and ranches to improve yields or feed quality, or both, where grazing land resources are limiting livestock output goals.

The design of a conservation crop rotation plan for the livestock-rearing land unit having cropland along with pastureland or hayland, or both, uses must serve many purposes. (Pasture referred to here includes all land uses grazed by livestock.)

(1) Livestock forage and feed

The crop rotation should strive to produce its portion of the livestock forage and feed requirements to be met by home grown crop production. This is established by the land unit manager. This decision can be influenced by pointing out alternative off-farm feed sources or livestock ration substitute feedstuffs. Perhaps increasing time on pasture by using grazable crop residue, forage aftermath, or supplementary cropland pasture and reducing stored feed and forage production are options to explore.

The rotation should meet the forage and feed requirement expected from it each production year. This means coordinating different crop rotations based on different fields' capability to produce crops without degrading the soil, water, and air resources associated with the land unit. Ideally, production targets for each crop are met each production year. This is done by scheduling the different rotations around the different fields to yield a similar amount of acres producing each crop every year. These are based on long-term average per acre yield projections times the average acreage each crop occupies on all the cropland through the longest rotation cycle.

Example 5–3 shows a crop rotation worksheet. It was idealized to come out with the same acres for each crop every year. Ordinarily, some year-to-year differences in acreage occur, but they should not be widely disparate. To arrive at these yield projections, each field must be given an estimated yield of each crop based on the forage suitability group potential to produce it and the accelerating conservation practices applied that move yields toward that potential. Refer to figure 5–39 to conceptualize this procedure. A crop rotation plan worksheet is developed that lists all crop fields and their subunits contributing to the livestock forage and feed demand requirement. Their acreage is listed, and the rotation sequence follows one crop at a time for each production year projected out from the time the conservation plan is prepared or updated. The length of the crop rotation, the number of years the crop remains in the rotation, and the number of crops grown simultaneously each year determine how many acres of a particular crop are growing on the field in any given production year.

Additional forage acreage may round out the rest of the forage needed to meet livestock demand. This may come from hayland or pasture, or both. All of this is detailed in a complete forage-livestock balance or inventory sheet. Production estimates by field may be included on the crop rotation worksheet or on the forage-livestock balance or inventory worksheet, or both. The number of different crop rotations should be kept to a minimum. If not, the worksheet becomes difficult to fill out and the producer has an even harder time trying to follow it. The number of different rotations can be kept low by stringing along enough conservation practices to meet soil loss and water quality goals while still meeting forage and feed production targets. In example 5–3, for instance, fields 2 through 4 may be contour stripcropped fields with different KLS soil loss ratios. To keep the same 6-year rotation without exceeding soil loss tolerance values, different residue management practices might be employed, no-till on one field and perhaps mulch till on another. Another option might be to construct a diversion terrace at midslope at a contour strip boundary on one of the fields with a high KLS value.

(2) Soil loss

Conservation crop rotations must meet soil loss objectives from wind or water erosion. Currently, the Revised Universal Soil Loss Equation is used to estimate present water erosion rates based on current management (benchmark) and future erosion rates based on alternative conservation management systems. The land manager selected alternative conservation management system becomes the planned conservation management system. The crop rotation for a particular field being evaluated is then set until a revision becomes necessary. The Wind Erosion Equation is used to estimate soil loss by wind erosion in similar fashion to water erosion prediction. This procedure is described in the current National Agronomy Manual.

(3) Soil organic matter and tilth

Conservation crop rotations can be designed to increase or restore soil organic matter and tilth. Close-growing forage crops with their large, well-distributed root biomass can increase organic matter and the percentage of water stable aggregates within 2 to 3 years. Soils that tend to lose their structure within a season or two, benefit by crop rotations that reintroduce a close-sown forage crop back within 2 to 3 years. Conservation crop rotations may also include a cover crop that grows between production crops. Cover crops add organic biomass to moderate the effect that low residue production crops have on lowering soil organic matter content and percentage of

Example 5–3 Crop rotation worksheet

Given: A continuous corn silage field and three other fields that have a 6-year rotation. The 6-year rotation consists of 2 years of corn silage followed by a year of small grain and 3 consecutive years of hay. They are systematically scheduled to produce the same acreage of a crop each production year. The 40 acres of corn silage, 10 acres of small grain, and 30 acres of hay from the cropland meet the desired amount of feed and forage from the cropland acres.

Crop Rotation Worksheet

Coop. Name		**Year**							
Tract number									
Field number	**Acres**	**Crop**							
1	*20*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*
2A	*10*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*
2B	*10*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*
3A	*10*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*
3B	*10*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*
4A	*10*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*
4B	*10*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*
Total	*80*								
Crop	*Corn silage*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Summary	*Small grain*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
	Hay	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*
	Totals	*80*	*80*	*80*	*80*	*80*	*80*	*80*	*80*

water stable aggregates. In example 5–2, for instance, the corn silage entries might have also included a symbol after a slash mark indicating that a cover crop followed the harvest of corn silage. Cover crops are not harvested and generally are killed before seed set. If the crop is harvested, it is just another production crop and reflects a double or multiple crop production sequence during a production year. Many forage crops can serve as cover crops. Notable examples are tall fescue in tobacco crop rotations; red clover, alsike clover, and timothy in potato crop rotations; and annual ryegrass and various clovers in corn silage crop rotations.

(4) Nutrient management

Conservation crop rotations can be designed to use and hold nutrients from leaching or runoff loss as they are applied through manures or fertilizers or fixed by legumes in the rotation in the case of nitrogen. Refer back to the nutrient management practice section where crop rotation nutrient balancing is described. This can help achieve downstream water quality goals by minimizing or eliminating nutrient runoff or loss to ground water. Cover crops again may be worth including in the crop rotation to use nutrients that might otherwise leach below the root zone while no production crop is actively taking up leachable nutrients. This works best in humid areas of the United States that have a substantial cool-season growing period after a production crop is harvested and before the next one is planted. There also must be a period where rainfall is in excess of the root zone's water holding capacity so that nitrogen, and sometimes phosphorus, would leach below the root zone if it were not for the cover crop. Cover crops also provide additional ground cover after low residue crop production. Runoff loss is mitigated under a conservation crop rotation by providing sufficient ground cover, soil structure, and canopy cover to intercept and infiltrate most precipitation and irrigation water received. Crop rotations can also resupply nitrogen stores in soils when legume crops are included in them. Crop rotations with legumes in the rotation should have crops following the legumes that have the highest nitrogen need of all in the rotation.

(5) Manipulate plant available water

Conservation crop rotations can also be used to manipulate plant available water in areas where a water budget must be closely watched to produce adequate crop yields from year to year. Crops may be sequenced that do not interfere with each other’s plant available water needs. This may include leaving part of the field fallow to restore plant available water for a crop in the ensuing year. Generally, low water demand plants are rotated with crops that have a higher water demand. They may exploit water from different rooting depths. This function also can be used in saline seep recharge areas by using crops, such as alfalfa, to use up soil water so that deep percolation is reduced or halted. This helps to prevent saline seep areas from occurring at lower elevation points. Refer to figure 3–4 in chapter 3 (page 3–78) for examples of saline seep formation. Note position of recharge areas and their relative proximity to the seep area itself.

(6) Break up pest cycles

Conservation crop rotations can also be used to break up pest cycles. This includes certain weeds, diseases, and insects. Crop rotations that include row crops, small grains, and forages restrict annual weed populations greatly. The growing conditions never last long enough for a particular weed to become abundant and dominant. Many forage crops work well as smother crops. Smother crops establish quickly and form a dense canopy that shades out other plants. Alfalfa, foxtail millet, ryegrass, and sudangrass are examples. Leaf diseases, such as scab, take-all, and cephalosporium stripe in small grains, are controlled well by crop rotation. Corn rootworm is an insect that can be controlled quite effectively by crop rotation. Care must be taken in formulating crop rotations not to introduce an alternate host immediately before or after a crop that you are trying to protect from a pest with this practice. It is also important not to replant the same crop too soon after being in the crop rotation earlier. Some carryover of the insect or disease pest may result in a serious reinfection and an economic loss without responsive treatment. Alfalfa seedings benefit by being in a crop rotation that kills off all previously growing alfalfa plants so that new seedlings are not subject to allelopathic substances in the tissue of the old plants.

(7) Species selection

While setting crop rotation lengths and the portion of the time forages occupy the rotation, work with the producer to determine which forages best meet their needs for forage production and will persist for the time needed in the rotation. This is not terribly important if an annual forage crop will be planted each year designated to fill the forage portion of the crop rotation. However, if the producer does not want to reseed annually, then it becomes more critical which species, set of species, or cultivars of the species selected are used. If the forage crop is only to last 2 consecutive years in the crop rotation, a biennial forage crop or a short-lived, inexpensive seed source perennial might be appropriate. If the forage crop is going to persist in the rotation for 2 or more years, long-lived perennials should be selected that has good disease and insect resistance and is climatically adapted to the site. The harvest regime should be adjusted to a less frequent cutting schedule for longer stand survival as the time in the rotation lengthens. Care must be taken not to schedule a forage to last longer in the rotation than that realistically possible because of local climatic conditions and insect and disease problems. An example of this is where clover root curculio feeding and *Fusarium* root rot infection combine to decrease alfalfa survival steadily and create an uneconomic stand within 2 to 3 years.

600.0508 Conclusion

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 or ready reference. 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. Simple fill-in-the-blank entries should be provided on the job sheets. The job sheets can be electronic or paper copies.

The reader is directed to Chapter 4, Inventory and Monitoring Grazing Lands Resources, which gives guidance on creating an inventory of a land unit's resources. This is done to see how pasture and forage crop production can be integrated to feed the livestock on the land unit in the most efficient way. Basic to the inventory is an assessment of the soils on the land unit. This is done using the forage suitability groups developed in your state as described earlier in this handbook. Once the inventory for the land unit is done, conservation planning options using the techniques described in chapter 11 are weighed and discussed with the land manager. Many of the conservation practices described in this chapter will make up the final resource conservation plan. Chapter 6, Livestock Nutrition, Husbandry, and Behavior, gives instruction on fulfilling the needs of the livestock raised on the land unit. The practices contained in the conservation plan must meet their needs efficiently and economically.

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Chapter 5 — Management of Grazing Lands

Section 3 — Procedures and Worksheets for Planning Grazing Management

Contents:

600.0509 General

(a) Calculating stocking rates

Determining the grazing capacity of an area can be complex and confusing and is the main factor affecting the success of a prescribed 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. Stocking rate is defined as the amount of land allocated to each animal unit for the entire grazable period of the year. Rates of stocking vary over time depending upon 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.

(b) 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.

(c) Adjustment factors used to determine stocking rate

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 starting stocking rates. Local guides should also contain adjustments for different kinds and classes of livestock. Table 3–12 gives example adjustments for slope on rangelands, and table 3–13 gives example adjustment for water distribution on rangelands.

Table 3–12 Adjustments for slope on rangelands (example only)

Percent slope	Percent adjustment
0 – 15	0
15 – 30	30
31 – 60	60
> 60	100

Table 3–13 Adjustments for water distribution on rangelands (example only)

Distance (miles)	Percent adjustment
1/2 to 1	0
1 to 2	50
2 to 3	75

600.0510 Forage inventory

(a) Based on trend, health, and utilization

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 exhibit 5–1). 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. 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 exhibit 5–2). Production from each management unit is then totaled to determine an estimated initial stocking rate for the operating unit.

(b) Based on production data and growth curves

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 estimated 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 (exhibit 5–2). 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 spread sheet 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 suitability groups and fertilization rates,
- pastureland and hayland species,
- forest ecological sites,
- transact data,
- plant vigor,
- adjustment factors resulting from accessibility, such as distance to water or elevation change
- harvest efficiencies resulting from grazing management scheme, and
- barriers that restrict travel to parts of the management unit.

Forage supply is determined for each of the response units (ecological site and similarity index, forage suitability group) 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.

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.

(c) Stocking rate determinations

(1) 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 AUM's. Air dry conversion factors can be determined by using conversion tables based on forage species or similar habit groups and stage of growth (see chapter 4, exhibit 4–2).

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, nonconsumed, 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.

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. Formula 5–1 at the bottom of this page 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 AUM's for that management unit (pasture), the AUM's per acre are multiplied by the number of acres represented by each level of production.

(2) Forage preference method

This is a method to determine stocking rate is based on consumption of forage allocated by preference of animal species and the competitive relationship between animal species. On rangeland, the Multi-Species Calculator in GLA calculates this precisely. It also calculates average harvest efficiency for the plant community selected. See exhibit 5–3 for guidance in making these calculations.

(d) Forage value rating method

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
- Nonconsumed plants
- Toxic plants

(1) Preferred plants

These plants are abundant and furnish useful forage for a reasonably long grazing period. They are preferred by grazing animals. These plants are generally more sensitive to grazing misuse than other plants and decline under continued heavy grazing.

(2) Desirable plants

These plants are useful forage plants, although not highly preferred by grazing animals. They either provide forage for a relatively short period or are not generally abundant in the stand. Some of these plants increase, at least in percentage, if the more highly preferred plants decline.

(3) Undesirable plants

These plants are relatively unpalatable to grazing animals or are available for only a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.

$$2{,}000\,\text{lb/ac} \times .25\left(\text{harvest efficiency}\right) = 500\,\text{lb forage consumed}$$

$$\frac{500\,\text{lb}}{790\,\text{lb}\left(\text{forage for 1 animal unit for 1 month}\right)} = .63\,\text{AUMs/ac or } 1.58\,\text{ac/AUM} \qquad [5\text{–}1]$$

(4) Nonconsumed plants

These 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 removed.

(5) Toxic plants

These 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.

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:

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

To achieve a given forage value rating, first achieve 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. 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. High forage value rating requires a total of 60 percent preferred and desirable with at least 30 percent being preferred.

The production of the understory plant 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. Exhibit 5–4 is a grazable woodland site guide that uses canopy class and forage value ratings and suggested stocking rates.

Exhibit 5–3 describes 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.

600.0511 Animal inventory

An inventory of the domestic animals occupying or planned to occupy the operating unit must be developed. This animal inventory should be separated into to the necessary herds to allow the desired husbandry to be practiced. This is 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.

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 in the management unit.

The animal inventory is used in combination with the forage inventory to balance the forage supply with the demand (see exhibit 3–5).

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Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization (Method For Determining Fixed Stocking Rate)

Cooperator: ______________________ **Technician:** ________________________ **Date:** ____________

Pasture	Acres	Current stocking rate			Trend	Percent use of key Species	Selected stocking rate		
		Au	Mo.	Aum			Au	Mo.	AUM
Total		XXXX	XXX		XXXX	XXXXX	XXX	XXXX	

Notes:

Instructions for Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization

1. Cooperator's name.
2. Technician'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 expected 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 animals 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 followup.

Example – Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization (Method For Determining Fixed Stocking Rate)

Cooperator: (1)________ **Technician:** (2)________ **Date:** (3)________

Pasture	Acres	Current stocking rate			Trend	Percent use of key	Selected stocking rate		
		Au	Mo.	Aum		Species	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
Total	(14) 1600	XXXX	XXX	(15) 1056	XXXX	XXXXX	XXX	XXXX	(16) 1032

Notes: (17)

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											
			xxxxxx	xxxxxx	xxxx	xxx													

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 a 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.

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				
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

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
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 are 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 are on the site, allocate feed to the larger animal first, then the smaller. This ensures 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 1/2 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: Preferred = 35%, Desirable = 25%, and Undesirable = 15%. Place the pounds consumed under the proper preference heading.
11. Total the pounds harvested for each preference heading. Then, sum the production for total forage consumed.
12. Compute the AUM/AC by dividing the total forage consumed by 790. (The pounds allocated to an AUM).
13. Determine the AC/AU by dividing 12 by the AUM/AC.
14. 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

15. Compute AUM/AC and AC/AU and the forage value ratingfor the other animals following the above guidance. (Steps 10 through 14.)
16. Compute the pounds per acre consumed by the different wildlife species presently on the site.

Example:
If site has one deer per 15 acres, divide 9490 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 pounds of forage per acre consumed by deer.

or

9490 divided by 5 deer = 1898 pounds of forage consumed by one deer. 1898 divided by 15 acres = 126.5 pounds per acre of forage consumed by deer when there is one deer per 15 acres.

17. 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.
18. 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 there will be none of the wildlife plants available for the livestock.

Note: The Multi-Species Calculator in Grazing Land Applications (GLA) will accomplish all these calculations. Average harvest efficiency will also be calculated for the plant community selected.

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) Plant species	(9) Present composition: Weight lb/ac	Present composition: %	(10) Potential consumed (lb/ac x HE) — Animal: Cattle P	Cattle D	Cattle UD	Animal: Deer P	Deer D	Deer UD	(17) Actual consumed — Animal: Deer P	Deer D	Deer UD	Animal: Cattle P	Cattle D	Cattle 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

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
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.

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:

Livestock Inventory and Forage Balance Worksheet

Cooperator: ______________________ **Date:** __________ **Technician:** ______________

Livestock Numbers and Forage Needs

Livestock	Planned number	AU equiv.	Animal units	Animal units of forage needed												
				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:

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 the 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 AUMs of 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 year.
14. Record notes needed to explain any part of the worksheet.

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)

Prescribed 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
TOTAL															

Notes:

Instructions for Prescribed 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 followup 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.

Example – Prescribed 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	
(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.

Chapter 6 Livestock Nutrition, Husbandry, and Behavior

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Chapter 6 Livestock Nutrition, Husbandry, and Behavior

600.0600 General

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 livestock husbandry and livestock management principles and practices applicable to obtain proper and efficient use of grazing resources. They should not provide technical advice or assistance to livestock producers on matters relating primarily to animal breeding, genetics, or animal health problems (except when animal health is related to forage resources). Conservationists should acquire enough information about these matters to enable themselves to adequately discuss livestock health, nutrition, and behavior with livestock producers.

The greatest challenge associated with successful livestock management and in 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.

600.0601 Nutrition

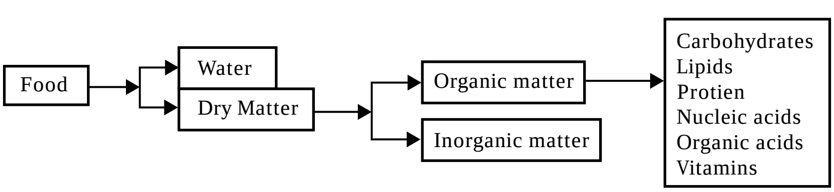
Developing a good feeding and management program is important for managers to meet livestock goals and herd performance objectives. Many factors affect the requirements of animals and the extent of nutrient utilization. The effect of genotype, physiological state, and environment on voluntary feed consumption is mediated by the animals' metabolism, and consumption is generally dependent upon diet.

When animals take in food of plant origin, 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). 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 6–1 for kinds of animals (beef and dairy cattle, sheep, goats, and horses) and representative breed types. The bulk of dry matter in plants is made up of three groups of organic compounds:

- Proteins
- Carbohydrates
- Fats

Carbohydrates, proteins, and fats (fig. 6–1) 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).

Figure 6–1 Components of a food



(a) Energy

The most important item in an animal's diet and overall feeding standards is based on energy needs. Meeting the energy requirements of an animal can be a major cost in feeding. Animals derive energy from partial or complete oxidation of carbohydrates, fats, and proteins ingested and absorbed from the diet or from breakdown of glycogen, fat, or protein absorbed in the body. Animals require some energy even in a nonproductive state for sustaining the body and maintaining body temperature and muscular activity. Additional energy is required when performing work and for growth and fattening, pregnancy, and lactation.

Energy is partitioned into various functions in terms of animal utilization (fig. 6–2).

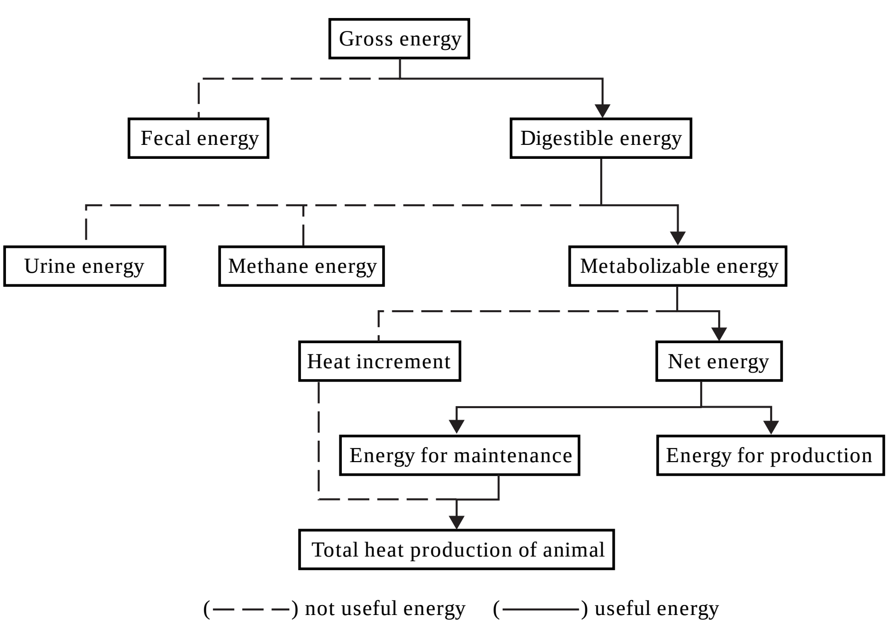
Gross energy (GE) is the amount of heat resulting from the complete oxidation of a food. GE values from feedstuffs are used in the process of evaluating energy utilization. Energy values and nutrients (carbohydrates, proteins, and fats) values vary in feedstuffs. The GE values for some feeds are given in table 6–1.

Digestible energy (DE) of a feedstuff is the consumed portion minus the fecal energy. Analyzing the fecal and feed energy allows for the calculation of DE. The energy lost in feces accounts for the single greatest loss of nutrients. Depending on species of animal and diet, fecal losses can be from 10 percent in milk fed animals to 60 percent for animals on poor quality diets.

Table 6–1 Gross energy values of feeds

Feeds	GE, KCAL/G
Corn grain	4.4
Wheat bran	4.5
Grass hay	4.5
Oat straw	4.5
Linseed oil meal	5.1
Soybean oil meal	5.5

Figure 6–2 Energy functions



Metabolizable energy (ME) is the gross energy of feed minus the energy in urine, feces, and gaseous products of digestion. The values of ME account for additional losses in the digestion and metabolism of ingested feed. ME is used to establish feeding standards because feces and urine are excreted together. Methane generally accounts for the most combustible gas in ruminant animals. In the fermentation process as much as 8 to 10 percent of the energy consumed is converted to methane. Diets low in quality result in larger proportions of methane, and the amount of GE lost as methane decreases as feed intake increases.

Net energy (NE) is equal to metabolizable energy minus the heat increment and the heat of fermentation. NE of a feed is the portion that is available to the animal for maintenance or other productive services. It accounts for most of the losses in metabolism of a feed or by the animal. NE is sensitive to changes in the environmental temperature as the animal leaves the thermoneutral zone (TNZ).

600.0602 Basal metabolism

Basal metabolism rate (BMR) may be defined as the condition in which a minimal amount of energy is expended to maintain the body. For an animal to meet the requirements for basal metabolism, the animal should be in the thermoneutral environment, a state of muscular repose, but not asleep and post-absorptive. Estimates of the needs for basal metabolism are that 25 percent of the energy needed is required for circulation, respiration, secretion, and muscle tone. The rest is the cost of maintaining electrochemical gradients across cell membranes and processes in replacement of proteins and other macromolecules.

(a) Factors affecting basal metabolism and voluntary intake

(1) Genetic factors

Part of the variations in the capacity for ruminants to consume feed has a genetic basis. 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 determined by the animal's genetic potential to use energy. For example, the Brahman breeds have a lower basal net energy requirement than British breeds, and a dairy cow has more soft tissue to maintain than a beef breed, making their basal net energy requirements higher. Table 6–2 gives some examples of breeds and energy adjustments.

Table 6–2 Energy adjustments for cattle

Breed	Energy adjustment
Brahman	– 20
British	+ 0.00
Dual purpose	+ 0.15
Dual purpose cross with beef	+ 0.10
Dairy	+ 0.20

Many studies indicate a significant voluntary consumption advantage of Bos tarus cattle (British breeds) over Bos indicus cattle (Indian breeds) under conditions of minimal environmental stress. The cross between the two breeds indicates a value intermediate to those of the parents. Voluntary consumption differences within and between species are clearly related to the animal's metabolic activity.

Voluntary feed consumption 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).

(i) 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.

(ii) 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 BMR of both sexes.

(iii) Body composition of the animal**—**Body condition scoring (BCS) allows producers of livestock to evaluate animals with a scoring system that reflects reproductive performance. 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. Several factors affect body condition scores:

- Climatic conditions
- Stage of production
- Cow age
- Genetics
- Calving date
- Weaning date
- Forage management

The amount and kind of supplemental feeding required to meet performance are influenced by the initial body reserves of protein and fat. 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.

BCS is numbers to suggest the relative fatness or body composition of the animal. The scores range from 1 to 9 for beef cattle and horses and from 1 to 5 for sheep and goats. A body condition score of 5 or more (at least 14% body fat) at calving and through breeding is recommended for good reproductive performance for beef cattle. 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—The relationship between body condition scores and pregnancy percentage is demonstrated in figure 6–3. 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 sufficient time is allowed to recover body tissues.

Description of body condition scores—The different BCS ratings are described in table 6–3. Figure 6–4 shows the reference points for body condition scorings.

Figure 6–3 Relationship between BCS and pregnancy percentage

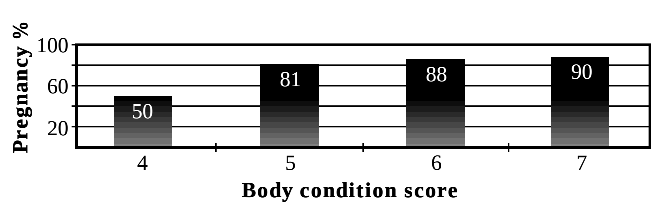
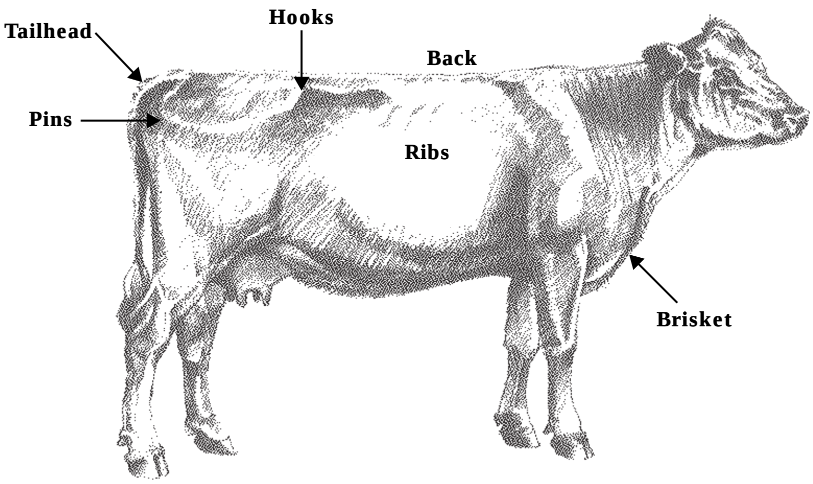


Figure 6–4 Reference points for body condition score



Reference points for body condition score

Table 6–3 Description of body condition scores

Body condition score	Description of cow
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 hindquarters. The backbone feels sharp to the touch.
3	Very thin, no fat on the ribs or brisket, and some muscle still visible. Backbone 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 can not 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. Animals mobility may actually be impaired by excessive fat.

(2) 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 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 cows peak lactation occurs in mature animals from 30 to 45 days after parturition and then gradually tapers off. This is why 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 carryover into the next pregnancy and the next lactation.

(3) Environmental factors

The climatic conditions browsing and grazing animals are exposed to can significantly affect the animal's intake. Most 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.

Animals loose 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.

(i) 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 6–4 shows typical TNZ's for different species.

***(ii) 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.

***(iii) 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 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 degrees and no night time cooling. At the same temperature with night time cooling, intake is reduced only 20 percent. Night time cooling allows animals to shift their grazing times to night, which can reduce time lost during the day.

(4) Forage quality and quantity

Forage intake is affected by several factors:

- Body weight
- Forage quality
- Forage quantity
- Stage of production
- Supplemental feeding strategy
- Environmental conditions

***(i) 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 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.

Table 6–4 Typical thermoneutral zones

Species	Temperature (°F)
Cattle	41 – 68
Calves	50 – 68
Sheep	70 – 88
Goats	50 – 68

600.0603 Maintaining a balance between livestock numbers and available forage

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.

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.

Avoidance of overgrazing is important 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 nutritious 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.

(a) Determining animal-unit equivalents

The animal-unit is a convenient denominator for use in calculating relative grazing impact of different kinds and classes of domestic livestock and of common wildlife species. An animal unit (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 animal unit for 1 month. Animal unit equivalents vary somewhat according to kind and size of animals. States can, therefore, establish their own AU guides on the basis of locally available data relative to forage requirements.

The Natural Resource Conservation Service 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). This consumption rate is equal to 2.6 percent of the body weight. 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
- physiological stage
- weather factors
- watering facilities

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.

NRCS grazing lands software, Grazing Lands Applications (GLA), calculates forage demand and stocking rates at 26 pounds oven-dry weight per day per animal unit. This value represents a conservative value for NRCS work. 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 6–5 is a guide to AU equivalents.

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)

Livestock and wildlife summary and data sheet (exhibit 6–1) is a field tool to collect the data necessary for inventory, husbandry, and nutritional information.

(b) 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:

- If the nutritional level of vegetation is low, more pounds of forage are needed per day to support the animal.

Table 6–5 Animal-unit equivalents guide

Kinds / classes of animals	Animal-unit equivalent	------ Forage consumed ------ day	month	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)				

- 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.
- 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. As much as a year may then be needed for adequate gut expansion for handling a compensating increased volume. 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.

(c) Chemical factors affecting forage quality

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:

- **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.
- **Glycosides—**These toxins are in several groups. The most common form is prussic acid or hydrocyanic acid (HCN). The materials result from cyanogenic glucosides. HCN is released from plants following freezing, wilting, or crushing.
- **Alkaloids—**These compounds cause physiological responses controlled by the nervous system. Poison is generally distributed throughout the plant. Animals cannot be treated with antidotes. The different types of alkaloids are:
  — Phalaris
  — Lupine
  — Tall fescue
  — Loline group of pyrrolizidine
- **Grass tetany—**This toxin is a deficiency of calcium and magnesium caused by rapid growing plants during cold and cloudy weather.

(d) Forage quantity

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.

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.

Daily herbage intake = Grazing time x Rate of biting x Intake per bite

Intake per bite = Bite volume x Bulk density of herbage in grazed area

Bite volume = Bite depth x Bite area

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.

(e) Nutrient needs of animals

Animals have a biological priority for nutrients as shown in table 6–6:

Table 6–6 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

(1) Protein content

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 his diet aggravates the condition. Protein supplement is often mistakenly advocated when total energy (carbohydrates and fats) intake should be increased. In many rangeland areas in fair to excellent range condition, and where adequate dry roughage is available, protein supplement is the only winter supplement needed.

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.

(2) Carbohydrates

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.

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.

(3) 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.

(4) Minerals

Minerals have three functions:

- Calcium and phosphorous are the main constituents of bones, teeth, and other organs.
- 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.

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

(5) Importance of water on nutrition

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. In comparison, a 40 percent loss of dry body weight caused by starvation usually does not cause death.

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 (fig. 6–5 and table 6–7). As the temperature increases, water consumption increases and feed intake decreases. The three sources of water are:

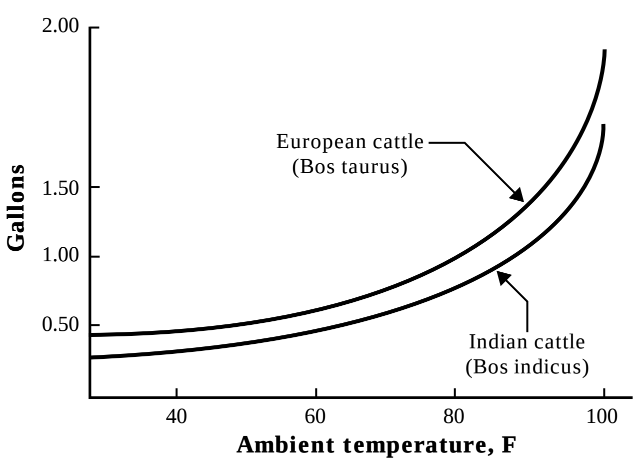
- drinking water
- water contained in foods
- metabolic water

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. Metabolic water is produced by metabolic processes in tissues through the oxidation of nutrients within the body.

Water quality is 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, and pesticide residue. Table 6–8 is a suggested guide for water quality standards for livestock.

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.

Figure 6–5 Water requirements of European and Indian cattle as affected by increasing temperatures (source: Winchester and Morris)



Water requirements of European and Indian cattle as affected by increasing temperatures. From Winchester and Morris (4).

Table 6–7 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

Table 6–8 Water quality standards for livestock

Quality category	Limit to maintain production	Upper limit
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 7,150 for dairy cattle 10,000 for beef cattle 12,900 for sheep	

(6) Nutritional deficiencies in animals

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.

(i) 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 6–1 profiles of a 1,000-pound Hereford cow for a year. In the example, 1 month represents each quarter of the cow year.

(7) 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. The data can then be used in the nutritional balance analyzer in the Grazing Lands Applications Program.

Example 6–1 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 .06 AUE, and consumes 1.8 pounds of forage per day

Period 2. (August)
Cow is now pregnant and lactating.
Animal unit equivalent = .9546 for this animal and .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 is allowed to 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.

600.0604 Feedstuffs

The composition of feedstuffs is broken into six fractions (fig. 6–6), 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.

Water content is determined for a feed by placing it in an oven at 105 degrees until dry and is used for analytical comparison of different feeds.

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.

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.

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.

Nitrogen-free extract is made up of carbohydrates, such as sugars and starch.

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.

600.0605 Husbandry

(a) Supplementing forage deficient in nutrients

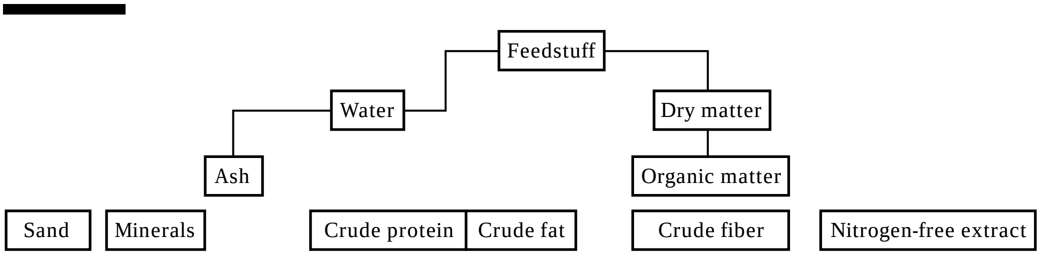
The purpose of supplemental feeding on grazing lands is to correct deficiencies in protein or other essential nutrients in the forage.

(1) Protein supplement

On most grazing lands dry standing forage does not constitute a balanced livestock diet. 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.

An example for feeding protein to cattle is 41 percent crude protein (CP) cottonseed cubes or 43 to 48 percent CP soybean meal. 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:

Figure 6–6 Fractions of a feedstuff



- Cost per pound of digestible protein in mixtures, compared with that of cottonseed or soybean derivatives.
- Quality of the product.
- Effectiveness of mixture in balancing the needs of the animal with the kind of vegetation grazed.
- Possible detrimental effects of the mixture to domestic animals and big game animals.
- Value of added trace elements and vitamins in mixture.
- Labor requirements.

(2) Feed additives

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.

(i) 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 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.

(ii) 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 cottonseed).
- Use of cottonseed or soybean meal.

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 then drink more water, which improves general health and performance.
- Provide sheds or windbreaks in cold regions to keep livestock from expending energy to maintain body temperature.
- 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

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 offspring.

Phosphorus supplements include dicalcium phosphate, steamed bonemeal, 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.

Magnesium is very unpalatable and must be mixed with an enticer for animals to consume it. Copper is often needed as a trace mineral in peat soils, as found in some marsh rangelands.

Vitamin A is often needed if animals graze mostly dormant, dry vegetation. The intramuscular injection is effective in providing sufficient amounts of vitamin A. It generally provides sufficient vitamin A for a 3-month period.

Local needs should be established, as applicable, relative to the kinds and amounts of minerals required.

(b) 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 undergrazed 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 (table 6–9) of the pasture and on the number and kind of livestock using the pasture.

(1) Salt locations

Salt locations should be no more than 0.5 to 1 mile apart on rough range and no more than 1.5 to 2 miles apart on gently rolling range. (Requirements vary according to such factors as climate, area, kind of vegetation, and stage of growth.) Note: When grass tetany is a threat, Mg should be easily accessible to animals. Table 6–10 give the general salt requirements for grazing animals

Table 6–9 Approximate number of animals at one salting location to provide enough salt and minerals on different types of terrain

Animal number	Type of terrain
40 to 60 cattle 125 to 200 sheep or goats	Level to gently rolling range
20 to 25 cattle 100 to 150 sheep or goats	Rough range

600.0606 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:

- 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.
- 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.
- Clean water.
- Calving, lambing, or kidding at a period of the year when losses from parasites can be reduced.
- Adequate control programs to reduce parasite problems.
- Cattle dusters, backrubbers, and other insect-control devices. (These devices often help to improve grazing distribution and to control livestock movement.)

Table 6–10 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

600.0607 Regulating the breeding season

(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.

(1) Advantages of controlled breeding

Advantages of controlled breeding are:

- 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.
- 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.
- Animals are more uniform in size and quality at market time and generally demand better prices.
- 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:

- Less efficient use of vegetation.
- Lower calving and lambing rates and greater difficulty in culling slow breeders.
- Higher labor costs.
- Greater feed costs.
- Less efficient marketing because of non uniformity in size of animals.
- Greater difficulty in manipulating livestock in planned grazing systems.
- Greater chance of adverse weather, both heat and cold, deterring optimum offspring growth.

(b) Factors in planning a breeding program

The following factors need to be considered in planning a program of controlled breeding:

- Birth of offspring should be scheduled to occur when adverse climatic conditions are likely to be minimal.
- Variability in breeds and in the ability of their young to adjust to adverse climatic conditions.
- Parturition should occur when the chances of seasonal diseases and parasite problems are less likely.
- 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.

(1) 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 or billy is generally enough for every 25 to 30 ewes or nannies.

(2) Breeding season for cattle

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 operators 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.

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.

Artificial insemination is sometimes used in the cattle industry. A followup bull is generally used with each 100 cows to breed those that fail to conceive after one or two services.

(3) Reproduction characteristics

Table 6–11 gives the reproduction characteristics of domestic 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.

(4) Additional factors in livestock breeding and selection

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.

In selecting breeding animals for range and pasture, the following significant qualities should be considered:

- Disposition
- Fertility
- Weight
- Rate of gain
- Conformation
- Hardiness, or environmental adaptability
- Milk production capability

Table 6–11 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

The ages of puberty for domestic animals (U.S. conditions) are:

Horses	Second spring (yearling)
Cows	5 to 13 months (depending on breed and condition)
Sheep	First fall
Goats	7 to 8 months

600.0608 Animal behavior

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. 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.

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. The two kinds of conditioning are:

- **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.
- **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.

Animals learn or develop behavior patterns through various processes of trial and error, reasoning, and imprinting.

(a) Systems of behavior

Animals exhibit several major systems or patterns of behavior:

- sexual
- care-giving
- care-soliciting
- agnostic
- ingesting
- eliminative
- shelter-seeking
- investigative
- allelomimetic

The systems of behavior that most affect the animal well-being and productivity are ingesting, eliminative, and diet selection.

(1) Ingesting behavior

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. Sheep rest and ruminate more than cattle. Cattle ruminate 4 to 9 hours a day and sheep 7 to 10 hours a day.

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.

Age and weather of the livestock 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 6–12 shows the activities of a cow on winter range.

Table 6–12 Behavior of a cow on winter range

Activity	Hours
Grazing	9.45
Ruminating	
Standing	0.63
Lying	8.30
Idle	
Standing	1.11
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).

Exhibit 6–1 Livestock and wildlife summary and data sheet

Example - 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		
TOTAL	287			201 AU						9 mon.		
TOTAL AUM'S										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
TOTAL												
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Worming schedule
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National Range and Pasture Handbook

Ch. 7

Chapter 7 Rangeland and Pastureland Hydrology and Erosion

Chapter 7 Rangeland and Pastureland Hydrology and Erosion

Chapter 7 will eventually consist of three sections. Section 1 has information about the hydrologic cycle and the effects of vegetation, grazing, and management on hydrology and erosion. Section 2 will have information about hydrology and erosion models and other decision support tools that relate to rangeland and pastureland hydrology and watershed management. Section 3 will have information about how to apply and interpret models and other decision support tools to rangeland and pastureland. Recently revised Part 630 of the USDA-NRCS National Engineering Handbook, Chapter 2, Procedures, has information about work plans, hydrologic computations, and the hydrologic evaluation process.

At this time, hydrology and erosion models that can be used as decision support tools for rangeland and pastureland planning and management are either in a state of technical development or development of user interfaces for managers, and are undergoing validation to evaluate actual measured infiltration, runoff, and erosion with model estimated values.

Chapter 7 Rangeland and Pastureland Hydrology and Erosion

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Section 1 Hydrologic Cycle and Effects of Vegetation, Grazing, and Management on Hydrology and Erosion

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Section 1 Hydrologic Cycle and Effects of Vegetation, Grazing, and Management on Hydrology and Erosion

600.0700 Introduction

The increasing importance of water to society has added a new dimension to the value of rangeland and pastureland and has reinforced and expanded the concept of multiple use. Society is challenging traditional uses as destructive and is demanding improved water quality, reduced erosion, new management alternatives, restoration of degraded lands, and more accurate soil erosion and water supply prediction techniques. The result is a critical need to understand rangeland and pastureland watersheds with respect to soil erosion and water quality, water yield, evapotranspiration, and the effects of global climate change.

The Soil and Water Resources Conservation Act of 1977 identified reduction of erosion and improvement of water quality and quantity as two of our Nation's highest resource priorities. Since the need for clean water is critical and rangelands comprise vast watershed areas in the United States (899.08 million acres in the 17 Western States of which 401.6 million acres are non-Federal), policies and activities must be formulated and implemented to arrest present resource degradation. With increasing concern over quantity and quality of surface and ground water supplies, judicious management of this natural resource is essential to the future well being of the Nation.

600.0701 Watershed management

Watershed management on rangeland and pastureland is concerned with the protection and conservation of water resources, but also considers that vegetation resources are managed for the production of goods and services. Rangeland and pastureland hydrology, which is founded on basic biological and physical principles, is a specialized branch of science in which land use effects on infiltration, runoff, sedimentation, and nutrient cycling (hydrologic assessments) in natural and reconstructed ecosystems are studied.

Why become astute in understanding the fundamentals of hydrology and how they are related to planning and management of range and pasturelands? Understanding hydrologic principles and processes and how these processes are affected by vegetation, vegetation management practices, and structural practices (engineering activities), allows land managers to integrate their thinking about how all the various activities in a given area affect the hydrologic cycle. The outcome of management decisions on upland environments must be understood because they directly impact the health and welfare of people and other resources downstream.

Conservation strategies on rangeland and pastureland watersheds can be classified as preventive or restorative. Generally, most situations are a combination of the two. Preventive strategies and sound management plans are equally as important as the more dramatic and sometimes more politically visible restorative actions. Preventing losses of soil, desirable vegetation, wildlife habitat, and forage production are much less costly than achieving the same benefit from a degraded situation by restoration. Depending on the severity of resource and watershed degradation (which includes water, soil, plant, animal, air, and human resources), restoration may not be feasible from an ecological and/or economic perspective. The results of rangeland and pastureland watershed degradation can be serious and irreversible. For each watershed and site within the watershed, a critical degree of deterioration from surface erosion exists. Beyond this critical point, erosion continues at an accelerated rate that cannot be overcome by the natural vegetation and soil stabilizing forces until a new equilibrium is achieved. Areas that have deteriorated beyond this critical point continue to erode even when the disturbance is removed and/or diminished.

Common problems and issues regarding rangeland and pastureland watersheds can be categorized as: ecological, management oriented, water quality and quantity, erosion, and economic. Table 7–1 summarizes the most common problems and issues on rangeland and pastureland watersheds.

Table 7–1 Common problems and issues on rangeland and pastureland watersheds

Category	Situation
Ecological	Understanding interrelationships: plant/soil complexes, ecology, environmental, hydrology
	Climatic shifts, vegetation response, and the hydrologic cycle
Management oriented	Trampling impacts and effect of grazing treatments on watersheds
	Water quality
	Range improvement practices and their effect on hydrology
	Riparian management and hydrologic implications
Water quantity and quality, and erosion	Enhancement of surface water, ground water, and aquifer recharge in response to vegetation manipulation
	Deficient water supplies
	Flooding
	Polluted surface water, reduced aquatic, fish, and wildlife habitat,
	Erosion and sedimentation from rangeland and pastureland watersheds
	Sludge and animal waste applications on rangeland and pastureland
Economic	Economics of watershed restoration

(a) Complexity of factors in rangeland and pastureland watersheds

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 interrelated and multivariate in nature (table 7–2). Interactions among plants, soils, environment, and management are complex.

Resource managers are challenged with synthesizing an overwhelming amount of scientific information relative to ecology, soils, hydrology, plant science, and grazing management. Simulation models and decision support tools offer help in understanding the correlation among many of the factors in a landscape. In conservation planning, many of the factors in table 7–2 must be integrated and considered with respect to the soil, water, air, plants, and animal components. With respect to hydrology and erosion, the land manager must consider how management alternatives and decisions will affect the hydrologic cycle.

Table 7–2 Interacting factors that affect the hydrologic cycle in rangeland and pastureland watersheds

Soils	Plants	Environmental	Management
Soil morphology	Types of plants	Climate	Grazing intensity
Texture	Rooting morphology	Types of storms	Timing of grazing
Bulk density	Plant growth form (bunch, sod)	Precipitation type	Continuous vs. rotational systems
Compaction	Plant life form (grass, shrub, forb, tree)	Duration of storm	Pitting
Organic matter	Plant biomass, cover, density	Intensity of storm	Chiseling
Aggregate stability	Cryptogams (mosses, lichens, algal crusts)	Topography	Herbicides
Nutrient levels	Plant canopy layers	Geology	Seeding
Soil structure	Plant architecture	Aspect	Brush management
Infiltration rates	Successional dynamics	Slope	Fire
Percolation rates	Native vs. introduced plants	Microtopography	Prescribed burning
Saturated hydraulic conductivity	Plant competition		Past management history
Runoff characteristics	Physiological characteristic of plant species		Fencing
Rills and gullies	Physiological response to grazing		Hoof impact
Porosity	Biodiversity		Class of livestock
Erosion dynamics	Phenological stages		Type of livestock
Salinity			Disturbance
Alkalinity			Stockwater location
Biotic components			Past disturbance from farm implements
Parent material			Recreation
Pedogenic processes			Kinds and types of wildlife
Soil chemistry			

(b) Hydrologic cycle and its components

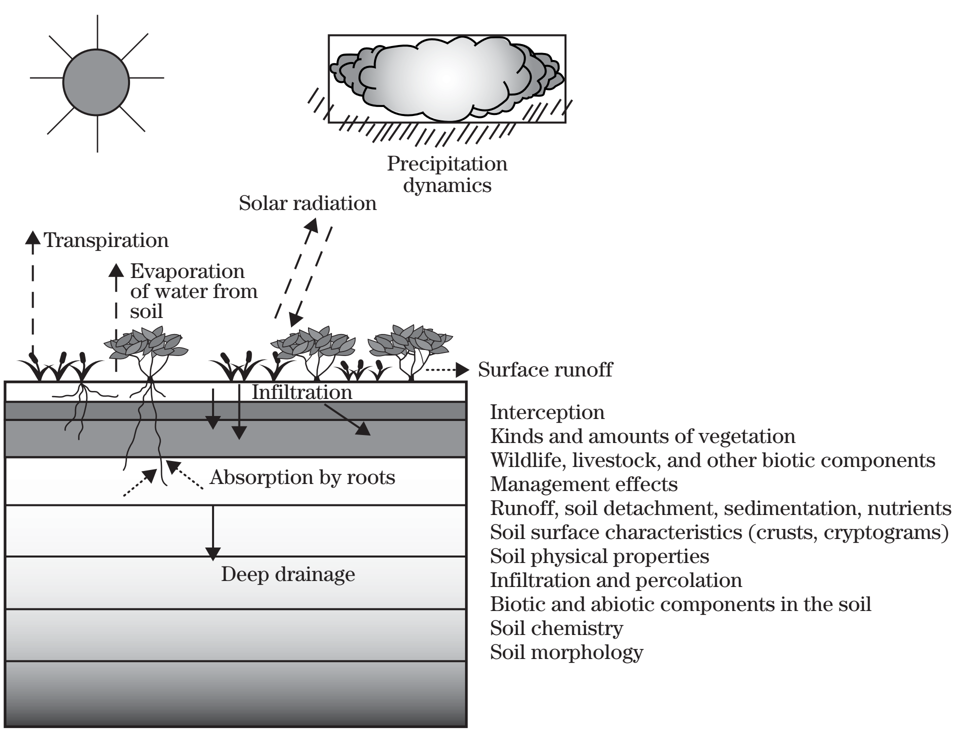
The hydrologic cycle is a continuous process by which water is transported from the oceans, to the atmosphere, to the land, through the environment, and back to the sea (fig. 7–1). Many subcycles exist, such as the evaporation of inland water, evaporation of water from the soil, transpiration of water from or by plants, and the eventual return of this water to the atmosphere. The sun provides the necessary energy required for evaporation that drives the global water transport system.

The complete hydrologic cycle is global in nature. On a worldwide basis, the amount of water is relatively constant. The problem of water supply lies with the uneven spatial and temporal distribution of this enormous quantity of water. Oceans cover 71 percent of the Earth's surface and contain 93 to 97 percent of the Earth's water. The fresh water supply available to people represents only 3 percent of the total global water supply, and 75 percent of it is frozen in glaciers and ice sheets. Only about 1 percent of the world's surface water is fresh water. Ground water accounts for about 25 percent of the fresh water supply. On a daily average basis, about 40 trillion gallons of water vapor exists in the atmosphere over the conterminous United States. Of this amount, about 4,200 billion gallons per day (bg/d) fall as precipitation. Approximately two-thirds of this amount returns to the atmosphere via evaporation and transpiration. The remainder, 1,380 bg/d of surface water is renewed daily to streams, lakes, oceans, or seeps underground.

During conservation planning, management alternatives and their effect on the hydrologic cycle should be considered and addressed. For example, a few questions with answers are given to demonstrate the process during planning.

Q1. What might be expected in terms of runoff if the plant community shifts from weedy annual species to more desirable perennial grasses?

Figure 7–1 The hydrologic cycle with factors that affect hydrologic processes



A. This depends on the species of weeds and perennial grasses (see section 600.0701(j), Vegetation effects on hydrologic processes).

What is the effect of juniper invasion (10, 25, 50 years) on understory vegetation, runoff and interill erosion?

Typically, over time, juniper increase in numbers and size, interrill erosion increases and gullies can develop because the understory vegetation decreases because of juniper competition for water, nutrients, space, and light.

What is the effect of heavy versus moderate stocking during a season where soils are typically wet?

This depends on the frequency and duration of wet soil conditions. Heavy stocking is detrimental to soil surface physical properties and consequently hydrologic condition, especially on heavier textured soils when soil conditions are wet. Research has shown that moderate season-long stocking generally maintains good hydrologic health. Other grazing systems involving rotations (of varying time and frequency of grazing) may also maintain good hydrologic condition and benefit key grazing species. Unfortunately, no set rule covers all rangeland plant communities and hydrologic response to grazing. Section 600.0702 has additional information on the effect of trampling and grazing on hydrology and erosion.

What are the benefits to a producer when forage grasses are managed to increase infiltration capacity twofold?

The response is significantly increased forage production, less runoff, and less soil loss.

What are the hydrologic effects of brush control in a particular rangeland plant community?

The influence of brush control on hydrology is dependent on the kind of brush, degree of brush in the stand, herbaceous cover, ecological site characteristics (soil, slope, vegetation composition), climate, weather before and after the treatment, kind of brush control treatment, and post-treatment practices. For example, the hydrologic effect of brush control in sagebrush, pinyon-juniper, mesquite, and chaparral are unique and cannot be generalized. For more specific information, refer to Hibbert 1979 and 1983, Branson et al. 1981, Blackburn 1983, Bedunah and Sosebee 1985, and Griffin and McCarl 1989.

What are the hydrologic effects of converting a sagebrush community to a grass dominated stand?

In one study where sagebrush cover was replaced with grass (via disk plowing the sagebrush), usable forage increased fourfold. Runoff from summer rainstorms was decreased by about 75 percent after the conversion. Another study compared chemical control of sagebrush with disk plowing. Infiltration was highest on the chemical treated sites, next highest in no treatment, and lowest on the disk plow sites for 3 years after the treatment. Sediment yield was also greatest on the disk plow sites after 3 years compared to the no treatment and chemically treated sagebrush sites. Sagebrush and grass use most of the onsite available water equally; therefore, little increase of water for offsite use can be expected following sagebrush control.

Do different shrubs and grasses affect infiltration and runoff differently?

Yes, certain grasses are associated with low infiltration and higher runoff. This phenomenon is described in section 600.0701(h and i). In an infiltration study in the Edward's Plateau, steady state infiltration rates among three vegetation types were as follows: sodgrass (1.8 in/hr); bunchgrass (6.3 in/hr); and oat mottes (7.8 in/hr). In question 6, it was shown that sagebrush converted to grass resulted in higher infiltration rates and less runoff. Making generalized statements about hydrologic response to vegetation is difficult. Specific knowledge about the site is recommended.

(c) Inputs to the watershed

(1) Precipitation

Precipitation, the source of all freshwater, is the single most important factor that controls the availability and variability of surface water resources. The average annual precipitation rate for the conterminous United States is about 30 inches per year. Some desert ecosystems receive less than 1 in per year, while the Olympic Mountains in Washington receive about 150 inches per year.

Departures from the mean may be extreme in any given year. When the overall supply of fresh surface water is considered without regard to distribution or quality, the resource far exceeds use. However, precipitation and subsequent streamflow are not constant, and there is no assurance that adequate supplies of surface water or quality will be available when it is needed.

Precipitation is the primary input of the hydrologic cycle. The three major categories of precipitation are convective, orographic, and cyclonic.

occurs in the form of light showers and heavy cloudbursts or thunderstorms of extremely high intensity. Precipitation intensity often varies throughout the storm. Most convective storms are random and last less than an hour. They generally contribute little to overall moisture storage in the soil.

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.

may be classified as frontal and nonfrontal and is related to the movement of air masses from high pressure to low pressure regions.

Water originating from other sources may affect a site. Deep-rooted shrubs, trees, and phreatophytes (riparian vegetation) may use shallow ground water or baseflow reserves.

Raindrop sizes vary with storm intensity, which affects soil surface stability and infiltrability. Average drop sizes for various storm intensities are:

- 1.25 mm diameter at 0.05 in/hr
- 1.80 mm diameter at 0.5 in/hr
- 2.80 mm diameter at 4.0 in/hr

Generally, a falling raindrop attains a terminal shape of a hemisphere or is oblate. An airborne raindrop over 1.5 mm in diameter travels at terminal velocity of 24.3 to 26 feet per second. Raindrops this size disrupt the soil surface on impact; whereas, drops smaller than 1 mm in diameter are less disruptive.

(d) Hydrologic factors in the watershed

(1) Interception

Vegetation intercepts raindrops, dissipating the kinetic energy of droplets. 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. 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. Some intercepted water runs down the stem or trunk of the plant and reaches the soil. 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. Interception loss during heavy storms is often a small proportion of the storm's total volume. Droplets, intercepted, and later falling from the canopy of shrubs and trees can form an erosive drip line under the plant.

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. During the growing season, alfalfa can intercept as much rainfall as a forest. Water storage by grasses, shrubs, and trees is proportional to average heights and ground cover.

(2) Surface detention or storage capacity

Surface water excess tends to accumulate in depressions, forming puddles. 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. Vegetation structure and lifeform characteristics as well as surface litter affect soil surface microtopography. As slope increases, initial runoff usually occurs sooner and at an increased rate because of a decrease in the size of detention storage sites. Ponded water on the soil surface is lost through evaporation, or it infiltrates into the soil.

(e) Infiltration and analogous concepts

(1) Infiltration

Infiltration is the process by which water enters the soil surface and is affected by the combined forces of capillarity and gravity. Under dry 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, but starts to decrease over time until a relatively constant rate is achieved (a curvilinear relationship). One or more of the following can cause decreased infiltration over time:

- gradual decreases in the matric suction gradient
- deterioration of soil structure
- the breakdown of soil aggregate stability
- consequential partial sealing of the profile by detachment and migration of pore-blocking particles
- a restricting layer in the soil profile

Typical "final" saturated steady state infiltration rates for sandy, loam, and clay soils that are void of vegetation are:

- sandy and silty soils—0.4 to 0.78 in/hr
- loams—0.2 to 0.4 in/hr
- clayey soils—0.04 to 0.2 in/hr

Note: These values give the order of magnitude. In actual situations infiltration rates can be considerable higher, particularly in the initial stages of the process where soils are well aggregated and surface mineral crusting is minimal.

Table 7–3 gives some approximate values for water storage and intake rates under irrigation.

(2) Infiltration capacity

When rainfall rates exceed infiltration capacity, surface runoff and/or ponding on the soil surface occurs. The infiltration capacity of the soil is dependent on soil texture, porosity of the soil, soil structure, soil surface conditions, the nature of the soil colloids, organic matter content, soil depth or the presence of impervious layers, the presence of macropores, soil water content, soil frost, and temperature of the soil.

(3) Infiltration rate

Infiltration rate is the volume flux of water moving into the soil profile per unit area of surface area.

(4) Infiltration curve

Figure 7–2 is an example of infiltration rates plotted against time (infiltration curves).

(5) Infiltrability

Infiltrability denotes the infiltration flux resulting when water at atmospheric pressure is freely available at the soil surface. Soil infiltrability depends upon the initial wetness, suction, texture, structure, soil layering and its uniformity, aggregate stability, and bulk density. Infiltrability may be high initially in some soils that have a high clay content and macropores and cracks in the soil surface; however, as these cracks swell, infiltrability decreases. Infiltrability may be impeded over time because clay particles expand, air pockets become entrapped, and the bulk compression of soil air is prevented from escaping as it is gradually displaced by water.

(6) 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). Hydraulic conductivity

Table 7–3 Approximate relationships among soil texture, water storage, and water intake rates under irrigation conditions

Soil texture	Water stored (in/ft of soil)	Max rate of irrigation per hour (bare soil conditions)
Sand	0.5 – 0.7	0.75
Fine sand	0.7 – 0.9	0.60
Loamy sand	0.7 – 1.1	0.50
Loamy fine sand	0.8 – 1.2	0.45
Sandy loam	0.8 – 1.4	0.40
Loam	1.0 – 1.8	0.35
Silt loam	1.2 – 1.8	0.30
Clay loam	1.3 – 2.1	0.25
Silty clay	1.4 – 2.5	0.20
Clay	1.4 – 2.4	0.15

differs between unsaturated and saturated soil conditions. A saturated soil has a positive pressure potential. However, an unsaturated soil has a subatmospheric pressure, or suction, that is analogous to a negative pressure potential. The higher the saturated hydraulic conductivity of the soil, the higher its infiltrability.

(7) Percolation

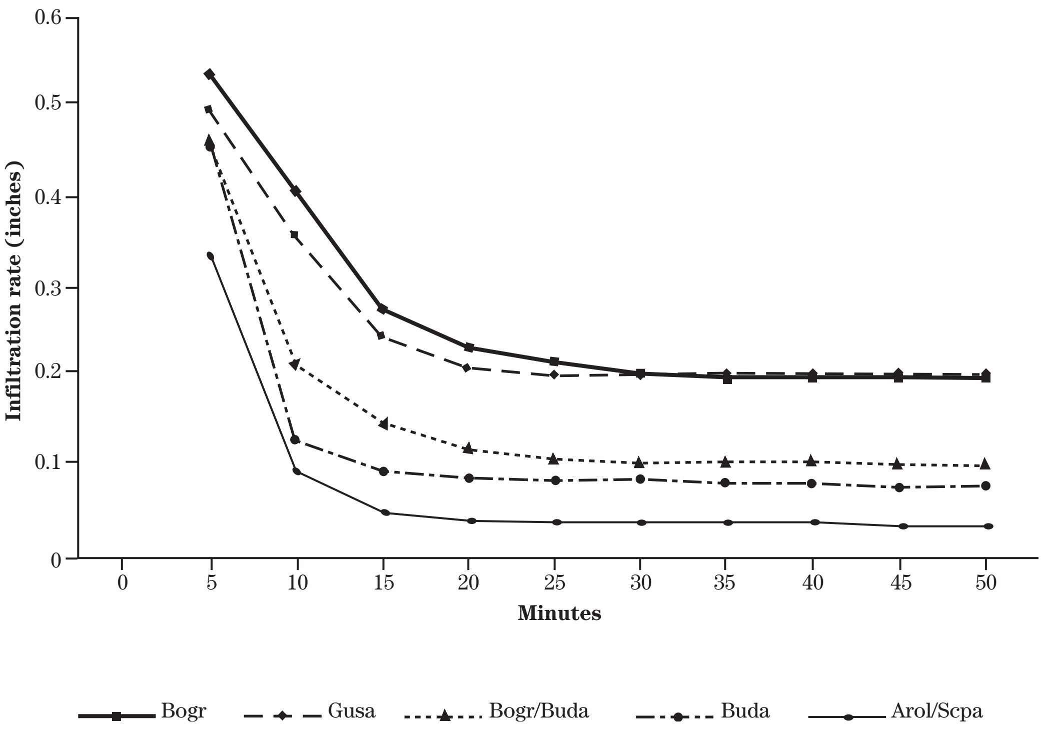
Infiltration is only as rapid as the rate at which water moves through the soil macropores and flows downward by the effect of gravity. This downward movement of water through the soil profile is percolation. Percolation of soil water past plant roots is deep drainage. The amount of water lost to deep drainage depends upon the infiltrability of the soil, the evapo-transpirational demand, and the substrate and geological conditions.

(8) Moisture profile

A moisture profile, comprised of the saturation and transition zone, transmission zone, wetting zone, and wetting front (fig. 7–3), is produced during infiltration. 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.

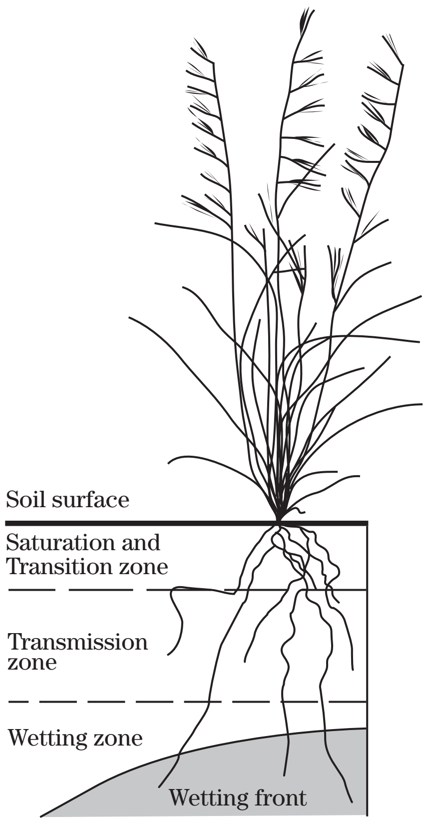
Depth to the wetting front is an important factor for sustained plant growth. Grasses that have laterally extending fibrous roots as well as a deep taproot are adapted to utilize precipitation from low precipitation events as well as subsurface water.

Figure 7–2 Average infiltration rates (50-minute simulated rainfall, 6.0 in/hr rate) on 5 plant community types associated with a loamy range site, Berda loam soil in west Texas [1/]



1/ Arol = perennial threeawn (*Aristida oligantha*)
Scpa = Texas tumblegrass (*Schedonnardus paniculatus*)
Buda = buffalograss (*Buchloe dactyloides*)
Bogr = blue grama (*Bouteloua gracilis*)
Gusa = perennial broomweed (*Gutierrezia sarothrae*)

Figure 7–3 Moisture profile during infiltration



(f) Watershed hydrograph

Various processes and pathways determine how excess water becomes streamflow. Hydrograph analysis is the most widely used method of analyzing surface runoff. A hydrograph is a continuous graph showing the properties of streamflow with respect to time. It has four component elements: channel precipitation, direct surface runoff, subsurface flow, and baseflow (fig. 7–4).

(1) Direct surface runoff

Surface runoff or overland flow occurs when rainfall rate exceeds infiltration capacity of the soil, the soil is impervious, or the soil is saturated. The rate and distribution of runoff from a watershed are determined by a combination of physiographic, land use, and climatic factors. These factors include:

- Form of precipitation (rain, snow, hail)
- Type of precipitation (convective, orographic, cyclonic)
- Seasonal distribution of precipitation
- Intensity, duration, and distribution of precipitation
- Plant community types and the character of vegetative cover
- Kind of vegetation as well as quantity of vegetation
- Watershed topography, geology, and soil types
- Evapotranspiration
- Antecedent soil moisture
- Degree of compaction; i.e., land use practices

Runoff is closely linked to nutrient cycling, erosion, and contaminant transport. It can be a sensitive indicator of ecosystem change.

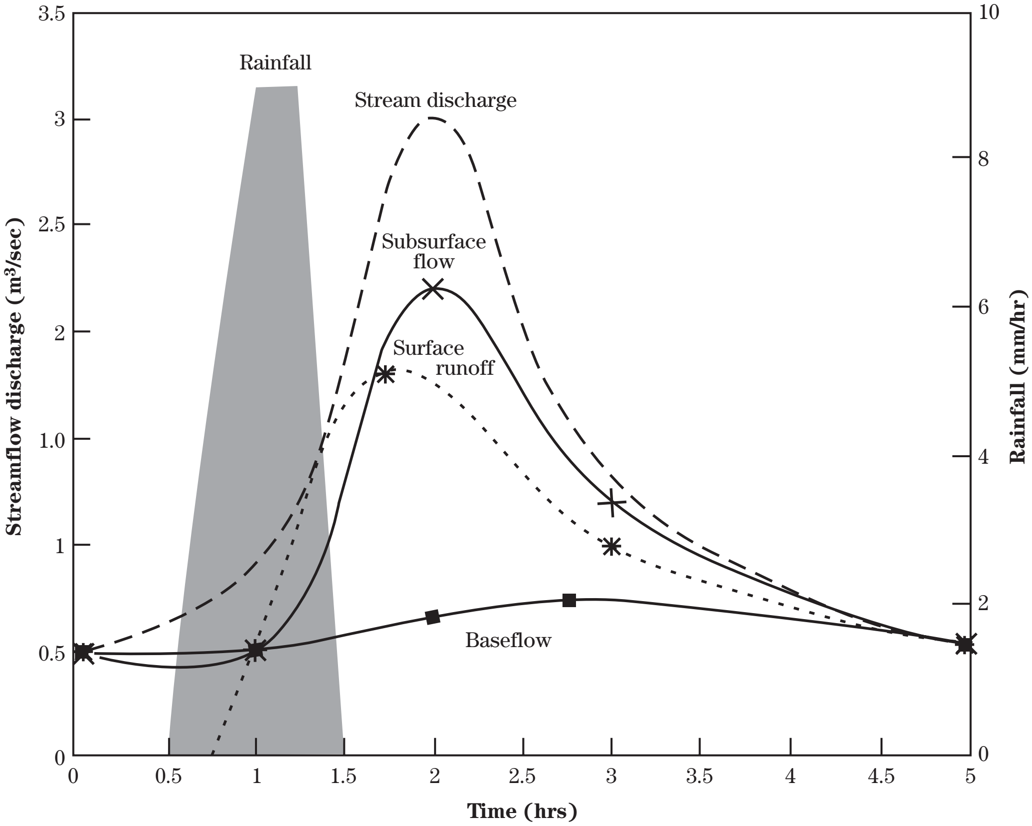
(2) Baseflow

Baseflow is the portion of precipitation that percolates into the soil profile and is released slowly and sustains streamflow between periods of rainfall and snowmelt. It does not respond quickly to rainfall.

(3) 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 period where it is considered part of the storm hydrograph.

Figure 7–4 Example hydrograph of a watershed showing the relationship of water flow pathways



(g) Evapotranspiration

Evapotranspiration (ET) includes evaporation from soil, water, and plant surfaces and transpiration from plants. About 99 percent of water taken up by the plant is lost through transpiration. It is the major component of water loss in semiarid and arid rangelands. Table 7–4 gives 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 groundwater recharge, whereas increases in ET have the opposite effect.

Vegetation cover, by shading and reduction of wind velocity, can reduce soil evaporation rates. The greater the vegetation cover, the greater the interception and transpiration loss, which generally offsets the benefits of reduced evaporation.

(h) Hydrologic water budgets

Water budgets can be developed for rangeland and pastureland to account for hydrologic components. The hydrologic budget can be written as an equation:

$$WS = P - R - G - ET$$

where:
WS = water storage
P = total precipitation
R = surface runoff
G = deep percolation and/or groundwater flow
ET = evapotranspiration

Water is generally regarded as the limiting factor in rangeland forage production. A hydrologic budget can effectively show landowners the benefits of various conservation practices. Water storage relates to what could be available for plant growth at any time scale (daily, monthly, yearly). For local situations, reliable

Table 7–4 Average evapotranspiration rates for various vegetation types

Vegetation	ET rate
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/d
Low sagebrush community, springtime	0.05 to 0.12 in/d under differing soil moisture and sunlight conditions (6-day average)
Wyoming big sagebrush/bluebunch wheatgrass, spring, Idaho, 12 in/yr ppt	0.07 in/d
Wyoming big sagebrush/bluebunch wheatgrass, summer, Idaho, 12 in/yr ppt	0.04 in/d
Low sagebrush/Idaho fescue, spring, Idaho, 13 in/yr ppt	0.09 in/d
Low sagebrush/Idaho fescue, summer, Idaho, 13 in/yr ppt	0.06 in/d
Mountain big sagebrush/grass, spring, Idaho, 19 in/yr ppt	0.10 in/d
Mountain big sagebrush/grass, summer, Idaho, 19 in/yr ppt	0.02 in/d
Mountain big sagebrush/grass, summer, Idaho, 30 in/yr ppt	0.12 in/d
Mountain big sagebrush/grass, fall, Idaho, 30 in/yr ppt	0.03 in/d
Forest, summer	0.12 to 0.2 in/d
Open desert vegetation	0.001 to 0.02 in/d

estimates can be made to determine available water storage. Precipitation is measured by rain or snow gauges. Surface runoff can be measured onsite. Deep percolation generally is not a significant factor in the equation when calculating a water budget for an individual storm or for short-term events (the exception being in sandy areas). For short-term events, assign a zero value to G.

Various estimates are available for ET (table 7–4). The luxury of having exact measurements is generally not available. Annual precipitation can be easily obtained, but estimates of surface runoff and ET need to be made. Observations during storms can be made with small rain gauges. Measure the total storm precipitation in one gauge and precipitation until runoff in another gauge.

Table 7–5 is an example of a water budget for various stands of grass in Major Land Resource Area (MLRA 102 A).

Table 7–5 Water budget examples for MLRA 102 A, Nebraska and Kansas Loess-Drift Hills; loamy site 25-inch average annual precipitation (data represent species composition for and water budgets for stands I, II, and III)

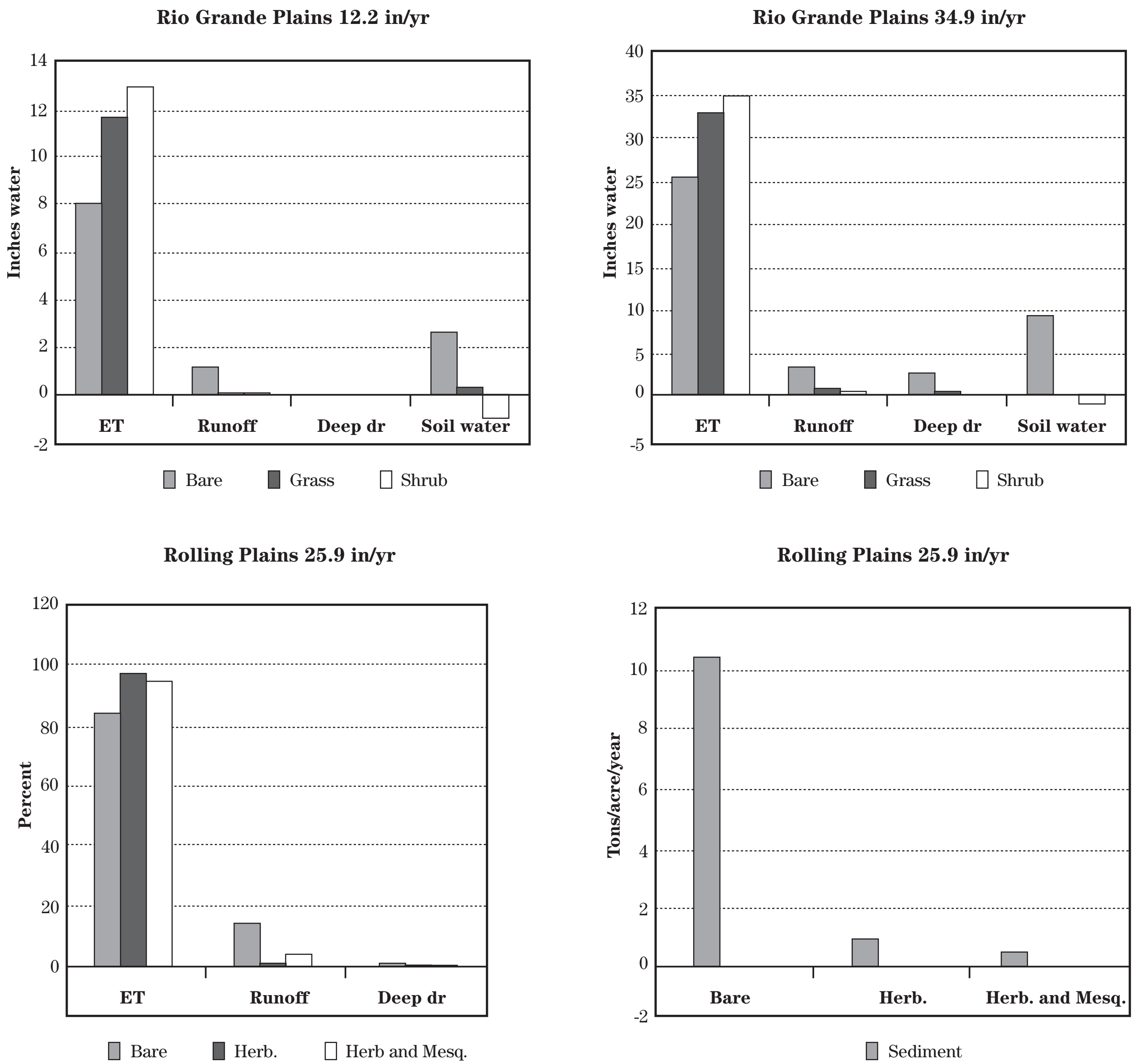
% composition	% composition		% composition
	stand I	**stand II**	**stand III**
Little bluestem	30-50	Kentucky bluegrass 75	25
Big bluestem	15-30	Smooth bromegrass 25	75
Prairie dropseed	10		
Porcupine grass	40		
Sideoats grama	5		
Grasses (subdominants)	5		
blue grama			
sedges			
prairie junegrass			
buffalograss			

	stand I		**stand II**		**stand III**	
Precipitation (in)	25		25		25	
	%	(inches)	%	(inches)	%	(inches)
Grass and litter interception	0.5	(0.13)	0.4	(0.10)	0.6	(0.15)
Surface runoff	20	(5.00)	45	(11.25)	30	(7.50)
Infiltration	77	(19.25)	52	(13.00)	68	(17.00)
Water loss after infiltation						
*Evaporation (ET)	94	(18.10)	95	(18.29)	95	(18.29)
Soil evaporation	60	(11.55)	60	(11.55)	60	(11.55)
Plant transpiration	34	(6.55)	35	(6.74)	35	(6.74)
Deep percolation	2.5	(0.63)	4	(1.00)	2	(0.50)
Change in soil water (affected by antecedent soil moisture)	0.0		–1.4		–0.6	

* Evapotranspiration (ET) is the sum of soil evaporation and transpiration.

Figure 7–5 shows water budgets for bare soil areas, grass interspaces, and shrub clusters for the Rio Grande Plains of Texas at two annual precipitation rates. It also shows a water budget for bare areas, herbaceous plants, and herbaceous and mesquite for the Rolling Plains of Texas and for sediment yield in that area.

Figure 7–5 Water budgets (in) for bare soil areas, grass interspaces, and shrub clusters for Rio Grande Plain of Texas at two annual precipitation rates and for Rolling Plains of Texas with sediment yield (ET = evapotranspiration, Deep dr = deep drainage, Herb. = herbaceous, Herb. and Mesq. = herbaceous and mesquite)



Sources: Rio Grande Plains data from Weltz, M.A., and W.H. Blackburn, 1995.
Rolling Plains data from Carlson, D.H., T.L. Thurow, R.W. Knight, and R.K. Heitschmidt, 1990.

(i) Water-use efficiency

The water requirement for a plant is the amount of water required to produce a given weight of above-ground dry matter (table 7–6). Water requirements for plants are affected by many factors, such as available water, physiologic characteristics of the plant, eco-typic variations of plants, environmental demands, phenology, plant rooting depth, length of growing season, temperature, and nutrient availability.

In some rangeland community types, comparing water-use efficiencies can show the benefits of converting shrublands to grass. Studies to determine water use efficiencies vary considerably; however, grasses tend to be more efficient in terms of water use compared to shrubs.

The water use efficiency of productivity is defined as

$$W_p = \frac{\text{Dry matter production (lb)}}{\text{Water consumption (gal)}}$$

Table 7–6 Water requirements

Plant species	Gallons water needed for 1 pound dry weight
Rangeland plant species in the pinyon/juniper type, for controlled field experiments at Cheyenne, Wyoming, and bermudagrass studies in Tifton, Georgia:	
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
Controlled field conditions at Cheyenne, Wyoming; water availability maintained at 0.3 to 0.8 bars at 12-inch depth; fine, sandy, clay loam, organic matter from 2-4%; data represents sixth harvest of the season (August 29):	
Blue grama	180
Slender wheat grass (*Agropyron trachycaulum*)	262
Western wheatgrass	191
Green needle (*Stipa viridula*)	293
Fawn tall fescue (*Festuca arundinacea*)	219
Garrison creeping foxtail (*Alopecurus arundinaceus*)	249
Latar orchardgrass (*Dactylis glomerata*)	253
Regar bromegrass (*Bromus bieebersteinii*)	267
Thickspike wheatgrass (*Agropyron dasystachyum*)	177
Alsike clover (*Trifolium hybridum*)	233
Dawson alfalfa (*Medicago sativa*)	385
Ladak alfalfa	332
Vernal alfalfa	332
Water use efficiencies at Tifton, Georgia:	
Coastal bermudagrass (*Cynodon dactylon*)	85
Common bermudagrass (*Cynodon dactylon*)	190

Studies at the Northern Great Plains Research Center in Mandan, North Dakota, showed that water use efficiencies of fertilized grasses generally increase. 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.

(j) Vegetation effects on hydrologic processes

Infiltration and runoff are regulated by the kind and amount of vegetation, edaphic, climatic, and topographic influences. Vegetation is the primary factor that influences the spatial and temporal variability of soil surface processes, which affects infiltration, runoff, and interrill erosion rates on arid and semiarid rangelands. Each plant-soil complex exhibits a characteristic infiltration pattern.

The impact of vegetative cover to infiltration is not constant from one range-soil complex to another. In semiarid climates, vegetal cover has a minimal influence on infiltration: the erosion process is more complex and is a function of plants, soils, and storm dynamics.

Each plant community type must be evaluated in terms of what variables affect hydrology on the site. No one factor ever varies alone, especially with regard to hydrologic processes. Some variables are not consistently correlated in natural rangeland plant communities. The variables include:

- above- and below-ground plant morphology
- total production
- production of individual plant species
- total canopy cover
- canopy cover of individual plant species
- plant architecture
- sod forming growth form
- bunchgrass growth form
- interspace
- shrub coppice
- soil physical properties
- soil chemical properties

On rangeland, the amount of interrill erosion is highly dependent on the growth form of grasses (table 7–7). Interrill erosion is less, given equal cover, in bunchgrass vegetation compared to sodgrass types. The bunchgrass growth form and accumulated litter at the base of the plant help retard overland flow by slowing or diverting the flow of water. This results in decreased sediment transport capacity.

Table 7–7 Summary of canopy interception, interrill erosion, runoff, and erosion from oak, bunchgrass, sodgrass, and bare ground dominated areas, Edwards Plateau, Texas, based on 4-inch rainfall rate in 30 minutes (data from Blackburn et al., 1986)

	Oak motte	Bunchgrass	Sodgrass	Bare ground
% canopy interception	7	–	–	–
% grass and litter interception	–	0.5	0.4	0.0
% litter interception	12	–	–	–
Interill erosion (lb/ac)	0.0	179	1,250	5,358
% surface runoff	0.0	24	45	75
% infiltration	81	75.5	54.6	25

The similarity index to the historic climax plant community of a site may or may not be correlated to hydrologic health or watershed stability. Some stands of exotic annual species and undesirable invader shrubs are associated with high infiltration capacities. Presence of such species tends to lower the similarity index even though infiltration capacity is high and runoff potential low. Above- and below-ground structure (morphology) can be associated with enhanced or non-enhanced hydrology, irrespective of whether the plant is desirable, undesirable, a noxious weeds, increaser or decreaser designation, invader species, or native climax or introduced exotic.

(k) Vegetation effects on infiltration

Semiarid rangelands throughout the Western United States have significant spatial and temporal variations with regard to 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 rangelands. On rangeland, shrub-coppice sites have a significantly higher infiltration rate under both frozen and unfrozen soil conditions than that in interspace areas.

Plant life forms, such as tall grasses, mid grasses, short grasses, forbs, shrubs, halfshrubs, 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.

Plant growth form can dramatically affect infiltration. Studies of fibrous-rooted plants, such as bluebunch wheatgrass (*Pseudoroegneria spicata*), yarrow (*Achillea lanulosa*), cheatgrass (*Bromus tectorum*), and Sandberg's bluegrass (*Poa secunda*), are associated with increased infiltration (up to 25 percent) compared to taprooted species, such as Balsamroot (Balsamorhiza sagittata), prickly lettuce (Lactuca scariola), and lupine (Lupinus caudatus).

On pasturelands, several researchers found that 70 to 75 percent ground cover is a critical threshold with regard to runoff—cover exceeding 70 percent is slight. Runoff accelerates rapidly below 70 percent cover.

Examples from the literature on plant species effects and hydrology:

- **Tall grass sites—**Big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*) generally enhance infiltration capacity compared to sideoats grama and blue grama.

- **Short grass sites—**Several studies documented infiltration capacity with species composition. Water infiltrates three times faster under blue grama and silver bluestem (*Bothriochloa saccharoides*) than areas dominated by annual weeds, such as summer cypress (*Kochia scoparia*) and windmill grass (*Chloris verticillata*). Buffalograss stands are commonly associated with lower infiltration rates (up to 3 times) compared to blue grama stands, holding the soil type constant.

- **Weedy species—**Some weedy species, such as broom snakeweed (*Gutierrezia sarothrae*), are associated with similar infiltration rates as those in climax stands. On identical sites in west Texas, infiltration rates in broom snakeweed stands are equal to those climax blue grama stands. The implication of this is that similarity index of the site or successional stage is not always correlated with hydrologic condition because high infiltration rates can occur in early successional or on sites with less than 25 percent of the historic climax plant composition.

- **Comparative infiltration rates**—In trial plots on a Sharpsburg silty clay loam near Lincoln, Nebraska, infiltration rates were ranked as follows from lowest to highest: buffalograss, smooth bromegrass (*Bromus inermis*), blue grama, sideoats grama, crested wheatgrass (*Agropyron cristatum*), western wheatgrass, and big bluestem.

- **Infiltration rates, plant growth forms—**In rainfall simulation studies near Lincoln, Nebraska, infiltration rates on soils at antecedent moisture were 2.5 times lower on Kentucky bluegrass (*Poa pratensis*) dominated sites compared to those on big bluestem dominated sites.

- **Clubmoss versus midgrasses—**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 inch per hour of runoff compared to near zero runoff on sites with native midgrasses.

(l) Runoff

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, decreasing as the size of the contributing area increases and provides more opportunities for infiltration. Soil moisture content and/or soil frost conditions are major determinants of runoff amounts. 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.

The rate and areal distribution of runoff from a watershed are determined by a combination of physiographic, land use, and climatic factors, such as:

- Form of precipitation (rain, snow, hail)
- Type of precipitation (convective, orographic, cyclonic)
- Seasonal distribution of rainfall
- Intensity, duration, and distribution of precipitation
- Plant community types and the character of vegetative cover
- Kind of vegetation as well as the quantity of vegetation
- Watershed topography, geology, soil types, vegetation
- Evapotranspiration characteristics
- Antecedent soil moisture status
- Degree of compaction; i.e., land use practices

Runoff dynamics are poorly understood, and predictive capabilities in arid and semiarid landscapes are limited. In semiarid rangeland ecosystems, runoff is quite sporadic and generally comprises a small percentage of the water budget. Runoff is closely linked to chemical and nutrient cycling, erosion, and contaminant transport. It can also be a sensitive indicator of ecosystem change.

(m) Erosion

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 regulating 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.

The key to developing more effective management systems is in 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 semiarid and arid environments, alterations of the natural plant community caused by either a natural event or human activity can cause the conversion of the original native plant species to exotic weedy species and deplete the already sparse vegetative cover in these areas. 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 a lower ground water table, decreased infiltration of snowmelt and rainfall, and lower streamflow. Perennial streams can become ephemeral because of depletion of ground water storage, which has a deleterious effect on riparian vegetation.

For every watershed and site within the watershed, there exists a critical point of deterioration resulting from surface erosion. Beyond this critical point, erosion continues at an accelerated rate that cannot be overcome by the natural vegetation and soil stabilizing forces. Areas that have deteriorated beyond this critical point continue to erode even when disturbance by human activity is removed.

Increases in erosion occur in watershed areas not protected by vegetation. Fine surface particles and organic matter are removed. Organic matter is rapidly decomposed on exposed soil, and raindrop impact further causes surface sealing, thus 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 waterflow to dislodge larger soil particles increases.

Sheet and rill erosion is common in more arid areas that have sparse vegetation cover and poor land use management. Rill erosion begins when water movement causing interrill erosion concentrates in discrete flow paths. This erosion produces the greatest amount of soil loss worldwide. Where soil is more resistant to sheet and splash erosion, erosion occurs mostly by rill and gullies. Sheet erosion is a more erosive process on sandy soil. Velocities of 6 inches per second are required to erode soil particles 0.3 mm in diameter. Velocities as low as 0.7 inch per second carry the particle in suspension.

Gully erosion occurs when runoff is concentrated at a nickpoint where elevation and slope gradient abruptly change and protective vegetation is lacking. Headcuts are caused as water falls over the nickpoint and undermines this point then migrates uphill.

Erosion on rangeland is often difficult to detect. Erosion can reduce productivity so slowly that the reduction may not be recognized until the site has reached a threshold level. Also, erosion can increase future runoff because of reduced infiltration. Increased runoff reduces available soil water, which affects plant growth. Less plant growth means less residue, and 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.

Water erosion on rangeland and pastureland can be determined in the field by a variety of indicators. (Some of these factors are accounted for in the rangeland health and pasture condition scoring models). The indicators include:

- Pedestalled plants and rocks
- Base of plants discolored by soil movement from raindrop splash or overland flow
- Exposed root crowns
- Formation of miniature debris dams and terraces
- 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
- Rill and gully formation
- Accumulation of soil in small alluvial fans where minor changes in slope occur
- Surface litter, rock, or fragments exhibit some movement and accumulation of smaller fragments behind obstacles
- Eroded interspace areas between plants with unnatural gravel pavements
- Flow patterns contain silt and/or sand deposits and are well defined or numerous
- Differential charring of wood and stumps indicating how much soil has eroded after a fire

Soil surface characteristics impact runoff and erosion from rangeland and pastureland. 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.

600.0702 Effect of trampling and grazing on hydrology and erosion

Rangeland and pastureland hydrology research has traditionally focused on the impacts of grazing on runoff and erosion. From a conservation-management perspective, the grazing management specialist should consider how the grazing practice or system is affecting the soil surface, plant species composition, and ultimately hydrology dynamics of the site, field, and watershed (fig. 7–6). The amount of disturbance to a site from hoof action by livestock depends on soil type, soil water content, seasonal climatic conditions, and vegetation type. The model in figure 7-6 shows that short-term reduction of infiltration occurs at the soil surface. Repetitive and continuous high intensity trampling increases bulk density (compaction) and breaks down soil aggregates. This results in lower infiltration, higher runoff, and a potential for erosion. If this action occurs on wet soil, soil aggregate stability is damaged even more, resulting in an impermeable surface layer. Modification of species composition over time can change hydrologic conditions on the site. Examples are given in section 630.0701(k) Vegetation effects on infiltration.

Figure 7–6 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 Composition

⇩

Hydrology (Infiltration and Runoff)

⇩

Energy and Nutrient Cycles

⇩

Erosion and Sedimentation Dynamics

Grazing affects vegetation stature and composition and soil surface factors, which subsequently affect the hydrologic cycle (fig. 7–7). On a watershed scale, livestock grazing at intensified levels 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 do alter plant composition, which may seriously affect the hydrology of a watershed.

Trampling activity by grazing animal hooves reduce infiltration by altering soil surface physical factors: bulk density or compaction, breakdown of soil aggregates, and reduced porosity. Intense trampling as a result of doubled or tripled stock intensities in smaller paddocks for a short 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 increasing the intensity of trampling enhances infiltration capacity.

Positive advantages to the environment, livestock, and hydrologic regime as a result of specialized grazing systems need to be documented in the plan and made available to others through the NRCS Grazing Land Technology Institute.

Hydrology studies on rangeland and pastureland summarize the following:

- Species composition changes can positively or negatively affect hydrology, depending on the individual species involved.
- 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.
- 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.
- On heavier textured soil, trampling impact on wet soil can break down soil aggregates and an impermeable surface layer can develop.

Figure 7–7 Diagrammatic representation of grazing and the relationship to soil surface modification, plant species compositional change, and the consequential effects on hydrology and erosion

Increase	Decrease
• plant cover • soil organic matter • infiltration rate • soil water content • subsurface flow • aquifer recharge potential • ET potential • litter • cryptogam response where present on ecol. site • rangeland health • plant community integrity • enhances soil structure • soil aggregate stability • balance nutrient and energy cycle	• runoff • soil bulk density • soil detachment and erosion • sedimentation • site entropy

Proper grazing management and expected plant community response

Excessive grazing and expected plant community response

Increase	Decrease
• runoff • soil bulk density (compaction) • soil detachment and erosion • sedimentation • site entropy • risk of a nonrecoverable situation	• plant cover • soil organic matter • infiltration rate • soil water content • litter • cryptogam response where present on ecol. site • rangeland health • plant community integrity • soil structure • soil aggregate stability • subsurface flow and aquifer recharge potential • soil surface stability • balanced nutrient and energy cycle • ET potential

- "Deferred rotation systems" with adequate rest periods generally maintain hydrologic parameters similar to those in ungrazed areas. Adequate rest periods vary with soil type and vegetation types. Monitoring soil surface conditions should be done on a site-specific basis.
- Watershed research data suggests that watershed conditions can be maintained and improved with light and moderate continuous grazing. There is little hydrologic response differences between light and moderate continuous grazing on rangeland hydrology.
- Heavy use by livestock may compact the soil, negatively impact soil structure, mechanically disrupt soil aggregates, reduce soil aggregate stability, and destroy cryptogamic crusts that may be essential to hydrologic stability. Infiltration capacity is generally reduced with increased grazing intensity mainly through vegetation removal, soil structure deterioration, and compaction.
- Short duration, high intensity grazing is associated with higher sediment production compared to moderate continuous grazing. The reduced standing vegetation and plant cover associated with this system appear to be the cause of the increased sediment production. A definite hydrologic advantage of increased stocking density via manipulation of pasture size and numbers has not been documented in the scientific literature.

  Caution needs to be exercised concerning short duration high intensity systems. Soil surface physical properties, mineral and cryptogamic 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-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 onsite monitoring is essential.
- Studies have shown that on continuous heavily grazed pastures removal of grazing after a 3-year period reduced total runoff to within 10 percent of that on ungrazed pastures.
- 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 cause the most concern in regards to soil erosion.
- Studies on pastureland in Ohio show that highest annual soil loss values (1.12 t/ac) occur on unimproved pastures grazed yearlong where cattle had direct access to riparian areas. Rotational summer grazing with more than 90 percent grass cover had trace amounts of soil loss.

Because grazing systems and hydrologic impacts vary, management specialists should consult references for particular grazing trials. (See Blackburn 1984; Blackburn et al. 1980 and 1981, Wood and Blackburn 1981, Warren et al. 1986, Weltz and Wood 1986, Warren 1987, and Holechek et al. 1989.)

(a) Sediment delivery

Sediment yield is the total sediment leaving a watershed as measured for a specific period of time and at a defined point in the channel. Most sediment is deposited at the base of hillslopes, on flood plains following high flows or floods, and in stream and river channels. Sediment yield predictions on Western rangelands are difficult and often subjective. Highly variable watershed characteristics make erosion prediction difficult.

On agricultural watersheds (cropland, pastureland), from 1 to 30 percent of the estimated erosion reaches and is delivered to rivers. About 8 percent of all erosion from cropland is deposited in estuaries and the ocean; however, cropland soil erosion is highly variable from site to site. Smaller watersheds generally have a higher sediment delivery ratio than that of larger watersheds.

Average sediment delivery ratios (SDR) for various sized watersheds are:

- 25 acre watershed—30–90
- 2,400 acre watershed—10–50
- 10,000 mi^2—5

Three examples of watershed and sedimentation case studies are given below:

Spomer et al. (1986)
- Dry creek basin in south-central Nebraska
- 20 square mile watershed area; 65 percent of land area is steep; 35 percent is relatively level
- 33 percent cropland, 66 percent rangeland
- High gully erosion rates
- About 60 percent of eroded soil reached the watershed outlet

Coote (1984)
- Prairie landscape in Manitoba and Saskatchewan, Canada
- Delivery of eroded soil to streams estimated to be about 5 percent

Lowrance et al. (1986)
- Forest, crop watershed in Turner County, Georgia
- 34 percent of watershed area was row crops
- 59 percent was forested
- About 1 percent of eroded soil was delivered to streams

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.

Models, such as the Systems Planning and Use on Rangelands [SPUR–2000 (SPUR with WEPP hydrology)], can be used to estimate sediment delivery (assuming proper calibration of model parameters for a specific site).

(b) Hydrology and erosion models

The following rangeland hydrology and erosion models are available to NRCS. These models can also be used on pastureland and other grazing land classes.
- Systems Planning and Use on Rangelands (SPUR–2000)
- Water Erosion Prediction Project (WEPP)
- Revised Hydrologic Curve Numbers (includes technology that recognizes the influence of plant species and spatial and temporal aspects of rangeland plant communities)

The Rangeland Health and Pasture Condition Scoring models can be used to obtain qualitative assessments of rangeland and pastureland. Both models are sensitive in detecting subtle changes that may indicate if a site is near or has passed a critical threshold. Once a resource manager is properly trained, a high degree of repeatability and reliability can be achieved.

The indicators of the Rangeland Health Model can be summarized into watershed function, site stability, and biotic integrity categories. All of these categories relate to watershed management and should be considered in planning and monitoring rangeland. A separate system for Pasture Condition Scoring exists for pastureland.

This section will be expanded as a separate section of the hydrology chapter when the WEPP and SPUR-2000 models have been validated and have user interfaces that facilitate use of the models. The applicability and appropriateness of available technologies will also be reviewed.

(c) Hydrologic effects of range improvement practices

Many researchers reported increases in infiltration following mechanical range improvement practices; i.e., root plowing, vibratilling, and pitting, by creating a macroporous surface that is able to store more water. On some mixed grass prairie sites, vibratilling and chiseling can break blue grama and buffalograss sod and allow the native midgrasses to reestablish (with proper grazing management). This procedure results in higher infiltration and lower runoff.

Brush control on rangeland can be accomplished by one or more means, such as prescribed burning, herbicides, and selecting the proper class of grazing animal. However, some managers are shifting more toward prescribed burning for managing rangelands. Generally, brush control on watersheds is done for two reasons:
- To increase available water to other usually more desirable forage plants, which can include seeding as part of the management action.
- To increase runoff water for offsite use by replacing deep-rooted shrubs with more shallow-rooted grasses and/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 and type of shrubs, understory vegetation, timing of shrub control, and management after treatment. Brush control impacts vary over time and from one rangeland plant community type to another because of these natural variations. Improvements in hydrologic response following brush control are not automatic and depend upon the factors listed above.

(d) Fire dynamics on hydrology and erosion

Fire effects have a varied affect on the hydrology and erosion dynamics of a site. Variability depends on the intensity of the burn, fuel type, soil, climate, and topography. The effects of fire can be good and bad, depending on the objectives and where and how fire is used. Using wisdom, prescribed burning can be a beneficial and versatile management tool without damage to soil productivity and water quality.

Fire temperature affects humic acids in organic matter differently. Humic acids and organic compounds (long-chain aliphatic hydrocarbons) are lost at temperatures below 212 degrees Fahrenheit. At temperatures between 212 and 390 degrees Fahrenheit, nondestructive distillation of volatile organic substances occurs, and at temperatures between 390 and 570 degrees Fahrenheit, 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 nonwettable 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 5 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. The thickness and depth of a hydrophobic layer depends on the intensity and duration of the fire, soil water content, and soil physical properties. Thicker hydrophobic layers form in dry soils than in wet soils; coarse-textured soils are more likely to become water repellent than fine-textured soils. Hydrophobic layers are also common in forest soils, particularly in ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and Douglas fir (*Pseudotsuga menziesii*) communities.

Grassland fires generally temporarily reduce infiltration and percolation rates. The extent of reduction is again dependent on the factors described above. In Chaparral, fire often reduces infiltration on moderate burns by forming the water-repellent layer. Cooler or very hot fires have either a lesser effect or no effect on infiltration. In forest communities, severe hot fires decrease infiltration; whereas, light burning has less effect and can increase infiltration.

Where increases in water yield are desired, brush-to-grass conversions should be done on sites where precipitation exceeds 16 inches per year and on slopes of less than 30 percent. This will minimize runoff and soil losses. Generally, conversion practices in pinyon-juniper communities with 14 to 20 inch per year precipitation rarely increase water yields. Successful grass cover establishment in 1 to 2 years on slight to moderate slopes and a cover of 60 to 70 percent is considered necessary for soil stability. In Arizona, shrub recovery after fire reduced runoff to similar levels of pre-fire conditions by the end of the fourth year.

(e) Riparian vegetation and grazing

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. Management and condition of the transitional zone (inactive flood plains, terraces, meadows) and upland sites are critical to the health of riparian ecosystems because they are areas of runoff and recharge. Excessive runoff and gully erosion on uplands ultimately impact the riparian zone and stream corridor.

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 these zones. Riparian zones compared to more rugged, steep upland sites in the Western United States provide available and easily assessable water, forage, and shade. Excessive livestock impacts; i.e., 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 water tables.

Livestock are perceived as a major cause of riparian degradation in the West. As a result, concerns from resource users have accelerated. In addition to forage for livestock, riparian areas often cover 1 to 2 percent of the summer rangeland 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 waterflows.

Rehabilitation of riparian zones can include rotation 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). 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.

Streamside use of herbaceous forage in riparian areas in summer grazed pastures should be used judiciously (not more than 50 percent, by weight), and in the intermountain region, riparian plant communities have limited regrowth potential after midsummer. Rule of thumb stubble heights proposed by some grazing guides (4 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) for pasture or domestic species.

Chapter 8 Wildlife Management on Grazing Lands

Contents:

Chapter 8 Wildlife Management on Grazing Lands

600.0800 General

Grazing lands support many species of wildlife as well as domestic livestock. As residents and consumers of vegetation on grazing lands, wildlife and their habitat must be properly managed if the land and associated resources are to be used wisely and efficiently. Wildlife, in the broadest sense represent all vertebrate species that are undomesticated (e.g., mammals, birds, reptiles, and amphibians). When providing technical assistance on grazing land resources, consideration of fish and wildlife in general will be guided by the desires of the cooperator, Natural Resources Conservation Service policy, the Endangered Species Act, sound resource management, and compliance with State laws and coordination with individual State policies and management goals.

The NRCS involvement in wildlife management is basically in the area of assisting private landowners and managers plan and apply conservation practices and resource management systems that create, maintain, or improve habitat for game and nongame wildlife species. The development of a wildlife habitat management plan is an integral part of the overall conservation plan as NRCS employees bring to the attention of the land manager all the soil, water, air, plant, and animal resource needs and concerns. All wildlife management planned and applied is the decision of the land manager in keeping with his or her overall objectives.

When it is the desire of the land manager, a wildlife management component of the conservation plan can be developed and implemented on almost any grazing land area. On rangeland or grazed forest, the native plant community can be managed to allow for healthy wildlife populations. On pasture, native or introduced species of vegetation that provide food, cover, or both, for the wildlife species being managed can be used as the primary forage species or as an overseeded species for seasonal use. A fence row or field corner might be developed as a source of wildlife food or cover on hayland or grazed cropland and a modified cropping system could provide food or cover for some target wildlife species throughout the field. A wildlife management plan provides food, cover, and water for the species of concern throughout appropriate areas of the farm or ranch.

For grazing land conservation planning, herbivorous wildlife species need to be considered as they impact forage resources, affect livestock management, or offer economic opportunities. Ruminant wildlife species are selective consumers whose degree of selectivity varies depending upon morphological and physiological adaptations. Diet composition for wildlife varies by season and location in response to the variability of the quantity and quality of food sources available.

Potential livestock impacts on fish and wildlife habitat as well as on wildlife social interactions need to be considered in conservation planning.

Some species of wildlife have become so greatly reduced in number, have such specialized habitat, or are so limited in distribution that they are threatened with extinction. The disappearance of any species is an ecological, cultural, and, in some cases, an economic loss. Productive wildlife populations in balance with available food, cover, and water resources fill a niche on grazing land ecosystems and can contribute to the overall environmental quality of the area. NRCS shall assist in the preservation of threatened and endangered species and their habitat, and avoid activities detrimental to them or their habitats. The Endangered Species Act requires NRCS to assess its activities that may affect a listed species.

Some wildlife species have expanded in number and range of occurrence as a result of improved conservation treatments and increased knowledge of wildlife management. Other changes in wildlife populations, both positive for some and negative for others, have resulted because of changes in landscape characteristics and plant community structure. Alteration of the natural fire regime, hydrologic parameters of wetland sites, and improper grazing practices have had a significant impact on some wildlife habitats. Some areas are experiencing habitat loss because of urban encroachment. In some locations game species are providing economic returns in excess of that received from traditional livestock operations.

NRCS helps landowners evaluate resource potential of their lands for wildlife habitat enhancement and sustainability. When providing assistance for enhancement of their grazing lands resources, including assessment of current conditions of the plant community, a description and methods for achieving the desired plant community for the wildlife species of concern is provided. NRCS planners assist landowners in planning for the maintenance or improvement of the habitats for the kinds and amounts of wildlife desired by the cooperator.

Biologists, range conservationists, foresters, plant material specialists, agronomists, and soil scientists need to work as a team to prepare local technical information. Information, such as plant lists interpreted for wildlife dietary preference and such other values as cover (i.e., escape, screening, nesting, or thermal), provides knowledge for effective conservation planning to meet wildlife resource concerns. Wildlife habitat interpretations are to be included in ecological site descriptions of rangeland, grazed forest, and native or naturalized pasture. Habitat attributes associated to site descriptions shall consider, but are not limited to breeding, fawning and calving, bedding, foraging, nesting, roosting, and dusting.

600.0801 Technical assistance to landowners and managers

NRCS policy and procedures for assisting landowners and managers, local units of government, and others in planning and applying wildlife and fish habitat management on private and other non-Federal land are in the *National Biology Manual.*

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 to address all resources, including wildlife, during the conservation planning process on all land units. Procedures for providing wildlife management assistance are described in the following sections.

(a) Determine objectives

Every 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, economic, and management aspects of the ranch or farm is necessary. The planner needs ask the landowner or manager which wildlife species they want to include in the plan and the intensity and extent of the management desired. The landowner may wish to manage the grazing lands with wildlife as a primary or secondary use. The landowner's objectives should be clearly defined.

The planner will discuss the present capability and potential opportunity for producing and sustaining wildlife populations on the farm or ranch. General discussion should be centered on ecological sites, habitat suitability, and land uses identified in the planning objectives. Neither livestock grazing nor wildlife production can be maximized without affecting the other, and tradeoffs are necessary to optimize either or both. Therefore, the landowner's or manager's goals should be realistic.

(b) Inventory the wildlife and habitat components

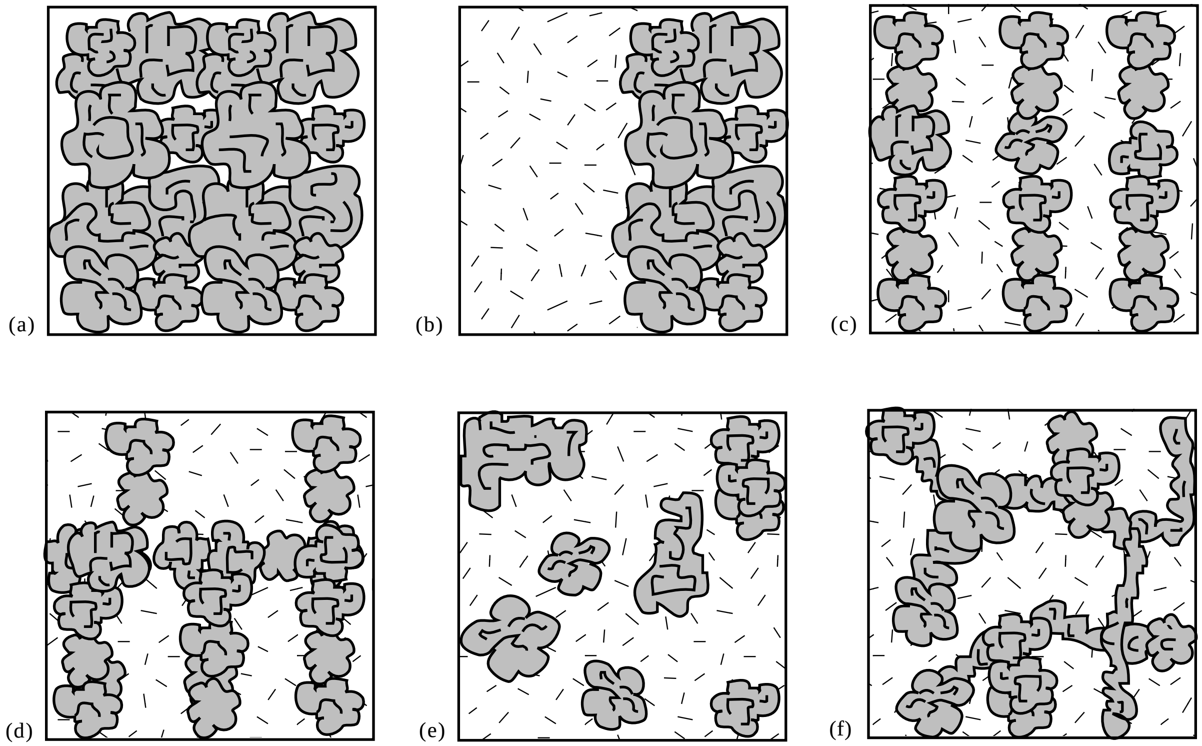
The quantity, quality, availability, and distribution, both seasonally and spatially, of all habitat elements (food, cover, and water) determine the carrying capacity of a given area of land for a given wildlife species. When one or more of these factors is limiting, it should be identified and appropriate plans developed to improve it.

(1) Plant community information

The planner will:

- Determine the ecological sites and their present status or condition for rangeland, grazed forest, native or naturalized pasture, pastureland, and hayland.
- Use soil surveys and ecological sites for rangeland, grazed forest, native or naturalized pasture, and pasture suitability group descriptions for interpretations of wildlife use and preferences for specific plant species.
- 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.
- Compare livestock grazing preferences and food requirements with preferences of wildlife species.
- Consider the critical periods for food, water, cover, nesting, and reproduction and parturition of resident and migratory wildlife species as they relate to management objectives (i.e., winter, lactation).
- Consider other spatial needs, such as interspersion of habitat types, and travel corridors between specific land use cover types and ecological sites. The diversity of plant species and plant communities is greater along the area where two habitat types come together; this is referred to as *edge effect*. When the amount of edge effect can be increased, wildlife populations (numbers and species) also generally increase. However, for some interior species, such as certain songbirds, an increase in edge may decrease their habitat and the value of remaining habitat. The size, shape, and location of various habitat types determine the amount of edge present. Interspersion of habitat elements in close proximity is important for some species. Example 8–1 describes design alternatives to provide edge in a rangeland pasture dominated by brush species.

Example 8–1 Alternative design of rangeland pasture to provide edge



A landowner wishes to apply brush management and range seeding on a rangeland pasture dominated by brush species. Many alternative designs can be considered in planning and implementing the practices (fig. 8–1). The five alternatives shown provide for half of the pasture (a) to be cleared and seeded and half to remain in brush.

Alternative b is the simplest approach and provides for some edge between the grass and brush halves of the pasture.

Alternative c provides six times the linear edge effect.

Alternative d provides even more edge plus wildlife travel corridors between the brush strips.

Alternative e provides a greater amount of edge and leaves brush motts that provide a natural appearance.

Alternative f provides for the greatest amount of edge and interspersion of habitat types, a natural appearance, and wildlife travel corridors between brush motts.

The concept displayed in this example can also be applied with pasture, hay, and croplands. Which alternative is the most favorable depends on the species being managed for and the plant community diversity.

(2) Animal information

The interactions between species of wildlife and between wildlife species and domestic livestock can present the land manager with a complexity of problems and opportunities. Ecologists have identified eight interactions that can occur between species populations. To appropriately manage the plant community and forage species, the landowner or manager and the planner need to be aware of and understand which of the interactions are applicable to the species of wildlife and livestock being managed. These interactions are:

- Neutralism, where neither population is affected.
- Competition, where each population affects the other.
- Mutualism, where interaction is necessary for the survival of both populations.
- Protocooperation, where both populations benefit, but it is not necessary for species survival.
- Commensalism, where one population benefits, but the other is not affected.
- Amensalism, where one population is inhibited and the other is not affected.
- Parasitism, where one species population is dependent upon the other and directly affects the other.
- Predation, also where one species population is dependent upon the other and directly affects the other.

The term competition is generally used to refer to any interaction where there is a negative outcome for one or more species. Competition occurs when a number of individuals use common resources that are in short supply or when they seek a resource that may not be in short supply, but cause harm to one another as they use the resource, or both situations. Competition between wild and domestic grazing animals can occur as forage competition, habitat competition, or both. Some grazing animals are more adaptable in their choice of forage and habitat than others. Several factors have been identified concerning competition between grazing animals, including:

- The grazing animals use the same range, sometimes simultaneously, sometimes not.
- Plant species are important to at least one species of animal and are used by both species of animals, either as forage or as a habitat element, such as nesting or cover.
- The plant species or water resources show deterioration as a result of overuse by one or more animal species.

Competition for space must also be considered. It may continuously occur or may occur only seasonally. Competition may occur during some years and not during others because of climatic and other conditions.

All wildlife species require food, cover, water, and space. The planner must know the requirements of each wildlife species of concern to provide the landowner with the proper technical assistance. The planner, along with the landowner, must determine the qualities and quantities of habitats throughout the farm or ranch and the general habitat conditions of surrounding areas. As the conservation plan is developed, the following habitat factors, some of which may be critical limiting factors, should be evaluated and planned for as needed:

- permanent food and cover
- edge effects, interspersion of habitats
- diversity
- season of use
- carrying capacities
- travel lanes to connect habitats (both on and off the farm or ranch)
- fencerow developments
- proper control of plant structure and succession
- use of native plants
- use of plantings
- water quantity (permanent source)
- water quality
- other appropriate factors, such as nesting, fawning, and calving sites

Each element can be provided in a variety of ways. The presence and condition of each element can vary depending upon the time of the year and the current conditions. The habitat elements need to be present in a favorable pattern that varies with species of concern. Food, cover, and water requirements of each species can vary seasonally as well as daily.

Just as the grazing land manager must keep livestock in balance with food and water, wild ungulate numbers must also be in balance with the habitat elements. Failure to maintain a proper balance of wildlife numbers with their habitat can severely damage the habitat, reduce forage for livestock, and affect the quality of the individual animals within the wildlife population. The NRCS planner, with prior agreement or assistance from the state wildlife agency, will assist the landowner or manager to estimate wildlife population numbers. The planner will provide techniques to estimate the density (number per area) or abundance (one population relative to another) for the primary wildlife species of concern. Techniques for determining wildlife population density or abundance include, but are not limited to the following:

Abundance:

- Number of animals seen per hour of observation or per area
- Number of animals seen per linear distance
- Number of tracks counted per hour of observation or per linear distance
- Number of calls heard per hour
- Pellet group transects

Density:

- Line transect—After the area being sampled is known, a line transect can be run and the number of animals observed or heard can be converted to the number per unit area.
- State wildlife agency estimates. In many states, the state wildlife agency can provide a general population density estimate for specific geographical areas of the state. This can be used when no site specific data is available or attainable.

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. The U.S. Fish and Wildlife Service has lead responsibility for migratory and Federally listed threatened and endangered species. NRCS responsibility lies in assisting the landowner or manager with habitat management in a manner that is compatible with the overall farming or ranching operation and other resource management objectives. When population management is needed, the landowner is to be encouraged to contact state and local wildlife agency personnel to determine what course of action may be possible within a given state. An agreement between the participants on methods used should be reached in the beginning.

Other factors that assist sound decisions concerning wildlife populations consider annual productivity and condition status of the species. Knowing the annual recruitment of new individuals into the population; their seasonal habitat needs, behavior; breeding, fawning, and nesting requirements; and the health of the species help identify important factors concerning their habitat and sustainability. NRCS planners should be aware of natural fluctuations in population numbers resulting from drought, wildfire, and other natural events. These changes are generally short-term phenomenon, and planners should encourage cooperators to consider referring to long-term data collected on their farm or ranch before making decisions that may have negative consequences.

Planners should encourage cooperators to include state and local game and fish agency personnel as well as NRCS biologists when emphasis of wildlife management is a major objective in the conservation plan. State and local fish and wildlife agency personnel have resources and knowledge that can be extremely beneficial to achieving the landowner or manager's objectives. When providing assistance on tribal lands, U.S. Fish and Wildlife Service is responsible for determining wildlife populations, at the tribe's request.

(3) Water

Water is an essential element to all wildlife species; some are more dependent on available water than others. A wildlife management plan includes the careful consideration of wildlife water availability. A careful inventory of wildlife watering sources is necessary. The planner and land manager must be aware of the target wildlife species' water needs. The type of watering facility may be critical for certain species (i.e., trough versus pond, fenced versus unfenced). Permanent watering sources are necessary for some species and must be available. To be accessible to all species, livestock water sources may need to be modified to provide water at ground level. Because livestock may concentrate around watering facilities, ground nesting bird habitat is an important consideration.

(c) Analyze the needs for improving, restoring, or maintaining wildlife habitat

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 may be affected differently by different classes of livestock and different types of wildlife because of differences in foraging behavior.

The planner will assist the landowner or manager in determining whether the wildlife habitat is currently improving, being maintained, or deteriorating and why. This determination should include an evaluation of current and past utilization of plant species and evidence of satisfactory reproduction and growth of species desirable for wildlife. The Browse Resource Evaluation worksheet (exhibit 4–5 in chapter 4) can be used for judging composition, trend, and utilization of the browse plant resource.

The planner will assist the landowner or manager to identify dietary overlap between major wildlife species and livestock if any exists. 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 overlap and the plant and animal species involved should be considered.

As the kinds and amounts of vegetation decrease, competition increases. Competition for plants can also change as physiological stages of the plants change. The optimum mix of grazing animals can be determined from a combination of the knowledge of the grazing animals foraging behaviors, their forage preferences and nutritional requirements, the kinds and amounts of plants present throughout the grazing season, past experience, and present conditions.

The planner may use a vegetation transect from the multispecies calculator that is in the decision support software, Grazing Lands Application (GLA), in the Field Office Computing System (FOCS). This gives a recommended stocking rate for all classes of domestic livestock based upon the allocation of forage to the wildlife species. The planner must first identify the kind and number of wildlife present and the dates and duration of their presence.

The planner may use habitat suitability indices and appropriate habitat evaluation procedures for the wildlife of concern. These tools can assist the NRCS planner and land manager with understanding which habitat elements are critical and which, if any, need to be provided or improved for the wildlife species of concern.

(d) Develop and evaluate alternatives

The planning process includes developing and evaluating alternatives to maintain, improve, or develop the desired wildlife populations and habitat. This includes plant and animal resources as well as water resources.

(1) Plant and animal resources

A major objective in many wildlife management plans is to increase diversity of plant and animal life through the use of edge effect between various plant communities. The proper management of plant communities is the key to healthy wildlife populations because plants supply wildlife with food and cover for nesting, loafing, resting, roosting, travel, and escape from predators and adverse weather.

The manipulation of plant succession in native plant communities is the primary element in managing wildlife habitat. The proper manipulation of succession can lead to the desired plant community necessary for the wildlife species of concern. Different wildlife species attain their optimum populations in plant communities in different successional stages. Knowing the animals optimum habitat and distribution among, and between, different successional stages is necessary for the manager to adequately plan wildlife habitat management.

Manipulating the successional stage of a plant community can slow down or speed up the development of the wildlife population being managed. The primary methods used to manipulate plant succession are grazing, burning, disking, mowing, cutting, and applying herbicides. These methods must be planned for the appropriate time. For example, in parts of the Southeastern United States, mowing and cutting should be after July. This allows ground nesting birds and other wildlife adequate time to complete nesting. Proper timing is determined by the objectives of the manipulation and the growth stage of the target plant species being affected. Patterns can be planned and applied that will increase the desired forage constituents for the preferred species while increasing the edge.

On grazing lands dominated by monocultures (pastureland, hayland, and cropland) and on native plant communities (rangeland and forest) where some habitat element is limiting, planting food and cover may be an effective and quick means of obtaining the desired plant community and wildlife habitat. Plants selected for plantings must be adapted to the ecological site or suitability group. Ecological principles must be used in planting, establishing, and managing the plantings to obtain the desired results.

A wildlife planting can provide food, cover, or both. Plants selected should eliminate the limiting factors where possible. Although any plant form can provide several habitat elements, annual plants are generally planted for food production, while perennial grasses, forbs, and woody plants may be planted for food and cover. The area selected for wildlife food and cover plantings should provide the optimum edge effect with other vegetation types. In some cases fences are necessary to manage livestock grazing, and exclusion is desirable.

A planned grazing system, as a part of the overall grazing prescription, can provide the land manager with opportunities and the flexibility to integrate wildlife use with domestic livestock grazing. The grazing plan must take into account the factors and criteria of competition to efficiently and effectively manage the grazing land resources. To restore, maintain, or improve the habitat for the wildlife species of concern where the grazing lands have deteriorated, livestock often need to be removed for a period to allow the plant community to respond. On the other hand livestock may be used as an effective tool to restore, maintain, or improve the habitat of the species of concern on many grazing lands. Livestock grazing can be planned and managed to open up dense vegetation that may support only a few species and create a diverse plant community favorable to more species of wildlife. To make the proper decisions concerning grazing timing, duration, intensity, and class of livestock, the grazing land manager must consider the condition and needs of all the resources.

Every grazing system must be planned for a specific area of land, and each system will vary in its effects and influence on wildlife. The manager must not only plan a grazing system that is tailored to fit the vegetation and livestock needs, but must also plan a system that is tailored to fit the needs of the wildlife species of concern. As livestock is rotated through a given area, the quantity and quality of food and cover species may be altered. The manager, therefore, must know the specific seasonal needs of the wildlife of concern to prevent degradation and to plan grazing that will enhance the habitat.

The NRCS planner will:

- Help the landowner or manager clarify the goals and objectives so appropriate treatment alternatives are considered in the planning process.
- Help the landowner or manager plan the appropriate treatment for the desired habitat.
- Give adequate consideration to the conservation 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.
  - — Developing accessible watering facilities while protecting riparian areas.
- Help the landowner or manager plan for proper use by livestock and wildlife species, balance forage supplies for both wildlife and livestock, meet needs of migratory big game animals and waterfowl, and adjust for variations in forage production by having flexibility in numbers of game animals and livestock.
- Provide recommendations to avert deficiencies in food quality and quantity to meet the projected carrying capacity for the wildlife species and kind and class of livestock desired.
- When appropriate, discuss the desired level of harvest of game birds and animals. Frequent opportunities for making adjustments are available by:
  - — Cooperating with State and Federal game management agencies and landowners
  - — Leasing trespass rights for hunting

- — Arranging for guide services and lodging for hunters.
- — Allowing a charitable hunt for disadvantaged youth.
- — Planning other appropriate practices or treatments needed to achieve the wildlife objectives of the landowner.

(2) Water resources

***(i) Wildlife water availability*—**A wildlife management plan includes the careful consideration of wildlife water needs and availability. The NRCS planner and land manager must be aware of the target wildlife species' water needs and plan to provide adequate water where it is not available, either year-long or during critical seasons. Wildlife water may be provided from a stream or pond, livestock watering trough adapted for wildlife use, or a specially designed wildlife watering facility planned for exclusive and specific wildlife use. A well-designed wildlife watering facility provides an adequate supply of quality water that meets the needs of the wildlife species of concern. Figure 8–1 is examples of wildlife watering facilities that provide an adequate supply of quality water to meet the needs of the wildlife species of concern. Figure 8–23 shows watering facilities used by different wildlife species.

Figure 8–1 Wildlife watering facilities

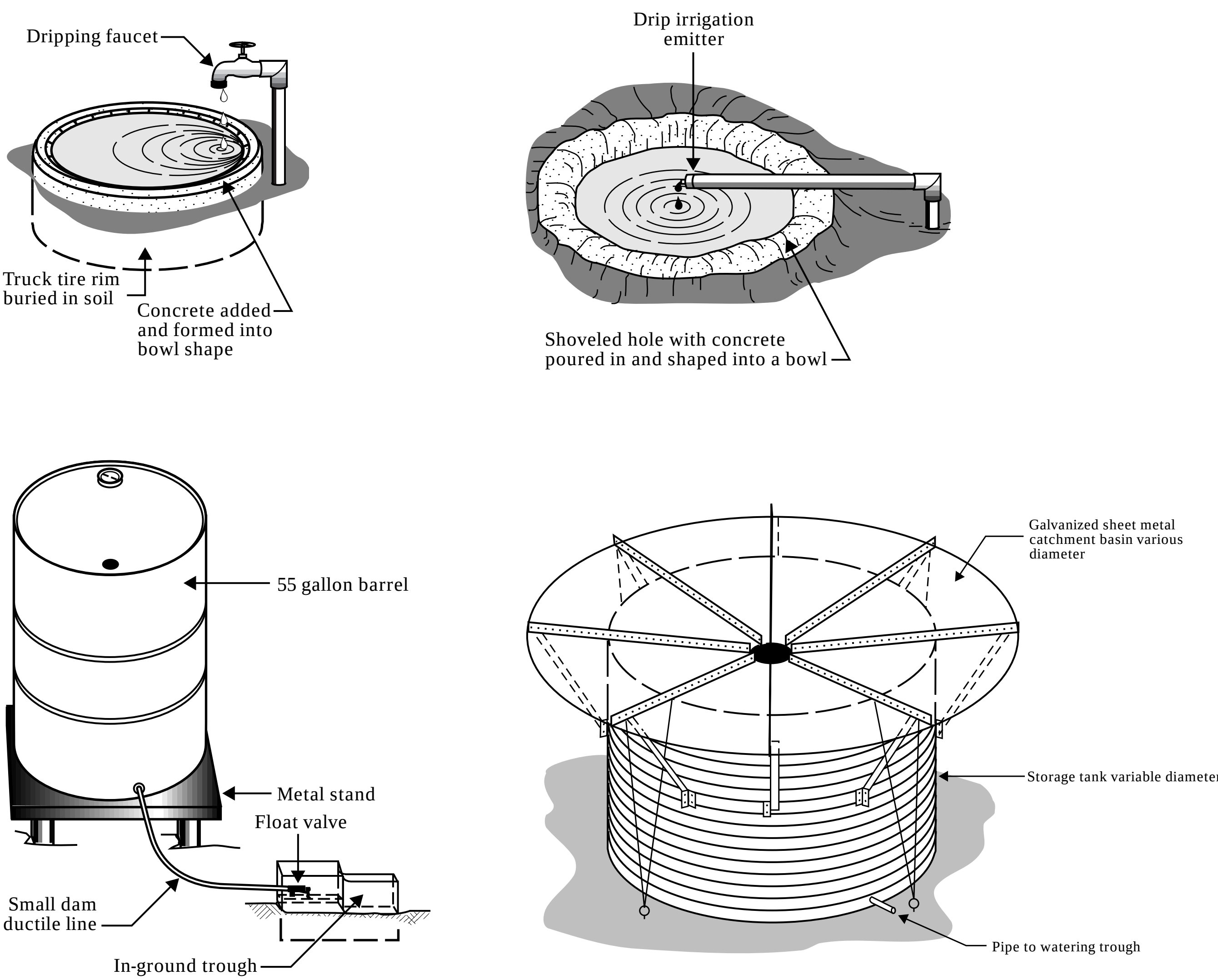


Figure 8–2 Properly designed watering facilities are used by many wildlife species

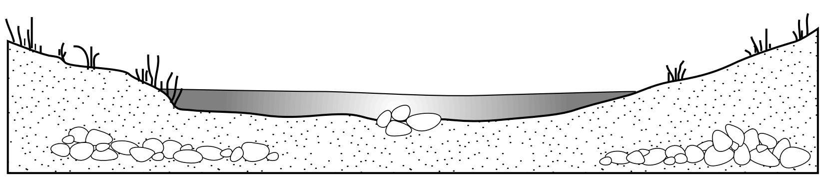
(ii) Riparian areas and fish habitat—The management of a fish population is dependent upon the availability of water of sufficient depth, temperature, and quality with adequate habitat structure for the fish species of concern. Proper planning and control of grazing are necessary to manage the fish habitat in streams and ponds adjacent to or contained within grazing lands. Control of grazing is necessary not only in the riparian area, but also in the upland areas of the watershed.

Riparian areas (fig. 8–3) are extremely important habitat for most species of wildlife at some time during the year. In some instances riparian areas need to be fenced. Overgrazing can severely degrade fish and wildlife habitat when the stream channel is altered through trampling and removal or destruction of streamside vegetation. 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:

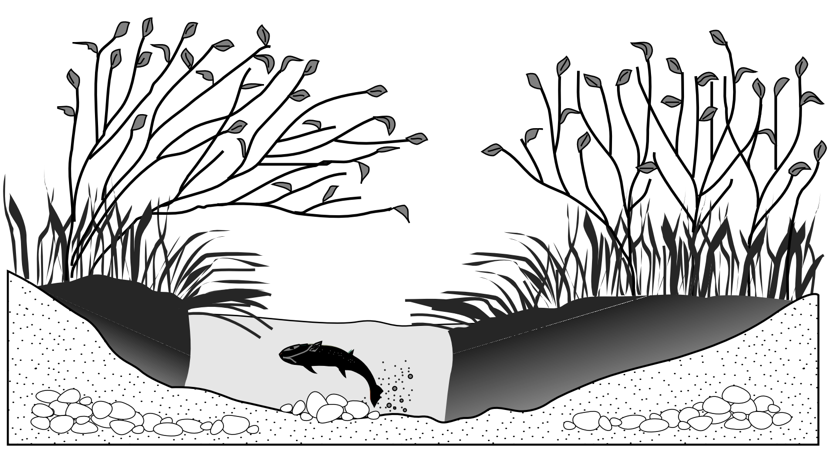
- stabilize the banks,
- keep sediment out of the channel,
- supply food in the form of insects,
- provide shade to keep the stream from getting too hot,
- provide large woody debris to form pools and hiding cover,
- provide energy to the stream in the form of leaves and other plant material that falls into the stream, and
- keep pollutants and nutrients out of the water.

Grazing management can improve water quality in ponds 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.

Figure 8–4 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)

Where fish management is an issue, 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 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.

(e) Provide follow-through assistance and evaluation

The planner will:

- Provide technical assistance to the landowner or manager in applying practices and implementing the total conservation plan. Quantifiable assessments should be done periodically to assure the objectives and goals of the conservation plan are biologically realistic and attainable.
- Assist the landowner or manager in checking habitat periodically to evaluate trend in habitat components. Appropriate monitoring techniques should be recommended to the landowner or manager to adequately evaluate food, cover, water, and spatial requirements for the wildlife species of concern. Particular attention should be given to riparian areas.
- Assist the landowner or manager in checking for proper utilization of key wildlife forage or browse species.

Chapter 9 Grazing Lands Enterprise Diversification

Contents:

Chapter 9 Grazing Lands Enterprise Diversification

600.0900 General

The owners of grazing lands are breaking with tradition and are considering various opportunities for increasing profits and diversifying their enterprises with multiple uses, nontraditional uses, alternative uses, and supplemental enterprises.

Most cash income from grazing lands has traditionally been from the sale of livestock and livestock products. Diversification of income-producing enterprises is increasing. Other products and services contributing to the total income include:

- Nontraditional marketing of domestic livestock products, such as direct marketing of meat to consumers
- Marketing of nontraditional animal products, such as game ranching of exotic deer
- Sale of plants and plant products
- Sale of access rights for hunting, fishing, and other recreational activities

600.0901 Enterprise diversification

An enterprise is any segment of the land unit's business that can be isolated by accounting procedures so that revenue and expenses can be allocated to it.

Enterprise diversification is the opposite of specialization. When the grazing lands owner chooses to specialize, the resources of the unit are concentrated on a special product or service. When the choice is to diversify, the resources are used in more than one enterprise to produce several products or services. The number and kind of diversified enterprises for any land unit are often limited and depend upon the resources available and other factors identified in the planning process. The enterprises may be competitive, supplementary, or complementary uses.

All grazing land operations are not able to diversify in the same fashion. The owner's or manager's ability to change enterprises depends upon how flexible existing enterprises are and the operation's ability to meet changing conditions and other physical, economic, institutional, or social factors. Some conditions and factors to be considered are:

- Prices received for livestock products
- Costs of livestock feed, labor, or other operating expenses
- Drought or other environmental conditions
- New regulations
- Changes made elsewhere that affect the existing enterprise(s), such as a neighbor selling to a real estate developer.

(a) Reasons to diversify

The number of reasons a grazing lands owner or manager might choose to diversify with new or additional enterprises is endless; however, the most common reasons are:

No profit—Current enterprise is not making a profit (i.e., cattle prices are low, feed prices are high, drought, fertilizer prices are high), and the owner or manager is looking to supplement income.

Reduction of financial risk—Distribution of resources into several enterprises reduces the risk of losing the resources. In other words, "Don't put all your eggs in one basket."

Increase ranch income—The current enterprises may be economically viable, but more income is desired and possible from existing resources.

Increase or obtain a better distribution of cash flow—Bring cash returns to the land unit's operation at various times throughout the year. Often a livestock grazing operation has only one time during the year when cash is received; for instance, when calves are sold once during the year from a cow/calf operation.

Utilize available resources:

- Labor—Often, labor is needed at peak periods and not at other times of the year. This creates a problem for the owner or manager in keeping labor available. When labor can be utilized all year, the owner can afford to keep labor employed, and employees are more assured of job security.
- Facilities and equipment—As with labor, facilities and equipment are often only needed during a specific time and are not returning anything to the operation during the rest of the year.
- Natural resources—Some natural resources are easily recognized and used in a grazing land enterprise. Others are not used, but could be. For instance, plants preferred by livestock are easily recognized as livestock forage in a grazing enterprise, while some may be aesthetically preferred by recreationists or wildflower enthusiasts in a recreational enterprise.

Keep family members on the farm or ranch—When the next generation is interested in remaining on the farm or ranch, income from existing enterprises is often not enough to support more than one family. Diversification can sometimes enable family members to remain.

Change operations because of regulations—A new law or regulation can force a change in the operation of the existing enterprises or cause the elimination of the current enterprise.

Recognize a consumer need or desire that could be produced or provided—A land unit close to a city could supply the demand for people to get out into the country and enjoy the open space. This could lead to a recreational enterprise, such as horseback riding, or a tourism enterprise, such as a bed and breakfast inn.

Personal preference—A new owner may simply desire to operate a different or additional enterprise than that previously operated.

600.0902 Diversification alternatives

Grazing land owners can diversify enterprises in many ways. However, four categories of production and marketing strategies are generally used. They are:

- Nontraditional crops, livestock, and other farm products
- Service, recreation, tourism, food processing, forest or woodlot, and other enterprises based on farm and natural resources
- Unconventional production systems, such as organic farming or aquaculture
- Direct marketing and other entrepreneurial marketing strategies

An enterprise should be based on the limitations and opportunities that the farm or ranch operation and resources present.

Many enterprises might be considered for adoption on a grazing land operation. Each of them is dependent upon and will be based around some natural resources, facilities, certain plants, specific wildlife, or other factors. Often the enterprises must be based on several of these factors; however, for sake of convenience, they are loosely organized in table 9–1 by being placed in one category. Example 9–1 describes diversification through agroforestry.

Table 9–1 Enterprise diversity

Livestock-based enterprises
Buffalo enterprise
Bull development
Cattle drives
Commercial cow/calf
Deer farming
Direct marketing of livestock products to consumer
Exotic livestock (ostriches, emus, rheas, llamas, miniatures)
Goats
Heifer development
Management services for other people's livestock
Pasture-based dairying
Pastured poultry
Registered cow/calf
Sheep
Starting yard for yearlings
Stocker operation

Natural resource-based enterprises
Biking trails
Camping
Farm & ranch vacations
Hiking trails
Historical outings
Horseback riding
Pack trips

Natural resource-based enterprises (cont.)
Painting
Photography
Picnicking
Rural experiences
Stargazing
Tours of the farm or ranch
Wagon trains
Wilderness experiences

Facility-based enterprises
Airplane & helicopter tours of surrounding terrain
Archery
Archery range
Arts & crafts
Bed and breakfast
Breeding & training hunting dogs
Bunkhouse camping mess hall
Business convention center
Camping
Canoeing
Center for research (lodging, classrooms, labs)
Chuckwagon meals
Commercial fish ponds (catfish, trout)
Concession stands
Cutting horse events
Dance

Table 9–1 Enterprise diversity—Continued

Facility-based enterprises (cont.)
Dog kennels
Dude ranch
Equestrian center
Exotic game farm
Farm stands
Farmers market sales
Feedlot
Festivals
Festivals during peak harvest season
Fish hatchery
Fly fishing & tying clinics
Football, basketball, other type sports camp
Games (horseshoes)
Golf
Golf driving range
Gun range
Hay rides
Historic museum
Home for children
Horse boarding & trail rides
Horse breeding & training
Hunting & fishing club
Hunting lodge
Motel units
Nature study
Obstacle course
Pick-your-own marketing
Professional workshops
Ranch rodeo
Recreation activities for the physically challenged
Restaurant
Rifle or skeet shooting
Rodeos
RV park
Seed & supplies distribution
Silhouette range (pistol & rifle)
Special Olympics type events
Sporting clays
Square dancing
Swimming
Swimming pool
Tennis
Theatrical productions
Track & field sports
Trap & skeet range
Working ranch vacations

Wildlife-based enterprises
Birdwatching - songbirds
Camera safari
Trapping - furbearers
Varmint calling
Video taping & still photos of paying hunter's hunt
Wildlife sightseeing tours
Hunting enterprises
- Big game hunting
  - Antelope
  - Bighorn sheep
  - Black bear
  - Elk
  - Exotic introduced species
  - Feral hogs
  - Moose
  - Mountain goat
  - Mountain lion
  - Mule deer
  - White-tailed deer
- Small game hunting
  - Fox
  - Prairie dogs
  - Rabbits
- Game birds
  - Grouse
  - Mourning dove
  - Partridge
  - Pheasant
  - Quail
  - Turkey
- Waterfowl
  - Cranes
  - Ducks
  - Geese
  - Rails
- Predators
  - Coyotes
  - Fox

Table 9–1 Enterprise diversity—Continued

Water-based enterprises
Fishing
- Warmwater (bass, catfish, panfish)
- Coldwater (trout)
- Native vs. stocked
- Streams
- Ponds

Boating
Canoeing
Crayfish or bullfrog production
Tubing in stream or river
Water skiing

Geology-based enterprises
Four-wheeler & cross-country motorcycle track
Jeeps tours
Landfill
Rock collecting
Rock climbing
Spelunking
Topsoil, sand, & gravel

Plant-based enterprises
Agroforestry (see example 9–1 for brief description)
Christmas tree farm
Harvest wildflowers
Hay production
Irrigated crops
Lease grazing to others
Native seed production
Wildflower tours
Wood products

Winter-based enterprises
Cross-country ski trails
Downhill skiing trails
Ice fishing
Sledding
Sleigh rides
Snowmobiling

Real estate-based enterprises
Outdoor recreation memberships
Ranchettes
Real estate development
Retirement village
Time-share cabins or condos

Example 9–1 Diversification through agroforestry

Diversification through agroforestry

Many opportunities are available to incorporate trees into a farm or ranch enterprise. Agroforestry is using trees to achieve an intended purpose in agriculture. Agroforestry systems produce more than one crop off the same acreage. These systems provide an economic benefit, protect livestock from environmental stress (cold winds or heat), protect the environment, improve biological diversity in the landscape, and provide habitat for wildlife species.

The area of the country, the climate, and the landscape dictate what agroforestry systems are applicable. Several common agroforestry systems that have potential application in a livestock enterprise are:
- Livestock windbreaks or living barns
- Living snowfences
- Alley cropping
- Silvapastoral systems
- Riparian forest buffers or riparian woody buffers

Livestock windbreaks or living barns are closely spaced trees, shrubs, or a mixture of these established perpendicular to the prevailing troublesome winter winds and strategically located adjacent to a setting where livestock naturally concentrate or are confined. They significantly reduce windchill thus controlling energy loss and feed intake requirements by livestock to maintain body weight and health. They also improve calf crop survival during inclement weather and provide similar benefits to wildlife.

Living snowfences are special purpose windbreaks designed to trap snow to prevent snow drifting onto travel lanes or other areas. This can be important in areas subject to severe drifting that may prevent servicing herd needs or other management activities.

Alley cropping is the planting of trees or shrubs in rows or corridors with alleys of agronomic crops or forage between. Plantings are placed at intervals across the field that allow the companion agronomic or forage crop adequate solar energy units required for plant production. These plantings are commonly used to:
- Produce wood or tree products, such as pecan, blackwalnut wood, and nut meats species, along with the desired agronomic crop or forage.
- Evenly distribute snow in a field to harvest moisture in moisture deficit areas.
- Improve crop or forage quality and quantity by enhancing microclimatic conditions.
- Reduce excess subsurface water or control water table depths.
- Provide favorable habitat for species beneficial to crops or forage.
- Provide wind or water erosion control.
- Improve waste application utilization.

Silvapastoral systems is the managing of the overstory trees and the understory forage to provide the desired economic and environmental benefits. The tree canopy is managed to allow sufficient solar energy for desired production. The primary purpose of a silvapastoral system is to:
- Produce wood or tree products in addition to forage.
- Improve forage quality and quantity by enhancing microclimatic conditions favorable to forage species.
- Improve utilization and recycling of soil nutrients for forage use.
- Reduce excess subsurface water or control water table depths.
- Provide conditions favorable for target wildlife species.

Example 9–1 Diversification through agroforestry—Continued

Trees are managed at a spacing wide enough to allow adequate light to the understory forage. Generally, canopy cover ranges from 5 to 50 percent depending upon the needs of the forage species and the desired production level. An analysis must be made on what system best meets the objectives of the enterprise. For example, it may be that maximizing the tree production while maintaining 50 percent of potential forage provides the greatest economic return or that managing the trees to provide maximum forage potential is the optimum economic return. Once the desired objective is selected, the management of both the trees and understory vegetation is essential for success of the system.

Riparian forest buffers or riparian woody buffers are a corridor of trees, shrubs, grasses, and forbs that are managed to protect and stabilize the stream system from some of the potential adverse impacts of agriculture. These adverse impacts can occur in animal concentration areas, animal waste application areas, or intensively cropped areas with potential nutrient and sediment impacts.

The primary purposes of a riparian forest buffer are:

- Protect near-stream soils from overbank flows.
- Trap and sequester chemicals or sediment transported by surface and subsurface flows from adjacent land uses.
- Provide shade, detritus, and large woody debris for the enhancement of the instream habitat.
- Provide wildlife habitat.

Riparian forest buffers must be sufficiently wide to achieve the primary purpose. They are generally from 15 to 100 feet wide.

Many opportunities are available for agroforestry to be incorporated into the traditional farm and ranch operation. Trees and agronomic crops or forages can be used in combination to solve specific problems, enhance the economies of the existing operation or provide opportunities for additional economic, environmental, or social benefits. Trees can provide the opportunity to utilize vertical space not typically used in conventional agricultural systems. The systems described in this section are only examples of some of the more typical systems that may be used. As technology or needs develop, expanded or new systems can be developed and tested to address unique situations and problems.

600.0903 Technical assistance policy and responsibilities

All enterprises should be managed so that the natural resources upon which they depend are maintained or improved. When planning and implementing any grazing land enterprise, the basic item that must be considered is the impact of the enterprise on the natural resources: soil, water, air, plants, and animals. The enterprise must also be compatible with other enterprises that are or will be in operation on the land unit.

The NRCS conservationist can assist the landowner in any planning stage. If the landowner is just beginning to think of diversifying, then the NRCS conservationist can assist with the identification of grazingland-based alternative enterprises and the evaluation of each alternative. If the landowner has already selected and is about to begin a new enterprise or is already operating it, then the NRCS conservationist can assist with the identification of alternative conservation practices and resource management systems and the evaluation of each of these alternatives.

It is not the NRCS conservationist's responsibility to select the appropriate enterprise for diversification; however, as with any land use, it is the NRCS conservationist's responsibility to provide assistance to the landowner or manager for conservation planning that meets the needs of the soil, water, air, plant, and animal resources while meeting the landowner's or manager's objectives. The NRCS conservationist can provide appropriate natural resource data, interpretations, and other information that will assist the landowner or manager to make the appropriate enterprise selection that will not adversely affect the natural resources.

NRCS conservationists who work with owners and managers of grazing lands should be thoroughly familiar with conservation practices that meet the needs of the natural resources and enhance any enterprise applicable to grazing lands within the local area. Conservationists should acquire enough information about various grazing land related enterprises to enable themselves to discuss the effects on the natural resources and how to present alternative resource management systems that complement the enterprise and adequately treat any resource concern.

NRCS helps landowners and managers evaluate resource potential of their lands for various grazingland-based enterprises. When providing assistance to these people, an assessment of current conditions of the plant community and other resources is made. This assessment along with a description and methods for achieving the desired resource conditions and plant community are provided. Conservationists assist in planning for the maintenance or improvement of the resources necessary for the selected grazing land enterprises desired by the cooperator. Conservationists also provide the landowner or manager with technical assistance in applying conservation practices and implementing the total conservation plan. Periodic followup assistance is also provided to help the landowner or manager assess and evaluate the success of the conservation treatment and identify further needs of the grazingland-based enterprise.

Assistance will be given in accordance with the National Planning Procedures Handbook (NPPH). All soil, water, air, plant, and animal resource concerns will be within the quality criteria identified in the local Field Office Technical Guide (FOTG).

Range conservationists, forage agronomists, foresters, plant material specialists, recreation specialists, economists, biologists, soil scientists, and other appropriate specialists need to work as a team to prepare local Field Office Technical Guide information. Information, such as plant lists interpreted for recreation enterprises and soils interpretations for various land uses, provides knowledge for effective conservation planning.

Appropriate local technical information must be incorporated into each section of the FOTG. Section I (General Resource Information) should contain reference information on grazingland-based enterprises that could be found within the field office area. Section II (Soil and Site Information) should contain soil and site interpretations for those potential enterprises that could be found within the field office area. Section III (The Five Resource Concerns and Conservation Management Systems) should contain scenarios for the most commonly found enterprises and their typical resource concerns. These scenarios will include sample conservation practices within Resource Management Systems that treat the resource concerns to acceptable quality criteria. Section IV (Conservation Practice Standards) should contain the conservation practice standards, adapted for local use, appropriate for use on the various grazingland-based enterprises within the field office area. Section V (Conservation Effects for Decisionmaking) will present a framework for decisionmaking that contains a benchmark condition without conservation and the conditions that would be expected with conservation treatment for each scenario contained in Section III.

600.0904 Decision process for selection of alternative enterprises

The landowner or manager must consider several factors when deciding upon the implementation of an alternative enterprise. These physical, institutional, economic, and social factors help identify possible alternatives, the consideration of the alternatives, and the implementation of alternatives chosen for the land unit.

For example, if a landowner is considering adding a fee-hunting enterprise to the existing operation, then the physical characteristics of the land and related resources will dictate whether the enterprise is possible. Some of the physical factors to consider are:

- Are there huntable populations of game species?
- Is there adequate habitat?
- Is the land unit large enough?
- Will the enterprise require additional facilities?

Examples of institutional factors to consider are:

- Do state laws and regulations allow such an enterprise?
- Is there sufficient information available?
- Can technical assistance be received to assist with the decision and with implementation?
- Are there permits to obtain?

Some economic factors to consider are:

- How much capital investment will be needed?
- What will be the return on the investment?
- What will be the annual costs?
- How much annual income will the enterprise generate?
- Will cash flow be adequate and timely to meet the operation's needs?

Examples of social factors are:

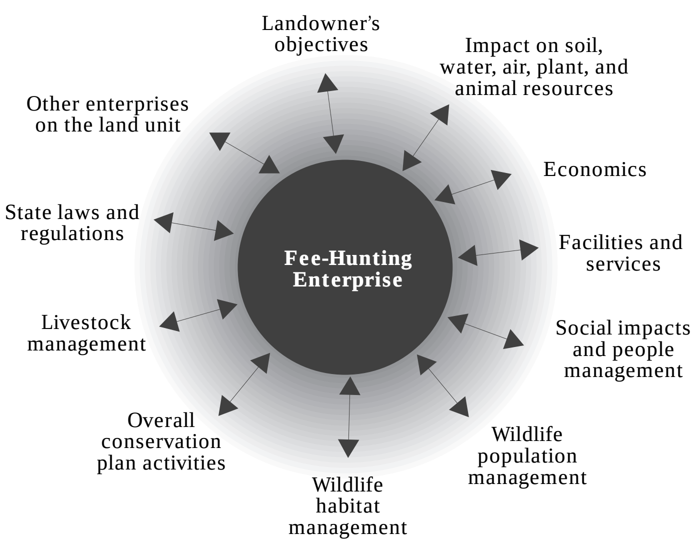
- Is the landowner qualified to operate the enterprise?
- Does the landowner desire to deal with the public, if necessary?
- Will the public accept this type of enterprise in their local area?
- Will the enterprise conflict with other enterprises on the land unit?

- Does the landowner have adequate labor to operate the enterprise?
- Is there a demand for this enterprise?

Diversification of enterprises may be possible on many grazing lands, but careful thought must be given to all possible interactions in the planning and implementation of the new enterprise. Figure 9–1 illustrates the complexity of possible interactions with a hunting enterprise used as an example. Examples 9–2 and 9–3 outline the consideration of factors for planning fee hunting and recreational enterprises, respectively.

The selection of an additional enterprise or significant change to an existing enterprise should be done following a full inventory of existing conditions and resources and an evaluation of the effects the enterprise will have on the resources and the operation as a whole. Obviously, the NRCS is concerned with assisting the entrepreneur with the inventory and evaluation of the human considerations and the soil, water, air, plant, and animal resources. The NRCS can also assist with interpretation of effects of, and upon, other enterprises, laws and regulations (State, Federal, and local), economics, facilities, services, social impacts, and overall conservation plan activities. For guidance in the analysis process, see Worksheet for Simple Analysis of an Enterprise Alternative (exhibit 9–1).

Figure 9–1 Interactions of a hunting enterprise with other factors



Example 9–2 Consideration of factors for a fee hunting enterprise

Physical factors

What species will be hunted?
Is there an adequate population to hunt?
How many of each species can be harvested?
Could overharvest be a problem?
What will be the expected hunter success ratio?
How many hunters could be on the property at the same time?
How many hunters could be on the property during the season?
Is the habitat being properly managed for the species of concern?
Is the land unit large enough to support hunting activities?
Are facilities adequate? Will any other facilities be needed?
Are roads adequate to handle increased traffic?
Are fences, gates, and stream crossings adequate and well marked?
Have potential dangerous situations been identified and taken care of?

Economic factors

Will the enterprise require an initial investment? If so, how much?
Will returns from hunters exceed the added costs of managing a hunting operation?
What is the economic value of the experience to the hunter?
What price should be charged?
Can fees be collected at intervals to spread the cash flow?
Should different hunting packages be offered (i.e., day hunts versus season hunts, guided versus nonguided, multiple opportunities such as deer and quail hunting, lodging provided versus no lodging)?
What will be the expected increase in maintenance costs to facilities, fences, roads, gates, and watering facilities resulting from potential damage caused by hunters?
What will be the expected labor costs?
Can liability insurance be obtained and what will it cost?
Will livestock losses increase? If so, by how much?

Institutional factors

Does the landowner or manager have a wildlife management plan?
What is the season on the game?
Does the season fit with ranch operations?
Will there be competition with other enterprises for labor, facilities, or other considerations during the hunting season or at other times of the year?
Are there special permits the landowner must obtain?
Is technical assistance or financial assistance available?

Example 9–2 Consideration of factors for a fee hunting enterprise

Social factors

Is there a special group of hunters that should be targeted as potential customers?

Will the expected hunter success ratio be acceptable to the targeted customers?

Is additional labor needed (guides, cooks)

Can adequate labor be obtained?

Is hunting for the selected species an acceptable enterprise in the local area (i.e., will there be anti-hunting protesters)?

Will a hunting enterprise prevent family and friends from hunting?

Can the ranch setting and hunting operation provide a quality experience?

Will problems with hunters increase or decrease?

Can hunters be managed to reduce livestock losses and property damage?

Can a written hunting lease agreement be developed and used?

Have the expectations of the hunters been ascertained (i.e., trophy hunting, meat hunting, companionship with friends, outdoor experience)? Has the enterprise been designed to provide for these expectations?

Is advertising needed? If so, what kind, where, and when?

Example 9–3 Consideration of factors for planning a recreational enterprise

Physical factors

Does the major recreational activity have an inherent effect on the natural resources? Can this be managed?

Will increased numbers of people or the activities of recreationists have a negative effect on soil, water, air, plants, animals?

Are existing facilities adequate for the new enterprise?

Are facilities properly located?

Will location of fences, livestock watering facilities, roads, and trails be an advantage or disadvantage to the operation of the recreational enterprise?

Will the recreationists adversely effect these facilities?

Could facilities be used in more than one enterprise?

Are there effects on the physical operation of other enterprises? For instance, will recreationists' activities affect livestock movement and implementation of a grazing system?

Will the new enterprise compete for resources (time, labor, capital, land) necessary for another enterprise.

Does it meet landowner's resource management objectives?

Is the recreation enterprise appropriately located to attract customers? (i.e., proximity to a population of potential customers, easily accessible)

Economic factors

Does it meet landowner's economic objectives?

Is it economically viable? Will it pay?

What mix of services or products should be produced or provided?

What is the return on investment? Best returns?

Does the new enterprise have an economic effect on other enterprises?

Will the enterprise have a potential for long-life or will it be a fad? Has an appropriate planning horizon been selected?

Is there a market for the product or service? Will a market outlet need to be established?

Institutional factors

Do laws and regulations allow this enterprise or limit it in any manner?

Is there sufficient information available to operate enterprise?

Is there a problem with liability? Can insurance be obtained? Has the landowner or manager obtained the services of an attorney or insurance agent for liability concerns?

Are there competing and/or complementary enterprises nearby?

Example 9–3 Consideration of factors for planning a recreational enterprise—Continued

Social factors

Is this enterprise acceptable to the local community?

Does the owner or manager possess enough people skills to effectively operate the enterprise?

Can the impact of people on resources be adequately managed?

Can the numbers of people be limited or managed?

Can inexperienced users of resources be adequately trained to help prevent pollution, fires, erosion, and disruption of livestock and wildlife?

Is there a demand for the services or products?

Can labor be efficiently used? Is labor needed for other enterprises at the same time?

Are there cultural resources that need consideration?

Are there sufficient activities available, enough diversity of activities, and quality of experiences to attract repeat customers?

Worksheet for Simple Analysis of an Enterprise Alternative

Enterprise being considered:

Goal for enterprise:

What resources are necessary for the enterprise? Are they available and/or can they be acquired? (Develop checklist on back of worksheet.) YES / NO

Are there laws and/or regulations affecting this kind of enterprise? YES / NO

Is it possible and/or feasible to comply with any pertinent laws and regulations? YES / NO

What effects will desired enterprise have on:

Soil resources? ____________________

Water resources? ____________________

Air resource? ____________________

Plant resources? ____________________

Animal resources? ____________________

Other farm or ranch enterprises or activities? ____________________

Offsite resources? ____________________

How can the enterprise be adapted and/or what conservation practices can be planned to eliminate or reduce to an acceptable level any negative effects?

____

Will adaptation of enterprise or implementation of planned items allow or inhibit goals of enterprise to be met? YES / NO

Will the enterprise meet acceptable economic and managerial goals? YES / NO

Is this a viable enterprise for this farm or ranch? YES / NO

Exhibit 9–1 Worksheet for simple analysis of an enterprise alternative

Resources	Available	Comments
1.________	Yes/No	________
2.________	Yes/No	________
3.________	Yes/No	________
4.________	Yes/No	________
5.________	Yes/No	________
6.________	Yes/No	________
7.________	Yes/No	________
8.________	Yes/No	________
9.________	Yes/No	________
10.________	Yes/No	________
11.________	Yes/No	________
12.________	Yes/No	________
13.________	Yes/No	________
14.________	Yes/No	________
15.________	Yes/No	________
16.________	Yes/No	________
17.________	Yes/No	________
18.________	Yes/No	________
19.________	Yes/No	________
20.________	Yes/No	________
21.________	Yes/No	________
22.________	Yes/No	________
23.________	Yes/No	________
24.________	Yes/No	________
25.________	Yes/No	________
26.________	Yes/No	________
27.________	Yes/No	________
28.________	Yes/No	________
29.________	Yes/No	________
30.________	Yes/No	________

Notes:____

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Chapter 10 Grazing Lands Economics

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Examples

Chapter 10 Grazing Lands Economics

600.1000 General

The grazing lands manager must be concerned with choosing among economically feasible alternatives for the economic survival and prosperity of a grazing lands enterprise. The conservationist must present alternatives that are ecologically sound resource management systems. Economic analysis tools can be used to evaluate and select possible alternatives.

Economic evaluation of conservation practices and systems can be a sensitive subject because it must involve personal information about costs, returns, and production. The conservationist’s objective is not to tell the manager whether an alternative is the correct economic choice for them. The conservationist's responsibility is to offer the manager assistance in evaluation of the economic feasibility of the alternative land uses, conservation practices, and systems.

Economic evaluation of a conservation practice or resource management system (RMS) can be estimated with partial budgeting. Partial budgeting examines only the **change in** costs, returns, and benefits resulting from the practice or RMS.

Knowledge of the science and application of the conservation technologies gives the conservationist and the decisionmaker the various alternative practices that will work for the resource problem or opportunity that exists. Knowledge of economic analysis techniques provides the tools to determine which alternatives are economically feasible (alternatives that will pay). An economically feasible alternative has a net present value (NPV) greater than or equal to zero, a benefit cost ratio (B/C) greater than or equal to one, and an internal rate of return (IRR) greater than or equal to the appropriate discount rate.

Failure to meet economic feasibility criteria does not mean the practice or RMS should not be chosen. Economic feasibility is only one criterion to use in decisionmaking. 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 resource concerns.

Conservation economic information reflects variable planning periods, which are dependent upon physical or economic life of the practice or system, 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. In situations where resources are declining or improving under current management, future without conditions must also be included in the analysis.

600.1001 Policy

NRCS policy allows the use of economic evaluations as one of the tools in planning alternative conservation practices and systems. Economic evaluations are to be used to the extent necessary to help owners and managers of grazing lands select feasible alternatives.

The economic analysis portion of the Grazing Land Applications (GLA) software is the tool predominantly used to conduct economic evaluations on grazing lands conservation practices and resource management systems. For complete instructions and assistance in using the GLA Economic Analysis program, refer to the *Grazing Land Applications User's Guide* or the *Grazing Land Applications Tutorial.*

600.1002 Purpose

The purpose of economic evaluations is to:

- Make decisionmaker(s) aware of the present and potential values of grazing lands.
- Encourage the application of conservation plans by pointing out the economic advantage of applying conservation management systems in the proper sequence.
- Encourage everyone concerned with planning and development of conservation programs to consider the economic impact that alternative land uses and conservation management systems will have on individuals, groups, communities, or regions.
- Help clients and interested publics to understand and appreciate the economic and environmental tradeoffs involved with alternative conservation decisions.

600.1003 Terms and definitions

The 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.

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.

Simple Interest—Simple interest is money paid or received for the use of money, generally calculated over a base period of 1 year at a set interest rate.

$$SI = (p)(i)(n)$$

where:
SI = Interest
p = Principal
i = Rate of interest
n = Number of periods (years)

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.

$$CI = P(1 + i)^n - P$$

where:
CI = Compound interest
n = Number of periods
i = Periodic rate of interest
P = Principal amount of loan or investment

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 someone is willing to take to allow someone else to use their money for 1 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.

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. When a land user considers applying a conservation practice, the opportunity cost is equal to the expected return that could have been earned on some other investment.

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 1 in 25 times in the past, then the risk is calculated to be 4 percent. The land user needs to consider risk and take the management steps necessary to minimize potential failure of any conservation system the landowner chooses to install.

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. A *real* discount rate is calculated by subtracting the desired risk and the expected inflation rate from the nominal borrowing rate.

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 what annual payment must be made to pay off the principle and interest over a given number of years (average annual cost). Also, it is an investment that yields fixed payments over a stated period.

600.1004 Amortization of cost of a conservation practice

A landowner may wish to know what a given conservation practice or system will cost on an annual basis over a given period of years. This can be determined by amortizing the initial cost of the practice over the specified number of years at a given interest rate (see example 10–1). The period of amortization should not exceed the life of the conservation measure or structure. If money is borrowed to make an improvement, the length of the loan determines the period of amortization. If the landowner uses his or her own money, the real or potential alternative uses of capital determines the period of amortization. Generally, the landowner wants to amortize the investment in the shortest time possible consistent with the benefits received. The interest rate is determined by the going rate charged by the lending institutions.

The amortization factors given in table 10–1 are for given rates of interest for given periods of time to retire a debt of $1.

Exhibit 10–1 is a worksheet for amortizing costs of conservation practices. It is available in the exhibits section of this chapter.

Example 10–1 Amortization

Given: A landowner borrows money to build a fence costing $5,000. The landowner borrows this money for 5 years at 8 percent interest and wishes to know what the annual return needs to be to cover the payments.

Solution: $5,000 x 0.25046 (from table 10–1) = $1,252.30 (the required annual payment). The landowner would need to add the expected operation and maintenance costs to this for the total annual returns needed to cover total annual cost of the fence.

600.1005 Economic analysis using net present value and internal rate of return

The economics module of Grazing Land Applications (GLA), as well as other economic software, calculates the Internal Rate of Return (IRR) and the Net Present Value (NPV) for a selected improvement practice based on the inputs provided. Refer to the GLA User's Guide or the GLA Tutorial for instructions to run the program.

The following sections are intended to assist in understanding and interpreting the primary economic analysis outputs from GLA. These are IRR and NPV.

(a) Understanding NPV and IRR

Most of the inputs are not economic terms; they are physical inputs. The inputs are numbers of animal units, calving percentages, calf weights, and other items relative to forage production and animal numbers, and how they are predicted to change because of the improvement practice.

Economic inputs include variable costs, cost of the improvement practice, prices received for products, and a discount rate.

When all the physical and economic inputs are properly made, the software programs take all the **added costs** incurred as a result of the improvement practice and all the **added returns** resulting from the improvement practice, and calculates the NPV and IRR.

Table 10–1 Amortization factors for common interest rates

Number of years	Interest rates 6%	7%	8%	9%	10%	12%
1	1.06000	1.07000	1.08000	1.09000	1.10000	1.12000
2	.54544	.55309	.56077	.56847	.57619	.59170
3	.37411	.38105	.38803	.39505	.40211	.41635
4	.28859	.29523	.30192	.30867	.31547	.32923
5	.23740	.24389	.25046	.25709	.26380	.27741
6	.20336	.20980	.21632	.22292	.22961	.24323
7	.17914	.18555	.19207	.19869	.20541	.21912
8	.16104	.16747	.17401	.18067	.18744	.20130
9	.14702	.15349	.16008	.16680	.17364	.18768
10	.13588	.14238	.14903	.15582	.16275	.17698
11	.12679	.13336	.14008	.14695	.15396	.16842
12	.11928	.12590	.13270	.13965	.14676	.16144
13	.11296	.11965	.12652	.13357	.14078	.15568
14	.10758	.11434	.12130	.12843	.13575	.15087
15	.10296	.10979	.11683	.12406	.13147	.14682
16	.09895	.10586	.11298	.12030	.12782	.14339
17	.09544	.10243	.10963	.11705	.12466	.14046
18	.09236	.09941	.10670	.11421	.12193	.13794
19	.08962	.09675	.10413	.11173	.11955	.13576
20	.08718	.09439	.10185	.10955	.11746	.13388

Net present value and internal rate of return provide land managers with information that helps them to decide:

- Whether the potential returns are acceptable to them.
- Whether the practice or system of practices is how they wish to invest their resources.

NPV and IRR do not provide the answer to the grazing lands manager as to whether to apply the improvement practice.

(1) 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. This is determined by computing the NPV and/or IRR values.

(2) Net present value

The net present value is the difference between returns and costs when compared in present dollars; therefore, if the NPV is zero, then the practice will exactly break even. If NPV is positive, then the practice will have a positive return to the investment in the practice.

Value of today's dollar = Present value

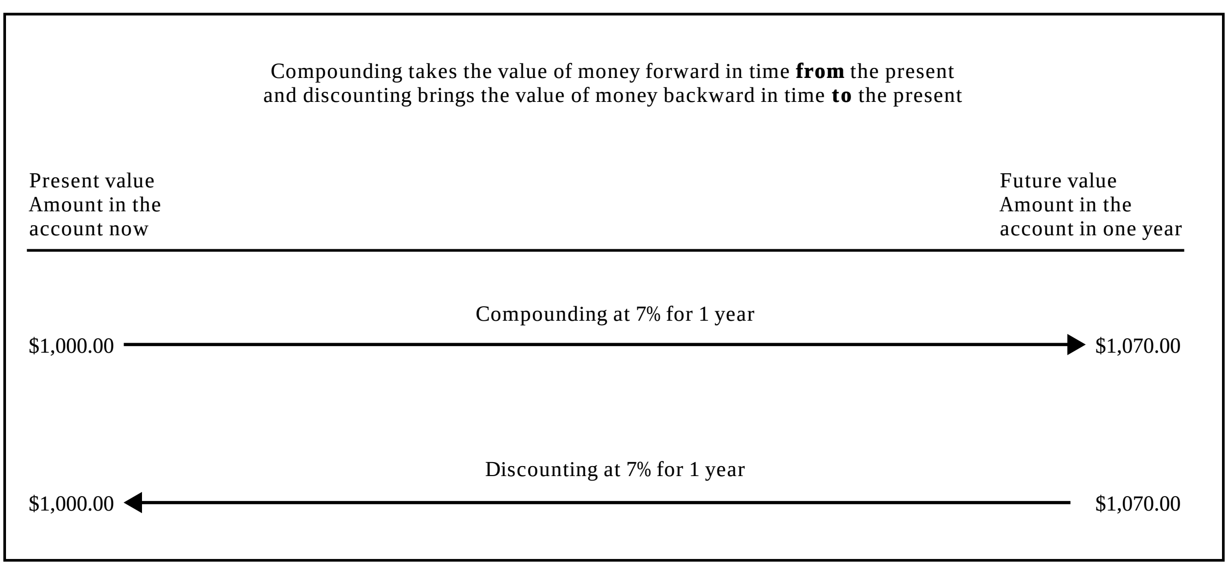
Total returns from an improvement practice calculated in today’s dollars minus the total costs resulting from the improvement practice calculated in today's dollars equals the net value in today's dollars, which is the same thing as net present value.

Dollars expected to be received in the future are equal to today’s dollars when discounted back to the present. Discounting is the reverse of compounding interest in a savings account that has a current balance of $1,000.00 and earns 7 percent compound interest obtaining a balance of $1,070.00 at the end of 1 year (fig. 10–1).

For example, if you are told you will have $1,070 in an account 1 year from now because the account will earn 7 percent interest and you want to know how much you have in the account now, you essentially remove the interest by the economic process of discounting. You will find that you currently have $1,000 in the account. This means the present value of $1,070 a year from now, at a 7 percent discount rate, is $1,000 (fig. 10–1).

Examples 10–2 illustrates one method to obtain net present value.

Figure 10–1 Net present value



Example 10–2 Net present value

Given: An improvement practice that costs $10,000 to implement today is expected to return $1,000 to the grazing lands operator each year for 20 years. The operator chooses a 7 percent discount rate because that is the rate at which money will be borrowed (see Acceptable return later in this chapter).

A total of $20,000 will be returned to the operation. However; this $20,000 is not worth $20,000 today because the $1,000 received each year is not worth the same amount of today's dollars. Each year's $1,000 return must be discounted and summed to find the total present value of the returns.

Solution: Table 10–2 illustrates the discounting of each year's return and sums them to calculate the net present value.

Table 10–2 Discounting of returns of example improvement practice

Year	Expected future return ($)	Discount rate (%)	Present value ($)
1	$1,000	7	$934.60
2	1,000	7	873.40
3	1,000	7	816.30
4	1,000	7	762.90
5	1,000	7	713.00
6	1,000	7	666.30
7	1,000	7	622.70
8	1,000	7	582.00
9	1,000	7	543.90
10	1,000	7	508.30
11	1,000	7	475.10
12	1,000	7	444.00
13	1,000	7	415.00
14	1,000	7	387.80
15	1,000	7	362.40
16	1,000	7	338.70
17	1,000	7	316.60
18	1,000	7	295.90
19	1,000	7	276.50
20	1,000	7	258.40

Total present value of returns resulting from improvement practice	$10,593.80
Cost of improvement practice today (already in present value)	–10,000.00
Net present value	**$ 593.80**

The improvement practice in example 10–2 has an NPV of $593.80. It does better than break even. Today's value of the added returns are $593.80 greater than the added costs. In other words, the practice is expected to pay for itself and is worth an additional $593.80 in today's dollars.

The NPV can be calculated by discounting the added costs and added revenues separately each year and subtracting their sums or by discounting each year's net cash flow and adding them for the total NPV. See tables 10–3 and 10–4 for examples.

Table 10–3 Example net present value (NPV) calculation discounting added costs and added returns separately

Year	Added costs	Added returns	Discount factor (10% rate)	Present value of added costs	Present value of added returns	Net present value
0	5,000		1.00	5,000		
1		500	.91		455	
2		1,500	.83	1,245		
3		2,000	.75	1,500		
4	2,500	3,000	.68	1,700	2,040	
5		2,000	.62	1,240		
6		2,000	.56	1,120		
7		1,643	.51	838		
8		1,000	.47		470	
Total	**7,500**	**13,643**		**6,700**	**8,908**	**2,208**

Table 10–4 Example net present value (NPV) calculation using net cash flow

Year	Added costs	Added returns	Net cash flow	Discount factor (10% rate)	Present value of cash flow	Net present value
0	5,000		–5,000	1.00	–5,000	
1		500	500	.91	455	
2		1,500	1,500	.83	1,245	
3		2,000	2,000	.75	1,500	
4	2,500	3,000	500	.68	340	
5		2,000	2,000	.62	1,240	
6		2,000	2,000	.56	1,120	
7		1,643	1,643	.51	838	
8		1,000	1,000	.47	470	
Total	**7,500**	**13,643**	**6,143**			**2,208**

(3) Internal rate of return

The internal rate of return (IRR) is the compounded interest rate the practice will return based upon the inputs provided. **If the IRR is equal to the borrowing rate (or the rate of an alternative investment opportunity), then the practice will exactly break even.** If it is higher, the practice will have a positive return. In example 10–2 the IRR is greater than the borrowing rate of 7 percent. Hint: An easy way to tell if the IRR is greater than the borrowing rate is to look at the NPV. If the NPV is greater than zero, the IRR will be greater than the borrowing rate. The actual IRR in the example is 7.75 percent. The example does better than break even since NPV is positive and IRR is greater than the borrowing rate.

***(i) What is an acceptable return?*—**The landowner or manager must decide what is acceptable. This differs from person to person. Generally speaking, an acceptable return (an acceptable IRR) is one that meets or exceeds the rate at which the manager would have to borrow money to carry out the practice or a rate which at least equals the rate of return on other investment options.

When land managers set the discount rate in the NPV calculations, they are setting their minimum acceptable rate of return. Therefore, any NPV that equals or exceeds zero is acceptable.

***(ii) Where is the best place to spend the money?*—**In an economic sense, the best place to spend the money is where the largest return will be received. In other words, “Where you get the biggest bang for the buck.” All things being equal (capital investment and time period), this is where the NPV or the IRR, or both, is the greatest. Example 10–3 illustrates five improvement practice options and their associated net present values and internal rates of return.

Example 10–3 Net present values for five improvement practice options

Given: An economic software package calculates returns IRR and NPV for the following five improvement practice options. In this example, the land manager will borrow money at a rate of 8 percent.

Improvement practice	Internal rate of return (%)	Net present value ($)
A	9.3	750
B	8.0	0
C	5.3	–600
D	0	–750
E	–2.4	–1,286

Interpretation of the example IRRs and NPVs

Practice A IRR = 9.3% and NPV = $750
- Does better than break even. (IRR is greater than the borrowing rate of 8%.)
- Exceeds manager’s acceptable rate of return. (NPV is greater than zero.)
- Is the best place to spend the money, all things being equal, among the five options.

Practice B IRR = 8.0% and NPV = $0
- Exactly breaks even. (IRR is equal to the borrowing rate of 8%.)
- Exactly equals the manager’s acceptable rate of return. (NPV is equal to zero.)

Practice C IRR = 5.3% and NPV = –$600
- Does not break even. (IRR is less than the borrowing rate of 8%.)
- Does not meet the manager’s acceptable rate of return. (NPV is less than zero.)

Practice D IRR = 0% and NPV = –$750
- Does not break even. (IRR equals zero, which is less than the cost of borrowing.)
- Does not meet the manager’s acceptable rate of return. (NPV is less than zero.)

Practice E IRR = –2.4% and NPV = -$1,286
- Does not break even. (IRR is less than the cost of borrowing; in fact, it is negative.)
- Does not meet the manager’s acceptable rate of return. (NPV is less than zero)

(b) Key points to understanding NPV and IRR

- Present value is simply the value of today's dollar.
- Net present value (NPV) is the difference between today's value of the added returns and today's value of the added costs.
- An improvement practice is an economically viable option if it, at least, breaks even (NPV is equal to or greater than zero).
- The break-even point hinges around the landowner's or manager's acceptable rate of return (the discount rate).
- If the NPV is equal to or greater than zero, then the internal rate of return (IRR) will be equal to or greater than the land manager's acceptable rate of return (the discount rate).

An understanding of net present value and internal rate of return helps the land manager to make informed decisions regarding application of ecologically sound conservation practices. With these tools, the land manager can also be assured that economically sound practices are selected and applied.

NPV and IRR are decision aid tools. Economics alone does not generally dictate which improvement practice, if any, the land manager will apply. Many other social, political, institutional, and personal preference reasons dictate why the land manager might choose an option that may not break even and may not be the best place to spend the money.

Chapter 11 Conservation Planning on Grazing Lands

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Chapter 11 Conservation Planning on Grazing Lands

600.1100 General

General Manual 180-CPA (Part 409) establishes Natural Resource Conservation Service (NRCS) policy that guides NRCS employees as they provide assistance to clients for planning and implementing resource conservation plans.

The NRCS National Planning Procedures Handbook provides guidance on the "how to" of the planning process as related to the planning policy established by the General Manual.

The National Range and Pasture Handbook (NRPH) provides NRCS policy and the "how to" of grazing lands resource conservation planning. This handbook provides guidance and information concerning the planning process specifically for rangeland, grazed forest land, naturalized pasture, pastureland, hayland, and grazed and hayed cropland. The NRPH provides the technical guidance for developing resource information for inclusion in the Field Office Technical Guide (FOTG).

General Manual 450-TCH, Amendment 4 (Part 401) establishes NRCS FOTG policy. The local 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 site (range ecological sites, forest ecological sites, and forage suitability groups descriptions) information, quality criteria to be met by Conservation Management Systems (CMS's), guidance documents depicting the resource management planning thought process, practice standards for all practices applicable to the local field office area, and examples of the Conservation Effects Decision Making Process.

The Grazing Land Applications (GLA) decision support system part of the Field Office Computer System (FOCS) provides automated assistance in working with grazing lands clients to develop their conservation plans.

600.1101 Objectives

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

- Understand the basic ecological principles associated with managing their land—the soil, water, air, plants, and animals.
- Realize they are part of the complex ecosystem and that their management decisions influence the ecological changes that occur.
- Realize their responsibilities and importance for protecting the environment and maintaining future options for the use of the resource.
- Develop a plan that meets the needs of the soil, water, air, plant, and animal resources and their management objectives.

Conservation plans for grazing lands include decisions for manipulating the plant community to manage the soil, water, air, plant, and animal resources. These five resources are clearly related and respond to each other in an interactive mode. On grazing lands, plants are the resource that directly affects the soil, water, air, and animal resources. Animals are resources, but they are also tools used in managing the plant resource that, in turn, affects soil, water, and air. Therefore, proper use of the grazing and browsing animals in managing plant communities is basic to achieving the desired results of an ecologically sound grazing lands conservation plan.

The major objective on grazing lands is the design and establishment of a grazing management plan that, when coupled with any necessary facilitating and accelerating practices, will meet the quality criteria for the five resources established in the local FOTG and the objectives of the client. When properly implemented, these conservation plans for ranches, dairies, and other livestock farms benefit the client, the local community, and the Nation. **Well-managed** grazing lands, along with the carbon sink they afford, the clean water and air they produce, the recreation they provide, and the plants, livestock, and wildlife they support, make a major contribution to the natural beauty of the landscape and to the maintenance of a quality and economically 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.

600.1102 Developing conservation plans

NRCS assists clients who own or control the land for which conservation plans are being prepared. It must be understood that:

- Clients make the decisions.
- Clients apply the practices and pay for them.
- NRCS is assisting them in preparing their plans.
- Conservation planning is productive when firm decisions have been made by the client. Recording practices in a conservation plan by NRCS personnel when the client has not made the decision to apply the plan, is not appropriate planning leading to resource management systems application. Conservation planning is productive when clients understand their ecosystem to the degree that their daily decisionmaking is impacted and they reflect this with decisions in the conservation plan.

For these reasons, **it is important that clients fully participate in all phases of planning.** Much of the understanding they acquire about the nature of their resources, on which they may base many of their decisions, comes during the inventory stage. Clients should know the kinds of plants on their land, how they grow, how they compete with each other, and how they respond to the intensity, frequency, and duration of harvest. Clients should also know how they can manage plants to achieve their objectives. It is essential to work on the land with the decisionmaker that is empowered to make the necessary resource management decisions.

(a) Areawide conservation plan

Conservation plans generally are developed by an individual client. This client has the authority to make decisions on their property that solve the resource problems and achieve their desired objectives. An individual client's conservation plan is called a *Conservation Plan*. See the National Planning Procedures Handbook (NPPH) page 8.

Clients cannot always solve the resource problems or meet the social objectives of management through their actions on their operating unit. This is a situation where neighbors can work together to develop a conservation plan that will solve their resource problems and take advantage of a socioeconomic opportunities.

Neighbors can work together in many ways to solve resource management problems and meet their socioeconomic objectives. They can work together to:

- Develop a wildlife management and recreational hunting enterprise.
- Solve water quality problems in a stream or lake.
- Manage a riparian area that transverses their land.
- Manage a stream as a fishery and recreational fishing enterprise.
- Develop a hiking, trail riding, canoeing, or birdwatching, or similar enterprise that requires cooperation of all the landowners.

In many instances, landowners not only need to work together to solve problems and improve their socioeconomic status, but need to include public land managers, resource management agencies, cities, districts, and organizations that have a bonafide interest in the activities planned and applied on the private land because of offsite impacts. In these instances an area wide plan can be developed that coordinates the activities of all concerned. See NPPH, Areawide Conservation Plan or Areawide Conservation Assessment, page 8. Many times the Coordinated Resource Management (CRM) process is useful in assisting all the interested parties to come together for direct participation in the planning process. In this way all that have a vested interest in the management and use of the identified area can have ownership in the plan that results. See Coordinated Resource Management in the NPPH, page 11.

600.1103 Conservation planning process

(a) Preplanning

Preplanning is of major importance to the effectiveness of the planning process. Preplanning for an individual ranch or livestock farm includes the following activities.

- Gather materials and information needed for the conservation planning process, such as:
  - — Maps (aerial, topographic)
  - — Soils information (maps and interpretations)
  - — Rangeland ecological site descriptions, forest ecological site descriptions, pasture and hayland suitability group descriptions
  - — Wildlife habitat evaluation procedures
  - — Conservation practice standards
  - — Grazing lands job sheets (similarity index, range trend, range health, pasture health, grazed forest and naturalized pasture health, forage and livestock inventory, grazing management plan, plan narrative)
  - — Equipment, such as forage clipping equipment, sharpshooter spade, knife
  - — Informational material used to demonstrate techniques and principles to land managers.
  - — Computer with Grazing Land Applications decision support system
- Prepare yourself for the planning effort:
  - — Be knowledgeable about the basic ecological principles of pastureland, hayland, rangeland, grazable forest, and naturalized pasture in your work area and be prepared to discuss them in a manner that land managers can understand.
  - — Be able to interpret maps; determine range similarity index, range trend, range health, pasture health, grazed forest health, forage value ratings, wildlife habitat evaluations, forage and animal inventories; and prepare grazing management plans and conservation plan narrative.
  - — Understand all the grazing land conservation practices applicable to your work area.
  - — Understand the husbandry for the livestock enterprises in the area.
  - — Understand the quality criteria for soil, water, air, plants, and animals as specified in Section III of your FOTG.
  - — Understand and be proficient in the nine steps of conservation planning.
  - — Understand and be proficient in the use of the GLA decision support system in FOCS to assist in the planning process.
- Determine as much as possible about clients. This allows you to understand their desires, objectives, and level of knowledge of ecological principles on grazing lands. Secure this information from notes in current conservation plans and visiting with field office personnel who may have worked with the individuals on prior occasions.
- Make firm dates with the clients and discuss the purpose of the planning dates. Ensure that they understand time requirements to schedule sufficient time for the planning dates. Arrive at the assigned time prepared for the day's work.
- Ensure that clients understand the basic knowledge and ecological principles for rangeland, grazed forest land, naturalized pasture, pastureland, hayland, and grazed and hayed cropland. Important items to know and understand are:
  - — Identity of plants on their land
  - — How plants grow
  - — Plant vigor
  - — Effects of kind, time, and degree of grazing use, lack of fire, and other management decisions on the historic edaphic climax plant community or the pastureland plant community
  - — How plants compete with each other in native plant, pastureland, or hayland plant communities
  - — Ecological site concept (explain the soil, plant relationship)
  - — Pasture and hayland suitability groups
  - — Range similarity index
  - — Range trend
  - — Range health
  - — Forest understory reactions to canopy manipulation and grazing management
  - — Forage value ratings
  - — Forage production and habitat values of the different range conditions or plant communities that can exist on a range site

— Multiple use opportunities on grazing lands
— Soil erosion, condition, and contamination
— Waste management on grazing lands
— How grazing lands are managed with livestock to protect or improve water quality and water yield
— Principles of water use by plants and how grazing management impacts it
— How grazing management can protect or improve air quality, such as odors or windblown dust
— Domestic animal need for food, water, and shelter
— Wildlife needs for food, water, and cover

An understanding of these basic principles by clients is essential to the grazing land planning process. Without this knowledge they cannot continuously inventory and analyze their resources, recognize problems and their causes, develop proper and obtainable objectives, formulate and evaluate treatment alternatives, plan a course of action, implement the plan, and continuously evaluate results and make improvements.

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 ensure that clients have this understanding as it relates to their lands.

(b) Nine steps of conservation planning on rangeland, grazed forest, naturalized pasture, pastureland, hayland, and grazed and hayed cropland

Phase I of the planning process includes the first four steps, which are: identify problem, 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 as shown in the National Planning Procedures Handbook (NPPH). Clients generally request NRCS to assist them with particular problems they have identified. If they do not understand the basic ecological principles associated with their problems, 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. For this reason, there is a logical sequence to follow in grazing land conservation planning even though the steps may occur concurrently, in any order, and may be repeated in the planning process.

After teaching or ensuring that the client understands the basic grazing lands ecological principles (part of preplanning), the first step in the planning process is to inventory resources. This is then followed by the analyze resource data, identify problems, and determine objectives planning steps. The following sections describe the planning steps in the order shown in the National Planning Procedures Handbook.

(c) Identify the problem

(1) General

When clients contact NRCS requesting assistance, they have perceived a problem and want to solve it. The perceived problem may actually be a symptom caused by the real problem. An example: the client has recognized streambank erosion occurring, and forage production is decreasing. To the client, these are definite problems, but both are symptoms of the problem of continuous grazing and poor grazing distribution. This problem has caused the plants in the pasture, particularly along the stream, to become very low in vigor and die. While doing so, they have not produced to potential and have been replaced with lower producing plants. The loss of cover and change in composition have decreased water infiltration, increased runoff, increased erosion, increased sediment yield to the stream, lowered water quality, reduced forage production and quality, reduced food and cover for wildlife, and continued to reduce forage for livestock production. The problem was not what the client originally perceived, but the lack of sound grazing management that caused the symptoms.

The NRCS objective is to help land managers recognize real problems, not just symptoms. When poor grazing management is a problem, the NRCS conservationist should not tell managers the problem is poor grazing management; instead, **the conservationist must lead them to recognize that grazing management is the problem.** This can be accomplished by helping them understand their grazing land ecosystems as described in preplanning. The process of recognizing the problem continues from preplanning through the steps of resource inventory and analyzing the resource data.

(2) Standard of recognizing problem

Land managers are led to recognize the symptoms and causes of problems through an understanding of the grazing land ecosystem and the inventory process.

(3) Activities

The activities needed to identify the problem are shown below.

What	How
Clients identify perceived problems	Personal observations, often without the knowledge required to identify the cause of the problem.
Clients develop an understanding of grazing lands ecosystems	NRCS personnel ensure that land managers understands their grazing lands ecosystems by teaching and showing them on their land.
Clients recognize the real problems, the causes of problems	NRCS assists land managers to: • Inventory of the resources in the grazing lands ecosystem. • Identify all the symptoms—soil, air, plant, and animal problems and potential problems—and the causes of each. • Recognize all the causes of symptoms as resource problems that must be addressed in the planning process.

(d) Determine the objectives

(1) General

All clients have a set of objectives. These objectives may or may not include the proper management of the grazing lands ecosystem to accomplish their desired objective. If not, the reason may be a lack of understanding of all the interactions in the ecosystem.

To assist clients in the planning process, objectives must be established by them after they fully understand the grazing lands ecosystem, have inventoried the resources, and identified the problems.

When working with clients, it is often best to not ask for firm objectives until these three processes have been accomplished. Some people do not like to change their mind once they have made a firm commitment to an objective. Assist them to understand and inventory their grazing lands resources and identify the problems before they express their objectives.

(2) Standard

NRCS employee leads the client to develop ecologically and economically sound objectives.

(3) Activities

The activities needed to determine the objectives are shown below.

What	How
Client expresses management objectives	This is accomplished many times without a sound understanding of grazing lands ecological principles, resource inventories, or problems identified.
Client expresses objectives for management that are ecologically, economically, and socially sound	NRCS personnel: • Ensure that client understands the grazing lands ecosystems. • Assist managers in inventorying their grazing lands resources. • Assist managers in recognizing resource problems and causes. • Assist clients to establish objectives that are ecologically, economically, and socially sound.

(e) Inventory the resources

(1) General

Once the client understands the ecological principles of their grazing lands, they generally ask:

"What is the similarity index on my rangeland?"
"What are my range trends?"
"What is the range health?"
"How does my pasture compare to its potential?"

At this point the client is beginning to understand the dynamics of the grazing lands ecosystem and the fact that it is important to determine and understand as much as possible about their grazing lands. They will desire your assistance in inventorying the grazing land resources.

(2) Standard

NRCS employees assist clients in inventorying their grazing lands ecosystems and facilitating practices currently in place, current grazing management schemes, current husbandry practices, livestock performance, wildlife habitat and numbers, etc., to gain complete knowledge of current ecological and performance status. During this process the conservationist should develop an understanding of the client's resources available to implement the conservation plan.

(3) Activities

The activities needed to inventory the resources are shown below.

What	How
Secure needed materials for inventory	NRCS secures maps (aerial photos and soil maps), equipment used in the field, and technical information, such as range ecological site descriptions, forest ecological site descriptions, and pasture suitability groups.
Conduct the inventory	NRCS personnel: • Assist the client to identify range sites, forest sites, and pasture suitability groups on aerial photos from soil interpretations and ground truthing. • Determine similarity index, trend and health, and record on the plan map. • Determine grazing distribution and indicate on map. Identify the key grazing sites and key species. • Record fences, watering facilities, salt and feeding areas, bedding grounds, roads, corrals and working pens, poisonous plant areas, and other important features on the plan map. • Complete wildlife habitat evaluations. • Determine soil erosion, condition, and contamination. • Identify sediment depositions. • Evaluate water quality and water yield. • Determine wildlife numbers and condition. • Develop forage inventory. • Develop livestock and wildlife inventory. • Develop forage and animal needs balance sheet. • Determine husbandry practices and livestock performance. • Identify cultural resources, if present. • Identify endangered plant and animal species and habitat, if present. • Identify active and potential recreation resources. • Identify available resources.

(f) Analyze resource data

(1) General

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 ecosystems and concepts before they can analyze resource data. It is only then that they can understand the relationship of soil, water, air, plant, and animal resources in ecosystems and the causes that create resource problems. The analysis may point out opportunities that the client has not recognized, such as fee hunting, camping, bed and breakfast, renting farm and ranch housing facilities for weekends, trail drives, fishing, hiking, bird-watching, and new livestock enterprises.

(2) Standard

NRCS assists client in analyzing the inventory data so they may recognize resource problems as well as new opportunities.

(3) Activities

The activities needed to analyze resource data are shown below.

What	How
Evaluate the current grazing lands ecosystem in relation to site potentials	NRCS assists land managers to determine: • If the current plant community provides the desired attributes of forage production, habitat, water quality and quantity, air quality, soil protection, and animal performance. • Plant vigor of desired species. • Range trend (on rangeland). • Grazing distribution uniformity. • Forage value rating on grazed forest and naturalized pasture. • Desirability of pastureland plant species for the season and forage production needed. • If pastureland is being managed for desired level of forage quality and quantity. • Forage production and wildlife habitat values in relation to potential for the site. • Balance between forage production and the forage requirements of domestic animals and wildlife. • Effects of the current grazing management program on the plant community, domestic animals, and wildlife of concern. • Significance of cultural resources, if present? • Endangered or threatened plant or animal species, if present. • Opportunity for new enterprises.

(g) Formulate alternative solutions

(1) General

Phase II of the planning process begins with development of alternative solutions. On grazing lands, the alternative solutions **must** include a forage inventory and a grazing management plan. These should be prepared for the first year of the plan. A future forage inventory and grazing management plan representing predicted responses and future grazing management plans should also be prepared.

At least one of the alternatives developed should be a Resource Management System (RMS), meeting the quality criteria for all resource problems identified and the objectives of the client. The Conservation Effects Decision (CED) worksheets generated in FOCS can be used to present impact of the RMS and other alternatives to the client.

In developing Resource Management System alternatives, vegetation management practices will be planned that meet the needs of the plants and animals. Facilitating practices, such as fences and water development, will be planned when needed to enable the application of the planned vegetative management practices. Accelerating practices will be planned when needed to treat specific problems or opportunities that grazing management alone will not solve.

(2) Standard

NRCS employees will assist the client to develop treatment alternatives that meet quality criteria in the FOTG for resource problems identified and that accomplish objectives of the client.

(3) Activities

The activities needed to identify the problem are shown below.

What	How
Develop treatment alternatives	Select the vegetation management, facilitating, and accelerating practices that will meet quality criteria established in local FOTG for all resource problems identified, and meet management objectives of client. Develop sufficient number of alternatives from which client may select an alternative to meet their needs.

(h) Evaluate alternative solutions

(1) General

After alternative solutions are developed, client evaluates them to determine which one best meets their objectives and solves the identified resource problems.

(2) Standard

Effects of each alternative are evaluated individually and compared to benchmark for their ability to solve or alleviate identified resource problems and meet clients objectives.

(3) Activities

The activities needed to evaluate alternative solutions are shown below.

What	How
Determine ecological, economical, and social effectiveness of treatment alternatives	Determine: • Effectiveness of the alternative to achieve the desired plant community. • Effectiveness of each alternative to solve or alleviate each of the soil, water, air, plant, and animal resource problems. • Economic and social feasibility of each alternative. Grazing Land Applications decision support system can assist in the economic evaluation of the treatment alternative. • If the producer has the willingness, values, skills, and commitment to apply the system of practices.

(i) Make decisions

(1) General

After all the alternatives have been evaluated, the client makes a decision on which alternative meets their objectives. This is accomplished by comparing the alternatives to determine which:

- Will best achieve the desired plant community
- Will meet the desired time schedule
- Is the most financially and economically sound
- Is consistent with the client's knowledge and skills
- Is consistent with the client's time and distance restraints

After the alternative is selected, it is recorded in a manner that will assist the land manager in application.

Application of the selected alternative is usually a logical sequence and should be reflected in the schedule of application in the plan narrative. The following logic provides ideas for scheduling application.

If livestock are on the operating unit, then prescribed grazing should be scheduled and applied from the beginning. If fencing and water development must be installed before applying the prescribed grazing plan, then they should normally be installed next.

Water developments generally are installed before fences 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 installed without worry of whether the pond can be built or the planned well will yield a sufficient water supply.

After the fences and water distribution are installed, the prescribed grazing plan can be initiated. Accelerating practices, such as brush management, range planting, prescribed burning, and critical area treatment, can now be performed as fencing and water development will allow the needed grazing management to be applied. Each operating unit will have its unique set of circumstances that dictate the schedule of application. **A major point to remember is that grazing management is the key to the success of all accelerating practices.**

(2) Standard

NRCS leads the client to select alternatives that best meet the manager's objectives. Decisions are recorded in the conservation plan.

(3) Activities

The activities needed to make decisions are shown on page 11–12.

What	How
Client selects best alternatives to meet their objectives	NRCS assists the client in comparing each of the alternative evaluations to determine the one that best meets the objectives.
Schedule of application	NRCS personnel assist the client in developing a long-term schedule of application that ensures proper sequence and timing of applications for success.
Conservation plan prepared	NRCS assists the client in preparing the conservation plan. Client's copy should contain: • Soil and water conservation district agreements. • Conservation plan maps, which should delineate as scale of map permits: — Operating unit boundary — Planned field boundaries, number, and acres — Land use of each field — Location of present and planned enduring practices — Range ecological site delineation — Range similarity index — Range trend — Pasture and hayland species — Pasture and hayland suitability groups — Forest ecological site delineation — Forage value ratings on grazed forest land and naturalized pasture — Other pertinent information, such as roads and livestock handling facilities • Soils map and legend • All inventory data • Forage inventory, livestock inventory, and grazing management plan • Record of treatment alternatives selected and schedule of application • Fact sheets and/or job sheets NRCS case file contains • All information placed in the client's copy • Directions for location of the land unit(s) • List of job sheets furnished to the client • Technical assistance notes • Record of accomplishments

(j) Implement plan

(1) General

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.

The most difficult and complex practices to apply are the grazing management practices—Forage Harvest Management and Prescribed Grazing. These practices, respectively, are the proper application of hayland harvest and the proper manipulation of livestock number, kind, and class through pastures in a time and manner that causes the plant community composition to move toward the one most desired and, at the same time, meet the needs of the livestock and wildlife of concern. For this to be successful, land managers often require close and continuous technical assistance from NRCS personnel as they learn to make the needed plant community observations and adjustments in management strategy.

NRCS does not establish grazing capacities. Neither does it require an agreed-on stocking rate in conservation plans. NRCS assists land users in making their own decisions concerning the number and kinds of animals that can be safely and profitably grazed.

(i) Forage inventory—Clients must have a clear understanding of their forage resources (their limitations and requirements) and of the grazing habits of the animals using the forage. In establishing an initial stocking rate, they should rely on their experiences as much as possible. Local production and stocking information can be used to supplement the client's experiences. This information is in the Ecological Site Descriptions for rangeland, forest land and the Forage Suitability Groups in Section III of the local Field Office Technical Guide.

A forage inventory must be developed that reflects an estimate of forage supply in each management unit (pasture or field) of the operating unit. See chapter 4 of this handbook for guidance in preparing a forage inventory.

(ii) Animal inventory—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 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 used to plan the forage demand in relation to forage production.

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, the time they are expected to be in the management unit must be determined. See chapter 4 for guidance on developing a forage inventory.

(iii) Activities affecting the prescribed grazing schedule—Items affecting the Prescribed Grazing Plan must be identified. Examples of these items include:

- husbandry practices
- nutrient requirements of animals
- forage quality requirements
- practice application requirements
- hunting season needs
- recreation activities, such as camping
- endangered plant and animal species needs
- 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

(iv) Scheduling grazing—After the forage and animal inventory is completed and other factors affecting the prescribed grazing schedule is determined, the prescribed grazing schedule can be developed. This is accomplished by the client scheduling the livestock movement through the pastures in a manner that will:

- Balance forage requirement with forage supply.
- Meet the growth needs of the plants.
- Meet the forage quality needs of the animals.
- Meet health and husbandry needs of the livestock.

- Meet the needs of the wildlife of concern.
- Meet the needs of all other activities in the management and operating units.
- Meet the client's objectives.

Supplemental feed requirements needed to meet the desired nutritional level for the kind and class of livestock and browsing and grazing wildlife of concern will be specified. See chapter 6 for guidance on animal nutrition.

The prescribe grazing plan includes a contingency plan that details potential problems; i.e., drought, and a guide for adjusting the grazing prescription to ensure resource management and economic feasibility. The plan should include how the client will recognize the potential problem 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. See chapter 5 for guidance in design of the Prescribed Grazing practice.

(v) Facilitating and accelerating practices— Facilitating and accelerating practices all require technical design or specific application instructions. NRCS personnel are responsible for providing this information to the client, and the necessary on-site technical assistance during application to ensure technical adequacy and success. See Chapter 5 for a discussion of facilitating and accelerating practices.

(2) Standard

NRCS provides technical assistance to the client to ensure the successful application of the planned practices.

(3) Activities

The activities needed to implement the plan are shown below.

What	How
Application of Prescribed Grazing Schedule	NRCS personnel provide technical assistance to client in the design and application of the prescribed grazing plans. Prescribed grazing plan application is an ongoing process. For many clients it is a change in lifestyle as it becomes a daily decision process that may affect their daily routine. Each management decision made on the operating unit that affects plants, livestock, and wildlife is part of the plan. Application is a daily process. NRCS personnel must provide onsite assistance in a timely manner to continually teach clients to observe their grazing lands, livestock, and wildlife and make the grazing management decisions that will ensure success. GLA decision support system is a tool to assist in this process.
Application of facilitating and accelerating practices	Facilitating 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 the onground technical assistance needed for design and installation. Accelerating practices, such as brush management, weed control, nutrient management, forest improvement, range planting, pasture planting, prescribed burning, waterspreading, critical area treatment, diversions, streambank and shoreline protection, and structures for water control, all need to be installed according to a technical design to ensure success. NRCS shall provide the technical assistance needed for design and installation.

(k) Evaluation of results

(1) General

After clients initiate the application of their grazing land management plans, NRCS should provide followup assistance. As previously stated, grazing management is an ongoing process. The client may need assistance of NRCS personnel to evaluate results of the applied Prescribed Grazing Schedule. It is a continuous learning process for the client and NRCS personnel who are gaining experience. Grazing management can often be fine tuned through adaptive management to more efficiently and effectively accomplish objectives. Many times, clients increase their knowledge in grazing management and desire to change to more intensive grazing management schemes. This often requires a plan revision to include more fences, water development, or both, as well as a completely revised Prescribed Grazing Schedule.

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 and skills of the client increases.

NRCS continuously gathers data from local grazing management application experiences. This information builds data bases of responses to treatment. These response evaluations are necessary to assist future clients in the planning process.

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 followup evaluation 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.

(2) Activities

The activities needed to evaluate results are shown below.

What	How
Provide needed followup for evaluation of results, fine tuning of grazing management plan, revision of plan, and obtaining response data	Make firm date with client for followup evaluation assistance. Explain the purpose of the contact so they may prepare. Review on the ground the 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 the grazing management to cause 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 application of facilitating and accelerating practices. Review those that have been applied to evaluate their continued success. Assist in improving the schedule of application. Assist in recognizing any maintenance needed on applied practices. Gather response data that will improve our ability to predict future responses to treatment. Special attention should be given to gathering response needed for the GLA decision support system. Assist clients to identify new resource problems that need attention. Provide clients new technical information applicable to their resource problems. Assist the clients to revise their conservation plans as needed. Follow the nine steps of conservation planning to accomplish this process.

References

Ahlgren, G.H. 1949. Forage crops. McGraw-Hill Book Co., New York, NY.

Anderson, E.W. 1974. Indicators of soil movement on range watersheds. Journal of Range Management 27:244–247.

Anderson, W.P. 1983. Weed science: Principles, 2nd ed. West Publishing Co., St. Paul, MN.

Archer, S., and F.E. Smeins. 1991. Ecosystem level processes. Grazing Management an Ecological Perspective, chapter 5, R.K. Heitscmidt and J.W. Stuth, eds., Timber Press, pp. 109–139.

Armbrust, D.V. 1968. Windblown soil abrasive injury to cotton plants. Agronomy Journal 60:622–625.

Ashton, F.M., and T.J. Monaco. 1991. Weed science, principle and practice. 3rd ed. John Wiley and Sons, New York, NY.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 1991. Southern forages. Potash and Phosphate Institute, Norcross, GA.

Barker, S., and K. Egen. 1993. Range trend monitoring in southern Arizona. Rangelands 15(4):166–167.

Barnes, K.K., W.M. Carleton, H.M. Taylor, R.I. Throckmorton, and G.E. Vanden Berg (organizers). 1971. Compaction of agricultural soils. American Society of Agricultural Engineers. St. Joseph, MI.

Barnes, R.F., D.A. Miller, and C.J. Nelson. 1995. Forages, the science of grassland agriculture. 5th ed., Vols. 1 and 2, Iowa State University Press, Ames, IA.

Barnes, T.G., R.K. Heitschmidt, and L.W. Varner. 1991. Wildlife. In Grazing Management: An Ecological Perspective, R.K. Heitschmidt and J.W. Stuth (eds), chapter 8, Timber Press, Portland, OR, pp. 179–190.

Baver, L.D. 1961. Soil physics. 3rd ed., John Wiley and Sons, New York, NY.

Bedunah, D.J., and R.E. Sosebee. 1995. Wildland plants, physiological ecology and developmental morphology. Society for Range Management, Denver, CO.

Belnap, J., and J.S. Gardner. 1993. Soil microstructure in soil of the Colorado Plateau: The role of the cyanobacterium *Microcoleus vaginatus.* Great Basin Naturalist 53: 40-47.

Black, C.A. 1957. Soil-plant relationships. John Wiley and Sons, New York, NY.

Blackburn, W.H. 1975. Factors influencing infiltration and sediment production of semiarid rangelands. Nevada Water Resources Res. 11:929–937.

Blackburn, W.H., and M.K. Wood. 1990. Influence of soil frost on infiltration of shrub coppice dune and dune interspace soils in southern Nevada. Great Basin Naturalist 50:41–46.

Blackburn, W.H., F.B. Pierson, C.L. Hanson, T.L. Thurow, and A.L. Hanson. 1992. The spatial and temporal influences of vegetation on surface soil factors in semiarid rangelands. Transactions of the ASAE. 35:479–486.

Blackmore, J. 1958. Do fertilizers pay? *In* Efficient use of fertilizers. FAO Agricultural Studies No. 43, Food and Agricultural Organization of the United Nations, Rome, Italy.

Blaser, R.E., et al. 1986. Forage-animal management systems. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Blue, W.G., and V.W. Carlisle. 1985. Soils for clovers. In Clover Science and Technology, N.L.Taylor (ed.), Amer. Soc. Agron., Madison, WI, pp. 185–204.

Bolton, J.L., and R.E. McKenzie. 1946. The effect of early spring flooding on certain forage crops. Scientific Agriculture 26:99–105.

Bond, R.D., and J.R. Harris. 1964. The influence of the microflora on the physical properties of soils. Effects associated with filamentous algae and fungi. Australian Journal of Soil Research 2:111–122.

Bondi, A.A. 1987. Animal nutrition. John Wiley and Sons, New York, NY.

Bonham, C.D. 1989. Measurements for terrestrial vegetation. Wiley-Interscience, John Wiley and Sons, New York, NY.

Bosworth, S.C. 1995. High potassium forages and the dry cow. University of Vermont, Burlington, VT.

Bower, C.A. 1959. Chemical amendments for improving sodium soils. Agric. Info. Bul. No. 195, U.S. Gov. Print. Off., Washington, DC.

Brady, N.C. 1974. The nature and properties of soils. 8th Ed., Macmillan Publ. Co., New York, NY.

Brady, N.C., and A.G. Norman. 1957, 1965, and 1970. Advances in agronomy. Vols. 9, 17, and 22, Academic Press, New York, NY.

Brady, N.C., and R.R. Weil. 1999. The nature and properties of soils, 12th ed. Prentice-Hall, Inc., Upper Saddle River, NJ.

Briske, D.D. 1991. Developmental morphology and physiology of grasses. Grazing Management, an Ecological Perspective, ch. 4, R.K. Heitschmidt and J.W. Stuth (eds.), Timber Press, pp. 85–107.

Briske, D.D., and J.H. Richards. 1994. Physiological responses of individual plants to grazing: Current status and ecological significance. *In* Ecological Implications of Livestock Herbivory in the West, N. Vavra, W.A. Laycock, and R.D. Pieper (eds.), Society for Range Management, Denver, CO, pp. 147–176.

Bryan, R.B. 1987. Processes and significance of rill development. *In* Bryan, R.B. (ed.), Rill erosion: processes and significance. Catena Supplement, 8, Catena Verlag, Germany, pp 1–16.

Buckner, R.C., and L.P. Bush. 1979. Tall fescue. Agronomy Monograph No. 20, American Society of Agronomy, Madison, WI.

Chapin, F.S., III. 1993. Functional role of growth forms in ecosystem and global processes. *In* J.R. Ehleringer and C.B. Field (eds.), Scaling physiological processes: leaf to globe. Academic Press, San Diego, CA, pp. 287–312.

Castle, E.N., M.H. Becker, and A.G. Nelson. 1987. Farm business management: The decision-making process. Macmillan Publ. Co., New York, NY, 413 pp.

Cathey, H.M. 1990. USDA plant hardiness zone map. Misc. Pub. No. 1475, USDA, Agric. Res. Serv., Washington, DC.

Chepil, W.S. 1945. Dynamics of wind erosion IV. The translocating and abrasive action of the wind. Soil Science 61:167–171.

Chepil, W.S., and N.P Woodruff. 1963. The physics of wind erosion and its control. Advances in Agronomy 15:211–302.

Chessmore, R.A. 1979. Profitable pasture management. Interstate Printers and Publishers, Danville, IL.

Church, D.C. 1991. Livestock feeds and feeding, 3rd ed. Prentice Hall, NJ.

Church, D.C., and W.G. Pond. 1976. Basic animal nutrition and feeding. John Wiley and Sons, New York, NY.

Clements, F.E. 1916. Plant succession: An analysis of the development of vegetation. Carnegie Inst., Washington Pub. 242:1–512.

Committee on Rangeland Classification, Board of Agriculture, National Research Council. 1994. Rangeland health: New methods to classify, inventory, and monitor rangelands. National Academy Press, Washington, DC, 180 pp.

Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, Board on Agriculture, National Research Council. 1989. Alternative agriculture. National Academy Press, Washington, DC, 448 pp.

Cook, C.W., and J. Stubbendieck, eds. 1986. Range research: Basic problems and techniques. Society for Range Management, Denver, CO.

Cooper, J.P. (ed.). 1975. Photosynthesis and productivity in different environments. Cambridge University Press, Cambridge, MA.

Copeland, J.D. 1995. Recreational access to private lands: Liability problems and solutions. National Center for Agricultural Law Research and Information, University of Arkansas, Fayetteville, AR, 215 pp.

Cornell University. 1987. Cornell field crops and soils handbook, Ithaca, NY.

Cornell University. 1992. 1993 Cornell recommendations for integrated field crop management. Cornell University, Ithaca, NY.

Cowan, J.R. 1956. Tall fescue. *In* Advances in Agronomy, Vol. VIII, Academic Press, New York, NY.

Dalrymple, R.L., R. Mitchell, B. Flatt, W. Dobbs, S. Ingram, and S. Coleman. 1999. Crabgrass for forage: management from the 1990s. The Noble Foundation, Ardmore, OK.

Daubenmire, R. 1968. Plant communities: A textbook of plant synecology. Harper and Row, New York, NY.

Dawson, T.E., and F.S. Chapin, III. 1993. Grouping plants by their form-function characteristics as an avenue for simplification in scaling between leaves. *In* Ehleringer, J.R., and C.B. Field (eds.), Scaling physiological processes: leaf to globe. Academic Press, San Diego, CA, pp 313–322,.

Decker, A.M., and T.S. Romingen. 1957. Heaving in forage stands and in bare ground. Agronomy Journal 49:412-415, American Society of Agronomy, Madison, WI.

Dethier, B.E., and M.T. Vittum. 1963. Growing degree-days. New York State Agric. Exp. Sta. Bul. No. 801, Geneva, NY.

Dubos, R.J. 1978. The resilience of ecosystems, an ecological view of environmental restoration. Colorado Assoc. Univ. Press, Boulder, CO.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. JRM 2:104–115.

Dyksterhuis, E.J. 1958. Ecological principles in range evaluation. Bot. Rev. 24:253–272.

Eldridge, D.J., and S.B. Greene. 1994. Microbiotic soil crusts: A review of their roles in soil and ecological processes in rangelands of Australia. Australian Journal of Soil Research 32:389–415.

Emmick, D.L., and D.G. Fox. 1993. Prescribed grazing management to improve pasture productivity in New York. Cornell University and USDA, Soil Conservation Service, Ithaca, NY.

Fahey, G.C. 1994. Forage quality, evaluation and utilization. Proceeding from National Conference on Forage Quality, Evaluation and Utilization, Lincoln, NE.

Farina, M.P.W., P. Channon, and G.R. Thibaud. 2000. A comparison of strategies for ameliorating subsoil acidity. I. Long-Term Growth Effects, Soil Sci. Soc. Amer. J. 64:646–651.

Fehrenbacher, J.B., R.A. Pope, I.J. Jansen, J.D. Alexander, and B.W. Ray. 1978. Soil productivity of Illinois. Univ. Illinois Coop. Ext. Cir. No. 1156.

Fick, G.W., and R.R. Seaney. 1988. Species selection as applied to pasture. *In* Pasture in the Northeast Region of the United States, Workshop Proceedings. Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Forage and Grazing Terminology Committee. 1991. Terminology for grazing lands and grazing animals. Pocahontas Press, Blacksburg, VA.

Forbes, T.D.A. 1988. Researching the plant-animal interface: The investigation of ingestive behavior in grazing animals. Journal of Animal Science 66:2369–2379.

Foy, C.D. 1974. Effects of aluminum on plant growth. *In* The Plant Root and its Environment, Proc. Univ Press of Virginia, Charlottesville, VA, pp. 601–642.

Foy, C.D. 1997. Tolerance of eastern gamagrass to excess aluminum in acid soil and nutrient solution. J. Plant Nutrition 20(9):1119–1136.

Friedel, M.H. 1988. Range condition and the concept of thresholds. *In* Abstracts of the Third International Rangeland Congress, Nov. 7–11, Vigyan Bhavan, New Delhi, pp. 1–3.

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: A viewpoint. Journal of Range Management, Vol. 44, No. 5, pp. 422–426.

Gasbarre, L.C. 1995. Control of gastrointestinal nematodes in dairy cattle under intensive rotational grazing management. SARE Grant Proposal. ARS, Beltsville Agric. Res. Center, Beltsville, MD.

Gee, C.K., and F. McWilliams. 1972. Irrigated pasture costs and production on the Golden Plains Area of Colorado. Colorado State University Cooperative Extension Service, Fort Collins, CO.

Geer, I.W. 1996. Glossary of weather and climate. Amer. Meteor. Soc., Boston, MA.

Gibbens, R.P., J.M. Tromble, J.T. Hennessy, and M. Cardenas. 1983. Soil movement in mesquite duneland and former grasslands of southern New Mexico from 1933 to 1980. Journal of Range Management 36:145–148.

Gilbert, C.F. 1999. Flooding tolerance of eastern gamagrass. Quicksand PMC, USDA-NRCS, Quicksand, Kentucky. *From* Gamagrass Home Page, Gamagrass Seed Co., Falls City, NE.

Gillette, D.A., and T.R. Walker. 1977. Characteristics of airborne particles produced by wind erosion of sandy soil, High Plains of west Texas. Soil Science 123:97–110.

Gillette, D.A., I.H. Blifford, and D.W. Fryrear. 1974. The influence of wind velocity on the size distributions of aerosols generated by the wind erosion of soils. Journal of Geophysical Research 79:4068–4075.

Gillette, D.A., I.H. Blifford, and I.H. Fenster. 1972. Measurements of aerosol-size distribution and vertical fluxes of aerosols on land subject to wind erosion. Journal of Applied Meteorology 11:977–987.

Graffis, D.W., E.M. Juergenson, and M.H. McVickar. 1985. Approved practices in pasture management. 4th ed., Interstate Printers and Publishers, Inc., Danville, IL.

Grafton, W.N., A. Ferrise, D. Colyer, D.K. Smith, and J.E. Miller (eds). 1990. Conference proceedings: Income opportunities for the private landowner through management of natural resources and recreational access. West Virginia University Extension Service, Morgantown, WV, 414 pp.

Grazing Lands Forum. 1987. Multiple use values of grazing lands. Second forum proceedings, October 5–7, 1987, Harpers Ferry, WV, 74 pp.

Grazing Lands Technology Institute. 1977. Inventorying, classifying, and correlating juniper and pinyon communities to soils in Western United States. USDA, Natural Resourc. Conserv. Serv., Fort Worth, TX.

Gustine, D.L., and H.E. Flores. 1995. Phytochemicals and health. Vol. 15, Current Topics in Plant Physiology, An ASPP Series, American Society of Plant Physiologists, Rockville, MD.

Hacker, J.B. (ed). 1981. Nutritional limits to animal production from pastures. Proceedings of an international symposium, St. Lucia, Queensland, Australia, pp. 183–473.

Hagen, L.J. 1984. Soil aggregate abrasion by impacting sand and soil particles. Transactions of the American Society of Agricultural Engineering 27:805–808.

Hanson, A.A. 1990. Practical handbook of agriculture. CRC Press, Boca Raton, FL.

Hanson, A.A., and F.V. Juska. 1969. Turfgrass science. Agronomy Monograph No. 14, American Society of Agronomy, Madison, WI.

Hanson, A.A., D.K. Barnes, and R.R. Hill, Jr. 1988. Alfalfa and alfalfa improvement. American Society of Agronomy, Madison, WI.

Harper, J.L. 1977. Population biology of plants. Academic Press, New York, NY.

Hayes, W.A. 1966. When to cut and graze grasses and legumes. Successful Farming Reprint, Meredith Publishing Company, Des Moines, IA.

Hays, R.L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. USDI Fish and Wildlife Service, FWS/OBS–81/47.

Heady, H.F. 1973. Structure and function of climax. *In* D.N. Hyder (ed.) Arid Shrublands, Proc. Third Workshop U.S./Australia Rangelands Panel. Soc. Range Mgt. Denver, CO.

Heinrichs, D.H. 1970. Flooding tolerance of legumes. Canadian Journal of Plant Science 50:435–438.

Hennessy, J.T., B. Kies, R.P. Gibbens, and J.M. Tromble. 1986. Soil sorting by 45 years of wind erosion on a southern New Mexico range. Soil Science Society of America Journal 50: 391–394.

Hennessy, J.T., R.P. Gibbens, J.M. Tromble, and M. Cordenas. 1983. Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico. Journal of Range Management 36:370–374.

Heppner, M.B. 1961. No summer dormancy. The Farm Quarterly 16(2):60–61, 107–108, 110, 112.

Herrick, J. E., W.G. Whitford, A.G. de Soyza, J.W. Van Zee, K.M. Havstad, C.A. Seybold, and M. Walton. In Press. Soil aggregate stability kit for field-based soil quality and rangeland health evaluations. CATENA.

Hester, J.W., T.L. Thurow, and C.A. Taylor, Jr. 1997. Hydrologic characteristics of vegetation types as affected by prescribed burning. Journal of Range Management 50:199–204.

Hodgson, J. 1990. Grazing management: Science into practice. Longman Scientific and Technical, New York, NY.

Hormay, A.L. 1970. Principles of rest-rotation grazing and multiple-use land management. USDA, Forest Service Training Text-4(2200), 25 pp.

Hormay, A.L., and M.W. Talbot. 1961. Rest-rotation grazing—A new management system for perennial bunchgrass ranges. USDA, Forest Service Production Research Report No. 15, 43 pp.

Hoveland, C.S. 1994. Alfalfa grazing management for yield, quality, and persistence. *In* National Alfalfa Grazing Conference Proceedings, Certified Alfalfa Seed Council, Davis, CA.

Hrivnak, D. (compiler). 1995. Fee hunting and fishing on private land. U.S. Department of Agriculture, National Agricultural Library, Rural Information Center, Beltsville, MD, 18 pp.

Hudson, N. 1993. Field measurement of soil erosion and runoff. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Hughes, H.A. 1980. Conservation farming. Deere and Co., Moline, IL.

Hughes, H.A. 1982. Crop chemicals. Deere and Co., Moline, IL.

Hughes, H.D., D.S. Metcalfe, and I.J. Johnson. 1957. Crop production. Macmillan Publ. Co., New York, NY.

Humphrey, R.R. 1945. Some fundamentals of the classification of range condition. J. Forestry 43:646–647.

Humphrey, R.R. 1958. The desert grassland, a history of vegetation change and an analysis of causes. Bot. Rev. 24:193–252.

Hunsaker, C.T., D.E. Carpenter, and J.J. Messer. 1990. Ecological indicators for regional monitoring. Bulletin of the Ecological Society of America 71 (3):165–172.

Hyder, D.N. 1972. Defoliation in relation to vegetative growth. *In* Biology and Utilization of Grasses, Academic Press, New York, NY.

Interagency Technical Reference. 1996. Utilization studies and residual measurements.

Interagency Technical Reference. 1996. Sampling vegetation attributes.

Ishler, V.A., et al. 1991. Harvesting and utilizing silage. Penn State University Circular 396. University Park, PA.

Jarrett, J.A. 1994. Dry cow ration was too high in potassium. Hoard's Dairyman 139(12):507.

Jarrett, J.A. 1996. What we're learning about growing grasses for dry cows. Hoard's Dairyman 141(6):224.

Jewiss, O.R. 1972. Tillering in grasses—Its significance and control. Journal of the British Grassland Society 27:65–82.

Johansen, J.R. 1993. Cryptogamic crusts of semiarid and arid lands of North America. Journal of Phycology 28:139–147.

Johnson, C.W., and N.E. Gordon. 1988. Runoff and erosion from rainfall simulator plots on sagebrush rangelands. Transactions of the ASAE 31(2):421–427.

Jurgens, M.H. 1988. Animal feeding and nutrition. 6th ed., Kendall/Hunt Publishing Co., Dubuque, IA.

Kabata-Pendias, A., and H. Pendias. 1984. Trace elements in soils and plants. CRC Press, Boca Raton, FL.

Karlen, D.L., G.E. Varvel, D.G. Bullock, and R.M. Cruse. 1994. Crop rotations for the 21st Century. *In* Advances in Agronomy, Vol. 53, Academic Press, San Diego, CA.

Karr, J. R. 1992. Ecological integrity: Protecting Earth's life support systems. *In* R. Costanza, B.G. Norton, and B.D. Haskell (eds.), Ecosystem Health-New Goals for Environmental Management, Island Press, Washington, DC, pp. 223–238.

Kilgore, E. 1989. Ranch vacations. John Muir Publications, Santa Fe, NM, 344 pp.

Kilmer, V.J. 1982. Handbook of soils and climate in agriculture. CRC Press, Boca Raton, FL.

Knight, W.E. 1959. The effect of thickness of stand on distribution of yield and seed production of crimson clover. Mississippi Agricultural Experiment Station Bulletin 583. Mississippi State University.

Koss, W.J., J.R. Owenby, P.M. Steurer, and D.S. Ezell. 1988. Freeze/frost data. Climatography of the U.S. No. 20, Sup. No. 1, Natl. Climatic Data Ctr., Asheville, NC.

Krausman, P.R. (ed.) 1996. Rangeland wildlife. Society for Range Management, Denver, CO, 440 pp.

Lackey, R.T. 1998. Ecosystem management: paradigms and prattle, people and prizes. Renewable Resources Journal 16:8–13.

Langer, R.H.M. 1994. Pastures, their ecology and management. Oxford University Press, Auckland 3, New Zealand.

Lathwell, D.J., and M. Peech. 1973. Interpretation of chemical soil tests. Cornell Experiment Station Bulletin 995, Cornell University, Ithaca, NY.

Lauenroth, W.K., and W.A. Laycock (eds.). 1989. Secondary succession and the evaluation of rangeland condition. Westview Special Studies in Agriculture Science and Policy, Westview Press, 155 pp.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: A viewpoint. J. Range Mgt., Vol. 44, No. 5, pp. 427–433.

Levitt, J. 1956. The hardiness of plants. Agron. Mono. No. 6, Academic Press, Inc., New York, NY.

Luthin, J.N. 1957. Drainage of agricultural lands. Agronomy Monograph 7, American Society of Agronomy, Madison, WI.

Maas, E.V. 1986. Salt tolerance of plants. Applied Agric. Research 1(1):12–25.

Marten, G.C., A.G. Matches, R.F. Barnes, R.W. Brougham, R.J. Clements, and G.W. Sheath. 1989. Persistence in forage legumes. American Society of Agronomy, Madison, WI.

Martin, J.H. and W.H. Leonard. 1949. Principles of field crop production. Macmillan Publ. Co., New York, NY.

Matches, A.G. 1973. Anti-quality components of forages. Crop Science Society of America Special Pub. No. 4, Madison, WI.

Mays, D.A. 1974. Forage fertilization. American Society of Agronomy, Madison, WI.

McClelland, S.D., D.A. Cleaves, T.E. Bedell, and W.A. Mukatis. 1989. Managing a fee-recreation enterprise on private lands. Oregon State University Extension Service, Extension Circular 1277, 17 pp.

McIntyre, D.S. 1958. Soil splash and the formation of surface crusts by raindrop impact. Soil Science 85:261-266.

McKee, G.W., J.V. Raelson, W.R. Berti, and R.A. Peiffer. 1982. Tolerance of eighty plant species to low ph, aluminum, and low fertility. Penn State Univ. Agron. Ser. No. 69, University Park, PA.

Meeker, D.O., Jr., and D.L. Merkel. 1984. Climax theories and a recommendation for vegetation classification: A viewpoint. J. Range Mgt., Vol. 37, No. 5, pp. 427-430.

Meister Publishing Company. 1993. Plant health guide. 1st ed., Willoughby, OH.

Meister Publishing Company. 1995. Insect control guide. Vol. 8, Willoughby, OH.

Metting, B. 1991. Biological surface features of semiarid lands and deserts. *In* Skujins, J. (ed.), Semiarid lands and deserts: Soil resource and reclamation. Marcel Dekkler, New York, NY, pp. 257-293.

Meyer, B.S., and D.B. Anderson. 1954. Plant physiology. D. Van Nostrand Company, Inc., New York, NY, pp. 618–622.

Michels, K., D.V. Armbrust, B.E. Allison, and M.V.K. Sivakumar. 1995. Wind and windblown sand damage to pearl millet. Agronomy Journal 87:620-626.

Millar, C.E., and L.M. Turk. 1954. Fundamentals of soil science. 2nd ed., John Wiley and Sons, New York, NY.

Morgan, R.P.C. 1986. Soil erosion and conservation. D.A. Davidson, (ed.), Longman Scientific and Technical, Wiley and Sons Press, New York, NY.

Morrison, F.B. 1959. Feeds and feeding. 23 Ed. The Morrison Publ. Co., Clinton, IA.

Moser, L.E., D.R. Buxton, and M.D. Casler. 1996. Cool-season forage grasses. Agronomy Monograph No. 34, American Society of Agronomy, Madison, WI.

Murphy, B. 1991. Greener pastures on your side of the fence. 2nd ed., Arriba Publishing, Colchester, VT.

National Academy of Sciences. 1975. Nutrient requirements of sheep. Publ. No. 5, Washington, DC.

National Academy of Sciences. 1976. Nutrient requirements of beef cattle. Publ. No. 4, Washington, DC.

National Oceanic and Atmospheric Administration, National Climatic Data Center. 1997. U.S. national 1961–1990 climate normals. Climatography of the U. S. No. 20, Sta. Climatol. Summ., Asheville, NC.

National Research Council. 1988. Nutrient requirements for dairy cattle. 6th rev. ed., National Academy Press, Washington, DC.

Nevada Range Studies Task Group. 1984. Nevada rangeland monitoring handbook. U.S. Gov. Printing Office:1985-587-052/20001.

Olson, B.E. 1999. Impacts of noxious weeds on ecological and economic systems. *In* Sheley, R.L. and J.K. Petroff (eds.), Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis, OR, pp. 4–18.

Oregon State University. 1987. Developing profitable resource-based recreation on private land. Proceedings 1987 Pacific Northwest Range Management Short Course, Corvallis, OR, 177 pp.

Pellant, M. 1996. Use of indicators to qualitatively assess rangeland health. N.E. West (ed.) Rangelands in a Sustainable Biosphere, Proc. 5th International Rangeland Congress. Society for Range Management, Denver, CO, pp. 434–435.

Pellant, M., P. Shaver, D. Pyke, and J. Herrick. In Press. Interpreting indicators of rangeland health, Ver. 3.0. USDI Bureau of Land Management. Denver, CO.

Perfect, E., R.D. Miller, and B. Burton. 1988. Frost upheaval of overwintering plants: a quantitative field study of the displacement process. Arctic and Alpine Research 20:70–75.

Peterson, M.L., and R.M. Hagan. 1952. Irrigation principles and practices for pastures. *In* Sixth International Grassland Congress Proceedings, Vol. 1:397–403.

Pierson, F.B., W.H. Blackburn, S.S. Van Vactor, and J.C. Wood. 1994. Partitioning small scale spatial variability of runoff and erosion on sagebrush rangeland. Water Resources Bull. 30:1081–1089.

Pimm, S.L. 1984. The complexity and stability of ecosystems. Nature 307:321–326.

Piper, C.V., and L.H. Bailey. 1941. Forage plants and their culture. Macmillan Publ. Co., New York, NY.

Pitt, R.E. 1990. Silage and hay preservation. Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Pomeroy, L.R., E.C. Hargrove, and J.J. Alberts. 1988. The ecosystem perspective. *In* Concepts of Ecosystem Ecology, Ecological Studies, Vol. 67, Springer-Verlag, New York, NY.

Portz, H.L. 1967. Frost heaving of soil and plants. Incidence of frost heaving of forage plants and meteorological relationships. Agronomy Journal 59:341–344, Am. Soc. of Agronomy, Madison, WI.

Prairie Agricultural Machinery Institute. 1996. The stockmans guide to range livestock watering from surface water sources. Prairie Agricultural Machinery Institute, Portage la Prairie, Manitoba, Canada.

Pye, K. 1987. Aeolian dust and dust deposits. Academic Press. San Diego, CA.

Pyenson, L.L. 1951. Elements of plant protection. John Wiley and Sons, New York, NY.

Pyke, D.A. 1995. Population diversity with special reference to rangeland plants. *In* N.E. West, (ed.), Biodiversity of rangelands. Natural Resources and Environmental Issues, Vol. IV, College of Natural Resources, Utah State University, Logan, UT, pp. 21–32.

Quansah, C. 1985. The effect of soil type, slope, flow rate, and their interactions on detachment by overland flow with and without rain. *In* P.D. Jungerius (ed.), Soils and Geomorphology, Catena Supplement 6, Catena Verlag, Germany, pp 19–28.

Rapport, D.J., C. Gaudet, J.R. Karr, J.S. Baron, C. Bohlen, W. Jackson, B. Jones, R.J. Naiman, B. Norton, and M.M. Pollock. 1998. Evaluating landscape health: Integrating societal goals and biophysical process. Journal of Environmental Management 53:1–15.

Rayburn, E.B. 1987. Pasture management facts and figures for New York. Seneca Trail Resource Conservation and Development Council, Franklinville, NY.

Reinhart, R. 1990. Alfalfa management/diagnostic guide. Pioneer Hi-Bred International, Des Moines, IA.

Rhoades, E.D. 1964. Inundation tolerance of grasses in flooded areas. *In* Transactions of the ASAE 7:(2)164–166, 169, American Society of Agricultural Engineers, Saint Joseph, MI.

Rhoades, J.D., and J. Loveday. 1990. Salinity in irrigated agriculture. *In* Agronomy Monograph No. 30, Irrigation of agricultural crops, B.A. Stewart and D.R. Nielsen (eds.), Amer. Soc. Agron., Madison, WI, pp. 1,091–1,131.

Robinson, W.L., and E.G. Bolen. 1989. Wildlife ecology and management. Macmillan Publ. Co., New York, NY, 574 pp.

Rollins, D. (ed). 1988. Recreation on rangelands: Promise, problems, projections. Society for Range Management, Symposia proceedings, February 23, 1988, Corpus Christi, TX, 82 pp.

Ross, T. 1999. Mean number of days with precipitation .01 inch or more. Comparative Climatic Data Table, NOAA, Natl. Climatic Data Ctr., Asheville, NC.

Ross, T. 1999. Cloudiness—mean number of days. Comparative Climatic Data Table, NOAA, Natl. Climatic Data Ctr., Asheville, NC.

Ross, T. 1999. Average relative humidity (%). Comparative Climatic Data Table, NOAA, Natl. Climatic Data Ctr., Asheville, NC.

Sanchez, P.A., W. Couto, and S.W. Buol. 1982. The fertility capability soil classification system: Interpretation, applicability, and modification. Geoderma 27:283–309.

Scheaffer, C.C., R.D. Mathison, N.P. Martin, D.L. Rabas, H.J. Ford, and D.R. Swanson. 1993. Forage legumes: clovers, birdsfoot trefoil, cicer milkvetch, crownvetch, sainfoin, and alfalfa. Station Bulletin 597, Minnesota Agricultural Experiment Station, Saint Paul, MN.

Semple, A.T., and T.E. Woodward. 1946. A pasture handbook. USDA Miscellaneous Publication 194, U.S. Gov. Printing Office, Washington, DC.

Serotkin, N., ed. 1994. The Penn State agronomy guide, 1995-1996. Pennsylvania State University. University Park, PA.

Shaw, B.T. 1952. Soil physical conditions and plant growth. Agronomy Monograph No. 2, Academic Press, New York, NY.

Shiflet, T.N. 1973. Range sites and soils in the United States. *In* Proceedings of the Third Workshop of the United States/Australia Rangelands Panel. Tucson, AZ, March 26-April 5, pp. 23–33.

Singer, M.J. 1991. Physical properties of arid region soils. *In* Skujins, J. (ed.), Semiarid lands and deserts: soil resource and reclamation, Marcel Dekkler, New York, NY, pp. 81–109.

Singer, M.J., and D.N. Manns. 1987. Soils, an introduction. Macmillan Publ., New York, NY.

Smith, D. 1975. Forage management in the north. 3rd Ed., Kendall/Hunt Publ. Co., Dubuque, IA.

Smith, D.D., and W.H. Wischmeier. 1962. Rainfall erosion. Advances in Agronomy 14:109–148.

Smith, E.L. 1988. Successional concepts in relation to range condition assessment. *In* P.T. Tueller (ed.), Vegetation Science Applications for Rangeland Analysis and Management, Kluwer Academic Publishers, Boston, MA, pp. 113–133.

Smith, E. Lamar. 1999. The myth of range/watershed health. *In* Riparian and watershed management in the interior northwest: An interdisciplinary perspective. Oregon State University Extension Service Special Report 1001, Corvallis, OR, pp. 6–11.

Snedecor, G.W., and W.G. Cochran. 1980. Statistical methods. Iowa State College Press, Ames, IA.

Society for Range Management. 1989. A glossary of terms used in range management. Denver, CO, 20 p.

Solbrig, O.T., E. Medina, and J.F. Silva. 1996. Biodiversity and savanna ecosystem processes: A global perspective. Springer, New York, NY.

Sprague, M.A., and M.M. Hoover. 1963. Seedling management of grass-legume associations in the northeast. Northeast Regional Publication No. 42, New Jersey Agricultural Experiment Station, Rutgers, New Brunswick, NJ.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill Book Co., New York, NY.

Steurer, P.M. 1999. Data documentation for TD 9641 daily normal growing degree units to selected base temperatures 1951–1980. National Climatic Data Center, Asheville, NC.

Stoddard, L.A., A.D. Smith, and T.W. Box. 1975. Range management. McGraw-Hill Book Company.

Stringham, T.K., W.C. Krueger, and P.L. Shaver. 2001. States, transitions, and thresholds: Further refinement for rangeland applications. Oregon Agric. Exp. Sta. Spec. Rep. 1024, Oregon State Univ., Corvalis.

Sumner, M.E. 1993. Gypsum and acid soils: the world scene. *In* Advances in Agronomy, Vol. 51, D.L. Sparks, (ed.), Academic Press, Inc., New York, NY, pp. 1–32.

Tanji, K.K. 1990. Agricultural salinity assessment and management. ASCE Manual No. 71, American Society of Civil Engineers, New York, NY.

Task Group on Unity in Concepts and Terminology. 1995. New concepts for assessment of rangeland condition. Journal of Range Management 48:271–282.

Taylor, N.L. 1985. Clover science and technology. American Society of Agronomy, Madison, WI.

Thorne, D.W., and W.H. Bennett. 1952. Soil management for grasslands on irrigated salted soils. *In* Sixth International Grassland Congress Proceedings, Vol. 1:805–812.

Thurow, T.L., W.H. Blackburn, and C.A. Taylor, Jr. 1986. Hydrologic characteristics of vegetation types as affected by livestock grazing systems, Edwards Plateau, Texas. Journal of Range Management 39:505–509.

Thurow, T.L., W.H. Blackburn, and C.A. Taylor, Jr. 1988. Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. Journal of Range Management 41:296–302.

Thurow, T.L., W.H. Blackburn, and C.A. Taylor, Jr. 1988. Some vegetation responses to selected livestock grazing strategies, Edwards Plateau, Texas. Journal of Range Management 41:108–114.

Tilman, D., and J.A. Downing. 1994. Biodiversity and stability in grasslands. Nature 367:363–367.

Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie, and E. Siemann. 1997. The influence of functional diversity and composition on ecosystem processes. Science, Vol. 277:1300–1302

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil fertility and fertilizers. 4th ed., Macmillan Publ. Co., New York, NY.

Toma, M., M.E. Sumner, G. Weeks, and M. Saigusa. 1999. Long-term effects of gypsum on crop yield and subsoil chemical properties. Soil Sci. Soc. Amer. J. 63:891–895.

Tongway, David. 1994. Rangeland soil condition assessment manual. CSIRO. Div. Wildlife and Ecology, Canberra.

Undersander, D.J., B. Albert, P. Porter, and A. Crossley. 1991. Wisconsin pastures for profit: A hands-on guide to rotational grazing. A3529. University of Wisconsin-Extension, Madison, WI.

Undersander, D.J., R.R. Smith, K. Kelling, J. Doll, G. Worf, J. Wedberg, J. Peters, P. Hoffman, and R. Shaver. 1990. Red clover: Establishment, management, and utilization. A3492, University of Wisconsin-Extension, Madison, WI.

United States Department of Agriculture. 1942. Keeping livestock healthy. Yearbook of Agriculture, U.S. Gov. Printing Office, Washington, DC.

United States Department of Agriculture. 1955. Water, the yearbook of agriculture. U.S. Gov. Printing Office, Washington, DC.

United States Department of Agriculture. 1994. Agricultural statistics. U.S. Gov. Printing Office, Washington, DC.

United States Department of Agriculture, Natural Resources Conservation Service. 1996. National soil survey handbook. Issue 4, U.S. Gov. Printing Office, Washington, DC.

United States Department of Agriculture, Natural Resources Conservation Service. 1997. National forestry manual. Washington, DC.

United States Department of Agriculture, Natural Resources Conservation Service. 1997. National range and pasture handbook. Washington, DC.

United States Department of Agriculture, Natural Resources Conservation Service. 1998. Field office guide to climatic data. Natl. Water and Climate Ctr., Portland, OR.

United States Department of Agriculture, Soil Conservation Service. 1976. National range handbook. Washington, DC.

United States Department of Agriculture, Soil Conservation Service. 1981. Land resource regions and major land resource areas of the United States. Agricultural Handbook 296, United States Government Printing Office, Washington, DC.

United States Department of Agriculture, Soil Conservation Service. 1994. Summary report, 1992 national resources inventory. Washington, DC.

United States Department of Commerce, Economics and Statistics Administration and Bureau of the Census, and United States Department of the Interior, Fish and Wildlife Service. 1993. 1991 national survey of fishing, hunting, and wildlife-associated recreation. Issued March 1993, 124 pp.

United States Department of the Interior, Bureau of Land Management. 1973. Determination of erosion condition class. Form 7310-12, Washington DC.

United States Department of the Interior, Bureau of Land Management. 1993. Riparian area management: Process for assessing proper functioning condition. Technical Reference 1737-9, Service Center, Denver, CO.

United States Department of the Interior, Bureau of Land Management. 1996. Sampling vegetation attributes. National Applied Resource Science Center Report BLM/RS/ST-96/002+1730, 163 p.

Vallentine, J.F. 1990. Grazing management. Academic Press, San Diego, CA.

Wagner, R.E. 1989. History and development of site and condition criteria in the Bureau of Land Management. *In* W.K. Lauenroth and W.A. Laycock (eds.), Secondary Succession and the Evaluation of Rangeland Condition, Westview, Boulder, CO, pp. 35–48.

Waldren, R.P., and A.D. Flowerday. 1982. Introductory crop science. Burgess Publ. Co., Minneapolis, MN, pp. 142–155.

Waller, S.S., L.E. Moser, and P.E. Reece. 1985. Understanding grass growth: The key to profitable livestock production. Trabon Printing Company, Kansas City, MO.

Waltman, W.J., E.J. Ciolkosz, M.J. Mausbach, M.D. Svoboda, D.A. Miller, and P.J. Kolb. 1997. Soil climate regimes of Pennsylvania. Penn State Agric. Exp. Sta. Bul. No. 873.

Webb, D.W. 1994. Dairy science handbook. Dairy Science Department, University of Florida.

West, N.E., K. McDaniel, E.L. Smith, P.T. Tueller, and S. Leonard. 1994. Monitoring and interpreting ecological integrity on arid and semi-arid lands of the Western United States. Report 37, New Mexico State University, New Mexico Range Improvement Task Force.

Westoby, M., B. Walker, and I. Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. J. Range Mgt. 42:266–274.

Wheeler, W.A. 1950. Forage and pasture crops. D. Van Nostrand Company, New York, NY.

White, J. 1979. The plant as a metapopulation. Annual Review of Ecology and Systematics 10:109–145.

Whitford, W.G. 1988. Decomposition and nutrient cycling in disturbed arid ecosystems. *In* E.B. Allen (ed.), The reconstruction of disturbed arid lands, American Association for the Advancement of Science, Westview Press, Boulder, CO, pp. 136–161.

Whitford, W.G. 1996. The importance of the biodiversity of soil biota in arid ecosystems. Biodiversity and Conservation 5:185–195.

Whittaker, R.H. 1975. Communities and ecosystems, 2nd edition. Macmillan, New York, NY.

Wicklum, D., and R.W. Davies. 1995. Ecosystem health and integrity. Canadian Journal of Botany 73:997–1000.

Wiens, J.A. 1984. On understanding a non-equilibrium world: Myth and reality in community patterns and processes. *In* Ecological Communities: Conceptual Issues and the Evidence, Princeton University Press, Princeton, NJ.

Wild, A. 1988. Russells soil conditions and plant growth. 11th ed., Longman Scientific and Technical, New York, NY.

Wood, M.K., and W.H. Blackburn. 1984. Vegetation and soil responses to cattle grazing systems in the Texas Rolling Plains. Journal of Range Management 37:303–308.

Workman, J.P. 1987. Range economics. Macmillan Publ. Co., NY. 217 pp.

Worthen, E.L., and S.R. Aldrich. 1956. Farm soils, their fertilization and management,. 5th ed., John Wiley and Sons, New York, NY.

Glossary

Terms used in the Grazing Land Applications (GLA) software are identified by a (GLA) after the term name.

Abbreviations used in this glossary:

Abbr.	abbreviation
e.g.	for example
i.e.	in other words
Syn.	Synonym
n.	Noun
v.	Verb
vi.	Verb intransitive
vt.	Verb transitive

Abiotic Nonliving components of an ecosystem; basic elements and compounds of the environment.

Accelerating practices Practices that supplement vegetative management; help to achieve desired changes in the plant community more rapidly than is possible through vegetative management alone. Included are such practices as seeding, prescribed burning, brush management, and certain other practices that accelerate vegetative change. See Facilitating practices.

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.

Adjustment (GLA) Change in animal numbers, seasons of use, kinds or classes of animals, or management practices as warranted by specific conditions.

Adjustment factor (GLA) A value used to adjust the recommended stocking rate for landscape attributes that limit capture of forage, such as distance to water, slope, barriers, terrain, or site preference.

Aftermath Crop residue and/or regrowth of forage crops, including growth of volunteer plants, used for grazing after a machine harvest.

Age-class (1) A descriptive term to indicate the relative age of plants. (2) Refers to age and class of animal.

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. Metabolic and reproductive disorders in livestock can occur from ingestion of the more toxic alkaloids. They are anti-quality chemicals.

Allelopathy Chemical inhibition of one organism by another.

Allotment An area designated for the use of a prescribed number and kind of livestock under one plan of management.

Allowable use (1) The degree of utilization considered desirable and attainable on various parts of a ranch or allotment considering the present nature and condition of the resource, management objectives, and levels of management. (2) The amount of forage planned to be used to accelerate range improvement.

Alluvium Sediment deposited by streams and rivers.

Amortizing The process of paying initial costs plus subsequent interest costs over a payment period, usually in equal periodic installments.

Anabolic stimulant (GLA) Growth hormones that affect the metabolic efficiency of an animal at the cellular level.

Anhydrous ammonia A nitrogen fertilizer that is 82 percent nitrogen. It is stored in pressurized tanks and injected into the soil to prevent loss to the air. Great care must be taken during application to avoid exposure to a vapor cloud of the ammonia. It is extremely toxic and can cause significant damage to eyes, nasal passages, and lungs.

Animal attributes (GLA) A listing of major domestic and wild animal species, major animal classes, and breed attributes.

Animal class (GLA) Age and/or sex groups of a kind of animal (e.g., cow, bull, calf, weaner steer, weaner heifer, yearling steer, yearling heifer, 2-year old heifer, 3-year old heifer, ox).

Animal-day One day's tenure upon grazing land by one animal. Most specify kind and class of animal. Not synonymous with animal unit day.

Animal-demand Energy requirement of ungulate herbivores based only on animal-related factors, such as body size, stage of life cycle, or production stage.

Animal kind (GLA) The common name of a kind or species of animal (e.g., cattle, sheep, goat, horse, white-tailed deer).

Animal-month A month's tenure upon grazing land by one animal. Must specify kind and class of animal. Not synonymous with animal-unit month.

Animal substitution ratio A numerical ratio of numbers, units or stocking levels of one animal species to another or in partitioning grazing capacity between two or more animal species.

Animal-unit An animal unit (AU) is one mature cow of approximately 1,000 pounds and a calf up to weaning, usually 6 months of age, or their equivalent.

Animal-unit-day The amount of forage required by an animal unit for 1 day. The NRCS uses 30 pounds of air dry forage or 26 pounds of oven dried forage per day as the amount of feed needed to meet this requirement. The pounds of feed needed to meet an animal's daily requirement is usually calculated by taking 2.5 to 3 percent of the animal's body weight.

Animal-unit-equivalent The amount of forage consumed by the different kind and class of animals expressed as a portion of an animal unit.

Animal-unit-month The amount of forage required by an animal unit for 1 month.

Animal-unit-year The amount of forage required by an animal unit for 1 year, equal to 12 AUM's. The NRCS uses 9,490 pounds of oven dried forage as required pounds of forage to equal an animal unit year.

Annual plant A plant that completes its life cycle and dies in 1 year or less.

Annual range Range on which the principal forage plants are self-perpetuating annual, herbaceous species.

Anti-quality chemicals Chemicals produced in some forages that reduce dry matter intake or cause negative responses in animals consuming those forages.

Apical dominance Domination and control of meristematic leaves or buds located on the lower stem, roots, or rhizomes by hormones produced by apical meristems located on the tips and upper branches of plants, particularly woody plants.

Apparent trend An interpretation of trend based on a single observation. Apparent trend is described in the same terms as measured trend except that when no trend is apparent it shall be described as not apparent.

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. See Semiarid.

Arroyo A ravine in southwestern United States.

Ash (GLA) The noncombustible portion of feedstuff, generally nonvolatile minerals.

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.

Association Syn. Plant association.

AU Abbr. for Animal-unit. (Usually no periods)

AUM Abbr. for Animal-unit-month. (Usually no periods)

Autecology A subdivision of ecology that deals with the relationship of individuals of a species to their environment.

Autogate See cattleguard.

Autotoxicity A specific type of allelopathy where the presence of adult plants of a species interferes with the germination and development of seedlings from that species.

Auxin A plant hormone promoting or regulating growth.

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.

Azonal soil A soil lacking a well-defined profile.

Backfiring Ignition of a fire on the leeward (downwind) side of a burn area, resulting in a slow moving ground fire that backs into the wind.

Bactericide A pesticide that kills bacteria.

Bag silo (plastic tube) Long (95 to 135 feet) plastic bags ranging from 8 to 10 feet in diameter that hold silage or haylage. They are filled with a wheeled machine that holds the open end of the bag and stuffs the bag with moist to wet forage. The machine is moved forward as the bag fills. For best forage quality, storage should be during cool weather and not exceed 5 months.

Balage Round baled, 40 to 60 percent moisture, grass or legume forage completely wrapped in plastic film or bagged. For best forage quality, storage should be during cool weather, in a shaded area, and not exceed 5 months.

Balanced operation (1) A livestock enterprise that provides sufficient feed and forage resources during each season to promote continuous satisfactory maintenance and production of its livestock and game. (2) An operation that integrates the kinds, classes, and numbers of animals (livestock or wildlife) to effectively use available forage resources to maintain continuous, sustainable production. (3) An operation that integrates various livestock, wildlife, and recreational enterprises which most effectively uses available forages and other range resources to maintain continuous, sustainable production.

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.

Band-day Tenure by a band of sheep of a given size and class for 1 day.

Bare ground All land surface not covered by vegetation, rock, or litter. See Ground 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.

Bed ground An area where animals sleep and rest.

Bench mark (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.

Biocide A chemical toxic or lethal to living organisms.

Biodegradable Capable of being decomposed by natural processes.

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.

Biomass The total amount of living plants and animals above and/or below ground in an area at a given time.

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.

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.

Bi-pass protein Protein that bypasses or escapes the rumen directly into the intestine, such as dehydrated alfalfa, blood meal, corn gluten meal, distillers grains, and feather meal.

Blackline A backfired area in front of the head fire used for stopping the head fire. Its area (length and width) is determined by the fuel load and risk. Can be burned in advance of prescribed fire. See Firebreak.

Blowout (1) An excavation in an area of soil, usually loose sand, produced by wind. (2) A breakthrough or rupture of a soil surface attributable to hydraulic pressure, usually associated with sand boils.

Body condition score (BCS) (GLA) 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.

Breeding herd The animals retained for breeding purposes to provide for the perpetuation of the herd or band. Excludes animals being prepared for market.

Breed type (GLA) Name of the breed (e.g., Hereford cattle, merino sheep).

Broadcast seeding Process of scattering seed on the surface of the soil prior to natural or artificial means of covering the seed with soil.

Browse (n) That part of leaf and twig growth of shrubs, woody vines, and trees available for animal consumption. (v) Act of consuming browse.

Browse line A well-defined height to which browse has been removed by animals.

Browseway A lane built through a dense brush thicket to provide access by herbivores and people and/or to encourage browse rejuvenation. See Sendero.

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.

Brushland An area covered primarily with brush; i.e., shrubland.

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.

Buck pasture In certain localities, a pasture or paddock for holding rams separately from ewes.

Bucking range In certain localities, range selected for placing rams with ewes.

Buffalo wallow A small natural depression of prairie occasionally containing standing water and having vegetation different from that of the surrounding area.

Buildup or corrective fertilizer applications Nutrient additions, especially phosphorus and potassium, that bring the soil up to the desired level of availability for optimum plant growth.

Bunch grass A grass so-called because of its characteristic growth habit of forming a bunch.

Bunker or horizontal silo Above- or below-ground, lined or unlined storage facility used to store fermented forage material (silage or haylage). Forage material must be machine compacted and covered with an air tight film of plastic to get proper fermentation and reduce storage losses. Unlined ones can leak silage effluent, a pollutant with high biochemical oxygen demand.

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 1 gram of water 1 °C measured from 14.5 to 15.5 °C.

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 maximum stocking rate possible without inducing permanent or long-term damage to vegetation or related resources. The rate may vary from year to year in the same area as a result of fluctuating forage production.

Catchment basin See Guzzler.

Cation exchange capacity The amount of exchangeable cations that a soil can adsorb at pH 7.0.

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.

Cattle walkway Syn. walkway.

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.

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.

Climax See Historic climax plant community.

Climax plant community Syn. historic climax plant community.

Clone A group of plants, growing in close association, derived by asexual reproduction from a single parent plant. Such plants are therefore of the same genetic constitution.

Closed range Any range on which livestock grazing or other specified use is prohibited. See Livestock exclusion.

Close herding Handling a herd in a closely bunched manner, restricting the natural spread of the animals when grazing. See Mob stocking.

Co-grazing Grazing the current year's forage production by more than one kind of grazing animal either at the same time or at different seasons.

Cold stratification Keeping seed in a cool, moist environment for a period of time to simulate overwintering thereby reducing dormancy and increasing seed germination.

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 (plant community) An assemblage of plants occurring together at any point in time, while denoting no particular ecological status. A unit of vegetation.

Community An assemblage of populations of plants and/or animals in a common spatial arrangement.

Community type An aggregation of all plant communities distinguished by floristic and structural similarities in both overstory and undergrowth layers. A unit of vegetation within a classification.

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.

Complementary pasture Short-term forage crop or perennial pasture used for special purposes, to extend grazing seasons, or to enhance productivity of the ranch.

Composition Syn. Species composition.

Concentrate (GLA) A feed or feed mixture for livestock that usually contains less than 18 percent crude fiber.

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.

Condition class (Term is no longer used by NRCS.) Syn. Range condition class.

Conservation The use and management of natural resources according to principles that assure their sustained productivity.

Conservation district A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. Usually a subdivision of state government with a local governing body and always with limited authorities. Generally called a soil and water conservation district.

Conservation plan The recorded decisions of a landowner or operator, cooperating with a conservation district, on how the landowner or operator plans, within practical limits, to use his/her land according to its capability and to treat it according to its needs for maintenance or improvement of the soil, water, animal, plant, and air resources.

Consolidated band A band of sheep made up of several small bands.

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.

Contact herbicide A herbicide that kills primarily by contact with plant tissue rather than as a result of translocation.

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.

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 offsprings are born during a desired period.

Controlled burning Syn. Prescribed burning.

Conversion factor A factor by which stocking rates are partitioned according to the kind or class of animal based on energy requirements. See Animal-unit.

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 planning The process whereby various interest groups are involved in discussion of resource uses and collectively diagnose management problems, establish goals and objectives, and evaluate multiple use resource management.

Corral An enclosure or pen for handling livestock.

Coulee A regional term used for deep gulch or ravine.

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.

Cropland Land used primarily for the production of cultivated crops.

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.

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.

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 Kjedahl 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.

Cured forage Forage, either standing or harvested, that has been naturally or artificially dried and preserved for future use.

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.

Dam (GLA) The female parent of a calf.

Damping off The rapid rotting of seeds or seedlings before they emerge from the soil or the rapid rotting of the stem bases and toppling of seedlings after emergence.

DBH Abbreviation of diameter-at-breast-height of a tree.

Death loss The number of animals in a herd that die from various natural and accidental causes. Usually expressed as a percentage.

Debris Accumulated plant and animal remains.

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.

Decreaser Plant species of the climax vegetation that will decrease in relative amount with continued heavy defoliation (grazing).

Deferment Delay of livestock grazing in an area for an adequate period to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants. 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.

Degenerated range Syn. Deteriorated range.

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.

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.

Desirable plant (GLA) See Plant preference classification.

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. Syn. Degenerated range.

Detritus Fragmented particulate organic matter derived from the decomposition of debris.

Dietary essentials (nutrient) Nutrients that must be orally ingested, in contrast to those which can be manufactured or converted in the animal, such as through microbial symbiosis in the rumen.

Digestible dry matter (DDM) See Digestible organic matter.

Digestible energy (DE) The gross energy of food consumed minus fecal energy. Energy in the feces accounts for the greatest loss of ingested energy. In ruminants the losses are 40 to 50 percent for roughage and 20 to 30 percent for concentrates. In horses fecal losses account for 40 percent of the energy ingested.

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.

Discounting The process of determining the present value of a stream of future financial returns.

Discount rate (GLA) The rate of return that could be earned if you chose an investment other than the one being analyzed; it is the minimum acceptable rate of return from an investment.

Diurnal Active during daylight hours.

Diversity A measure of the number of species and their relative abundance in a community.

Docking v. To surgically shorten an animal's tail.

Doggie Syn. Orphan.

Domestication status (GLA) The animal ranking status used in GLA (i.e., domesticated - controllable, wild/feral - uncontrollable, or domestic wild - wild animals that are being managed in a semi-controllable situation, such as game farms).

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.

Drag An implement used for control of vegetation, e.g., chain drag.

Drainage class A method of classifying the natural drainage condition of the soil that refers to the frequency and duration of soil wetness.

Draw A natural watercourse, including the channel and adjacent areas on either side, which may occasionally overflow or receive extra run-in water from higher adjacent areas; generally having intermittent flows associated with higher intensity rainfall.

Drenching (v) Giving orally a forced dose of a specific solution to an animal, usually to control internal parasites.

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.

Drift fence An open-ended fence used to retard or alter the natural movement of livestock; generally used in connection with natural barriers.

Drill seeding Planting seed directly into the soil with a drill in rows, usually 6 to 24 inches apart.

Dripline The area under the outermost branches of a tree or shrub.

Drip torch Portable equipment for applying flammable liquids to ignite a vegetative area to be burned. Primarily used in prescribed burning.

Drive The moving of livestock under human direction. In cowboy parlance, the term drift is often used in lieu of drive when animals are slowly urged in a certain direction.

Drop band A band of ewes that are giving birth or are expected to give birth within a few days.

Drouth (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.

Drouth (drought) plan The livestock operator's contingency plan to make necessary adjustments during unfavorable years of low forage production.

Dry band A band of ewes without lambs.

Dry flowable A water dispersible granule pesticide formulation rather than being suspended in a liquid carrier. See Flowable. Mixed with water and sprayed. Less inhalation hazard to the user.

Dry matter The amount of a feedstuff remaining after all the free moisture is evaporated out. The feedstuff is placed in a oven at a temperature of 100 to 105 °C.

Dry matter digestibility (DMD) The percentage of energy and protein in forages expressed as dry matter intake minus fecal dry matter divided by dry matter intake times 100.

Dry meadow A meadow dominated by grasses which is characterized by soils that become moderately dry by midsummer.

Dual use Grazing the current year's forage production by two species of grazing animals at the same time. See Co-grazing.

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. See Stock pond.

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.

Early head Flower head (seedhead) of a grass is emerging or emerged from flag leaf sheath, but not shedding pollen.

Earmarking The process of removing parts of the ears of livestock to leave a distinctive pattern for the purpose of designating ownership and identification.

Ecesis Establishment and development of a plant in the plant community.

Ecological site A distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.

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.

Ecotone A transition area of vegetation between two communities, having characteristics of both kinds of neighboring vegetation, as well as characteristics of its own. Varies in width depending on site and climatic factors.

Ecotype A locally adapted population within a species that has certain genetically determined characteristics; interbreeding between ecotypes is not restricted. See Biotype.

Edaphic Refers to the soil.

Edge effect (1) The influence of one adjoining plant community upon the margin of another affecting the composition and density of the populations. (2) The effect executed by adjoining communities on the population structure within the margin zone.

Effective precipitation That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone, to surface runoff, to evaporation, or to rainfall that falls during the dormant season and is gone from the soil profile prior to the growing season.

Effluent (silage) Leachate produced by excess moisture in silage during anaerobic fermentation; often called silage juice or silo juice. If allowed to escape the silo facility, it poses a significant threat to receiving water because of its high biochemical oxygen demand.

Emergency crops Crops, not part of a planned rotation, grown either because of primary crop failure (planting delayed past time needed for maturity or failed growth after planting) or lack of grazeable forage on fields used for pasture, or both.

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.

Emulsifiable concentrate A pesticide formulation with the active ingredient and an emulsifier suspended in a liquid. It mixes well and easy to handle, but is more easily absorbed through the skin. Can be corrosive and of greater toxicity.

Enclosure An area fenced to confine animals.

Endemic Native to or restricted to a particular area, region, or country.

Energy adjustment factor (GLA) An adjustment factor in GLA for the animal's net energy level.

Energy for maintenance Energy used to carry out service functions that are performed by the tissues and organisms for the benefit of the organism.

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.

Epinasty The bending or twisting of twigs or leaf petiole or blades; often used in diagnosis of herbicidal effects on plants.

Eradication (plant) Complete kill or removal of a noxious plant from an area, including all plant structures capable of sexual or vegetative reproduction.

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.

Esophageal-cannula A device used for maintenance and closure of an esophageal fistula.

Esophageal-fistula A permanent, surgically established opening in the esophagus of an animal used for collecting diet samples. See Esophageal-cannula.

Essential element A chemical element that is essential to the life of an organism.

Evapotranspiration The actual total loss of water by evaporation from soil, waterbodies, and transpiration from vegetation over a given area with time.

Evergreen (plant) A plant that has leaves all year round and sheds them more or less regularly through all seasons.

Exchangeable aluminum (extractable) The amount of aluminum extracted in one normal potassium chloride that was on the cation exchange sites in the soil.

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 Practices that control or influence the movement and handling of grazing animals and make it easier to apply vegetative management practices. Facilitating practices include practices, such as water developments, stock trails, walkways, fencing, salting, and herding.

Fauna The animal life of a region. A listing of animal species of a region.

Fecal analysis A process of analyzing livestock manure for diet content of crude protein and digestible organic matter.

Feed (n) Any non-injurious, edible material having nutritive value when ingested. (v) The act of providing feed to animals.

Feed additive (GLA) A feed ingredient provided to animals that improves the conversion efficiency of ruminants.

Feed additives Materials other than the feeds themselves added to diets; e.g., vitamins, mineral supplements, or antibiotics.

Feed conversion (feed efficiency) (GLA) Units of feed consumed per unit of body weight gained; the production (meat, milk) per unit of feed consumed.

Feed ground A designated place on a range where livestock are fed.

Feed reserve Feed stored for future use. See Forage reserve.

Feedstuff profiles (GLA) A list of common feedstuffs and their nutritional value to cattle, sheep, goats, and horses.

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.

Fescue foot A malady in cattle that commonly occurs during late fall and winter grazing of endophyte infected tall fescue. Symptoms range from hind quarter tenderness (slow walk with limp) to gangrene and tissue death of tail, ear, and feet. In extreme cases a tail or hoof may be lost. Constriction of blood vessels at the extremities limits blood flow to them and causes tissue death.

Fescue toxicosis A malady in cattle that commonly occurs during summer grazing of endophyte infected tall fescue. Symptoms include rough hair coat, low weight gain or milk production, rapid breathing, excess salivation, increased body temperature, depressed serum-prolactin levels, poor conception rates, and general unthrifty condition. Cattle spend an inordinate amount of time in shade or water, or wallow in the mud if accessible. This malady is directly linked to ergopeptine alkaloids.

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.

Firebrand A piece of burning wood or other material. A term used in prescribed burning describing a piece of burning material drifting away from the primary fire and capable of starting another fire.

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 Fuelbreak.

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.

First-last grazing A method of using two or more groups of animals, usually with different nutritional requirements, to graze sequentially on the same area.

Fixation A soil process that renders available plant nutrients unavailable or fixed in the soil.

Flail conditioner A machine used to abrade the waxy outer plant layer and break plant stems that have been cut for harvest. It uses steel or nylon free-swinging fingers on a revolving shaft (rotor). It was developed for use on grass hay crops only.

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.

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 allocation The planning process or act of apportioning available forage among various kinds of animals; e.g., elk and cattle.

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, greenchop, 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 (herbage) on-offer (1) Total forage presented to livestock on a pasture at any moment in time. It is equal to available forage times pasture acreage. (2) A term that is synonymous with forage allowance. See Forage allowance.

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 moisture content (GLA) The percent of plant weight that is water.

Forage production The weight of forage that is produced within a designated period in a given area. The weight may be expressed as either green, air-dry, or oven-dry. The term may also be modified as to time of production, such as annual, current year's, or seasonal forage production.

Forage reserve Standing forage specifically maintained for future or emergency use.

Forage suitability groups Soils with similar species adaptation, production potential, and management needs. A planning tool for species selection, practice selection, management options, forage production levels, and recommended initial stocking rates.

Forage utilization The percentage of available forage actually consumed by the grazing animal based on net forage accumulation that occurs prior to and while they occupy the pasture unit.

Forage value (GLA) The classification scheme for determining stocking rates in grazeable forest land based on the minimum percent of preferred species and minimum percent of preferred and desirable species in a stand. Values are very high, high, moderate, and low.

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.

Forb Any broad-leafed herbaceous plant other than those in the Gramineae (or Poaceae), Cyperaceae, and Juncacea families.

Ford A constructed or natural stream crossing for equipment, humans, or animals at a point where water is shallow, footing is firm, and banks are low or inclined for easy approach and exit. The bottom of the channel and approaches are either naturally or artificially paved to facilitate ease of crossing and to reduce muddying of the water.

Forest land (forest) Land on which the historic climax plant community is dominated by trees.

Formulation (1) A pesticide product supplied by the manufacturer for practical use composed of the active ingredient and a carrier. (2) The process of preparing pesticides for practical use carried out by manufacturers.

Frame score A score based on a subjective evaluation of height or actual measurement of hip height, related to slaughter weights at which cattle will grade choice or have comparable amounts of fat cover over the loin eye at the 12th to 13th rib. For horses, frame score is the measure of the size by height at the withers (shoulders).

Free range Range open to grazing regardless of ownership and without payment of fees. Not to be confused with open range.

Free ranging Ability to roam or forage at-will, unrestricted by fences.

Frequency (relative) The ratio between the number of sample units that contain a species and the total number of sample units.

Fresh mulch The primary layer of bulky, coarse, largely undecayed herbage residuum. See Mulch.

Fresh weight The weight of plant materials at the time of harvest. Syn., green weight.

Frontal grazing A stocking method by which ungrazed forage within a management unit is allocated by moving a portable fence ahead of a herd of livestock.

Frost action potential The rating of the susceptibility of a soil to frost heave upward or laterally by the formation of segregated ice lens wedges between soil peds.

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.

Fuelbreak A strategically located block or strip on which existing flammable vegetation has been replaced by vegetation of lower fuel volume and/or flammability and subsequently maintained as an aid to fire control. See Fireline.

Fumigant A volatile chemical that kills pests with a gas or vapor.

Fungicide Any chemical agent that kills or inhibits fungi that cause plant diseases.

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.

Game ranching (game farming) Maintaining game animals under semidomestication and maximum animal management to control breeding, health, nutrition, and production as a ranch based enterprise.

Game range Range that is predominantly grazed by wildlife seasonally or year around. Especially pertinent with migratory big game herds; e.g., winter elk or deer range.

Game refuge An area set aside as a sanctuary for game.

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.

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.

Grade (1) In livestock breeding, an offspring resulting from mating a purebred with a non-purebred or from mating animals not purebred, but having close purebred ancestors. (2) Livestock marketing classification. (3) To evaluate live animals in relation to a standard of quality.

Graminoid Grass or grass-like plant, such as Poa, Carex, and Juncus species.

Grams per plot to kilograms per hectare

Plot size	Multiply grams by:
0.25 M^2	40
1.0 M^2	10
10.0 M^2	1
100 M^2	0.10
400 M^2	0.025

Grams per plot to pounds per acre

Plot size	Multiply grams by:
1.92 ft^2	50
2.4 ft^2	40
4.8 ft^2	20
9.6 ft^2	10
96 ft^2	1

Granule (1) A soil aggregate. (2) A pesticide formulation of dry, ready-to-use, low-concentrate pesticide with a particle size less than 10 cubic millimeters. Drift hazard is low. Contamination hazard to the user is low. Soil applied. May be ingested by birds.

Grass A member of the family Gramineae (Poaceae).

Grassland Land on which the vegetation is dominated by grasses, grasslike plants, and/or forbs.

Grassland agriculture A land management system emphasizing cultivated forage crops, pasture, and rangelands for livestock production and natural resource protection.

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.

Grazeable forest land Land capable of sustaining livestock grazing by producing forage of sufficient quantity during one or more stages of secondary forest succession.

Grazed forest land Land that is currently used for forest land and livestock grazing.

Grazed rangeland Rangeland that is used primarily for the production of livestock. Grazed rangelands include native plant communities and those seeded to native or introduced species, or naturalized by introduced species, that are ecologically managed using range management principles.

Grazer A grazing animal.

Grazier A person who manages grazing animals.

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 district (1) An administrative unit of federally managed, public rangeland established by the Secretary of Interior under the provisions of the Taylor Grazing Act of 1934, as amended. (2) An administrative unit of state, private, or other rangelands established under certain state laws.

Grazing fee A charge, usually on a monthly basis, for grazing a given kind of animal.

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.

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 privilege Permissive use of lands for grazing by livestock.

Grazing right A right to graze specified lands, permanently vested in the beneficiary as specified by the terms of the law or contract.

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 survey The systematic collection of data pertaining to forage resources and other information pertinent to range management. May be either extensive or intensive grazing survey. See Forage inventory.

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 trespass The grazing of livestock on range without proper authority and resulting from a willful or negligent act.

Grazing unit An area of land which is grazed as an entity.

Green chop Mechanically harvested forage fed to animals while still fresh.

Green manure Any crop or plant grown and not harvested that is used to improve the soil's organic matter content and structure. It may or may not be incorporated by tillage.

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. Syn. cover, see Foliar cover.

Ground datum A point on the earth's surface used as reference for measuring the height of aerial photography and for calculating photo scale.

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.

Growth form The characteristic shape or appearance of a plant.

Growth regulator An organic substance effective in minute amounts for controlling or modifying plant processes.

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.

Guzzler A device for collecting and storing precipitation for use by wildlife or livestock. Consists of an impenetrable water collecting area, a storage facility, and a trough from which animals can drink. Syn. Catchment basin.

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, sesquioxides, 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.

Headfiring Ignition of a fire on the windward (upwind) side of a burn area resulting in a fairly rapid moving flame front moving with the wind.

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 (GLA) 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.

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 allowance Weight of forage available per unit animal demand at any instant.

Herbage disappearance rate The rate per unit area at which herbage leaves the standing crop by grazing, senescence, or other causes.

Herbage growth rate The rate of addition of new mass per unit area to the standing crop.

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.

Herder One who tends livestock on a range. Usually applied to the man herding a band of sheep or goats.

Herding The handling or tending of a herd.

Hide factor (GLA) Indicates the thickness of the animal's hide. This factor is used in GLA to compute the insulating value of the animal's hide relative to energy requirements for the thermal environment of the animal (e.g., Holstein-thin, Hereford-thick, Angus-moderate).

High intensity, low frequency Usually a single herd multipasture grazing system, that normally includes a slow rotation for range improvement (usually characterized by relatively long grazing periods and substantially longer rest periods).

Highlining Syn. browse line.

Historic climax 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.

Holding ground An area where livestock are often held during roundups.

Home range The area over which an animal normally travels in search of food.

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 anti-quality 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.

Ice-cream species A slang term used to indicate obvious grazing preference by livestock and game animals. Such species are the first plants grazed by livestock and are often overutilized under excessive grazing.

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 The climax native plants in a community of different plants that, under excessive continuous grazing by livestock, are not selected initially, and increase in abundance. If the heavy grazing continues, livestock will reduce the more palatable plants and shift to the increaser species causing them to decrease in abundance.

Indicator species (1) Species that indicate the presence of certain environmental conditions, range condition, previous treatment, or soil type. (2) One or more plant species selected to indicate a certain level of grazing use. See Key species.

Indigenous Born, growing, or produced naturally (native) in an area, region, or country.

Infestation Invasion by large numbers of parasites or pests.

Infiltration The intake of water into the soil profile. It connotes flow into a substance in contradistinction to the word percolation.

Infiltration rate Maximum rate at which soil under specified conditions can absorb rain or shallow impounded water, expressed in quantity of water absorbed by the soil per unit of time; e.g., inches per hour.

Infiltration velocity The actual rate at which water is entering the soil at any given time. It may be less than infiltration rate because of limited supply of water. Expressed in same units as infiltration rate.

Ingest Nutritive materials consumed by the animal.

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.

Intake adjustment (GLA) A percent of feed consumed either above or below the average Animal Unit Equivalent intake by specific breed types of cattle. Used to calculate feed and nutritional demands in GLA.

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.

Internal rate of return (GLA) An estimate of the average annual rate of return that an investment will produce over a given period. It is the discount rate that results in a Net Present Value of zero.

International feed number (INF) (GLA) A number that applies to a feedstuff and animal kind. This number is used for identification and computer manipulation. It is particularly useful as a tag to recall nutrient data for calculation of diets. Numbers are assigned to individual feed samples by the National Research Council.

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.

Invasion The migration of organisms from one area to another area and their establishment in the latter.

Invert emulsion A water soluble pesticide dispersed in an oil carrier. Forms large droplets that do not drift easily.

Inverter A swathing machine that lifts a swath of cut forage and turns it over to speed drying and avoid weather damage to a hay crop.

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 A single plant species (or in some situations two or three similar species) chosen to serve as a guide to the grazing use of the entire plant community. If the key species on the key grazing area is properly grazed, the entire plant community will not be excessively grazed.

Kid crop The number of kids produced by a given number of does, usually expressed in percent kids weaned of does bred.

Kid house A small structure designed to give shelter to a newborn kid. The doe or the kid is staked so that both remain in or near the shelter.

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.

Lambing ground Range reserved for grazing during lambing period.

Land capability Land capability, as originally used in the United States, is an expression of the effect of physical land conditions, including climate, on the total suitability for use without damage for crops that require regular tillage.

Land use class (GLA) The classification of land based on the primary use and associated management practices (i.e., rangeland, pastureland, hayland, native pastureland).

LD50 The relative degree of toxicity of pesticides to warmblooded animals. Defined as the single lethal dosage by mouth that kills 50 percent of test animals, expressed as mg/kg of body weight.

Leaf area index (LAI) Sum of leaf area expressed as a percentage of ground surface. Leaf area index may exceed 100 percent.

Lessee One who has specified rights or privileges under lease. Syn. permittee.

Lessor One who leases specified rights or privileges.

License See Grazing license or Permit.

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.

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.

Livestock Domestic animals used for the production of goods and services.

Livestock exclusion Land closed to grazing by domestic livestock.

Livestock flexibility The ability to alter the number, kind, or class of animals within a livestock enterprise as warranted by variability in forage, economic, weather, or other conditions.

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.

Local plant code (GLA) A four character code system for identifying the plant common name in GLA

Common Name	Local
Single name	SING
Double Name	DONA
Some Triple Name	STNA

Maintenance Condition in which a nonproductive animal neither gains nor loses body energy reserves.

Maintenance burning The use of prescribed burning to maintain vegetation in a desired condition or to maintain the desired composition. Most often used to reduce woody species.

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.

Maintenance fertilizer applications Nutrient additions that replace losses by one or more of the following: crop removal, erosion, leaching, denitrification, fixation, and volatilization.

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 site potential The kinds of levels of productivity or values of a range site that can be achieved under various management prescriptions.

Management unit (GLA) In GLA this is synonymous with pasture or field number.

Management unit A subdivision of a management area.

Marginal land Land of questionable physical or economic capabilities for sustaining a specific use.

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.

Marsh Flat, wet, treeless areas usually covered by standing water and supporting a native growth of grasses and grasslike plants.

Mast Nuts, acorns, fruit, and similar plant products that may be consumed by animals.

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 coat length (GLA) The maximum length of the animal's hair coat in the coldest period of the year. GLA uses this value to determine body nutritional needs.

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.

Metabolizable energy (ME) The gross energy of feed minus energy in feces, urine, and gaseous products of digestion.

Metric units

To Convert:	To:	Multiply by:
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

Microencapsulate A formulation where particles of a pesticide, either dry or liquid, are surrounded by a plastic coating. Can be used as a slow release product. Safer to the user since active ingredient is not exposed. Hazard to bees if picked up by a worker and taken back to hive. Can settle to bottom of spray tank unless agitated.

Migrant One that moves from place to place.

Miticide A pesticide used to control mites and ticks. Also called acaricide.

Molluscides Poisons used to kill terrestrial mollusks, such as slugs.

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.

National plant symbol (GLA) A unique plant code assigned to each scientific plant name in the National List of Scientific Plant Names.

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.

Naturalized pasture Forest land that is used primarily for the production of forage for grazing by livestock rather than for the production of wood products. Overstory trees are removed or managed to promote the native and introduced understory vegetation occurring on the site. This vegetation is managed for its forage value through the use of grazing management principles.

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.

Nematicide A pesticide used to control nematodes.

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 present value (GLA) Today's worth of a sum of money that is to be available sometime in the future.

Net primary production The net increase in plant biomass within a specified area and time interval; i.e., primary production less that used in metabolic processes.

Niche The ecological role of a species in a community.

Nonconsumed plant (GLA) See Plant preference classification.

Nonprotein nitrogen Sources other than natural protein, such as urea, biuret, and ammonia hydroxide.

Nonjointed See Culmless.

Nonuse (1) Absence of grazing use on current year's forage production. (2) Lack of exercise, temporarily, of a grazing privilege on grazing lands. (3) An authorization to temporarily refrain from placing livestock on public ranges without loss of preference for future consideration.

Nose pump A livestock watering device that operates a plunger by the action of the watering animal pushing on a nose plate. The animal pushes the nose plate forward while drinking water from the cup below it. When it drinks all the water, the nose plate is fully forward. Once realizing the water is gone, the animal raises it head, the nose plate is released, and the plunger it is connected to forces more water into the cup.

Noxious species A plant species that is undesirable because it conflicts, restricts, or otherwise causes problems under management objectives. Not to be confused with species declared noxious by laws concerned with plants that are weedy in cultivated crops and on range.

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.

NPK (GLA) Letters used to designate the elements of nitrogen, phosphorous, and potassium in that order; usually expressed as a percentage by weight of fertilizer.

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 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.

On-off stocker operation A grazing system where the grazing is dictated by moving livestock on and off the ranch, such as early intensive stocking.

Open (GLA) 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

Opportunistic species A species adapted for utilizing variable, unpredictable, or transient environments; characteristic of ephemeral plants.

Opportunity cost The financial returns given up by not putting a factor of production, particularly capital, to a different use.

Organism Any living entity: plant, animal, fungus.

Orphan An offspring whose mother has died.

Outcrop The exposure of bedrock or strata projecting through the overlying cover of detritus and soil.

Oven-dry weight The weight of a substance after it has been dried in an oven at 60 degrees for 48 hours.

Overgrazed range Rangeland that has experienced loss of plant cover and accelerated erosion because of heavy grazing or browsing pressure.

Overgrazing Grazing that exceeds the recovery capacity of the individual species or the plant community.

Overland flow Surface runoff of water following a precipitation event. 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.

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 A limited budgeting procedure used to evaluate a proposed investment in an existing earning enterprise requiring only that additional costs and returns associated with the investment be considered. Results are often expressed in terms of an internal rate of return.

Pasture (1) Grazing lands comprised of introduced or domesticated native forage species that are used primarily for the production of livestock. They receive periodic renovation and/or cultural treatments such as tillage, fertilization, mowing, weed control, and may be irrigated. They are not in rotation with crops. (2) A grazing area enclosed and separated from other areas by fencing or other barriers; the management unit for grazing land. (3) Forage plants used as food for grazing animals. (4) Any area devoted to the production of forage, native or introduced, and harvested by grazing.

Pasture budget A plan developed to allocate forage to one or more groups of livestock over the grazing season. It is used to identify shortfalls and excesses in forage production, and to evaluate alternatives to either meet or reduce forage demand. It indicates when and how much excess forage to harvest and conserve.

Pastureland See Pasture.

Pasture planting Establishing adapted herbaceous species on land to be treated and grazed as pasture.

Peak milk yield (GLA) The maximum daily milk yield from a lactating cow. Usually occurs 60 to 90 days after calf birth.

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.

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.

Percentage allowable (GLA) The percentage that is specified in the relative percentage list of range site descriptions for individual plant species or groups of species. This percentage represents the maximum amount of these species, individually or collectively, that can be counted when determining range condition.

Percolation The flow of a liquid through a porous substance.

Perennial plant A plant that has a life span of 3 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.

Phenotype The appearance of an individual as contrasted with genetic makeup or genotype.

Phenoxy herbicide Syn. Translocated herbicide

Photo interpretation The art and science of identifying objects and conditions from photographs.

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.

Photo toxic Toxic to plants.

Phylogeny The origin and evolution of higher taxa.

Physiological stage (GLA) A unique phase of biological functions of an animal (e.g., growth, pregnancy, lactation).

Phytomass Total amount of plants (including dead attached parts) above and below ground in an area at a given time. See Biomass.

Phytomer One modular unit of a plant; consisting of the leaf, sheath (or petiole), and internode.

Pioneer species The first species or community to colonize or recolonize a barren or disturbed area in primary or secondary succession.

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 kind of climax plant community consisting of stands with essentially the same dominant species in corresponding layers.

Plant community type Each of the existing plant communities that can occupy an ecological site. Several plant community types will typically be found on an ecological site, including the historic climax plant community for that site.

Plant growth curve (GLA) The percent growth occurring on a specific location expressed as a monthly percent of the total yearly production. GLA uses growth curves to project daily, monthly, and yearly production on various vegetative areas. Growth curves reflect differences in ecological condition, composition of warm-season and cool-season annuals, herbaceous species, and level of woody plant components.

Plant preference classification (GLA) Five plant classifications used in GLA:

Preferred plant—Composition of a plant species is greater in the diet of the target animal than found in the area being grazed by this animal.

Desirable plant—Composition of plant species is approximately the same in the diet of the target animal as that found in the area being grazed by this animal.

Undesirable plant—Composition of plant species is lower in the diet of the target animal than is found in the area being grazed by this animal.

Toxic plant—Rare occurrence in the diet of the target animal and, if consumed in any tangible amounts, will result in death or severe illness in the animal.

Nonconsumed Plant—Plant species that would not be eaten under normal extremes in forage conditions, but if no other forage is available, the target animal will attempt consumption although at greatly reduced rates.

Plant succession Syn. succession.

Plant symbol An abbreviation used to indicate the genus and species of a plant.

Plant vigor Plant health.

Plant vigor index An estimate of plant vigor based on measurement of one or a few attributes.

PLS Abbreviation for pure live seed.

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.

Poloxalene An anti-foaming agent fed to prevent legume bloat in ruminants.

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.

Postemergence A herbicide applied after emergence of a specified weed or planted crop.

Potential ADG (GLA) The potential average daily weight gains of domestic livestock. Weight gains expressed as an average daily gain over a given time period.

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 Rainfall; also include snow, hail, and sleet.

Precision farming Variable rate seeding and/or application of fertilizers and pesticides based on very precise mapping of soil conditions and yield variability done by a computerized global positioning system. It requires grid sampling of soils for fertility and organic matter levels. Harvesting equipment is equipped with a yield monitor linked to GPS receivers. Degree of resolution is cost and equipment driven.

Pre-emergence A herbicide applied prior to emergence of a specified weed or planted crop.

Preference See Grazing preference.

Preferred plant (GLA) See Plant preference classification.

Preferred species Species that are preferred by animals and are grazed first by choice.

Premature grazing Grazing before range readiness; may be allowable if done infrequently and followed by adequate rest.

Preparatory crop A residue-producing temporary crop used as part of seedbed preparation to provide mulch into which forage plants can be directly seeded.

Preplant A herbicide applied on the soil surface before seeding or transplanting.

Preplant incorporated A herbicide applied and tilled into the soil before seeding or transplanting.

Prescribed burning The use of fire as a tool to achieve a management objective on a predetermined area under conditions where the intensity and extent of the fire are controlled.

Prescribed grazing The controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective

Prescription fertilization method A procedure that accounts for nutrient inputs from different sources, primarily from soil residual fertility, manure (when available for use), and commercial fertilizer, if needed. Manure and commercial fertilizer applications are coordinated to deliver the proper ratio of nutrients for the crop.

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.

Problem area An area that is difficult to manage because of its shape, size, accessibility or other limiting factors.

Producer Rancher or stock farmer

Productivity The rate of production per unit area, usually expressed in terms of weight.

Propagule Any part of an organism produced sexually or asexually that is capable of giving rise to a new individual.

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 harvest efficiency (GLA) The level of harvest efficiency that meets management objectives for range improvement, sustained current levels of production, and short term use.

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.

Proper woodland grazing Grazing wooded areas at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity and quality of trees and forage vegetation.

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.

` **Quality criteria for native grazing lands** One or several plant communities occupying an ecological site that will meet the minimum quality criteria for the soil, water, air, plant, and animal resources and the landowner's or manager's objectives.

Quiescence A temporary resting phase characterized by reduced activity, inactivity, or cessation of development.

Rain shadow The region of diminished rainfall on the lee side of a mountain range, where the rainfall is noticeably less than on the windward side.

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 Rangelands, native and naturalized pasture, forest and woodlands, and riparian areas that support an understory or periodic cover of herbaceous or shrubby vegetation useful for grazing or browsing by wildlife and/or livestock and that are amenable to range management principles or practices.

Range condition (Term is no longer used by NRCS.) The present status of vegetation of a range site in relation to the historic climax or natural potential plant community for the site. Range condition is expressed as a percentage of the climax plant community presently occurring on the range site and grouped into the following range condition classes:

Range condition class	Percentage of climax plant community present on the site
Excellent	76–100
Good	51–75
Fair	26–50
Poor	0–25

Range forage Forage produced on rangeland.

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 lambing Permitting females to drop their offspring on the rangeland under approximately natural conditions of shelter and forage.

Rangeland Land on which the historic climax plant community is predominantly grasses, grasslike plants, forbs, or shrubs. Includes lands revegetated naturally or artificially when routine management of that vegetation is accomplished mainly through manipulation of grazing. Rangelands include natural grasslands, savannas, shrublands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows

Rangeland ecological site A distinctive kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.

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 normal variability.

Rangeland hydrology The study of hydrological principles as applied to rangeland ecosystems.

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 remote sensing The detection, identification, and assessment of rangelands with a camera, or other imaging device, usually with the aid of aerial or satellite photography.

Rangeland renovation Improving rangeland by mechanical, chemical, or other means.

Rangeland trend The direction of change in an existing plant community relative to the historic climax plant community for the ecological site.

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.

Range suitability The adaptability of a range to grazing by livestock and/or game animals.

Re-entry interval Time span that must pass after application of a pesticide before it is safe to enter the treated area. It applies to people and livestock.

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.

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 feed value (RFV) An index that ranks hay crops relative to the digestible dry matter intake of full bloom alfalfa (RFV = 100).

Remote sensing The measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study. Often involves aerial photography or satellite imagery. See Rangeland remote sensing.

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 native 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 native 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.

Response unit (GLA) A relatively homogeneous area within a management unit in GLA. Response units are defined by soils, range sites, range condition, slope classes, distance to water, barriers, brush densities, past practices resulting in different plant communities, and/or suitability groups.

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. Syn. deferment.

Rest period A period of deferment included as part of a grazing system.

Restricted area An area on which grazing tenure is limited.

Rest-rotation See Grazing system.

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.

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.

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.

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.

Rodent control Measures taken to reduce or control the rodent population of a given area. This may apply to a specific species or rodents in general.

Rodenticides Poisons used to control rats, mice, and other rodents.

Roller conditioner A machine that uses intermeshing and nonintermeshing steel or rubber rollers to crush and crack stems of cut legume forages. It was developed for use on legume hay crops to speed drying without shattering leaves.

Rotary mower A power takeoff driven machine that cuts and shreds plants with a horizontal revolving blade held underneath a metal shroud.

Rotation fertilization method Some nutrients are added in higher amounts than needed for the current crop in the crop rotation. They are later drawn down by a following crop to keep all nutrient levels within acceptable soil loading levels. Often, it expedites manure spreading and utilization of its nitrogen content.

Rotation grazing A type of grazing system and involves moving grazing animals from one pasture to another to achieve a desired management objective.

Rough (1) The accumulation of mature living and dead vegetation, especially grasses and forbs on rangeland. (2) May refer to land surface with uneven terrain.

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.

Roundup The purposeful gathering of animals from a specific area.

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.

Sacrifice area (1) A portion of the range, irrespective of site, that is unavoidably overgrazed to obtain efficient overall use of the management area. The area is generally a small area adjacent to a feed trough, water trough, gate, etc. (2) A fenced-off, small portion of a grazing management unit intentionally overgrazed and heavily trafficked to prevent lasting damage to the entire unit. This is only done for short periods during extreme weather conditions. Site is then deferred from grazing until it recovers (includes reseeding if necessary).

Saline soils Soils with an electrical conductivity greater than 4 millimhos per centimeter that have less than 15 percent of the cation exchange capacity occupied by sodium ions and a pH below 8.5. See sodic soils for a comparison.

Salt ground An area where salt is placed for use by livestock or game; often relocated periodically to achieve improved animal distribution.

Salt lick Spots containing unusually large quantities of salts in the soil where animals consume the soil to obtain salt.

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.

Salvage value (GLA) The value remaining in a piece of equipment or other asset at the end of its intended useful life.

Sample Part of a population taken to estimate a parameter of the whole population.

Sand tank A water development constructed by placing a dam in a rock-bound channel and bonded to bedrock and by using the sand/gravel trap above the dam for water storage.

Saponins Any of the various plant glycosides that form soapy colloidal solutions when mixed and agitated with water. When present in forages, the anti-quality chemical depresses growth and intake of grazers and may worsen bloat in ruminants. However, they also impart resistance in forages to disease and insect pests.

Savanna (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.

Seasonal zone An area of rangeland that livestock and wildlife prefer at certain seasons.

Seed A fertilized ripened ovule of a flowering plant.

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.

Seed certification A system whereby seed of plant cultivars is produced, harvested, and marketed under authorized regulation to ensure seed of high quality and genetic purity.

Seed, dormant Live seed in a nongerminative condition because of internal inhibitions in the seed; i.e., hard seed, or unfavorable environmental conditions.

Seed dribbler A metering device that drops seed onto the track of a crawler tractor for the purpose of being carried forward and pressed into the ground as the tractor passes.

Seed, hard Live seed in a physiological condition that prevents or delays germination, even when a favorable environment exists.

Seedhead The inflorescence (flowering part) of a grass where the seed will develop.

Seed inoculation Treatment of legume seed with rhizobium bacteria before planting to enhance subsequent nitrogen fixation.

Seed purity The percentage of the desired species in relation to the total quantity, including other species, weed seed, and foreign matter. See Pure live seed.

Seed scarification Mechanical or acid treatment of seedcoats to improve moisture absorption and enhance germination.

Seedstock (1) Livestock raised to refine the genetics of a particular breed and sold for breeding purposes primarily. (2) The label applied to a producer of such animals. See Commercial for contrasting term.

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.

Selectivity ratio The fraction or decimal indicating the proportion of the diet contributed by a plant species, species group, or plant part; an expression of relative preference.

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.

Sendero A path or lane cut or dozed through brushy areas to provide access by livestock, pedestrians, or vehicles. A term commonly used in the Southwest.

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.

Sex ratio The ratio existing between the number of male and female animals within a given herd, band, or population.

Shearing pens A general term used to describe the buildings, machinery, pens, and other appurtenances of an establishment where animals are shorn.

Shed lambing Housing and feeding females during the time offspring are dropped.

Shinnery Range vegetation having dwarf oaks as dominants.

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.

Shrink-swell The action of soils that are high in montmorillinite clay content. When wet, the clays expand causing the soil to swell. When the soils dry, the clays shrink leaving cracks in the soil from 1 to 2 inches wide and commonly 6 to 20 inches deep. Expansion of the clays is even more pronounced in sodic soils.

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 similarity index is the percentage of a specific vegetation state plant community that is presently on the site.

Sire (GLA) The male parent of an animal.

Site See Ecological site.

Skylining The development of a line of uniform height of vegetation that gives an illusion of a horizon, usually associated with excessive use of browse. May refer to either top line or under line.

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).

Slugs Terrestrial mollusks without a shell that prey on seedlings.

Snow fence A fence used to retard or alter the movement of snow by wind.

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.

Sodic soil (nonsaline) A soil with an electrical conductivity of less than 4 millimhos per centimeter where exchangeable sodium occupies more than 15 percent of the total cation exchange capacity.

Sodic soil (saline) A soil with an electrical conductivity greater than 4 millimhos per centimeter where exchangeable sodium occupies more than 15 percent of the total cation exchange capacity.

Sod seeding Direct drilling of seed on sites on which no seedbed preparation had been made.

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 Granules formed from the arrangement of primary soil particles (sand, silt, and clay) by flocculation and cementation processes. Plant roots, especially fibrous root systems of grass forage crops, aid in their formation.

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 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 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 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.

Soluble powder A dry pesticide formulation that dissolves readily in water and forms a true solution. It is not very common because few active ingredients are water soluble.

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 allowable (GLA) The maximum percent composition by weight that an individual plant species is expected to contribute to the total composition on a particular site.

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.

Spot grazing Repeated grazing of small areas while adjacent areas are less intensely grazed.

Spray drift The movement of airborne spray particles from the intended area of application; i.e., horizontal displacement.

Spreader dam Syn. water spreader.

Spring Flowing water originating from an underground source.

Spring development Improving spring and seeps by excavating, cleaning, capping, or providing collection and storage facilities.

Spring-fall range Rangeland that is grazed primarily during the spring and fall.

Stable The condition of little or no perceived change in plant communities that are in relative equilibrium with existing environmental conditions; describes persistent, but not necessarily culminating stages (climax) in plant succession. Implies a high degree of resilience to minor perturbations.

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 (GLA) The amount of forage available to a target grazing animal at a given time.

Standing crop The total amount of plant material, in aboveground parts, per unit of space at a given time. It may be modified by the words dead or live to more accurately define the specific type of biomass.

State A condition of an ecological site's characteristics. As characteristics change, there is a transition to a new state. See Vegetation state and Transition pathway.

Stem The culm or branch of a plant.

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.

Stock driveway Syn. driveway.

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 plan The number and kind of livestock assigned to one or more given management areas or units for a specified period.

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.

Stock pond A water impoundment made by constructing a dam or by excavating a dugout or both, to provide water for livestock and/or wildlife.

Stock trail A trail constructed across a natural barrier to permit movement of livestock to otherwise inaccessible areas.

Stock trails and walkways A livestock trail or walkway constructed to improve grazing distribution and access to forage and water.

Stock water development Development of a new or improved source of stock water supply, such as well, spring, or pond, together with storage and delivery system.

Stolon A horizontal stem which grows along the surface of the soil and roots at the nodes.

Strip grazing Confining grazing animals to a specified portion of a grazing area for a limited time. Strip grazing usually refers to temporarily subdividing a grazing area into subunits with temporary fences so grazing for short periods, often 4 hours or less, can be achieved.

Stubble The basal portion of herbaceous plants remaining after the top portion has been harvested either mechanically or by grazing animals.

Submarginal land Land that is either physically or economically incapable of indefinitely sustaining a certain use.

Substitution ratio Number of animals or animal-units of one kind or class that can be substituted for another kind or class to meet a specified management objective. Syn. animal-substitution ratio.

Subunit The subdivisions of a single grazing system. See Paddock and Pasture.

Succession The progressive replacement of plant communities on an ecological site that leads to the climax plant community. Primary succession entails simultaneous successions of soil from parent material and vegetation. Secondary succession occurs following disturbances on sites that previously supported vegetation, and entails plant succession on a more mature soil.

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.

Suitable range (1) Rangeland accessible to a specific kind of animal and which can be grazed on a sustained yield basis without damage to the resource. (2) The limits of adaptability of plant or animal species.

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 cropland pasture An annual forage crop planted between two primary cultivated crops to provide supplemental grazing of enhanced nutritive quality during periods of low production and/or forage quality on other pastures or rangeland.

Supplemental feeding Supplying concentrates or harvested feed to correct deficiencies of the range diet. Often erroneously used to mean emergency feeding.

Surfactant (surface active agent) Materials used in herbicide formulations to bring about emulsifiability, spreading, wetting, sticking, dispersibility, solubilization, or other surface-modifying properties.

Suspension fence Nonwoven wire fence comprised of high tension wire supported by widely spaced posts to which the wire is firmly attached, but is loose against the post to allow the wire to move back-and-forth at the point of attachment.

Sustained yield Production of specified resources or commodities at a given rate for a designated unit of time.

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.

Synecology A subdivision of ecology that deals with the study of groups or organisms associated as a unit; i.e., communities.

Tag (1) A label attached, usually to the animals, for identification. (2) A discolored and dirty part of a fleece.

Tagging (1) The process of attaching identifying tags to animals. See Brand and Marking. (2) Clipping manured and dirty locks from sheep.

Tagging chute A narrow enclosure (of board, pole, or steel construction) to hold animals during tagging.

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.

Tank A reservoir of any construction for water storage.

Tannin An antiquality chemical consisting of a broad class of soluble polyphenols that occur naturally in many forage plants. They all condense with protein to form a leatherlike substance that is insoluble and of impaired digestibility. This can be good if it allows some protein to bypass the rumen and be digested in the lower digestive tract of ruminants. Excessive levels, however, interfere with digestion rate by reducing rumen microbial populations.

Taproot system A plant root system dominated by a large primary root, normally growing straight downward, from which most of the smaller roots spread out laterally.

Tedder A machine used in very humid areas to aid forage drying. It stirs cut forage lying on a field with metal tines that rotate on a series of horizontally spinning rotors.

Temporary license or permit A document authorizing grazing of a certain number of livestock on public lands during an emergency or for a certain period, terminable at the end of such period and with no guarantee of renewal in whole or in part. See Grazing license or Permit.

Term license or permit A document authorizing grazing on public lands for a stated number of years as contrasted with an annual or temporary license or permit. See Grazing license or Permit.

Terracing Mechanical movement of soil along the horizontal contour of a slope to produce an earthen dike to retain water and diminish the potential of soil erosion.

Theoretical length of cut The length of cut set with the shear plate on a forage harvester. Setting is critical to ensure forage pieces will be small enough to ensure good compaction in a silo while preserving effective fiber length for good rumen function.

Thermoneutral zone (comfort zone) Within a certain range of ambient temperature the heat produced by nor mal metabolism of a resting animal is minimal and is enough to cover the heat loss.

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.

Total annual production The total annual production of all plant species of a plant community.

Total digestible nutrients (TDN) The total digested energy in a feedstuff expressed in units of weight or percent.

Total digestible nutrients (TDN) (GLA) The total digested energy of a feed expressed as a caloric value.

Toxic plant species A species of plant that may accumulate or produce a substance toxic to animals. See Poisonous plant.

Toxicant The chemical ingredient(s) that may injure or cause death in either plant or animal life exposed to it.

Trace element An element essential for normal growth and development of an organism, but required only in minute quantities.

Trafficability The condition presented by the soil that influences the degree of ease of movement by livestock, humans, or machinery across its surface. This is influenced by the size and number of surface rock fragments, soil wetness, degree of plasticity, organic matter content of soils, and the climatic setting that drives those characteristics to affect ease of movement.

Trail A well-defined path created by repeated passage of animals.

Trail herding Directing and controlling the movement of a group of livestock on restricted overland routes.

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.

Transition pathway Process(es) that cause a shift from one state to another on an ecological site.

Translocated herbicide A herbicide moved within the plant from the point of entry.

Trap A relatively small enclosure used as a temporary holding or catching area in the handling and management of livestock.

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.

Trespass Syn. grazing trespass.

Trick tank A modification of a guzzler in which the collection basin is elevated and the storage tank is located directly below.

Trophic levels The sequence of steps in a food chain or food pyramid from producer to primary, secondary, or tertiary consumer.

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.

Turnout Act of turning livestock out on rangeland at the beginning of the grazing season.

Type Syn. Vegetation type.

Type line The boundary line that separates two distinctive vegetation types on a map or photograph.

Unauthorized use The grazing of livestock on a range area without proper authority.

Unconsumed plant (GLA) See Plant preference classification.

Under grazing The act of continued underuse.

Under stocking Placing a number of animals in a given area that will result in underuse at the end of the planned grazing period.

Understory Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs, and low shrubs under a tree or shrub canopy.

Underuse A degree of use less than the desired use.

Undesirable species (1) Species that are not readily eaten by animals. (2) Species that conflict with or do not contribute to the management objectives.

Ungulate A hoofed animal, including ruminants, but also horses, tapirs, elephants, rhinoceroses, and swine.

Unsuitable range Range that has no potential value for, or which should not be used for, a specific use because of permanent physical or biological restrictions. When unsuitable range is identified, the identification must specify what use or uses are unsuitable (e.g., unsuitable cattle range).

Upright or tower silo, conventional A cylindrical silo made of concrete staves, generally ranging from 12 to 30 feet in diameter and up to 80 feet in height. The staves are held together by steel rods that encircle them. It is usually unloaded from the top.

Upright or tower silo, oxygen-limiting A cylindrical silo made of steel with a glass fused coating on it. The steel panels are bolted together. The silos range in diameter from 20 to 27 feet and in height from 32 to 104 feet, are unloaded from the bottom, can be refilled at any time, and continue to unload oldest silage first.

Usable forage The portion of the standing forage crop that can be grazed off without damage to the forage plants. It varies by plant species, season of use, and companion plant species that need favoring to promote their continued existence in the stand. The pasture management section refers to it also as available forage.

Usable forage production (GLA) An entry method that allows you to enter an estimate of annual production that is consumable by the target livestock population.

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.

Vapor drift The movement of pesticidal vapors from the area of application.

Variable cost (GLA) Expenses that change with the number of animals in the herd. Examples of variable costs include supplemental feed, veterinary services and supplies, and labor.

Variable rotational stocking A stocking method that adjusts the recovery period between grazing periods to the variable growth rate of the forage species being grazed. It attempts to offer a uniform forage allowance to livestock each day of the grazing season through the allocation of forage by sequential grazing of paddocks.

Variable stocking The practice of varying the stocking rate through the plant growing season with the objective of utilizing forage at a rate similar to its growth rate. This can be done by either varying the number of animals on a set acreage or varying the acreage offered to a set number of animals.

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 management practices Practices that are directly concerned with the use and growth of plants. These include such practices as prescribed grazing and livestock exclusion.

Vegetative production Production of new plants by any asexual method.

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.

Veld The open temperate grassland areas of Southern Africa, typically containing scattered shrubs or trees.

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.

Volunteers Plants not purposely planted germinating from seed laid down from imported plant residue or by parent plants growing on the site at some previous time. How distant the time is dependent on the longevity of the seed. These plants are aggressive enough to fill in voids in the plant canopy or grow after dormancy or harvest of the planted crop.

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 budget An irrigation tool that keeps track on a daily basis of the amount of plant available water in the soil over a 12 month period. It sums soil water depletion by evapotranspiration using one of the climatonomic estimators and deducts water inputs from precipitation or irrigation. This yields the amount of irrigation water needed to be applied to bring the soil back to field capacity within the root zone of the crop being irrigated. Water applications in excess of field capacity are assumed lost to percolation or runoff.

Water gap (1) A specially constructed fence across a drainage. The fence is easily moved by the forces of a flood, thus preventing damage to the permanent fence. (2) An opening or fenced area providing access to a developed or natural water supply permitting one watering facility to serve two or more pastures.

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.

Water ram A hydraulic pump that uses water power (flow rate or hydraulic head) to pump a small portion of the total water inflow through a pipe to a higher elevation.

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.

Water-soluble packet Wettable powder or soluble powder formulations of low dosage, highly toxic pesticides packaged in soluble plastic bags. Packets are dropped into a sprayer tank where they dissolve and mix with the spray liquid.

Water spreader A terrace, dike, or other structure intended to collect and distribute surface-water runoff from natural channels, gullies, streams, or broad drainage areas. The purpose is to increase the area of infiltration.

Waterway A way or channel for water.

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.

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.

Wet meadow A meadow where the surface remains wet or moist throughout the growing season, usually characterized by sedges and rushes.

Wettable powder Dry, finely ground formulation where the active ingredient is combined with a dry carrier, usually mineral clay, along with other ingredients that enhance suspension of the material in water. Very widely used. It is of lower toxicity than other formulations, but can be inhaled while dispensing and needs constant, effective agitation in the spray tank to avoid uneven application.

Wildlife Undomesticated vertebrate animals considered collectively, with the exception of fish.

Wildlife refuge A land area reserved and managed for the benefit of one or more species of wildlife.

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.

Wolf plant (1) An individual plant that is generally considered palatable, but is not grazed by livestock. (2) An isolated plant growing to extraordinary size, usually from lack of competition or utilization.

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 1 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.

Yearlong range Rangeland that is, or can be, grazed yearlong.

Yield (1) The quantity of a product in a given space and/or time. (2) The harvested portion of a product.

Zoning (rural) A means by which governmental authority is used to promote a specific use of land under certain circumstances. This power traditionally resides in the state, and the power to regulate land uses by zoning is usually delegated to minor units of government, such as towns, municipalities, and counties, through an enabling act that specifies powers granted and the conditions under which these are to be exercised.

Appendix A NRCS Policy on Prescribed Burning on Grazing Lands

NRCS supports and encourages the use of prescribed burning on rangeland, pastureland, forest land, hayland, Conservation Reserve Program (CRP) land, and wildlife land to meet specific resource management objectives. The national standard for prescribed burning is in the National Handbook of Conservation Practices.

Training, certification, and authority

NRCS encourages its employees to participate in prescribed burning training activities and workshops. Training is required to address both the principles of planning and safely executing the prescribed burn, as well as the effect that the fire will have on the plant and animal species and communities within the burn area.

Only trained and qualified personnel are authorized to provide assistance in planning or implementing prescribed burns. The extent to which an NRCS employee may provide technical assistance will be restricted by the job approval authority and/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 to do so. Example A–1 of this appendix is job approval authority criteria.

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.

Planning prescribed burns

Burns planned with NRCS assistance must adhere to all Federal, State, and local laws regarding outdoor burning, fire control, smoke management, and air quality. 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, U.S. Forest Service, Bureau of Land Management, and state forestry, wildlife, and natural resource agencies, as applicable.

The landowner is responsible for obtaining all permits and clearances as required by law. Adherence to the Clean Air Act (42 U.S.C. 7401 - 7671q) is required for all prescribed burns.

The national and state practice standards for prescribed burning are used to guide the overall development of the detailed plan. A detailed plan for the prescribed burn must be prepared. Example A–2 of this appendix is a prescribed burn detailed plan. Required items to be addressed include, but are not limited to:

- Location of the burn
- Resource management objectives of the burn
- Pre-burn vegetative description of the area
- Prescription for weather conditions required
- Description of the burning method to be used
- Description of pre-burn preparation
- Firing sequence of area to be burned
- Job assignments and descriptions of responsibilities for all persons assisting with the burn
- Equipment and materials checklist
- Job assignments and descriptions of responsibilities for all persons assisting with the fire patrol, containment, mop-up, and suppression of the burn
- Post-burn evaluation and management

Technical application assistance

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 job approval authority, certification level, or both.

For purposes of training landowners and managers and other NRCS employees, properly trained and certified NRCS personnel may participate in the following activities:

- Development of the prescribed burning plan
- Serve as fire boss
- Determine field and weather conditions for compliance with the prescription
- Serve as team leader for the implementation and completion of burn
- Direct field operations and make decisions, adjustments, and corrections necessary to ensure that the fire meets the planned objectives and that all participants are safe
- Assist with ignition of the fire

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. 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 an emergency situation develops, NRCS employees are to follow the direction of the designated fire boss and act responsibly to resolve the situation.

NRCS employee liability

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.

State office responsibility

The NRCS state office will be responsible for providing adequate training and equipment for employees involved in prescribed burning activities. States will develop job approval authority 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. Job approval criteria are reviewed and concurred in by the appropriate rangeland management specialist, forage agronomist, or other designated grazing lands specialist.

Prescribed Burning
Job Classifications

Class Ia - Maintenance Burn

* Size of area: Less than 100 acres
Vegetation: non-volatile herbaceous and woody species
Terrain: 5% slope or less

Class Ib - Maintenance Burn

* Size of area: Less than 320 acres
Vegetation: non-volatile herbaceous and woody fuel
Terrain: 5% slope or less

Class Ic - Maintenance Burn

* Size of area: Less than 640 acres
Vegetation: non-volatile herbaceous
Terrain: 5% slope or less

Class II - Maintenance Burn

* Size of area: Less than 100 acres
Vegetation: Same as Class Ia plus volatile herbaceous species and live volatile woody species less than 4 feet tall.
Terrain: 8% slope or less

Class III - Maintenance Burn

* Size of area: Less than 640 acres
Vegetation: Same as Class II plus live volatile woody species greater than 4 feet tall and dead volatile woody species.
Terrain: 12% slope or less

Class IV - Maintenance Burn

* Size of area: no restrictions
Vegetation: no restrictions
Terrain: no restrictions

Class V - Reclamation Burn

*Size of Area: no restrictions
Vegetation: no restrictions
Terrain: no restrictions

* Size of Area — Contiguous acres to be burned on a single management unit during the same growing season are considered to be one prescribed burn regardless of the number of individual segments the fire is divided into. Total acres for any prescribed burn can't exceed the Size of Area limits for the appropriate job classification.

SEPARATE PRESCRIBED BURNING PLANS MUST BE DEVELOPED FOR EACH IDENTIFIABLE PRESCRIBED BURN.

To have job approval authority, an employee must have completed a formal NRCS prescribed burning training course including participation in a field training burn and supervised participation in at least three prescribed burns at which NRCS provided technical assistance. The individual must demonstrate good judgment, knowledge, and skills in prescribed burning.

The following are the requirements for the job approval authority:

Class I — Individual must have properly planned at least three Class I burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class I burns.

Class II — Individual must have Class I approval authority, must have properly planned at least three Class II burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class II burns.

Class III — Individual must have Class II approval authority, must have properly planned at least three Class III burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class III burns.

Class IV — Individual must have Class II approval authority, must have properly planned at least three Class IV burns which have been approved and must have demonstrated good judgment, knowledge, and skills for Class IV burns.

Any NRCS employee who violates NRCS Prescribed Burning Policy will have their job approval authority revoked immediately.

Job approval authority may be granted to employees who have documented evidence of previous training or experience that equals or exceeds NRCS prescribed burning training requirements. NRCS occasionally hires an employee with extensive training, experience, and education in prescribed burning while in college, at another agency, etc.

Prescribed burn management plans are valid only for the area planned and for the burning season planned. If the landowner decides to change the location of the burn or is unable to burn during the prescribed time frame, a new plan must be prepared prior to conducting the burn.

Prescribed Burn
(Planning)

* Landowner/Operator: ______________________________ Date: ________________
Address: ______________________________ Phone: ________________
Acres to burn ________________ Planned date of burn: ________________
Location (county): ________________ T _____ R _____ S _____ Field # __________

A. Description of burn area: Land use : ________________________

1. Present plant cover
   a. Woody plants

Species	**Height (ft)**	**Basal diam in.**	**% Canopy**
____________	______	________	______
____________	______	________	______
____________	______	________	______

   b. Herbaceous plants: Amounts in tons/acre

Species	**Cured**	**Green**
Cool-season grass	______	______
Warm-season grass	______	______
Forbs	______	______

2. Slope ____________ % Aspect ____________ Soil type ________________

B. **Objective and timing of burn:**

Stimulate WS grass (1-3" WSG)
Distribute grazing (1-3" WSG)
Stimulate CS grass (1-3" CSG)
Remove litter (1-3" C&WSG)

Control woody plants (full leaf)
Reduce CS grass (1-3" WSG)
Improve wildlife habitat (1-3" WSG)
Stimulate forbs (Before forb Growth)
Reduce wildfire hazard (1-3" WSG)

Reason(s) for burning:
____
____

C. Acceptable conditions for prescribed burns:

Relative Hum. (%)	Wind speed in miles/hour: 4	6	8	10	12	14	16	C – 60% to 90%
25-34	C-S	C-S	C-S	C	XXXXX	XXXXX	XXXXX	cloud cover or
35-39	C-S	C-S	C-S	C-S	C	XXXXX	XXXXX	before 10:00 a.m.
40-44	C-S	C-S	C-S	C-S	C-S	C	XXXXX	after 3:00 p.m.
45-59	C-S	C-S	C-S	C-S	C-S	C-S	C	
60-69	S	C-S	C-S	C-S	C-S	C-S	C-S	S – 0% to 59%
70-79	XXXXX	S	C-S	C-S	C-S	C-S	C-S	cloud cover or from
80-89	XXXXX	XXXXX	S	C-S	C-S	C-S	C-S	10:00 a.m. until 3:00 p.m.

1. Comments: (firing method, starting time, wind direction, soil surface moisture condition, etc.) _____
____
____

2. Ignition plan and/or firing sequence (see plan map).

* Parties igniting a prescribed burn may be liable for damages resulting from the fire and control cost, should fire escape the designated area.

D. Preparation of area for burning:

1. Firebreak construction:
   a. Firebreak widths will be equal to or greater than two times the height of adjacent vegetation.
   b. Plowed, disked and burned firebreaks, being essentially devoid of fuel, provide least danger of fire escape.
   c. Close mowed and cool-season grass firebreaks have fuel available that can provide an avenue for fire escape. Smoke, from green growth, reduces visibility, inhibiting burn monitoring.
   d. High mowed fire intensity reduction lines (“ - 12” stubble), will be installed if fine fuel exceeds 1.5 ton/acre. Line with will be at least 10 feet @ 1.5-3 T/A and 20 feet @ >3 T/A.
   e.

Kind of fireline	Width feet	Length feet	Date to apply
______________	_________	__________	____________
______________	_________	__________	____________
______________	_________	__________	____________

   f. Existing firebreaks, streams, roads, tilled fields, etc. (Show on plan map). Describe

   g. Potential hazards are present within the burn area: _____ yes _____ no
   e.g.: power lines, snags, structures, etc. (Show on plan map). If yes, explain precautions:

E. Adjacent areas (Outside of burn area)

1. Special precaution areas: e.g. Leaf litter, dry grass, roads, structures, smoke dispersion, _______etc. (Show on plan map). Precautions needed:____
____
____
2. Backup or secondary firebreak locations: (Identify) ______________________________
____
____

F. Equipment/personnel needs:

1. Safety equipment: ____
____
2. Tools/equipment needed for burn: ( ) rakes ( ) swatter ( ) drip ( ) torches, ( ) backpack pump, ( ) other:____
3. Personnel needed for burn:____
____
____

G. Special considerations:

1. Precautions to prevent fire escape:
2. Suppression plan if fire escapes:_______________________________________
____
____
3. Patrol and mop-up plan: ____
____
____

Prescribed Burn Plan Map

(use aerial photos if scale is appropriate)

(Identify land use in adjacent fields)

Legend

Approximate Scale: _________ inches = mile

B-B-B-B-B-	Burned firebreak	W	Water source
P-D-P-D-P-	Plowed / Disked Firebreak	(A, B, etc.)	Firing crews
C-S-C-S-C-	Cool-season Grass Firebreak	(1, 2, etc.)	Firing sequence
CM-CM-CM-	Close Mowed firebreak	(A1) ->->->	Firing direction
-HM-HM-HM-	High Mowed intensity reduction	——WIND——	Wind Direction

Other legends or information: ____

____

____

Plan prepared by: ______________________ Date: ______________________

Plan checked by: ______________________ Date: ______________________

I, ______________________, have requested the preparation of this prescribed burn plan; my signature establishes my acceptance of full liability resulting from the implementation of this plan.

Landowner/Operator: ______________________ Date: ______________________

____

____

____ (signature)

Prescribed Burn Application

* Landowner/Operator: ______________________________ Date ______________

Acres to burn: ______________ Date burn applied: ______________________

Location: County: ______________ T _____ R _____ S _____ Field # ______________

A. Preburn checklist: (day of burn)

1. Weather forecast favorable — yes _____ no _____
2. Necessary firebreaks constructed — yes _____ no _____
3. Potential hazards accounted for — yes _____ no _____
4. Special precaution areas noted — yes _____ no _____
5. Backup/secondary firebreak locations noted — yes _____ no _____
6. Safety equipment adequate — yes _____ no _____
7. Tools/equipment onsite — yes _____ no _____
8. Personnel needed available — yes _____ no _____
9. Special considerations reviewed with crew — yes _____ no _____
10. Actual weather at burn: Temp. _________ Humidity _________ Wind-Speed ________
    Cloud cover _____ % Fronts or changes expected? — yes _____ no _____
11, Appropriate neighbors informed — yes _____ no _____
12. Notification of units of government made: — yes _____ no _____
    Local fire department (phone) ______________ USFS (phone) ______________
    Sheriff (phone) ______________ MDC (phone) ______________
13. Necessary permits obtained — yes _____ no _____
14. Test burn performed as expected — yes _____ no _____

Explanation of no response ____

____

Checked by: ______________________________________ Date: ______________

B. Post-burn evaluation (day of burn):

1. Burning method used:
2. Start of test burn — Beginning Time ____________ a.m.( ) p.m. ( )
   Mop-up completed — Ending Time ____________ a.m. ( ) p.m. ( )
3. Observed change in weather conditions during the burn: ______________________

   ____
4. Fire behavior: (check one)
   a. Spotting — one ( ) few ( ) many ( )
   b. Difficult to control — yes ( ) no ( )
   c. Convection column — yes ( ) no ( )
   d. Fire whirls — yes ( ) no ( )
5. Objective of burn met ____

   ____
6. Post-burn management plan (additional treatment needs):____________________

   ____
7. Future burn needed: yes ( ) no ( ) estimate when ______________________
8. Other comments: ____

   ____

Checked by: ______________________________ Date ______________

* Parties igniting a prescribed burn may be liable for damages resulting from the fire and control cost, should fire escape the designated area.

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C. Followup evaluation (60-90 days after burn)

1. Objectives of burn met: ____
____
____
____
____

2. Post-burn management plan (additional treatment needs): ____________________
____
____
____

3. Future burn needed: yes ( ) no ( ) if yes, when?___________________________
for what purpose? ____
____
____
____

4. Other comments: ____
____
____
____

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