GUIDE TO RANGELAND MONITORING AND ASSESSMENT

Basic Concepts for Collecting, Interpreting, and Use of Rangeland Data for Management Planning and Decisions

A publication of the

ARIZONA GRAZING LANDS CONSERVATION ASSOCIATION

Written by

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Arizona Grazing Lands Conservation Association

This guidebook was instigated, written and published by the Arizona Grazing Lands Conservation Association (AGLCA). AGLCA was formed in 2004 under the national Grazing Lands Conservation Initiative (GLCI). AGLCA is composed of non government organizations representing owners and managers of grazing lands in the State of Arizona. At present, the regular members of the Association are the Arizona Cattle Grower's Association, the Arizona Natural Resource Conservation Districts State Association, and the Arizona Section, Society for Range Management. Associate members are the Natural Resources Conservation Service, the University of Arizona, the U.S. Forest Service (USFS), the Arizona State Land Department, and the USFS Rocky Mountain Experiment Station. Other regular and associate members will be added in the future.

The purpose of this association is to address the needs of grazing lands in Arizona by:

- Promoting voluntary approaches for the management of grazing lands
- Promoting respect of private property rights
- Strengthening partnerships between grazing lands managers and others who support the purposes of the Association
- Increasing economic, environmental, and social stability on grazing lands
- Increasing the information base from which to make sound policy and management decisions on grazing lands
- Closing the gap between availability of knowledge and application of said knowledge on grazing lands
- Enhancing the rancher's ability to achieve greater profitability on an ecologically sound and sustainable basis
- Educating the public through the dissemination of scientific knowledge on the conservation and management of grazing lands in Arizona.

In addressing the issues listed above, the Association seeks to coordinate and support those organizations, federal and state agencies, or other groups already in existence, rather than to create new or duplicative programs. The Association serves to coordinate the efforts of its member organizations to influence programs, policies, funding levels, incentives, and priorities at all levels of government that will promote the objectives listed above. AGLCA recognizes that, in Arizona and most other western states, management of private grazing lands is usually inextricably linked with that of state and federal lands and thus neither can be addressed in isolation.

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The authors also appreciate the monitoring manuals, publications, and technical references developed for the states of Wyoming, Nevada, Idaho, and Utah, and by federal agencies which we have used as reference materials. We believe that these sources are in general agreement with the principles and concepts we have presented, although there are some differences of opinion. These and other references are listed in the Appendix.

Cover photo by John Hays.

CONTENTS AT A GLANCE

INTRODUCTION

Some Background

Rangelands—grasslands, forests and woodlands that support livestock grazing—are found across much of the western United States. These rangelands supply the bulk of the forage for western livestock production. Such lands are also important providers of water, wildlife habitat, wood products, and outdoor recreation. Rangelands also furnish open space and scenery valued by residents and visitors. It is important that these rangelands be managed to sustain these benefits for present and future generations.

Management objectives for rangelands should reconcile the economic and environmental goals of landowners, interest groups and other citizens, and also the requirements of state and federal laws. Objectives also balance short-term demands with long-term options for future management. Appropriate management decisions on how to meet these short and long term objectives are based on scientific principles and experience. Sound decision making requires information about the kind, amount, status, and trend in status of the rangeland resource that is relevant, objective, reliable, and understandable. Goals and objectives for rangeland management may differ depending on land ownership, land management policy and the differing values of professional resource disciplines and other interested parties. However, data that are properly collected and interpreted and relevant to the resource objectives for a specific management area will help make good decisions regardless of management goals or values.

Ownership of western rangelands is a complex pattern of state, federal, tribal, county, and private lands (Figure I-1). Most ranches are also a mixture of land ownerships, often including private, state, Bureau of Land Management (BLM), and/or Forest Service (FS) lands. Wildlife habitat reaches across various land ownerships. The quantity and quality of water produced from rangelands depends not only on climate but on the characteristics of the watershed, which usually extends across ownership boundaries. Clearly, it is advantageous to have some coordination of management across land ownerships, with due consideration for the differing management goals of different landowners. Also, it is useful to have a coordinated approach to collection and interpretation of resource assessment and monitoring data as a basis for management decisions.

The need for coordinated resource management has been widely recognized, if not always implemented. Federal land management agencies are directed by law and regulation to coordinate their management planning with other federal agencies, state government agencies, tribal governments, and affected individuals. For example, all federal and state agencies, plus some other organizations, have signed the Memorandum of Understanding (MOU) for Cooperative Resource Management (CRM) in Arizona where they agree to work together for coordinated management planning and implementation. Cooperative Resource Management Plans are most often applied to ranch planning, especially grazing management plans. Federal agencies like the BLM do provide opportunity for grazing permittees or lessees, state and federal agencies having lands or responsibility for managing resources within the affected area and interested public an opportunity to review, comment, and give input during the preparation of reports that evaluate monitoring and other data that are used as a basis for making decisions to change the terms and conditions of a grazing permit or lease. However, as yet, there is no statewide coordinated approach to collection and interpretation of rangeland monitoring and assessment data for making livestock management decisions that affect state, private and federal lands.

Purpose of the Guide

This document outlines a set of principles and guidelines for a coordinated, science-based approach to rangeland monitoring and assessment to evaluate progress towards achieving management objectives and compliance with management plans primarily associated with range livestock production (ranching). It provides the framework for making management adjustments when planned objectives are not being met. While the emphasis in the guide is on livestock grazing management**,** there are specific elements that may be used for other purposes or uses on rangelands. The principles and guidelines outlined here are intended only for on-the-ground management decisions. They do not consider, nor are they necessarily appropriate for, regional or national reporting on the "state" of the resource.

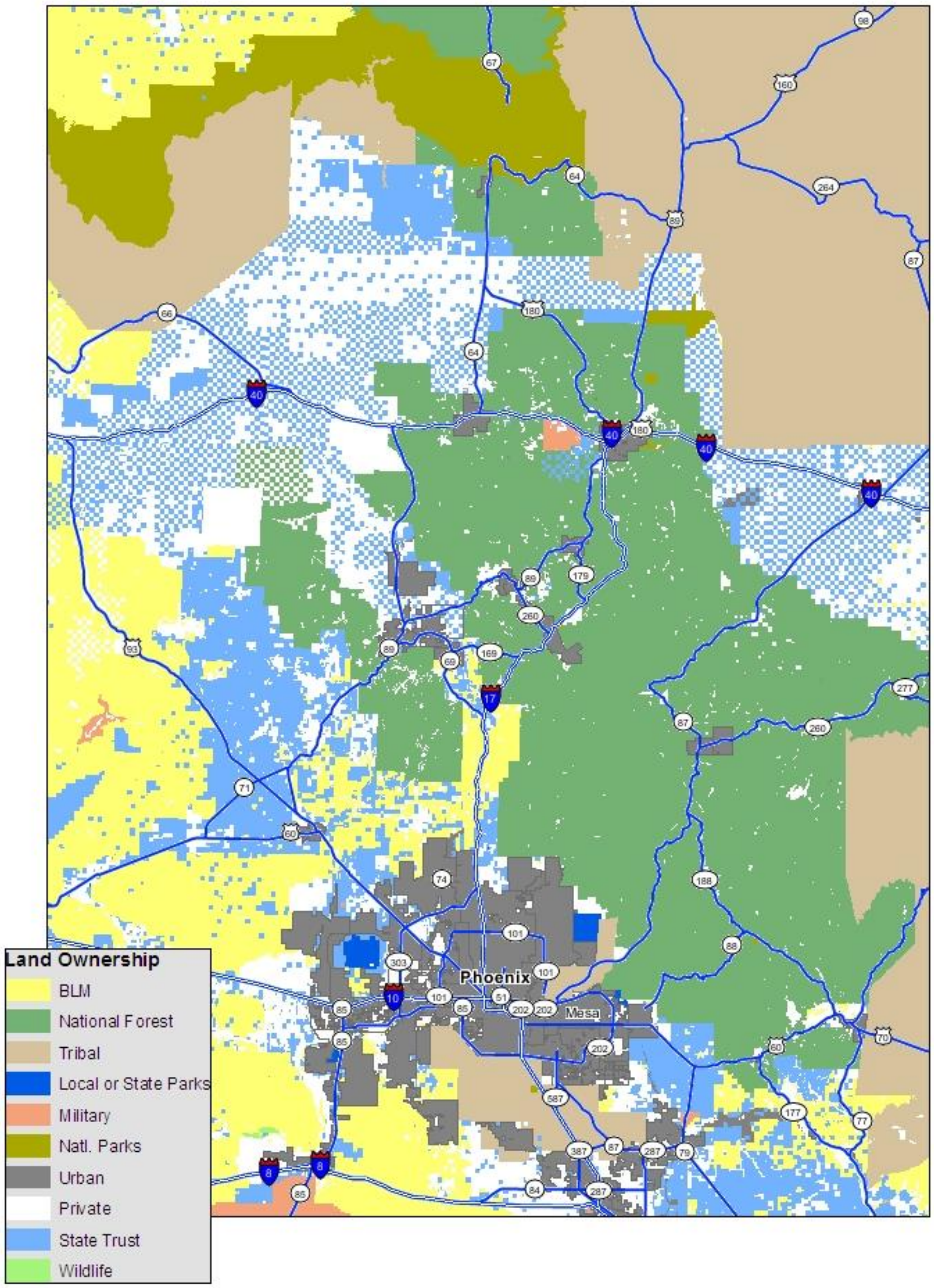


Figure I-1. Land ownership patterns are complex in most parts of the west as shown in this example from Arizona.

Also, the guide may not address concepts or methods that are relevant to monitoring or assessment that are specific to some situations. For example, procedures that are specific to the habitat of a particular endangered animal species may require methods or procedures not generally used for rangeland decision making and will not necessarily be addressed in this guide. The principles and guidelines discussed in the guide are generally applicable both to upland and riparian situations.

State and federal agencies operate under policies and procedures established by law and regulations. These agencies have manuals and handbooks that establish accepted procedures for inventory and monitoring of rangelands as well as the process for developing, implementing, and establishing compliance with rangeland management plans. *This guide is not intended to supersede any agency policy, regulatory authority, or valid established procedures for rangeland inventory, monitoring, planning or management practices. Rather, it is intended to establish science-based concepts and recommended procedures that reflect the principles and experience of range professionals.*

This guide was originally developed in response to a perceived need for the state of Arizona. The authors and organizations involved are all based in Arizona and the Southwestern U.S. As a consequence, most of the examples relate to Arizona and Southwestern situations. However, because Arizona encompasses such a wide array of different rangeland types, we believe that the guide will have wide application across the rangelands of the western U.S. and in other countries with similar vegetation and needs.

How to Use This Guide

This guidebook is intended to help ranchers, range professionals, and others, decide what kinds of data they need to develop grazing management plans, help them interpret the data they collect, make management decisions based on the data, and document progress toward meeting management objectives. This book is not intended as a "how-to" manual because good manuals already exist and are referenced in this guidebook (Appendix C). The guidebook is intended to be consulted in sections as necessary, not read from start to finish. Cross referencing is used to help you locate additional information on particular topics.

How This Book is Organized

Immediately following this introduction there is a section called "Summary of Recommendations for Monitoring, Inventory and Assessment of Western Rangelands." This section provides a condensed summary of conclusions and recommendations for management oriented rangeland monitoring for the most common vegetation types and management objectives. Each recommendation is referenced to the portion or portions of the book that discuss the topic in more detail. The summary is intended to allow you to identify our recommendations and guide you to portions of the guidebook that will allow you to decide whether the recommendations are appropriate for your needs or not.

Sections 1-4 outline basic principles and concepts that relate to rangeland inventory, monitoring, and assessment, and how these fit into the management planning and decision making process on rangelands. The aim is to present these concepts in simple terms that can be understood by most users, yet at the same time to present the material in sufficient depth so that the basis for the concepts can be fully understood. In our opinion, it is essential to understand the concepts in Sections 1-4 when designing a range inventory or monitoring effort, and interpreting the data obtained as a basis for management decisions. These sections are a primer on basic concepts for those without academic background in range management and a refresher course for those who have taken college courses in range management.

Sections 5-7 are intended to guide users in selecting the best attributes to measure, and techniques for measurement to meet his/her objectives and available resources. Section 5 lists the most common management objectives for collecting rangeland resource data. Use this section to help define objectives. For each of the list of objectives, a recommended attribute and method(s) is indicated, as well as the appropriate vegetation types for their use. After identifying the appropriate attribute of vegetation or other resource, see Section 6 for a description of the attribute and how it can be interpreted for different types of vegetation. Or go to Section 7 to find a brief description of methods for collecting data needed. Sections 5-7 are extensively cross-referenced so that the user may start either with an objective (Section 5), an attribute (Section 6), or a method (Section 7), and be directed toward pertinent chapters. Finally, the appendices contain a glossary of terminology, scientific names of plants mentioned in the guidebook, and references to other manuals or publications that furnish more detailed information on certain topics.

SUMMARY OF RECOMMENDATIONS

There is no “silver bullet” for range studies. No one measurement or technique provides enough information to guide management in all situations. Monitoring, inventory, and assessment, although related, are different processes that may require different sampling strategies and methods. Factors that may dictate measurement of different attributes and/or different methods include vegetation type, management objectives and concerns, time and money available, qualifications of personnel, and other factors (These topics are discussed in Sections 1-4, it is highly recommended that these sections be read prior to deciding upon a plan for data collection and interpretation). The following is a general guide to our recommendations on appropriate attributes and methods for general rangeland inventory, monitoring and assessment in major vegetation types in the Western United States.

Basic Inventory

The basis for rangeland management planning, inventory, assessment, and monitoring is a map of the basic, and relatively permanent, rangeland resources – soils and vegetation. Maps of soils, current vegetation, ecological sites and/or terrestrial ecosystems are essential; the latter two are preferred since they integrate soils, topography, climate and potential vegetation. Mapping can best be done on color aerial photographs (see Chapters 9, 10, 11, 24).

Monitoring

Monitoring aims to document change in selected attributes over time (usually several years), thus it is essential that data be sufficiently free of sampling variability and observer bias to give confidence that differences measured over time are real and not just artifacts of the sampling process. Rangeland vegetation varies greatly in both time and space, and thus presents a formidable challenge to gather data of sufficient repeatability to interpret change. Thus, it is important to recognize and account for these differences when data are collected. This is why it is important to classify ecological sites (other other landscape units) as a basis for sampling, and to sample vegetation at similar growth stages in different years in order to control variability and allow interpretation. Attributes selected should not only be relevant to management objectives, but capable of objective measurement or estimation by different observers with reasonable training (see Chapter 13). Finally, a guiding principle is that repeatability requires observing a large number of sampling units from a given monitoring location. Thus, methods that allow a large number of sampling units for a given expenditure of time, even if individual observations are relatively crude, will yield more repeatable results than selecting methods requiring more time on each sampling unit (see Chapter 14).

The timing and frequency of monitoring may vary depending on the purpose of the monitoring. For example, data collection may be done during the growing season or at the end of it (see Chapter 16). For some purposes annual monitoring is required or desirable, but for long-term trends less frequent monitoring can be adequate (see Chapter 29). Decisions about the frequency of monitoring may be a compromise between what is desirable and what is practically feasible.

Selection of attributes and methods is also influenced by vegetation type (see Chapter 23). The following is a quick guide to selection of attributes and methods for routine monitoring of changes in vegetation and soil for common Arizona vegetation types.

Any Vegetation Type (Almost)

Photos

Photographs are a rapid, simple, inexpensive, and objective way to document conditions of vegetation or soil at a given point in time or to document changes over time. Photos can be used in any vegetation type, although they have some limitations in very dense tall shrub and tree vegetation types (or those that may develop into such types such as riparian zones). Photos are highly recommended either alone or in combination with almost every other monitoring method (see Chapter 39).

Ground Cover

Ground cover (basal vegetation cover, litter, gravel and rock) is highly related to soil protection from erosion on a given site. Measuring ground cover using points located by pacing is recommended for quantitative documentation of the amount of ground cover and changes over time. Ground cover is fairly objective and repeatable if criteria for kinds of cover are adequately specified. Ground cover can be measured in any vegetation type, but may be less useful in very dense vegetation where ground cover is usually complete (see Chapters 28, 33).

Grasslands

Most rangelands have a moderate to dense cover of perennial grasses, forbs, and low shrubs, although in many cases this cover has been reduced due to increase in shrubs or trees. Examples are desert grassland, Great Basin grassland, mountain grassland, pine or oak savannahs, mesquite savannah, and dry meadows. The following methods are recommended in any of these types where the primary interest is documenting the amount or composition of perennial grasses and forbs, or low shrubs and half-shrubs (see Chapter 23).

Frequency

Frequency is recommended as a basic method to document changes in plant abundance over time because it provides better repeatability for the time expended than most other methods. Rooted frequency should be used for smaller plants, and canopy frequency for larger shrubs and trees. Frequency is best suited for moderate to dense stands of perennial grasses, forbs and/or low shrubs. It is not suited for very sparse vegetation of any kind (due to a required excessive quadrat size) or to very dense stands of taller shrubs and trees (see Chapters 27, 35).

Fetch

Fetch is an index of the distance between plants. This measure gives additional information on patchiness of vegetation which is related to effectiveness of ground cover in protecting soil from erosion due to overland flow. It is a quantitative index to soil protection that can be objectively and easily measured to establish trends in risk of soil erosion. Fetch could be measured in any vegetation type, but has the most interpretive value in moderate to dense perennial grasslands or low shrub type vegetation (see Chapters 27, 38).

Species Composition- Dry Weight Rank Method (DWR)

Species composition is the relative amount of each species present in a plant community. It can be based on any attribute, but is usually based on either current year's dry weight production or canopy cover. Both production and cover are subject to seasonal and annual variability and are affected by grazing, fire, and other influences. Composition based on cover may have relevance to some management objectives, but generally weight based composition is considered more nearly related to the importance of a species in terms of ecological processes such as nutrient cycling, energy capture, and net productivity. Therefore, composition based on weight is preferred. The dry-weight-rank (DWR) procedure is an objective, simple, and repeatable method and is recommended for monitoring species composition. DWR is best suited to moderate to dense stands of grasses, forbs, and low shrubs. It is less useful in sparse vegetation because of excessive quadrat size requirements. It becomes difficult to apply in dense, tall shrubs or trees (see Chapters 27, 32).

Wet Meadows

Community Type Method

In dense riparian meadows composed of grasses, forbs, and some shrubs, the community type method is recommended for characterizing changes in plant composition and structure. With a simple community type classification this method can provide useful and repeatable trend data where other methods do not work well (see Chapters 23, 36).

Shrublands

These rangelands are dominated by dense stands (usually > 30% canopy cover), taller shrubs and/or trees. Examples are chaparral, riparian shrublands or forests, dense mountain forests, dense stands of juniper, mesquite, whitethorn and other tall shrubs. Methods useful in more open grasslands are hard to use in these vegetation types, and generally are not well-suited for measuring a dense shrub/tree vegetation type. Most monitoring methods are difficult to use in such vegetation (see Chapter 23).

Prominence Rating Method

The prominence rating method is recommended for dense, tall shrubs or trees such as occurs in chaparral and riparian forests, where more quantitative methods do not work well. This procedure provides a fairly objective record of the relative abundance of shrub and understory species (see Chapter 37).

Very Sparse Vegetation

Rangelands with very sparse stands of perennial grasses and forbs, such as occur in desert shrub vegetation or as understory in tall shrub or forest types, are not adapted to methods used in denser grasslands because the required sampling unit size makes those techniques impractical. The same is also true in vegetation where the shrub component is sparse, i.e. where there are scattered mesquites or junipers in a grassland type (see Chapter 23).

Density in Belt Transects

If individual plants can be consistently identified (as is the case with single stemmed shrubs, most succulents, and bunchgrasses), belt transects can be used to estimate density. The belt transect should be long enough and wide enough to give an average of at least 7-10 plants per transect (see Chapters 27, 34).

Density from Distance Measurements

Density can be estimated by measuring distance between plants (see Chapters 27, 34).

Cover or Density from Aerial Photos

Aerial photos (or digital imagery) of the proper scale and type can be used to estimate either cover or density of trees, shrubs, succulents, and some grasses or forbs (see Chapters 27, 34).

Annual Grasslands

True annual grasslands are of limited extent and usually the annual component is not the main interest for monitoring rangelands. In general, annuals can be monitored using the techniques recommended above for perennial grasslands.

Utilization/Residual Plant Height

Estimation of utilization on key species in key areas as an aide in short term decision making and helping to establish cause and effect for long-term trends in other attributes is recommended. Mapping of use patterns is also recommended as a valuable aid to identifying grazing distribution problems and planning grazing management and improvements (see Chapter 24).

Landscape Appearance Method

This method is recommended for use pattern mapping, and for documenting use in key areas. This method is adaptable to most types of vegetation including shrubs (see Chapters 30, 40).

Stubble Height (Average Remaining Leaf Height)

For a more quantitative method that does not require site-specific calibration (although interpretation of the data does require consideration of site potential and current growing conditions), the "stubble height," or average remaining leaf height method, is recommended. This method is suited for sparse to very dense herbaceous vegetation, but is not suited for shrubs. Depending on the species selected for measurement, it may provide useful information on watershed protection or wildlife cover (see Chapters 30, 40).

Height Weight Method or Grazed Class Method

Either of these methods is recommended as reliable quantitative indices of utilization for perennial grasses, but is not appropriate for annuals, forbs, or shrubs. However, both depend on the ability to predict utilization based on weight from observation of utilization based on height. Thus the estimate of utilization is based on a relationship which can be, but often is not, verified on a site-specific basis (see Chapters 30, 40).

These methods provide a quantitative index of utilization, but both require additional site-specific studies if an estimate of utilization by weight is desired. Both are recommended as repeatable and quantitative indices of utilization with sufficient sample sizes and attention to ground rules. The percent plants grazed method is best suited for sparse to dense perennial bunchgrasses, and with adaptations to very dense swards of grasses. The percent twigs grazed method is best suited where key species are shrubs where grazed twigs are observable--it will not work where utilization on shrubs is mainly on leaves, flowers, or seeds only.

Assessment

Assessments involve making an interpretation of data relative to one or more management objectives. The assessment is a value judgment which should be based on professional experience and sound scientific information. Assessments can be based on a qualitative evaluation based on professional judgment, a quantitative one point in time comparison to an established guideline or standard, or on observed change (trend) toward or away from a stated objective based on repeated quantitative measurements over time (monitoring). Qualitative assessments, such as range health, can be useful for planning and identifying needs for monitoring. Guidelines or standards usually are not sufficiently site-specific unless they are stated in very general terms, and they do not usually allow for the variability introduced by other factors. We discourage the use of narrowly defined, quantitative guidelines to make range livestock management decisions, and recommend a monitoring approach to evaluating vegetation and soil changes, utilization, and stocking rates based on trends over time (see Chapters 8, 24, & Section 4).

SECTION 1
BASIC CONCEPTS

What You Will Find in Section One

- Can this guidebook be used for both upland and riparian systems?
- What are inventory, monitoring, and assessment and what are they used for?
- What are the fundamental premises of range monitoring and management?

CHAPTER 1
Upland versus Riparian Systems

As science-based range management was applied to western rangelands, and especially government lands, during the first 60 years of the last century, most of the emphasis was to balance livestock numbers with the carrying capacity of the range and to improve the forage production on rangelands. The "free range" days on government lands had resulted in excessive livestock grazing over much of the rangeland due to a lack of established grazing rights which gave no incentive for moderate grazing (Hardin 1968) and inadequate knowledge of sustainable stocking levels of western rangelands. Therefore, as more knowledge became available, the emphasis was on reducing stocking, adjudicating grazing rights, increasing forage production on depleted rangelands by reseeding and brush control, and improving distribution by water development and fencing.

By the 1960s and 70s, these efforts had met with considerable success in stabilizing or improving the condition of upland rangelands and watersheds on both government and private land. However, at about this time it became apparent that, although upland rangelands made up a vast majority of the watershed area and the forage supply for livestock, the watercourses themselves had often remained in poor condition even though the uplands had started to improve. Riparian areas and other concentration areas within the rangelands often received livestock grazing that was excessive in either intensity or duration, or both, due to the fact that these areas had water and forage that was green when the uplands had dried out. Also at this time, it began to be realized that riparian areas were important not only for watershed function and water quality, but also for wildlife, especially non-game species and some endangered species (e.g. native fish, neo-tropical birds, etc). Because of these values, management of government lands and private lands has put increasing emphasis on riparian areas.

We considered including a special Section on monitoring in riparian areas in this guidebook. We decided not to do this because the principles and concepts of measuring vegetation and soils in riparian areas are not different from those on uplands. However, the attributes measured and the methods or sampling strategies employed in riparian areas often will differ from those employed on upland areas in the same locale. The reason is that riparian vegetation is nearly always denser than adjacent upland vegetation and often composed of different life forms. For example, many riparian areas have a high component of tall shrubs or trees, or very dense herbaceous sod. Appropriate techniques for monitoring this type of vegetation are covered in the guidebook but not specifically for riparian areas. Riparian areas also tend to have a more complex pattern of site factors than uplands, are more subject to "disturbance" related to flooding or drought, and have a faster rate of vegetation changes due to better growing conditions than on uplands. These factors affect not only what is measured and how, but how the data are interpreted (see Chapter 11).

There are a number of technical references that have been developed by federal agencies which describe methods for inventory, monitoring and assessment specifically for riparian areas (Appendix C).

CHAPTER 2
What are Inventory, Monitoring, and Assessment?

The fundamental data components useful for management of rangelands include inventory and monitoring data on soils and vegetation. A clear distinction must be made between the concepts of inventory and monitoring. An inventory is a survey of natural resources that documents the amount, kind and or location of different resource types at one point in time. The purpose of an inventory is to characterize all parts of a management unit (such as a soil survey) or estimate average values of certain attributes such as forage production. Inventories may involve a complete accounting as in soil or vegetation mapping, or an inference based on statistical (representative) sampling as done in the National Resource Inventory (NRI) or Forest Inventory and Analysis (FIA). Inventories may also include location of critical areas and cultural features that may affect management.

Monitoring is defined by the dictionary as “to watch, keep track of, or check usually for a special purpose.” Rangeland monitoring means to make repeated measurements or observations over time to establish whether or not changes in selected resource attributes have occurred. The purpose of monitoring is to document change over time in vegetation or other rangeland resources. The emphasis on change is what distinguishes monitoring from rangeland inventories. Repeated complete inventories can be used to identify changes but are generally too expensive and/or too qualitative to provide resource trends except at very extensive spatial and temporal scales (e.g. as used in the National Resource Inventory). Such generalized monitoring is useful for establishing regional or national trends and establishing government policy, but does not provide much information useful for managing specific ranches or grazing allotments.

Monitoring for site-specific management usually relies on data collection at specific points that are either chosen at random or, more commonly, selected to be representative of larger areas (key areas). For management purposes, the locations and attributes selected for monitoring are specific to the characteristics of the management unit (pasture or allotment) and to the management objectives for the unit. Therefore, since both the resources and management objectives vary from one unit to another, the data collected may be of limited use for broad scale interpretations such as regional or national reporting. To make assessments on a national or regional basis generally requires statistically based data collection. Data collection based on selected areas (key areas) involves professional judgment and therefore aggregation of such data carries any observer bias upward (West et al. 1994). Areas selected for sampling are generally based on specific uses or concerns, and therefore may not be representative of broader areas (see Chapter 15).

Rangeland assessment is the process of interpreting data and making value judgments about them. It is highly desirable to collect monitoring or inventory data that are objective and do not incorporate interpretations or value judgments into the basic data. For example, data on vegetation, gravel and litter cover can be recorded and these data can then be interpreted as being “good, fair or poor” in terms of soil protection. Making that interpretation requires knowledge about site capability and the relationship of ground cover to erosion rates for the specific site. Objective data allow for later re-interpretation if new knowledge becomes available. Data initially recorded as “good, fair or poor” contains the built-in conclusion of the observer which cannot be re-evaluated by another or by the original observer whenever new information becomes available (see Chapter13, & Section 4).

In some cases it may be useful to make rangeland or riparian assessments directly in the field. Examples are use of assessment of upland range health, proper functioning condition of riparian areas, or apparent trend by some agencies (Prichard 2003, Pellant et al. 2005). Such qualitative assessments provide land managers and technical assistance specialists with a communication tool. These procedures are not intended nor designed to replace quantitative monitoring (Pellant et al. 2005). Such qualitative assessments may also be tools used to help identify problems and to set priorities for management and monitoring. Qualitative assessments depend on professional judgment, and should be conducted in an interdisciplinary fashion whenever on public lands. By themselves, they do not constitute either monitoring or inventory data because they involve interpretations rather than direct observation or measurement of objective attributes (see Chapters 19, 20, 24).

Sound range management decision making requires information that is objective, relevant, and factual. That is true regardless of the type of decision to be made or the objectives of the decision maker or landowner. Conducting rangeland inventory and monitoring is expensive and time-consuming. Therefore, data needs have to be carefully identified to make sure the data collected best meet the objectives at a reasonable cost. Some discussion of the kinds of decisions to be made by different interests and the types of data required seems warranted (see Chapter 13).

Rangeland inventories are useful mainly for planning. As stated previously, inventories are usually not suitable for measuring trends except on a very long term basis because they either are too expensive or too imprecise to provide the type of information needed for interpretation of trends. However, some basic inventory information is desirable, if not required, for adequate rangeland planning. Planning involves making decisions about the uses to be made on the land, the goals and objectives to be achieved, the management practices and physical developments required to reach those objectives, and a strategy for monitoring to determine if goals and objectives are being met.

Basic inventory data include a map and/or description of the management unit showing property boundaries, fences, roads, utilities, water sources and other structures or improvements (Figure 1.1). In addition, an inventory of the basic rangeland resource is needed.

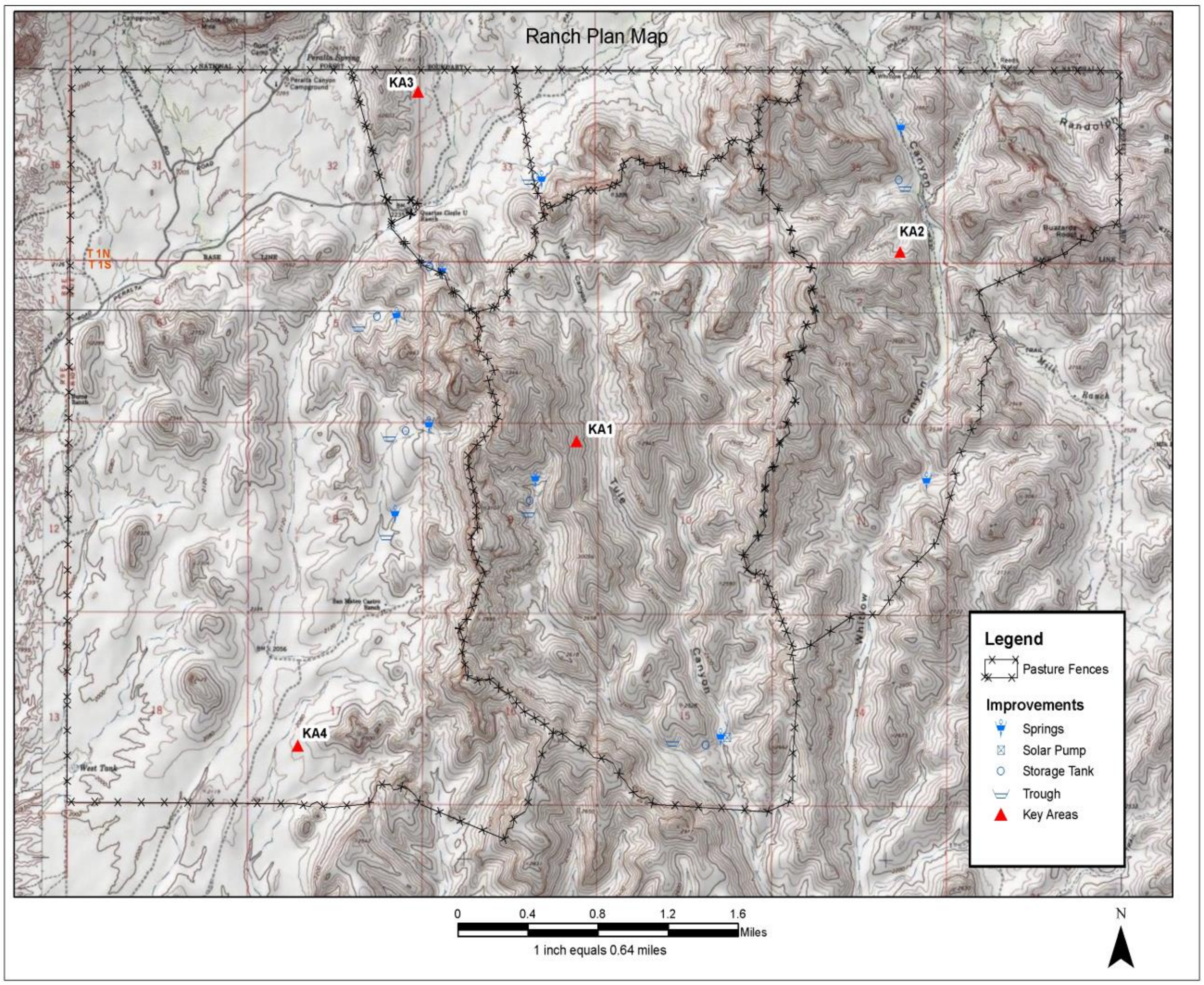


Figure 1-1. Ranch plan map showing boundary and pasture fences, other improvements and key monitoring areas. *Map courtesy of Emilio Carrillo and Don Decker, AZNRCS.*

Ideally, this should include site mapping units, such as a soils map and/or ecological site map (or similar map of ecological potential) of the area. Essentially, these maps serve as permanent base maps upon which most planning and monitoring rely. Soils or ecological sites establish the potentials, limitations, location and extent of each land type. In addition a survey of current vegetation and soil conditions that characterizes each of the site mapping units is needed. This may involve quantitative data on composition of vegetation and/or ground cover, or it may involve visual assessment of these attributes such as that provided by the rangeland health (Pellant et al. 2005) or proper functioning condition (Prichard 1994, Prichard 1998) procedures. In any case, this information, when interpreted in consideration of site potential, management history, and other factors, will help to establish goals and objectives, appropriate grazing strategies and other management practices, location of key areas and key species, and a framework for monitoring. Years of experience on a ranch help ranchers develop an understanding of these features that guides their management decisions. The formal process of mapping and resource characterization is beneficial to any range manager, and is essential to good communication and planning where several people or interests are involved (see Section 3).

The information described above is the basic information needed for planning rangeland management for livestock grazing. Multiple use concerns and certain legal requirements may require additional inventory information such as wildlife population surveys, occurrence of noxious weeds, existence of endangered species and their critical habitat, recreational use, water quality, cultural or archaeological sites.

Monitoring is the process of observing how well a management plan is being applied and its results. Monitoring is used to make decisions about how or whether livestock grazing or other management practices need to be changed to meet management objectives. These decisions are described in Section 2.

CHAPTER 3
Basic Premises

Sustainability Is the Basic Goal

The basic goals in management of rangelands are to achieve and maintain plant communities that will protect the potential productivity of the soil and to provide desired benefits (livestock forage, wildlife habitat, "ecological services," etc) on a sustainable basis. Therefore, the final test of whether the goal of sustainability is being met rests in assessing the general direction of vegetation dynamics as moving toward or away from a desired plant community description that will meet both ecological and resource output goals. That is what rangeland assessment and monitoring should primarily address (see Section 2).

Desirable Attributes Can Be Directly Observed or Measured In the Field

Attributes should be capable of being reliably measured or, at least, described by qualified personnel in the field. Attributes that depend on lab analysis, such as soil organic matter, may be useful for long-term monitoring, but do not lend themselves to adaptive management decisions. Attributes that are significantly influenced by weather, season of year, vegetation type, or site conditions are difficult to apply in general monitoring because they require studies or calibration to account for these factors. For example, infiltration rates are influenced by site and antecedent moisture conditions. Soil slake tests are affected by site factors such as soil texture. The relationship of visual obstruction ratings to standing biomass varies depending on vegetation type. Such variability means that interpretations of data must be specific to the ecological site or vegetation type being sampled. Ecological processes that either cannot be directly observed (for example, nutrient cycling), or which occur episodically and are not likely to be observed (soil erosion), are not attributes that can be quantitatively monitored for routine rangeland monitoring or assessment (see Chapter 13).

Attributes Should Have Demonstrable Relationships to Resource Outputs or Processes

Many attributes of rangeland ecosystems can be measured or observed, but unless they can be demonstrated to be reliable indicators of the desired vegetation in terms of resource protection and/or resource outputs, they are not useful for measuring achievement of management objectives. For example, it is known that compaction of the soil surface can reduce infiltration and increase runoff. Compaction can lead to reduced vegetation production, changes in species composition, and/or increased soil erosion. However, unless it has been demonstrated by site-specific studies that a given level of soil compaction does, in fact, result in undesirable changes in either vegetation or soil stability on a site-specific basis, then a one-point-in-time measurement of soil compaction does not provide a basis for deciding whether the level of soil compaction is acceptable or not. Assuming that repeatable methods are available, soil compaction levels can be monitored over time to establish trends toward greater or less compaction. In particular, the size of the area affected by compaction due to livestock grazing is also critical. For example, small areas of compaction around a livestock watering area are not usually significant on a landscape basis.

The same principle applies to many attributes of rangelands. For example, bare soil can be measured and is known to be related to risk of soil erosion. However, without site-specific information on the nature of the relationship it is not possible to set sound guidelines on what constitutes acceptable levels of bare soil for a given site. Likewise, visual obstruction ratings of vegetation are known to be related to quality of nesting cover for certain birds, but without specific information on levels and patterns of such cover, sound guidelines cannot be established. Of course, such site-specific or quantitative studies are not always (probably not even usually) available. That is why we recommend more reliance on monitoring trends in attributes known to be related to desired resource outputs rather than setting rigid standards or thresholds that do not apply equally well across the landscape. Lacking information necessary to establish the relationship and critical values of measured attributes and related resource attributes it is advisable to focus on measurement of trends rather than threshold values (see Chapter 21).

Plant (species or life form) diversity is often indicated as an attribute that should be measured and may even be described as a management objective. However, diversity can be defined in a number of ways and at varying scales. Diversity may be related to ecological goals (such as sustainability or stability of ecosystems; protection of endangered species) or to economic goals (such as forage and habitat for livestock and game animals), but it is necessary to establish how the definition and scale of diversity measured is related to the actual resource output desired. In other words, if plant diversity is not a management goal in itself, but is measured because it is known or believed to be correlated with some attribute of the ecosystem such as productivity, stability, or sustainability, but the relationship between the measure of diversity used and the desired output needs to be established by research or studies (see Chapter 24).

Rangeland Systems Change Over Time

The rangeland vegetation and animal populations we see today on any particular landscape are the product not only of the basic productive potential of the climate, soil and topography but also of all of its history of natural and human-caused influences. Most rangelands are characterized by highly variable and unpredictable precipitation, wind, and temperature (weather). Extreme drought or heavy precipitation as well as extremes of temperature occur in episodic fashion over periods of decades. Shifts in average weather patterns (climate) may occur over longer periods of time. Rangeland vegetation (and its dependent animal populations) are in a continual state of change and adaptation to both short and long term variations in weather. Wildfire frequency and intensity also varies with weather conditions to affect plants, animals, and soils. Human caused effects (burning, grazing, cultivation, hunting, plant introductions, predator control, etc) interact with environmental fluctuations to alter responses of vegetation, animals and soils. Such interactions are the reason for some significant changes observed due to heavy grazing, altered fire regimes, excessive hunting and other human influences since European settlement. However, it is now thought that human influence has been a significant influence on vegetation and wildlife populations for several thousand years before that. Understanding how the intensity, frequency, and timing of such actions, interact with environmental influences is the basis for scientific natural resource management.

When natural or human effects are severe and/or of long duration dramatic changes in species or life form composition of the vegetation may result. In some cases reducing or removing the influence may result in re-establishment of vegetation resembling that which existed prior to the disturbance. In other cases, species composition and productivity may remain in a very different condition without substantial management input (e.g. if an exotic species becomes “naturalized”, a different life form dominates the site, or loss of soil changes the site potential). In some cases, events set in motion years ago (e.g. gully development) continue in spite of improved management. However, even when historical changes in species composition have been marked, there is little evidence that in the majority of cases the ecosystem has lost its productive potential (although it may not produce the kind of vegetation we would like); it is just different.

Range management (and other resource management disciplines) has been characterized by rather loose and undefined application of terms such as “stability”, “resilient”, “disturbance”, “degradation”, “restoration”, “integrity”, and “health”, all of which are rooted in theories of natural ecosystems based on predictability and equilibria (steady states in the balance of nature concept) between the natural environment and native vegetation, soils, and wildlife (Pete Sundt 2010). Although the scientific basis for such theories has been mostly abandoned, these terms continue to be part of the lexicon of natural resource management and environmental interest groups, and therefore are also found in laws and government policies. We believe that such terminology results in a tendency to look back in time to re-establish a condition which is believed to have existed (whether it really did or not) and to represent that condition as the most balanced and productive system attainable for a given site. We do not think this orientation is well founded scientifically or very useful from a practical standpoint. Rangeland assessment and monitoring will be more usefully based on trying to understand the reasons for the present state of the resource, its potential for change, and its future response to both the natural environment and human management practices (see Chapters 5, 6).

SECTION 2
USES OF INVENTORY, ASSESSMENT AND MONITORING DATA FOR MANAGEMENT

What You Will Find in Section Two

- How do planning and monitoring go together?
- What's the difference in goals and objectives, and how do they relate to monitoring?
- What is the difference between "present vegetation" and "potential vegetation"?
- Different views on nature of vegetation change (succession).
- How goals are expressed as "desired conditions".
- What is a "desired plant community" and how does it establish objectives for monitoring?
- What kinds of management decisions are based on short-term monitoring?
- What kinds of management decisions are based on long-term monitoring?

CHAPTER 4
Establishing Goals and Objectives for Management

Rangeland monitoring and assessment at the ranch or government grazing allotment level is primarily done for the purpose of establishing whether rangeland management is achieving management goals and objectives, or is making progress towards those goals and objectives, and, if not, to help in deciding what changes in management are needed. Thus, monitoring and assessment are integral parts of a management plan. A monitoring and assessment program cannot rationally be developed in the absence of stated goals and objectives and a plan for implementing grazing management, range improvements, or other management practices. Management plans usually include objectives that go well beyond livestock production and management, and often include objectives for wildlife, soil conservation, water quality, or even esthetics. Therefore, the monitoring plan should also address these values or outputs.

Establishing management goals and objectives for rangeland management depends on two basic considerations. First, the potential or capability of the land to produce different kinds and amounts of vegetation must be established so that management objectives are realistic in terms of what is possible to achieve. Site potential (soil, climate, topography) establishes the natural limits on what can be produced in terms of vegetation and related resource values like forage, wildlife habitat and watershed characteristics. Making this interpretation requires classification and inventory of land capability (see Chapters 9, 11, 12).

The second consideration concerns the values and desires of those who own and manage the land. A fundamental goal of all landowners should be to manage the land so that its ability to produce various kinds and amounts of resource values is maintained or enhanced in the future (sustainability). That goal may be stated as law or policy for government owned lands, but it is also recognized by responsible private landowners whether it is explicitly stated or not. Additional goals are determined by the desires of interested parties for specific outputs (forage, wood, game, water) or values (open space, esthetics). These goals may be constrained by economic or technological feasibility, or by legal restrictions (e.g. Endangered Species Act).

Clearly stated goals and objectives provide the framework for deciding what to monitor, where to monitor, and how often to monitor. Goals and objectives may refer to physical/biological characteristics of rangelands (vegetation, soil, hydrology, etc.) or social values (income, employment, recreation experiences, etc). This guide will only address the former.

Goals are general statements of the desired resource uses and resource conditions for a given area of land. For private land, that would generally be a ranch unit, or several ranch units. On government land, it may be National Forest, a BLM Field Office, or an entire state or region. Some goals are established by local, state or federal law. For example, laws governing water use or water quality, laws protecting endangered species of plants or animals, hunting laws, zoning, or other laws may restrict certain uses or prescribe standards that must be achieved. Federal or state laws may establish the basic uses and priorities for government lands, and may also require government land managers to coordinate and cooperate with the plans and desires of other landowners in establishing goals for government land. Within this legal framework, landowners establish resource goals that will best meet their economic and social goals. On private land, this may be a simple process. On government land, it can be a fairly complicated process of involving numerous interested parties in public comments and discussion.

A resource goal might be to minimize soil erosion rates on a watershed to maintain soil productivity and water quality. If it were determined that juniper cover on certain ecological sites was contributing to soil erosion by reducing perennial grass cover, a resource objective might be to reduce juniper cover to 10% or less within 10 years. Both the desired level of cover and the time frame may vary depending on the ecological site, the practice (s) to be employed for juniper control, and the expected availability of funds for implementing the practices. In this example, the practices applied (fire, herbicide, or mechanical clearing) can be reasonably predicted to result in the desired reduction in canopy cover provided they are done correctly. Obviously in this case, another objective would be to increase perennial grass cover to a level that would result in the desired reduction in soil erosion. However, caution should be used in establishing desired amounts or composition of grasses or the time frame since the response of the grass cover to the juniper treatment is less predictable than the effect on the juniper itself.

CHAPTER 5
Current and Potential Vegetation

The current vegetation on a particular area consists of the species and/or life form composition (relative amounts) of the vegetation and its productivity. It may be directly observed and described or measured. Current vegetation is to a great degree a result of site conditions such as soil, topography, climate and wildlife. It may also be influenced by current weather patterns such as drought or wet years, or other factors such as fire or grazing. The current vegetation in a particular location is formed by its unique history of climatic changes, landscape development, plant and animal migrations or extinctions, and human influences over long time periods, as well as fairly recent weather patterns, fire history, and land use. Thus current vegetation is not the same as it was at some time in the past, and it will likely be different to some degree in the future as a result of both natural and management-related influences.

Predicting future changes in vegetation due to management prescriptions and natural influences is the essence of range management planning. Realization that current vegetation is not necessarily what it “could be,” or what we would like it to be, resulted in the concept of “potential vegetation.” Ecological sites are based on the idea that differences in soils, climate and topography establish the “site potential”, or the basic adaptability of plant species and life forms to grow on a given location. Plant interactions and the effects of fire and animals, including range management practices, shape the actual vegetation that develops on a site.

The concept of “potential vegetation” has changed as our theories of plant ecology and succession have changed. In the early days of range management, the potential vegetation for an ecological site (then called a range site) was considered to be the “climax” vegetation (Dyksterhuis 1949). Under the then-accepted successional theories, the climax vegetation was the one stable endpoint of succession. The climax was the vegetation that existed, in the absence of “abnormal disturbance” (such as a catastrophic fire or windstorm) before it was “disturbed” by man’s activities (such as livestock grazing, cultivation, or clearing). In the absence of abnormal or human-caused disturbance vegetation would return to its pristine condition through a predictable process of succession. An exception was when a “disturbance” was a regular part of the environment (such as grazing or repeated fire) in which case a stable “disturbance climax” (disclimax) would result. The climax view was modified somewhat by the concept of "potential natural vegetation" (PNV). This theory recognized that some disturbances resulted in changes that were not reversible. PNV was defined as "the vegetation that would exist today if man were removed from the scene and if the resulting plant succession were telescoped into a single moment" (Kuchler 1964). Kuchler said the latter point eliminates the effects of future climatic fluctuations while the effects of man's earlier activities are permitted to stand. The basic theory of plant succession was not changed, only the recognition that succession can only go forward in time.

The linear, predictable successional theories supporting both climax and potential natural vegetation have been questioned for many years. The individualistic theory of succession postulated that plant species each react individually to gradients in environmental factors, thus "plant communities" are only chance assemblages of species, not entities in themselves (Gleason 1926). Later, the concepts of "multiple stable states" and "multiple successional pathways" were proposed in opposition to the single stable climax and predictable direction of succession concepts. Most recently the "state and transition" theory has gained acceptance (Westoby et al. 1989, Bestelmeyer et al. 2003) (Figure 2-1). This theory holds that several stable "states" may be possible on a given site. Vegetation composition may fluctuate around a given stable state due to weather, fire, or management. In some cases, an extreme event, or the combination of several factors may move vegetation to a different state from which it will not return without an "outside" influence sufficient to change the equilibrium of the alternative state, for example, brush clearing. If soil erosion changes site potential the site may be permanently changed to a new state and transition model. For example, in Figure 2-1 the Sandy Loam Upland site is converted to a Loamy Upland site in transition 6 due to loss of sandy loam surface soil.

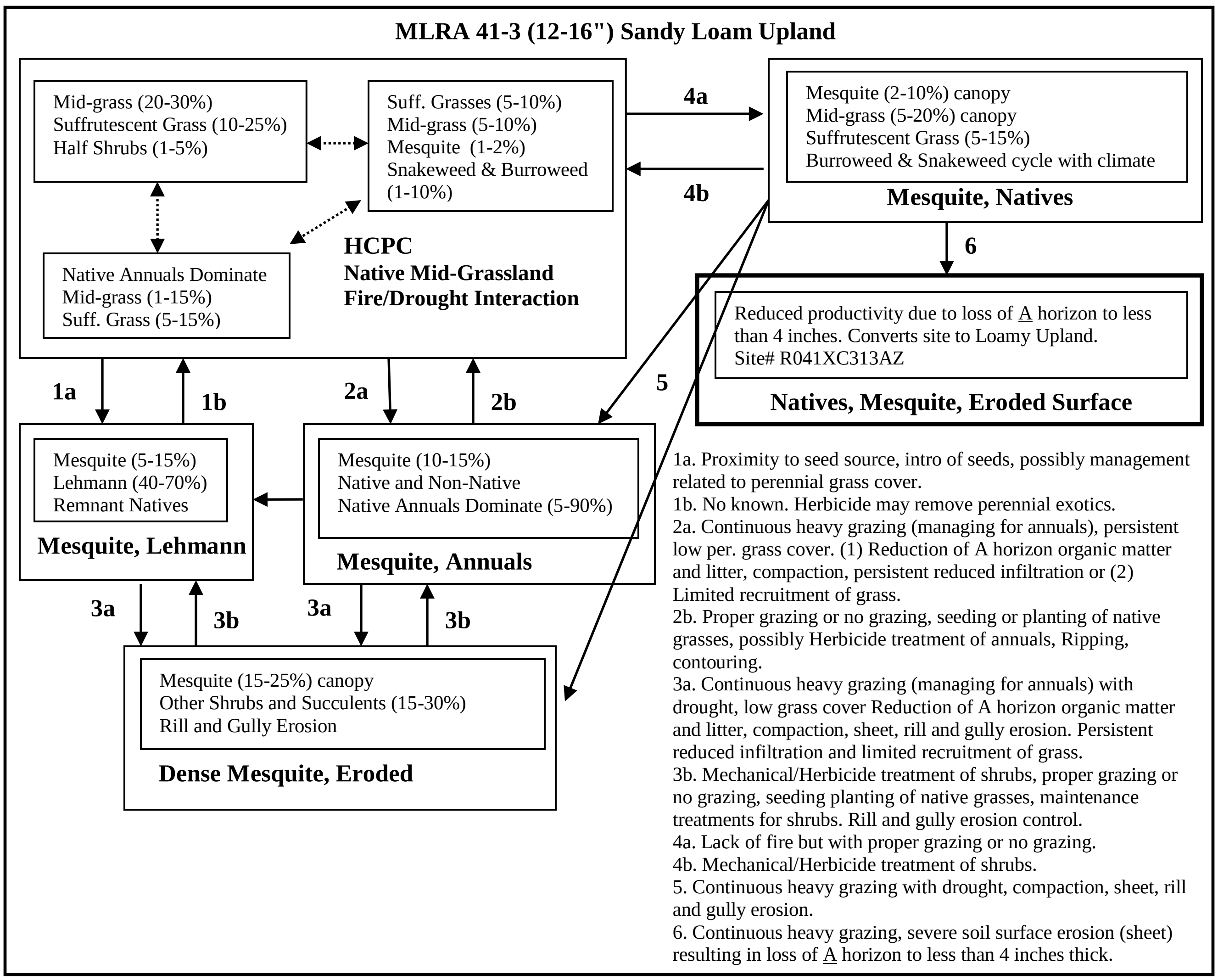


Figure 2-1. Example of a state and transition model for a specific ecological site. The various states are enclosed in boxes; the transitions are described by the arrows between boxes. *Adapted from NRCS Ecological Site Description.*

All of the concepts of vegetation change summarized above are only theories. They have more similarities than differences. All of them basically postulate stable states. None of them really consider long-term directional environmental changes, such as climate change, soil erosion due to landscape evolution, or genetic changes in either plants or animals. Therefore, we advise caution in describing presumed "potential vegetation" for a given site in other than general terms. The concept is useful for planning purposes when sufficient knowledge of the interaction of site potential, natural influences, and management actions exists. However, the level of understanding of such interactions and lack of knowledge of future environmental conditions makes such predictions less than absolute. It is precisely for this reason that monitoring is important so that we can document changes and attempt to understand whether the changes, or lack thereof, are the result of our management, other environmental effects, or an unrealistic "potential" set as a management goal.

CHAPTER 6
Desired Condition

Resource goals are expressed as desired conditions (DC), i.e. the general characteristics of the natural resources that management will aim to achieve in the future, or to maintain where such conditions already exist. Stating these desired conditions does not require much specific information on land potential or existing resource conditions, although obviously goals should reflect the general potential of the land to which they apply. For example, one would not set goals for wood production or increasing water yield in the desert grassland

An example of desired condition is the Arizona BLM's standards for rangeland health.(Bureau of Land Management 1997) These standards were developed to guide BLM's rangeland management throughout the state. Although the standards were tied specifically to livestock grazing in the grazing regulations, in practice they are applied to the land, not the use. In other words a failure to meet standards may be due to uses other than livestock grazing. The standards express the desired ecological conditions to be attained and the legal requirements to be met for all BLM land. These standards are:

1. Standard 1 Upland Sites – Upland soils exhibit infiltration, permeability, and erosion rates that are appropriate to the soil type, climate and landform (ecological sites).
2. Standard 2 Riparian-Wetland Sites – Riparian-wetland areas are in properly functioning condition
3. Standard 3 Desired Resource Conditions – Productive and diverse upland and riparian-wetland plant communities of native species exist and are maintained.

For each of the three standards, appropriate indicators are listed. These indicators provide a basis for monitoring to determine if standards are met, but the threshold values and description of the Desired Plant Community are only determined at the site-specific level. Desired Plant Communities (DPCs) are determined for each ecological site to meet legal requirements and specific management objectives. DPCs at the site specific level are indicated by species composition, vegetation structure, and plant distribution.

Another example of desired condition is the landscape goals used by the Holistic Management International. Its landscape goals describe the general condition of the resources to be achieved by such statements as:

- Maintain a diverse mixture of grasses and shrubs for livestock and wildlife.
- Maintain a good cover of vegetation and litter on the soil surface.
- Provide reliable stream-flow with good quality of water.
- Prevent invasion of noxious weeds.

CHAPTER 7
Desired Plant Communities

Desired conditions establish the basic requirement for monitoring to determine whether goals are being met, or whether significant progress toward those goals is occurring. Some monitoring may be carried out on a "landscape" level to document attainment of landscape goals. However, before site specific monitoring plans can be developed, it is necessary to develop site specific objectives to be met. An important part of this process is to describe desired plant communities which express the type of vegetation in terms of life form or species composition, age structure, or cover capable of being produced on a given ecological site that will meet the goals established for management.

Desired Plant Community (DPC) is defined as: "Of the several plant communities that may occupy a site, the one that has been identified through a management plan to best meet the plan's objectives for the site. It must protect the site as a minimum"(Glossary Update Task Group 1998). Selection of a DPC depends on the development of site specific objectives in a local management plan, such as an allotment management plan, ranch plan, or wildlife management unit plan. To develop site specific objectives in a management plan requires information on an assessment of rangeland potential and existing conditions and upon identification of desired uses, outputs and/or values. One of those values would be to meet minimum conditions for "rangeland health", i.e. sustainability of ecological functions on the site. Assessing rangeland potential involves classification of rangeland according to the various kinds and amounts of vegetation it can produce.

The most common basis for this classification is the ecological site which will be described in more detail in Section 3. Ecological sites are kinds of land that differ in their potential to produce a distinctive kind and amount of vegetation and in their response to management. Each ecological site can produce various types of vegetation communities depending on how it is managed (see example in Figure 2-1). A map of the ecological sites that exist on a management unit furnishes a relatively permanent basis for land management planning and rangeland assessment

Along with identification and mapping of ecological sites should be an assessment of existing vegetation types and soil conditions on each site mapping unit. This information provides a basis for deciding whether existing conditions are meeting the desired management objectives or not. If existing conditions (vegetation state) are not adequately meeting objectives, ecological

Desired Plant Communities

The definition of Desired Plant Community (DPC) is: "Of the several plant communities that may occupy a site, the one that has been identified through a management plan to best meet the plan's objectives for the site. It must protect the site as a minimum"(Glossary Update Task Group 1998). The question is: How do you decide on a DPC for a given situation and how do you describe it?

The definition above infers that three fundamental concepts are involved:

1. Plant communities that will not protect the site from degradation by erosion are unacceptable if there are other feasible types of vegetation that the site can produce which will provide such protections.
2. There may be, and generally are, more than one vegetation type capable of being produced on the site that will meet the previous requirement. ***The "historic" or "climax" plant community is not necessarily the DPC.***
3. The DPC is selected to meet management goals and values for all proposed uses of the site. Since it may not be possible to maximize benefits to all uses on one location, it may be necessary to seek an optimum balance among uses either on a given location or by setting priorities among locations.

It may not be possible to define one DPC for the entire extent of an ecological site within a management unit (pasture or ranch). Landscape goals may dictate that more than one DPC will be desirable on different parts of a site. For example, if site A can produce either grassland or a mixed grass/shrub vegetation, it may be desirable to have some of both to provide optimum cover and nutrition to wildlife and livestock. This decision may also be influenced by the juxtaposition of ecological sites with other capabilities. If site A is intermixed with site B, which produces shrubs but has little grass potential, then the DPC for site A may be shifted more to a grassland.

Economics and technology also enter into the decision on the DPC. If the most desirable vegetation type for a site can only be reached by practices that cost more than the expected benefits, or have not been adequately developed, then an alternative vegetation type may be selected. In other words, the community selected is not what we would like to have, but it may be most realistic goal to shoot for.

Finally, the DPC should be described in general terms rather than attempting to prescribe the desired amounts (percent composition or pounds/acre) for each species. We generally lack the knowledge to predict changes in response to management or weather that accurately. Specifying the desired amount of each species will only lead to difficulty and disagreement on whether progress is being made toward the DPC or not. It is more useful to describe the DPC in terms of structural and/or functional groups, rather than species. For example, the DPC could be described as "predominantly composed of mid- tall warm season grasses with scattered shrubs and succulents". It may be useful to list some of the desired grasses and shrubs, but not give exact percentages expected. Perhaps the simplest way to identify the DPC for a given site is to select on the "vegetation state" or "community phases" from the Ecological Site Description (Figure 2-1). Not all ESDs currently have the states and transitions developed well enough to do this yet.

site descriptions can help decide where it is possible to move toward a vegetation state that will better meet management objectives, and what management practices are required to do so. Vegetation and soil conditions that either exist or can be achieved on a site by economically feasible and acceptable management practices define the DPC for that ecological site in that management unit.

CHAPTER 8
Data Needs for Management Decisions

Livestock Grazing Management Decisions

As pointed out in the sections above, rangeland inventories of basic soil/vegetation characteristics and potentials provide the basis for establishing management goals and objectives and establishing management practices to obtain those goals and objectives. On the other hand, monitoring is done to determine whether those goals and objectives are being met and to establish a basis for making decisions about adjustments in management.

Livestock grazing decisions can be roughly grouped into three categories:

1. Day-to-day livestock grazing management and short-term planning. These decisions are made by ranchers, sometimes with the assistance of technical advisors or agency range specialists. They are made in the context of constraints imposed by legal agreements and land use plans.
2. Compliance with legal agreements. People who administer grazing leases or sub-leases (public or private), grazing permits, annual operating instructions, conservation easements, cost-sharing agreements, grants, bank loans, land use plans, or other types of legal agreements must establish that grazing is in compliance with the terms of such agreements. These people are the authorized officers or agents of the entity(s) with authority to regulate grazing use on a management unit.
3. Attainment or satisfactory progress toward attainment of management objectives. Such objectives may be stated in a formal land use plan on government land, or only reflect the desires of the landowner on private land.

The people involved in the first two categories of decisions should obviously be involved in the last, but the plans will often deal with many other interests and/or disciplines in those plans and decisions. The livestock producer may have relatively little input to these plans, but will have a responsibility, in part, to meet these long-term goals.

The first two categories of decisions rely mainly on short-term monitoring; the third depends mainly on long-term monitoring.

Day-to-Day Grazing Management

Almost none of the day to day decisions involved in managing rangeland grazing depend on monitoring as defined by the Society for Range Management or other range management sources. Some of the day-to-day decisions include when and how many livestock to put into a pasture, when and how many to take out, where and how much salt or supplement should be put out, whether livestock need to be moved by riding, and the need to check on waters, fences, and livestock. These decisions are based on several kinds of "data" the ranch operator observes (monitors) day by day.

One example of this kind of data is actual use. For example, most ranchers keep a tally book record of numbers of livestock moved or removed from pastures. Actual use data can be compared to historical levels of use or climate and weather information and serve as a check on current practices.

Another example is "utilization' (see Chapters 24, 30, 40). A rancher may observe the degree of use on forage plants and the pattern of use within the pasture to help decide whether distribution needs to be improved and when to move livestock out of the pasture. It is not necessary to measure utilization quantitatively to make those decisions. However, it is often desirable to record observations and/or measurements in some orderly way. Such data can be helpful in two ways. One is that using an established method for observing utilization helps focus attention on the utilization of specific plants (key species) which can be overlooked or underestimated if obscured by an abundance of less preferred species with little or no utilization. Another reason for a rancher or an agency range specialist to make quantitative observations is to provide an objective record for a given date. However, all parties should recognize that a number of observations are necessary in a particular location to establish the variability in the estimate, that utilization measured in one location may or may not be typical of a larger area, and that the "utilization" measurement may only provide an index to use and not a true estimate of the percentage utilized of total annual production. Thus, utilization measurements and observations are valuable tools for identifying management problems, making short-term management decisions, and interpreting trend data, but are not of sufficient reliability to be used as rigid guidelines.

The third observation made by ranchers is the condition and behavior of the livestock. Changes in the condition or behavior of range livestock can indicate changes in the amount or quality of forage available to the animals that make it desirable to move animals or to supplement them. For example, when cattle have removed a substantial part of the more palatable forage they may spend a longer time grazing to seek forage, turn to plants that are normally not relished, or congregate near fences seeking to move to more favorable forage. When the amount and/or digestibility of the forage decreases due to weather and/or utilization of the better forage, animal intake declines and animals may lose weight.

In addition to these direct observations ranchers must consider a variety of other factors in deciding when and where to move animals from one pasture to another. It may be desirable to move livestock to another part of the range to take advantage of seasonal palatability of browse or other species, or the need to rest forage plants during part of the year. The grazing management plan, allotment management plan, or annual operating instructions may specify on and off dates for livestock or restrictions on grazing at certain times in certain areas to protect riparian values, wildlife habitat, or to avoid conflict with other uses. Therefore, the operator needs to insure that livestock numbers or time of grazing do not conflict with legal requirements of plans, permits, leases, or easements.

The rancher also has to plan management needs for the short-term future (up to a year or more) based on availability of forage and water for different seasons, feasibility of feeding, gathering, weaning, or working livestock, potential seasonal conflicts with recreationists and hunters, problems with predators or poisonous plants, economic constraints, or other reasons. To do this the rancher needs to monitor weather, forage growth, and water availability over the entire management unit in order to anticipate conditions in the succeeding seasons. Sometimes long-range weather reports are useful.

At the end of the growing season and the end of the grazing season, the rancher needs to make decisions about what changes, if any, need to be made during the remainder of the year or in the coming year. For example, if the pastures remaining for use until the next growing season do not appear to have enough forage, then reduction by early sales and/or heavier culling may be desirable.

Grazing Administration

"Grazing administration" means oversight to ensure that the terms and conditions of legal agreements regarding grazing management are met. Most ranches in the West operate with some amount of state lease or federal grazing permits. These leases and permits specify the number of livestock allowed, the season of use, and, sometimes, other restrictions or provisions. In addition to the specific leases and permits, there are allotment management plans and/or annual operating instructions that impose additional requirements on grazing management. Examples are specified pasture rotation dates, salting and supplementing rules, areas where grazing is prohibited or restricted due to conflict with endangered species, wildlife, or recreation, and other multiple use concerns. It is the duty of the "responsible officer" (District Ranger, Field Office Manager, or State Range Section Leader) to determine whether grazing carried out under the terms of these documents is in compliance with those terms and conditions.

Even on private lands there may be certain legal requirements that restrict grazing. Some livestock operators lease private land for grazing, and private lessors may specify stocking rates or other restrictions in the lease. Some private landowners have entered into conservation easements or other arrangements designed to prevent fragmentation of ownership or for certain environmental considerations. Often, these contracts contain provisions regarding the amount, timing, or location of grazing. Concern over non-point source water pollution has led to the development of the concept of "best management practices" for water quality (Arizona Administrative Code 2010). A ranch operator who follows such practices would be deemed to be in compliance with state or federal water quality laws. It seems likely that private lands will be increasingly subject to this kind of regulation of grazing activity that may have impacts on resources beyond the borders of the private land. Finally, many private landowners enter into contracts with government cost-sharing programs aimed at encouraging range management practices that provide environmental benefits in the public interest or other government or private programs granting money to landowners for specific purposes. These contracts typically have requirements for grazing management to ensure that the benefits of the program are not negated by overstocking or other practices.

All of the legal programs described above require some kind of oversight on the part of the administering party (government agency, easement holder, lender, etc.) to determine that the ranch operator or landowner is in compliance with the terms of the contractual arrangement. Obviously, the kind of information required will vary depending on the terms specified in the agreement (contract, lease, permit, easement, etc.). Probably the most common information would be the number and type of livestock grazed, the period of grazing, and the dates that livestock were in specific pastures or management units. Other information could include location of salt or supplement, riding to improve distribution, construction or maintenance of improvements, use of pesticides, or other provisions. The responsible person must carry out periodic field checks or depend on the operator to supply this information. The livestock operator should keep his own records of compliance with terms of legal agreements in case there is a dispute.

Utilization is an attribute that can be used for grazing administration and that comes under the usual concept of “rangeland monitoring”; it involves observation or measurement of vegetation (see Chapter 24, 30, 40). Management plans, permits, leases, or other grazing agreements often require “proper use”, “moderate use”, or utilization at specified levels (50% or 30%). These requirements are there because it is assumed that excessive forage utilization by livestock (overstocking) will affect the vegetation and soils in ways that are unfavorable to achieving the goals of the agreement such as maintenance or improvement of ground cover, positive changes in vegetation composition, or protection of endangered species. This assumption is reasonable because it is well-accepted that long-term excessive grazing pressure can lead to negative effects. However, utilization measurement is subject to substantial spatial and temporal variability, as well as unverified assumptions involved in the methods themselves, and thus precise, quantitative guidelines should be avoided in the types of legal documents mentioned above (Smith et al. 2007).

Developing and Revising Rangeland Management Plans

A management plan states the long-term goals to be achieved over a period of years, sometimes decades or longer. The plan involves prescribing the type of grazing management, other management practices, and physical improvements that will be used to achieve those goals. A management plan usually also states objectives that are more specific, measurable indicators that progress is being made toward the goals of the plan. For example, goals might include “sustainable” livestock production, “stable” soils, “healthy” ecosystems, or “viable” populations of endangered species. These goals would be defined in more concrete and site-specific objectives such as certain levels of ground cover, desired proportions of plant species or life forms, structural characteristics of vegetation and/or water quality parameters. Rangeland monitoring generally aims to measure these specific attributes to detect whether the management actions taken under the plan are resulting in the expected progress toward the objectives, and thus toward the goals, and if not, what corrective measures may be needed.

Much of the rest of this guidebook deals with the identification of suitable attributes for monitoring and the measurement and interpretation of monitoring data to determine whether long-term resource objectives are being met. A scientifically sound monitoring program is essential for tracking the effectiveness of management plans and providing a basis for plan revisions if necessary. Government officials responsible for the management and/or regulation of government lands, agents for land trusts or estates, and other legal or fiduciary agents require this type of information. Managers of such lands are generally subject to policies, laws, or rules requiring accountability for their management.

Ranchers operating on their own lands, and people who work with them in an advisory capacity, may have less need for quantitative, long-term monitoring data. This type of information does not have much effect on day-to-day or year-to-year management decisions. However, even on private lands, it is useful to establish long-term objectives and to collect a certain amount of monitoring data to measure progress toward objectives and to document land stewardship if issues such as endangered species or water quality arise. Most ranchers feel they know what is happening on the range they see almost every day and may not see the need for formal range data collection, although most understand the value of keeping records on rainfall and livestock. Some photographic or other quantitative information on vegetation and/or soil may provide information that selective memory has erased (We are always amazed to see photos that show how much children have changed even though we see them every day).

Those operators who lease or have permits to use government land (and some other categories such as Indian lands or trust lands) should work with the administering agency to insure that long-term monitoring is properly carried out to establish whether management is achieving objectives or not. A monitoring plan should be developed cooperatively by the livestock operator, agency personnel, and other interested parties. The plan should specify monitoring to be carried out (what, when, where, and how) and who is responsible for the various components of the monitoring plan. Monitoring can be conducted by various individuals, including interested parties, provided adequate training has been provided. The monitoring plan should also provide guidelines on how the resultant data will be interpreted and used for decision making, and who will make such interpretations. There are many benefits to cooperative monitoring. Benefits to the livestock operator, agency personnel, and interested parties include: increased knowledge for all, increased commitment to management objectives, increased communication and trust among parties, and a better basis for decision making. Operators should encourage the responsible agency to monitor and cooperate to the extent possible in collecting and interpreting monitoring data. If necessary, the operator should take the responsibility to do the monitoring themselves (or with a consultant). If the plan is not achieving stated objectives, even though the operator has conscientiously carried out the prescribed grazing plan, the lessee/permittee needs to know as soon as possible so adjustments can be made. If the plan is working, the lessee/permittee may have to provide his own evidence of success to represent his interests. In fact, it is virtually impossible to demonstrate a plan is working, thereby achieving objectives, without monitoring data.

The goals and objectives in a range management plan are not the same as actions required by a permit or operating plan. Determining compliance with a plan, permit, contract or other legal document should be based on whether the operator has conscientiously carried out the actions required under the document within the limits of his ability to do so. If so, he is in compliance with the plan or agreement. If the plan is not achieving the desired and stated objectives, then the plan must be adjusted accordingly. Long-term goals and objectives should be stated in a land use plan, allotment management plan, or ranch plan, not in a permit, annual operating plan, or contract because no one can know with certainty that the prescribed management will in fact produce the desired goals and objectives or in what length of time.

SECTION 3
PLANNING FOR DATA COLLECTION AND INTERPRETATION

What You Will Find in Section Three

- Why are maps important as a basis for monitoring and assessment?
- How do mapping units relate to taxonomic units?
- How are vegetation maps used in range assessment?
- Why are ecological sites important for data interpretation?
- Do ecological sites occur in riparian areas?
- How do ecological sites relate to management on a landscape basis?
- What information can be use to establish desired conditions?
- How do I select what to measure and how to measure it? (attributes and methods)
- How can sampling efficiency and precision be improved?
- Where should I monitor?
- When should I monitor?

CHAPTER 9
Stratification and Mapping

Range management plans generally depend on inventories or assessments that document the kind, amount and/or condition of resources over a management unit. Although it is possible to obtain this type of information by some kind of random or systematic point sampling over the entire unit, the usual procedure is to make maps of basic resources as a basis for management plans and to aid in selection of key areas or other locations for monitoring studies. Such maps serve as a basis for stratification of data collection and for extrapolation of results of monitoring data. Useful resource maps include soils maps, topographic maps, ecological site maps, wildlife habitat maps, or vegetation type maps. Maps of land ownership, roads, fences, water sources, buildings or other improvements are also very useful (see Figures 1-1, 3-7).

Understanding of some basic concepts of classification and mapping is desirable in order to recognize the value and limitations of resource maps. Before a map can be made, the resource must first be classified in some way, and the different types or categories of resources being mapped must be defined. The classification may be one that has been developed independently for general use such as the soil taxonomy developed by the USDA (Natural Resources Conservation Service 1975), vegetation type classification developed by Brown, Lowe, and Pase (Brown et al. 1979), the ecological site descriptions developed by the NRCS (Natural Resources Conservation Service 2005), or Terrestrial Ecosystem Survey (TES) (Robertson and Robbie 2003) used on some National Forests . In some cases, an *ad hoc* classification may be developed specifically for certain purposes, such as a classification of shrub cover type and density as a basis for planning brush treatments.

Any classification system involves the description of taxonomic units within the system. For example, plants are classified in a hierarchical system with the following categories: division, class, subclass, order, family, genus and species. Species constitute the lowest (most detailed) categorical level in the system. Thus an individual plant is assigned to a species, the basic taxonomic unit for plants. Soils are also classified on an hierarchical system with six categorical levels: order, suborder, great group, subgroup, family and series. The soil series is the most detailed category in the system and constitutes the basic taxonomic unit. Soil phases are subdivisions of series, or higher categorical levels, based on characteristics that affect plant growth or land use, such as surface texture, rockiness, or soil depth.

Mapping units define the areas mapped in terms of the taxonomic units in the classification. Mapping units are usually assigned unique numbers or names which are explained in the legend of the map. For example, a soils map might have mapping unit #85, with the taxonomic unit defined in the legend as Whitehouse sandy loam (Whitehouse is the series name and sandy loam indicates the phase based on surface texture). This would be an example of a simple mapping unit that only references one taxonomic unit, although it may have inclusions of other types that cannot be shown at the scale of mapping. In the Southwest Region, the Forest Service does not classify soils beyond the family level, therefore the family is the taxonomic unit used to name mapping units, and phases of families may be used when these make an important difference in site potential.

When mapping at small scales, or when mapping in very complex landscapes, it may not be possible to identify simple mapping units. In this case, a complex mapping unit may be used to indicate an association or pattern of two or three taxonomic units that cannot be readily separated at that scale of mapping. For example, mapping unit # 101 might be defined in the legend as Whitehouse sandy loam – Hathaway Association. This means that two different soil taxonomic units with very different characteristics occur in a complex pattern in the area mapped as # 101.

Map users must understand the above concepts because they have important implications for planning and for selection of data collection sites. Although one mapping unit covers a part of a management unit, this doesn't mean that every spot covered by the mapping unit is the same taxonomic unit. There may be inclusions (usually up to 15% of the area) of other taxonomic units that could not be mapped at that scale, or the whole mapping unit may have more or less equal parts of several taxonomic units in addition to inclusions. The point is that data collected on one spot within a mapping unit cannot necessarily be extended to every acre of the mapping unit, especially in complex mapping units. Likewise, any given sampling point within a mapping unit may or may not be on the taxonomic unit describing the mapping unit in the legend. In other words, the sampling point may fall on an inclusion or another taxonomic unit or on a transition between two taxonomic units. The correct identification of the taxonomic unit must be verified in the field. For example, a mapping unit name may indicate a ponderosa pine forest type, but a randomly selected point within the mapping unit may fall in an inclusion of grassland within the mapping unit and would not be a suitable location to characterize the mapping unit. Similar considerations apply to soils or ecological site maps.

Although riparian areas are important in setting management objectives and monitoring changes these areas often cannot be mapped out at the scales commonly used for grazing allotment maps or ranch maps. In other words, riparian areas (and some other critical areas) may be inclusions within mapping units unless the areas are large or mapping is done at very large scale.

CHAPTER 10
Vegetation Types and Plant Communities

Vegetation types were often used in the past for basic rangeland mapping, and are still used, but generally for specific purposes. Most of the early range mapping was based on "range types." These were first developed by the U.S. Forest Service and 18 standard range types (Figure 3-1) were used in the 1930s by the Interagency Range Survey for mapping most of the western rangelands (Stoddart and Smith 1955). Some agencies continue to use these range types (often with some modification) until the present time (U.S.D.A. Forest Service 1997) Many of these maps are still in allotment files. The "range types" were based on the most prominent plant types and "subtypes" were based on the most common species in the subtype. The range types were a use-oriented classification of vegetation.

Other vegetation maps are based on classification of vegetation "communities" which may consider plant life-forms (such as forest, shrubland, grassland) at higher categorical levels and species composition at lower levels of classification (such as cottonwood-willow, or western wheatgrass-blue grama). Vegetation units that describe similar types based on species composition in different layers are called plant associations.

Type Number	Type Name	Description
1.	Grassland	Grasses and grasslikes prominent
2.	Meadow	Grassland with moist/wet soils
3.	Perennial forb	Usually a degraded grassland
4.	Sagebrush	One or more species of sagebrush dominant
5.	Mountain brush	Tall foothill shrubs, (e.g. bitterbrush)
6.	Coniferous tree	Pine overstory with grass/shrub understory
7.	Waste (ungrazed)	Dense forest overstory with minimal forage
8.	Barren	Rock outcrop, talus slopes, badlands
9.	Pinon-juniper	Juniper, sometimes with pinon
10.	Broad-leaved tree	Oak, aspen
11.	Creosotebush	Cresotebush, often with other shrubs
12.	Mesquite	Mesquite with grass/shrub understory
13.	Saltbush	Shadscale, desert saltbush,
14	Greasewood	Greasewood
15.	Winterfat	Winterfat
16.	Desert shrub	Southern desert shrub/cactus
17.	Half-shrub	Degraded grassland (e.g. snakeweed)
18.	Annuals	Cheatgrass, red brome – usually a burned or degraded desert shrub or sagebrush type

Figure 3-1. The eighteen standard range types used by the Interagency Range Survey (Stoddart and Smith 1955). These types may reflect differences in site potential, management, weather, fire and/or other factors.

Vegetation types may be based on existing vegetation without reference to successional status (see Chapters 5, 24, 36). Other vegetation classifications are based on climax or potential natural vegetation, which is that vegetation that is presumed to exist on a given area if undisturbed by man's activities.

Whatever system is used to classify vegetation requires a classification of vegetation "communities." A plant community is an assemblage of plants growing together and can be described by species composition or life forms. Some early ecologists (Clements 1916) considered that plant communities, especially those undisturbed by man, were highly organized co-evolved systems that existed as a "quasi-organism" with distinct boundaries between different communities (ecotones). In this view, communities were objective entities that could be described and classified. Others saw plant communities as combinations of species each of which varied more or less continuously in space due to environmental conditions, competition or other influences (Gleason 1926). Thus, a "plant community" was only a loose association of species based on individual reactions to ecological influences, and the appearance of a fairly uniform plant community was due to uniformity of site factors or historical influences rather than complex interactions among species. In this approach, classification of plant communities is only a matter of convenience and communication, since plant community classification is strictly an arbitrary human concept. The latter view is more generally prevalent among ecologists, but many in the resource and environmental fields maintain the former view to some extent at least. This has led them to assume more predictability in the species or life form composition of "a plant community" than is realistic (Smith 1989).

CHAPTER 11
Ecological Sites – The Basis for Resource Interpretations

The Ecological Site Concept

Establishing desired resource conditions or objectives and the collection and interpretation of monitoring and assessment data must consider the potential of the site to produce certain kinds and amounts of vegetation and expected amounts of soil erosion. Because of its widespread use and application the preferred basis for this is an inventory (map) of ecological sites as used by the Natural Resource Conservation Service (NRCS), Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), Arizona State Land Department (ASLD), and other agencies (Task Group on Unity in Concepts and Terminology 1996). Ecological sites were formerly called range sites. Lacking an ecological site map, a soil survey map or map of Terrestrial Ecosystem Units (TES) (U.S.D.A. Forest

Service 1997) can be used. Recently the U.S. Forest Service has agreed to adopt the ecological site approach and integrate this with the TES approach currently used. Ecological sites are defined as “a kind of land that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation and to respond to management.” If no inventory of sites or soils is available, it is still essential to identify the ecological site where data are collected**.**

The vegetation existing on any given area of land is a product of two kinds of site factors. One is the combination of soil, topography, and climate that determines the moisture, temperature, and nutrient relationships of the site. The other is the natural and land use history of the location over time. These factors may include a combination of plant invasions, climatic changes, fire, disease, animal influences (including not only grazing animals and predators, but also insects, soil organisms and birds), and human impacts (including livestock grazing, clearing, reseeding, burning, wood cutting, seed harvest, or other influences, not only since European settlement but extending back to the beginnings of human occupation). Likewise, the soil present in any given location is also influenced by most of the same factors. Every specific location is unique because no two spots have exactly the same combination of site factors and history.

Soil properties are heavily influenced by the geomorphic history of the landscape. Soils on stable landscape positions may reflect thousands or millions of years of soil formation (such as the development of clay subsoils or caliche layers). Soils in dynamic environments such as riparian areas may have a complex history that represents frequent episode of erosion and deposition. Trying to understand these complex relationships to predict the capability of the site to produce different kinds and amounts of vegetation and the way it will respond to management is the job and the lifelong learning experience of range professionals, ranchers, and other resource managers.

Classification of Ecological Sites

Classification of ecological sites starts with identification and delineation of Major Land Resource Areas (MLRAs) (see Figure 3-2). MLRAs are geographic zones characterized by a pattern of climate, topography, soils and geology which affect land productivity and use. There are portions of seven MLRAs in Arizona, some of which also lap over into New Mexico, Utah, Colorado, Nevada and California. For example, MLRA 39 Arizona-New Mexico Mountains includes most of the higher elevation mountainous portions of Arizona and New Mexico characterized by pinyon-juniper, Ponderosa pine, chaparral, mixed conifer and mountain grassland vegetation. The southern portion of Arizona is classified into three MLRAs in the basin and range geologic province. They are MLRA 30 Sonoran Basin and Range, MLRA 40 Central Arizona Basin and Range, and MLRA 41 Southeastern Arizona Basin and Range. These three MLRAs all have a basin and range (mountain ranges with intervening alluvial basins) topography, but the climate ranges from low, predominantly winter rain on the west (MLRA 30) to a higher, predominantly summer rainfall in the southeast (MLRA 41). These differences affect the general pattern of vegetation types and productivity across the region.

Within a MLRA there may be different environmental zones (variously called precipitation zones, common resource areas, or sub resource areas). For example, in MLRA 41 there are three zones based on average annual precipitation: 41-1 Mexican Oak-Pine Forest and Oak Savannah (16-20 inches); 41-3 Chihuahuan-Sonoran Semi-Desert Grassland (12-16 inches); and 41-2 Chihuahuan-Sonoran Desert Shrub (8-12 inches). The vegetation in these zones reflects mainly the influence of altitude on the amount of plant available moisture determined by precipitation and temperature.

Within each of the precipitation zones (or common resource areas) ecological sites are classified based on differences in site factors (soil, slope, aspect, parent material, topographic potential, etc) that affect the potential to produce vegetation. Each site is given a name that describes the main site factors. For example, Granitic Hills refers to sites with granite parent material with mostly steep slopes, while Volcanic Hills refers to site with similar topography but developed on volcanic parent materials. Limy Upland sites are found on alluvial materials with slopes less than 15%, calcareous soils and a caliche layer at shallow depth. Limy Slopes sites also have calcareous soils, but occur on slope greater than 15% and generally lack a hard caliche layer. Loam Bottom, Clay Bottom, and Sandy Bottom all occur in areas that receive some extra moisture by flooding, but vary in soil texture. There may be 15-30 different ecological sites identified in each precipitation zone. The same name may be used in different precipitation zones or MLRAs.

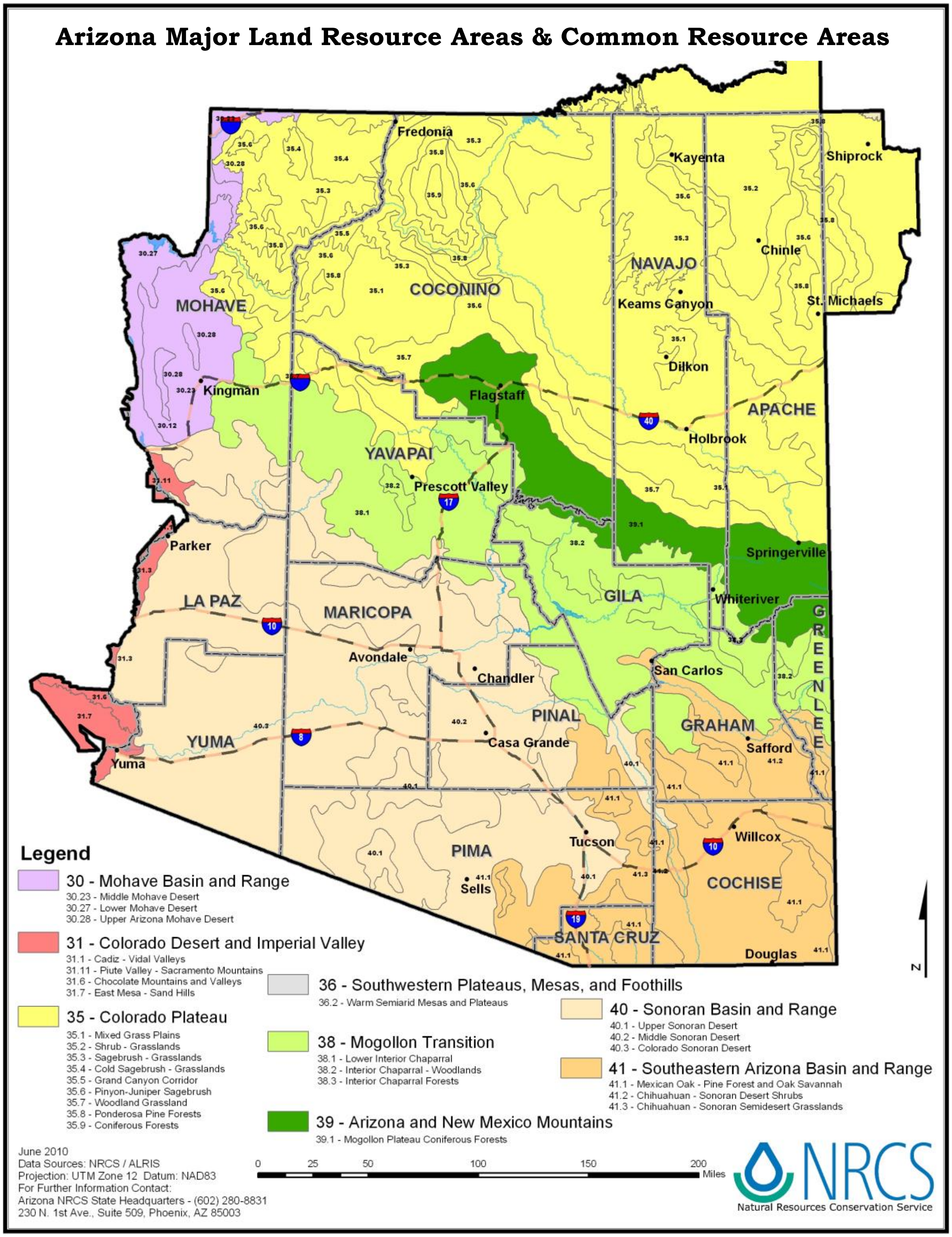


Figure 3-2. Major land resource areas and common resource areas in Arizona.

For example, MLRA 41-3 Loamy Upland (12-16 pz) is a different site than MLRA 41-1, Loamy Upland (16-20 pz).The soils are similar but the added rainfall produces a different type of vegetation and higher production in the higher precipitation zone. Likewise a Loamy Upland site in MLRA 41 would be different than a Loamy Upland site in MLRA 40.

Ecological Sites in Riparian Areas

Riparian areas are those adjacent to running or standing water during all or most of the year. Areas along intermittent or ephemeral channels may not meet the definition of true riparian areas but do receive some added moisture through periodic water flow or flooding. Their characteristics with respect to inventory and monitoring are similar to riparian areas, and the following discussion relates to both.

The ecological site concept applies to both riparian areas and uplands. In other words, the vegetation found in a riparian area is the product of site characteristics, management history, and other environmental influences, such as the amount and timing of water and oxygen in the soil. However, application of the ecological site concept in riparian areas is more complex than for most upland areas due to several reasons discussed below (Figure 3-3).

The spatial pattern of site factors is often more complex in riparian areas than in uplands. Soils in riparian channels or floodplains are alluvial and their characteristics largely reflect the hydrologic conditions (discharge and channel slope) under which they were deposited. For example, high flows in steep or confined channels will deposit coarse materials (gravel, boulders), while lower flows or channels with gentle gradients will deposit finer materials (sand, silt, clay). The size of material deposited also depends on the geology of the watershed which determines the availability of particles of various sizes. Since runoff events in a given channel and its adjacent floodplain vary in size over time, and the channel varies in slope along its course, the size of material deposited can vary greatly across the channel and floodplain and along the channel. This can produce a more complicated pattern of soil texture horizontally and vertically than typically exists in uplands.

Another important site factor that leads to complexity is the availability of moisture. In riparian areas, this is affected not only by soil texture, but also by depth to the water table and/or frequency of flooding. Relatively small differences in depth to water table or frequency of flooding can lead to major differences in the kind of plants that will grow on a given spot and the productivity of those plants (Figure 3-4).

The vegetation found in riparian areas is much more subject to disturbance from "natural" factors than is the case in most uplands. In uplands vegetation often exists for considerable periods in an equilibrium state reflected in the kind and/or amount of plant species on a given ecological site. That equilibrium can be in response to site factors or to continuous or repeated "disturbance" such as grazing or fire. However, in riparian areas vegetation is much more subject to "disturbance" than is usually the case on uplands, and therefore the concept of climax vegetation, stable states, or equilibrium has little value. (Many would argue that these terms have little value in uplands and that the difference is only a matter of degree). Vegetation in riparian areas is subject to "disturbance" of several types and time scales.

First, plants growing in riparian areas may be subjected to extreme differences in water availability from one year to the next due to differences in stream flow and flooding. For example, a dry year may lower the water table, or perennial flow may not reach as far downstream, and make it impossible for some plant roots to reach free water.

Even if the difference in depth to water is only a few inches, large patches of the riparian system can be affected and plants may die out after a short time of deprivation of that water source. The opposite can occur in a wet year or a unusual amount of runoff that floods some areas for several days or months and kills plants not tolerant of such flooding. A similar process can occur seasonally. When deciduous riparian vegetation leafs out in spring perennial flow can be reduced, or the depth to water below the soil surface increased, due to water use for evapotranspiration.

Second, large floods occur periodically on arid/semi arid streams and these floods may destroy existing vegetation, remove soil, or deposit large amounts of new material. The entire location of the stream channel may change, leaving some plants in a different situation with respect to subflow and flooding that they were previously. These events may re-arrange the spatial distribution of ecological site factors within the overall stream system. Such events occur at various intensities and unpredictable intervals ranging from a few years to decades.

Figure 3-3. Complex patterns of plant communities make sampling a "uniform" area very difficult.

Figure 3-4. Vegetation patterns along streams reflect depth to water table, flood frequency, and texture of depositional materials.

Third, the fundamental properties of some riparian systems can be changed by geomorphic effects in ways that persist for decades or longer time spans. The best example is the widespread arroyo cutting that occurred in Arizona starting in the late 1800s, and continuing into the 1920s and 30s. For a good discussion see Cooke and Reeves (1976), and Webb et al. (2004). Stream channels that previously were shallow and overflowed a broad floodplain periodically were changed to a narrow, deep cross section with no flooding of the original floodplain. Water tables also dropped in response to the new base level. The arroyos then begin to widen and fill through erosion and deposition until, eventually; the previous relationships of stream channel and floodplain are more or less regained. This process has occurred several times over the past several thousand years (Waters and Haynes 2001). During the time the arroyo exists, the potential of both the floodplain and the channel is changed compared to “historical” times. For example, the mesquite forests that occur on the floodplain of some Arizona rivers replaced sacaton-dominated grassland that formerly occupied such floodplains. Likewise, the deep, unstable channels created conditions for increased occurrence of gallery forest composed of cottonwood and willow along these streams. Both of these riparian vegetation types will be reduced if geomorphology of the stream systems evolves to something similar to pre-arroyo conditions (Figure 3-5).

All of the changes described above mean that riparian vegetation is very dynamic and in a constant state of re-adjustment to changing environmental conditions. Such changes make the interpretation of “trend” data (determining cause and effect) much more complicated than on most upland situations, and this must be recognized in designing and interpreting monitoring data.

Figure 3-5. This arroyo cut down below the former floodplain (seen on far bank); a new floodplain (near bank) is forming as the channel widens and deposition increases.

Ecological Sites in Relation to Management – Landscape Issues

Ecological sites are the basic taxonomic unit for classifying land potential. They are the result of the interaction of soil, current and past climate, topography, introduction and/or extinction of plants and animals, and land use history that may have caused more or less permanent site changes. Since all of these vary in complex ways, the theoretical number of sites that could be identified is limitless. As is the case with classification of soils, rocks, and other natural phenomena, ecological site classification is man's effort to organize information as a basis for scientific discovery, communication, and management predictions. Therefore, the number of ecological sites actually identified is determined mainly by the total area occupied by a given site. Unique areas that have little real extent may not be described as a separate ecological site. Thus, the majority of the landscape should fit reasonably well into one ecological site description or another, but there are small areas that do not fit any site description (the same is true for soils).

One ecological site may cover a large contiguous area (tens to thousands of acres) if the site factors (soils, topography, climate) are relatively uniform. If the landscape is complex, as in much of the Southwest, the pattern of occurrence of ecological sites in the landscape is also complex. In such cases, it is virtually impossible to map individual ecological sites. Mapping units are usually composed of complexes of two or three ecological sites that occur in a specific pattern in the landscape (see Chapter 9). For example, a Loamy Upland site on flat ridgetops, Limy Slopes site on sideslopes, and Loamy Bottom site in the drainages may form a repeating pattern. Some of these sites may occur in a different pattern where landscape evolution is more advanced, for example, Limy Upland on ridgetops, Limy Slopes on sideslopes and Sandy Bottom in drainages. Thus, individual ecological sites are the "building blocks" of landscapes and the type, pattern, and relative extent of different sites is what differentiates landscapes (Figure 3-6).

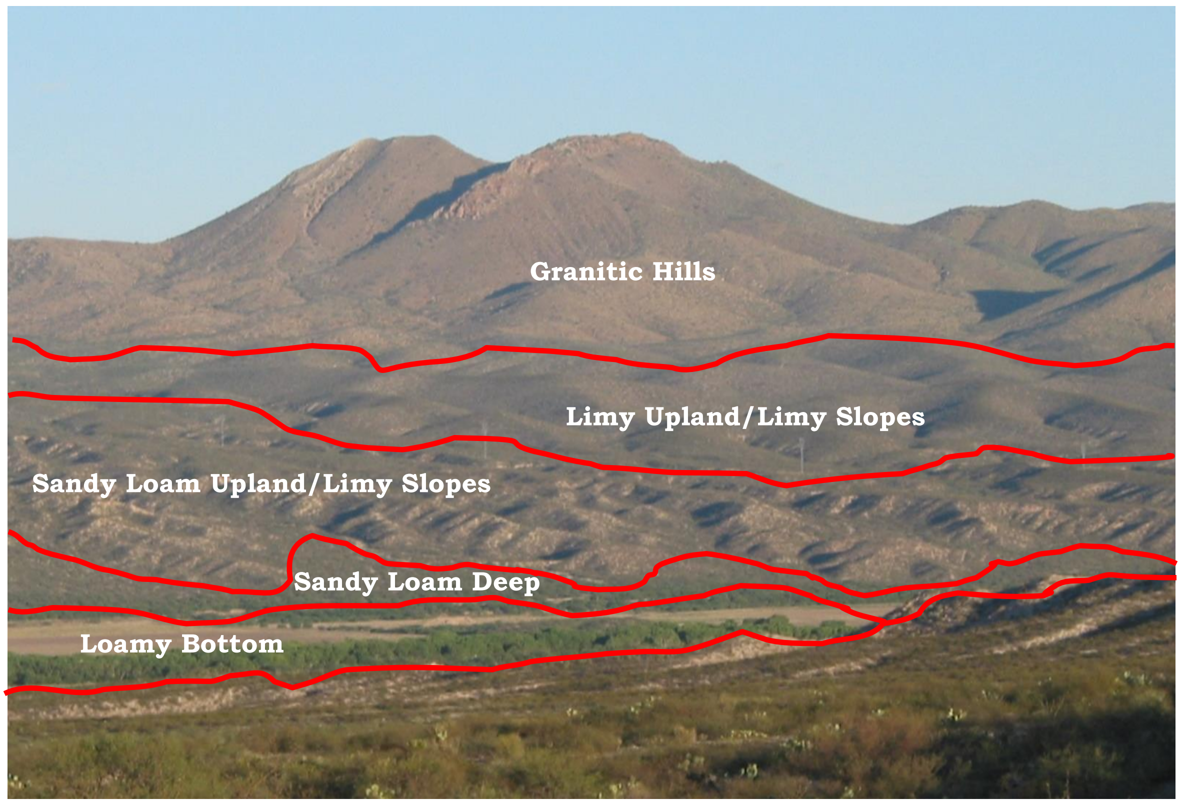


Figure 3-6. Landscape relationships of ecological sites, MLRA 41-3.

- Granitic Hills occurs on steep slopes of the Johnny Lyon Hills with granite parent materials - site varies from pockets of deep soil to exposed bedrock.
- Limy Upland/Limy Slopes association occurs on an old dissected bajada surface - shallow soils underlain by hard caliche at shallow depth (Limy Upland) on bajada surface with deep, limy soils lacking caliche on slopes (Limy Slopes).
- Sandy Loam Upland/Limy Slopes association occurs on more recent bajada surfaces - sandy loam surface >4 inches thick over clay B horizon with soft to moderate caliche at some depth (Sandy Loam Upland) on bajada surface, Limy Slopes on sideslopes.
- Sandy Loam Deep occurs on active inset fans composed of deep, sandy/gravelly soils with no restrictive soil layers, may be limy.
- Loam Bottom - recent alluvium on former floodplain of the San Pedro River (no longer floods due to downcutting), loamy soil with no restrictive layers, deep rooted shrubs may reach into water table; actual river channel is riverwash site.

Although ecological sites are the basis for setting management objectives and the collection and interpretation of data to guide management, it is not usually practical to manage individual sites separately. For livestock grazing, the basic management unit is the pasture (or paddock). Although, it is sometimes feasible to fence pastures along topographic breaks that coincide with ecological site differences or to fence riparian pastures composed mostly of riparian ecological sites, most pastures will contain more than one ecological site. Each site within the pasture may receive somewhat different grazing pressure due to the selectivity of livestock and each may respond differently to the overall grazing regime being applied. Therefore, to assess the effects of grazing in the pasture it is necessary either to sample all major ecological sites occurring within the pasture, or to select key areas that represent the most common sites, the sites that provide the bulk of the grazing, and/or the most sensitive sites. Data interpretation is greatly improved if the collection of data is stratified by ecological sites. If range assessment is based on selected key areas rather than a complete, statistically-based inventory of the entire pasture (as is usually the case), then it is crucial that the data collected be confined to specific, identified ecological sites (Figure 3-7).

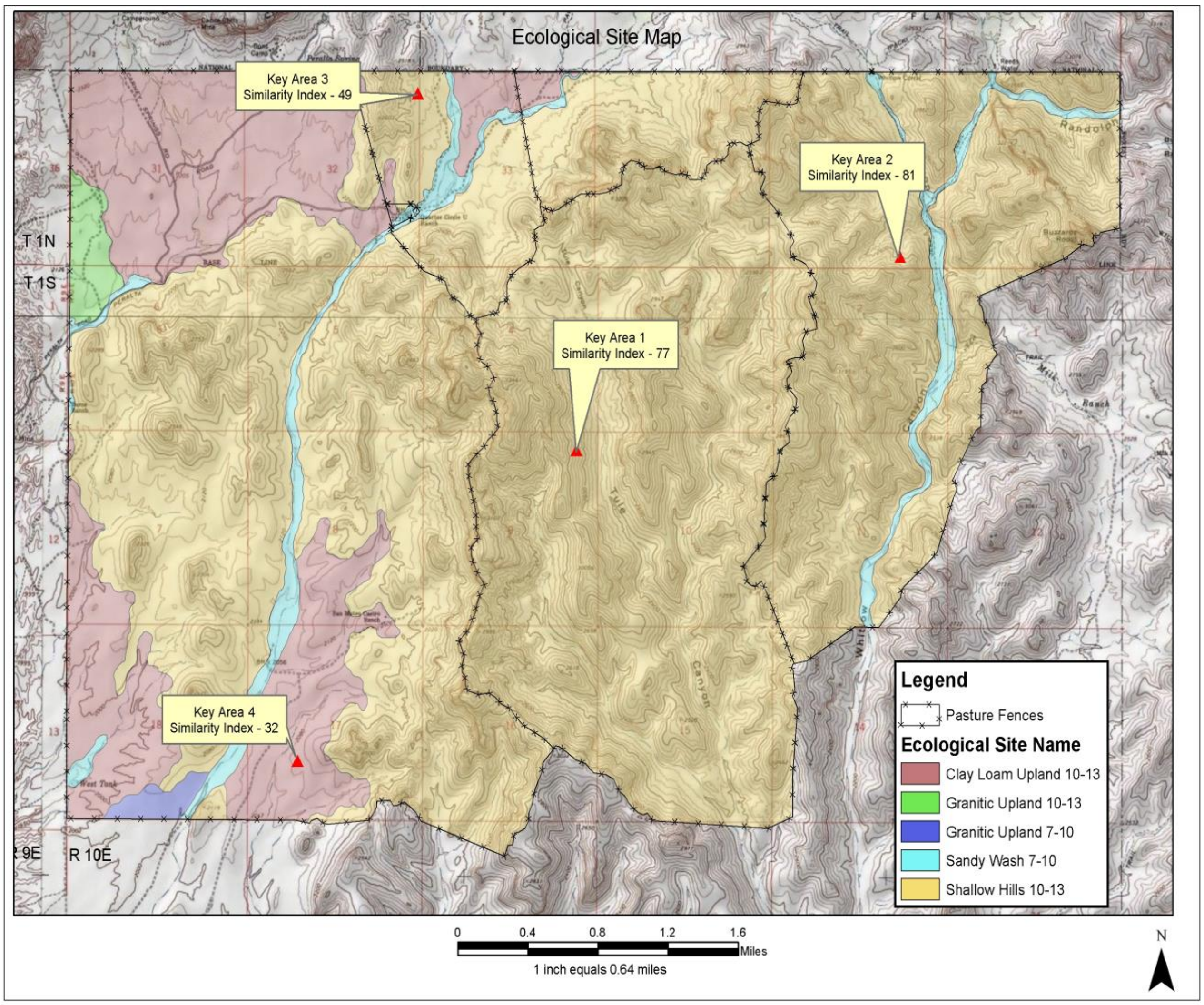


Figure 3-7. Map for a ranch showing location of ecological sites and the percent similarity to the reference condition for the sites at key areas (Figure 1-1). *Map courtesy of Emilio Carrillo and Don Decker, AZNRCS.*

CHAPTER 12
Establishing Desired Conditions

Historical Data

All available historical data should be obtained, organized and analyzed. Such data include weather, actual livestock numbers, wildlife population trends or harvest data, vegetation and/or soil monitoring data, utilization surveys, range condition surveys, environmental assessments or environmental impact statements, allotment inspections, time and location of wildfires or controlled burns, brush treatments, erosion control, seedings, timber or firewood sales, photographs, research studies, or any other information that may help interpret the condition and trend of resources on the area. Some ranchers or others with long experience in a particular area have a good perspective on historical changes and influences. But agency personnel tend to change frequently and, increasingly, ranches also change ownerships. Thus, local experience may be limited and the importance of data, written notes, and photos increases.

The importance of historical data for data interpretations and establishing management goals underline the importance of a consistent, safe and accessible method for storing and retrieving such information. Much of the existing historical information is not sufficiently protected from loss and not adequately catalogued to be useful. Some agencies have fairly extensive data in their files that include stocking records, allotment inspection reports, utilization surveys, fire occurrence, trend data and photos, and other information. However, in many cases this information is stored in old files or boxes and presents a formidable job to sort through and interpret. Often, current employees are unaware that such data exist or where to find it. This situation is unfortunate because only with some understanding of what has happened in the past can we interpret what we now see on the land and make reasonable predictions of the future.

Current data are the historical data of the future and provision must be made to store such information in a form that can be used and interpreted in the future. Much of the data being collected now is either collected directly on hand-held computers in the field, or is entered into computer programs in the office for analysis. Computers have greatly facilitated both the collection and analysis of monitoring and inventory data. However, long-term trend monitoring data become increasingly valuable as the length of record increases. For example, rainfall records of several decades allow us to put current wet or dry seasons into perspective. The same is true of vegetation and soil data. Therefore, it is essential to store data in a way that can be useful in the future. At present, hard copies of data should be stored. Electronic data bases are subject to loss due to computer failure, viruses, deterioration of disks, or obsolescence of hardware and software. Unless databases are continually updated to new equipment and programs and backed up, they are subject to loss.

The same considerations apply to digital photos. Although, digital photos have advantages of cost and immediate availability, it is recommended that photos needed for long term records either be obtained using film or printed on good paper from high-quality digital images.

Review of Literature

Reviews of scientific literature and other documents can be useful for interpreting data or suggesting management changes. For example, research can help us understand ecological processes and/or document responses to management in particular places and under certain conditions. However, such results cannot usually be applied directly under conditions that differ from those where the research was conducted. Therefore, such studies cannot usually be directly used to establish site-specific management objectives, to decide whether objectives are being met, or to identify specific management adjustments. Such decisions involve site-specific characteristics of the land as well as the values and experience of the local managers. In other words land managers are responsible for making such decisions and should be expected to understand and explain why and to what extent available research is relevant and applicable to the process.

Management Objectives

Management objectives must be established as a basis for assessment and monitoring. Without management objectives there is no basis for establishing desired plant communities and, consequently, there is no basis for selection of attributes to be measured or criteria for interpretation of data. Implicit objectives include maintaining or improving vegetation in terms of species composition and site protection (see Section 2).

Desired Plant Community

Desired plant community objectives should be established based on ecological site potential and management goals (Task Group on Unity in Concepts and Terminology 1996). Management goals must fully recognize the limitations of technology and economic cost/benefits when establishing DPC. If there is no reasonable way to achieve the DPC, or the cost would be prohibitive, then it is not a realistic management goal. The time required to achieve the DPC must also be considered in establishing expected management effects.

Description of the DPC should not be overly specific. Variability in ecological potential within an ecological site, plus our lack of ability to predict management responses precisely due to extraneous factors beyond our control (e.g. weather) mean that precise goals for species composition and other vegetation attributes are not appropriate. Rather the DPC should be described in terms of the balance of life forms and groups of desired or less desired species that will achieve management objectives. If plant diversity (species or life forms) is an objective for the desired plant community, then the definition of diversity must be clearly defined and the effects of temporal and spatial variability taken into account. The emphasis should be on deciding whether measured trends of certain attributes will be considered as positive, negative, or neutral with respect to management objectives (see Chapter 7).

CHAPTER 13
Selection of Attributes and Methods

Attributes selected for assessment or monitoring should have a known relationship to the management objectives and practices applied (see Chapter 3). Management objectives include resource outputs and ecological processes (erosion rates, biomass production, species composition, etc). Practices include grazing, fire, or other treatments (attributes selected are those affected by the practice). For example, amount of bare ground is known to be related to the risk of soil erosion and therefore would be an appropriate and measurable indicator related to the management objective of reducing soil erosion. On the other hand, species diversity in a riparian system may or may not be related to the hydrologic function of the stream (although it could be important for other objectives) and therefore may not be appropriate to evaluate hydrologic function. Cover, density or age classes of vegetation life forms on the other hand may be a more appropriate indicator of hydrologic function than plant species diversity.

Selecting attributes to measure in a specific situation must also consider data previously collected, if any, and how to build on that record. In other words, if a long history of monitoring data exists based on certain attributes and/or techniques, one should not arbitrarily drop those methods even though they may not be considered optimum for present purposes or technology (for example, some of the longest data and photographic records of ground cover and species composition available are the Parker 3 step transects installed by the Forest Service starting in the early 1950s). Every effort should be made to provide continuity of current attributes and methods with older data if possible to take advantage of the older data (see Chapter 12).

Field data should meet several criteria:

1. To the extent possible data should be value free. In other words recording observations of attributes as "adequate," "impaired," "proper", good – fair – poor, does not provide an objective set of data that can be re-interpreted if objectives change, and it depends entirely on the ability (bias) of the observer.
2. Field data should reflect observable features; objects or attributes that can be directly measured, estimated or described. Inferences about processes that cannot be directly observed (nutrient cycling) or about changes over time (trends) should be avoided. For example, erosion usually cannot be directly observed or measured without detailed, long-term studies. Therefore we use such attributes as soil cover, plant spacing, or litter distribution, that are known to be related to overland flow and soil erosion because these attributes

can be objectively measured (or at least objectively described) in the field. Inferences about erosion rates or probable trends in erosion rates are then based on objective data.

3. Attributes should be capable of repeatable measurement or estimation by different observers with reasonable skill or training levels.
4. Data should be as quantitative as feasible. Quantitative does not necessarily imply measurement, but may be based on estimates. In other words, a series of cover measurements in plots provides objective data capable of statistical analysis, but merely describing something as big, small, smallest is completely qualitative and not capable of analysis unless the categories are described as a range of values such as 0-10 feet, 10-30feet, >30feet.
5. Collateral data should be collected to help in interpreting trend data. Such data could include precipitation, actual stocking, fire occurrence, utilization, and photographs.

Methods selected must, of course, be appropriate for the desired attribute to be measured. Methods selected also depend on the kinds of life forms and species to be measured, the thickness of the vegetation layer of interest, the amount of time and money available, the level of training required of personnel, and the purpose of the monitoring. For example, desirable methods and sampling intensity may be different on private land where data are collected mainly for the use of the manager, than when monitoring is done on public land where agencies need to document results of management plans and various interests may challenge the results (see Chapter 8).

CHAPTER 14
Basic Statistical Concepts

This chapter requires understanding a few basic concepts of sampling. Several terms need clarification. In most cases, monitoring is done on a key area or designated monitoring area selected as representative of a larger area (see discussion of selection of monitoring locations below). Therefore, this discussion relates to the process of collecting data on one monitoring location to represent some larger area.

Accuracy of a sample or of an observation within a sample refers to how well the observed estimated value approximates the real value. If the sample is not accurate it means there is a bias in the sample or there is some systematic error built into data collection that makes the observations consistently higher or lower than they should be. An example of the latter would be scales that are not balanced correctly, or a tendency of the observer to estimate consistently high or low. Statistical analysis cannot account for lack of accuracy, i.e. bias in the sample. Accuracy depends on good professional knowledge, training, and integrity of the observers. If there is no bias in the sampling, then accuracy and precision are synonymous.

Precision refers to repeatability of the sample, or the level of confidence we have that the results of one sampling exercise are within reasonable limits of the values that would be obtained by a large number of repeated sampling on the same area. This is very important for monitoring because we need to know within reason whether different values found at two sampling dates or two places are real differences, or whether they are just accidental differences caused by lack of precision of the estimates. Statistical analysis is used to measure precision of the sample. The usual illustration is to compare accuracy with hitting the bullseye when target shooting, while precision is the size of the group of several shots. For monitoring it may be more important, within reason, to achieve precision (repeatability or reliability) than to have an accurate estimate, because the emphasis is often on detecting change, not estimating absolute quantities. Sampling efficiency refers to the level of precision achieved for a given amount of time and money expended in data collection.

To achieve a representative (accurate) sample it is important to make sure the sample is located on the correct ecological site and the entire sample is located within that ecological site (see Chapters 9, 11). The sampling area should be large enough to characterize the natural variability within the site sampled. In other words, if the sample is taken in a very small area on the site, there may be differences in soil and vegetation that are not adequately included. If you want to describe a horse, you have to look at the whole horse, not just a part. Accuracy of observations within the sample depends on proper use of equipment, training and experience. For this reason it is very important to decide upon a monitoring protocol, or set of ground rules, for how various attributes will be defined and measured. These rules should be written down so that procedures can be duplicated by other people or on different sampling dates.

A sampling unit refers to the individual sample observations that are used to carry out statistical calculations such as computing a mean. The number of sampling units in the sample is the *n* in statistical formulas. Sampling units are defined differently for different attributes and methods. The sampling unit may be an individual plant (when measuring utilization); a quadrat (when clipping production); a set of quadrats (for Daubenmire canopy cover); a point (when points are located at random); a group of points (when points are located in frames or along transects); or a line intercept transect.

Sampling precision is a function of the variability among sampling units and the size of the sample. Sample variability is expressed statistically as the standard deviation (s). The less difference there is among sampling units, the lower the value of s. Also, as the number of sampling units (n) increases, the precision increases. The more sampling units we take, the more confidence we have that the calculated mean is correct. The confidence interval expresses the probability that the true mean of a population is contained in a certain interval of values above or below the calculated mean. The confidence interval is calculated by $CI = s_x \times t$, where s_x is the standard error of the mean of the sample, and t is the value of the t statistic for a given sample size and selected probability level. For example, we could say that we are 80% sure that the estimated average forage weight of 1000 pounds/acre is within +/- 200 pounds of the true value. The value of t decreases as n increases and as the desired level of probability decreases. For example, the value of t is less for 80% confidence intervals than for 95%, and thus the CI is narrower using that value of t. In this example,. we might be 95% sure that the 1000 pounds/acre is within 400 pounds of the true mean, but only 80% sure that the true mean is within +/- 200 pounds. (See sidebar on next page for further explanation).

The estimated number of sampling units required for achieving a desired level of precision in a sample can be calculated by: $n = s^2t^2/(CI)^2$, where n = the estimated number of sampling units required, s = the standard deviation, t = the "t" statistic for the desired probability level, and CI = the allowable amount above or below the mean. Another way to decide if the sample is large enough is to plot a running mean (Figure 3-8) for increasing sample size until the calculated mean fluctuates within the desired limits (Grieg-Smith 1964).

WAYS TO HELP OBTAIN CONSISTENT DATA OVER TIME

By Dr. Phil R. Ogden, Professor and Range Management Extension Specialist, Retired, University of Arizona

Rangeland monitoring is initiated to identify and document changes in vegetation and/or other variables over time, and interpretations based on analyses of the monitoring results are intended to establish cause and effect relationships to provide information for management decisions. Consistent data and documentation of field observations over time are prime requirements to fulfill the expectations for monitoring efforts. The following outline provides some ways to help attain consistent data over years.

Plan Ahead

Maintain an individual or individuals in leadership roles to schedule, sample, and summarize the monitoring data. Prepare and maintain a field notebook with detailed plot descriptions and monitoring protocol. Plot descriptions and a photo help to insure that the monitoring plot transects are consistently located among years. Protocols may vary for different monitoring situations, but should be very specific to meet objectives of a monitoring project. For instance, define what constitutes a hit on litter or live basal vegetation. Furnish field forms with plant species names printed on form. Previous pictures of plots and data summaries should readily be available in the field. Pictures may be helpful to locate the monitoring area and bearing for transect lines. Field notes based on comparison of a current plot aspect with previous pictures may aid future data interpretation.

Training

Review monitoring protocol with monitoring team. This should be done at the beginning of monitoring with any group of monitoring participants, even if the individuals are experienced in monitoring. All individuals need to follow the protocol developed for specific locations. Review plant species identification. A review of the plant species found at the monitoring location is essential. Especially look at the forbs and discuss which are annuals to be lumped (if this is the case) and perennials to be listed as species.

Data Collection

Compare previous pictures and description of transects to correctly locate transects.

Pair experienced personnel with volunteers or new personnel. Ideally, it helps to have an experienced individual as a "floater" who can answer questions for individuals and teams.

Field Check Before Leaving Monitoring Plot

Take some time to compare data among the different teams. Teams or individuals should summarize a few species for frequency and some cover data to determine consistency among teams or individuals. Compare some current data with data from a previous year. If it is different, is there an obvious explanation? Are dead plants or new seedlings evident? Write down comments about observations. Note new seedlings, dead plants, insect damaged or diseased plants, livestock and wildlife use, fire, and other factors. Insure that field notes are included with annual data summaries.

Data Summary and Analyses

Develop a consistent format that is easily shared with interested individuals. Confirm that the interpretations are consistent with the data and field observations.

SOME BASIC CONCEPTS FOR SAMPLING PRECISION

SAMPLING UNITS AND POPULATIONS

Sampling units are the individual observations used to compute a mean value. These may be quadrats, points, transects (line, points, or quadrats). Sampling units are the "n" in statistical formulas.
Sample consists of all the sampling units chosen for measurement, i.e. if you clip 30 quadrats, that is your sample.
Population consists of all the possible sampling units that could have been chosen – all the sampling units that exist within the area you are sampling.

CONFIDENCE INTERVALS

A confidence interval defines the probability that the true mean of the population is within certain limits of the estimated mean.

$$CI = \bar{x} \pm (s_{\bar{x}} \times t_p)$$

CI = confidence interval, $\bar{x}$ = estimated mean, $s_{\bar{x}}$ = standard error of the mean
t_p = t value for desired probability level
Example: Estimated mean forage production per acre = 500 pounds.
$s_{\bar{x}}$ = 25 pounds per acre $t_{.05}$ = 2.086 (20 df)
CI = +/- (25 X 2.086) = +/- 52 pounds per acre, or +/- 10% of the mean

HOW BIG SHOULD THE SAMPLE BE?

The formula to estimate the required sample size is:

$$n = \frac{s^2 t^2}{CI^2} \quad \text{or} \quad n = \frac{t^2 CV^2}{se^2}$$

In both formulas, n = estimated number of sample units required to obtain the desired precision.

In the first formula:
s^2 = variance or standard deviation squared; it represents the variability of the sample expressed in whatever units are being measured (pounds, inches, etc.)
CI^2 = confidence interval you will accept expressed in the units being measured (e.g. +/- 100 pounds/acre)

The second formula is similar, but variation is expressed in percent rather than actual units:

cv^2= coefficient of variation (%) squared, CV (%) = $\frac{s_{\bar{x}}}{\bar{x}}$ X 100
se^2= standard error as % of mean, squared

Example:
If you want to sample forage production within 10% of the mean with a 95% probability that the true mean lies within the confidence interval. If the estimated coefficient of variation is 30%;

$$n = \frac{30^2 \times 1.96^2}{10^2} = \frac{900 \times 3.84}{100} = 35 \text{ samples}$$

THREE WAYS TO REDUCE THE REQUIRED SAMPLE SIZE

The formulas above illustrate that sample size (n) can be reduced in one or more of the following three ways:

1. Increase the size of the confidence interval you will accept.
2. Decrease the probability you will accept that true mean is within the confidence interval .
3. Reduce the variability of the sample (i.e. s^2).

The first two are decisions that relate to the purpose or expectations from the sampling. In other words you can just decide the level of confidence you are willing to accept for a given purpose. Usually confidence intervals for management purposes can be less precise than for research purposes. The third option, reducing the variability in the sample, requires other measures, such as using different size or shape of sampling units, stratification of the population sampled, etc.

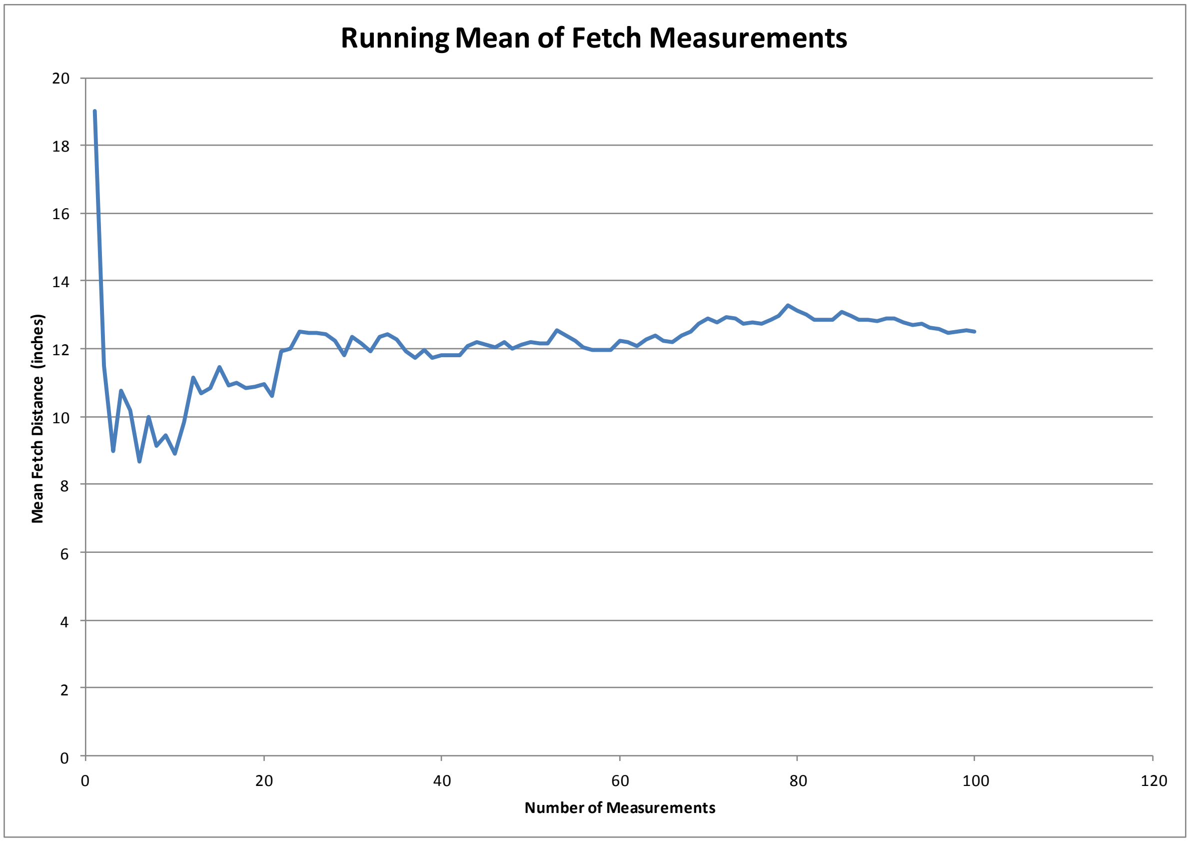


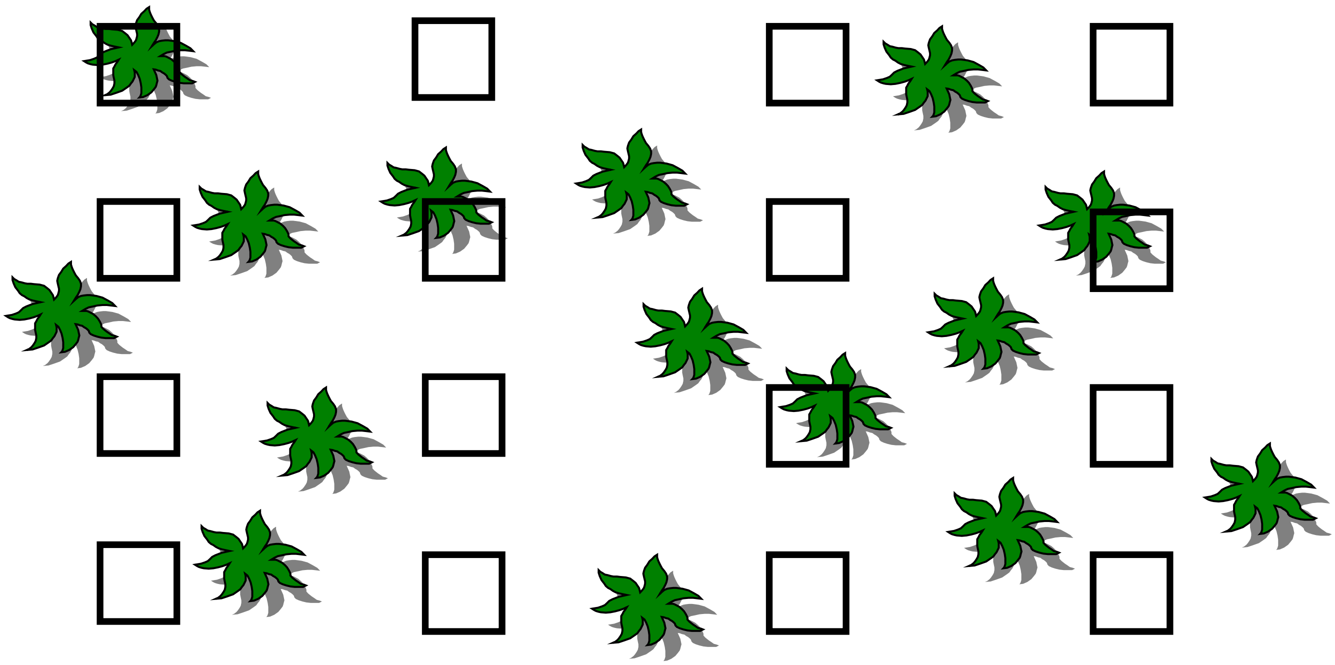
Figure 3-8. Running mean of fetch measurements to nearest inch collected in 4 paced transects in a degraded desert grassland vegetation type near Willcox, Arizona. The mean of 100 measurements was 12.5 inches; a sample of about 25-30 measurements were necessary to approximate this mean. The slight increase in estimated mean with 70-90 measurements reflects lack of uniformity of the sample site, i.e. variation among transects.

There are several ways we can reduce the required sample size, and thus save time and money. The first is to reduce sample unit variability. Sampling unit variability is in large part a function of the spatial variability of the vegetation being sampled, that is, it will be lower in uniform vegetation than in diverse or patchy vegetation. However, the size, shape, orientation, and spacing of sampling units can also affect it. The idea is to include as much of the spatial variation as possible within a sampling unit, rather than have it reflected among sampling units. Using very small quadrats tends to result in high variability; increasing quadrat size to include more diversity of vegetation will generally reduce variability (Figure 3-9).

Rectangular quadrats generally are less variable than round or square quadrats with the same area. However, the advantage of rectangular for precision has to be weighed against the possibility of introducing more bias due to edge effects. Possible bias can be introduced where decisions have to be made whether to count plants in or out of the quadrat along the perimeter. A round or square quadrat has less perimeter, and thus less chance for bias, than a rectangular quadrat of the same area. A rule of thumb: if more than 5% of quadrats are empty ,increase quadrat size (Don Hyder, pers. com.).

Line transects should be long enough to cut across a number of plants or clumps of plants. Line transects should be oriented across expected gradients in the vegetation. For example, vegetation may change as we go downhill because of soil depth and moisture changes. Therefore, line transects should be oriented up and down the hill so that each line cuts across that gradient and the mean for all lines are closer to each other. For this reason, we recommend that transects should be oriented parallel to each other or end-to-end, rather than radiating out from a central point as suggested by (Herrick et al. 2005). Also, transects radiating from a central point concentrate the sampling near the central point with areas on the outer perimeter having less chance for representation.

Example using small square quadrat - 12 of 16 empty.



Example using large square quadrat - 1 of 9 empty.

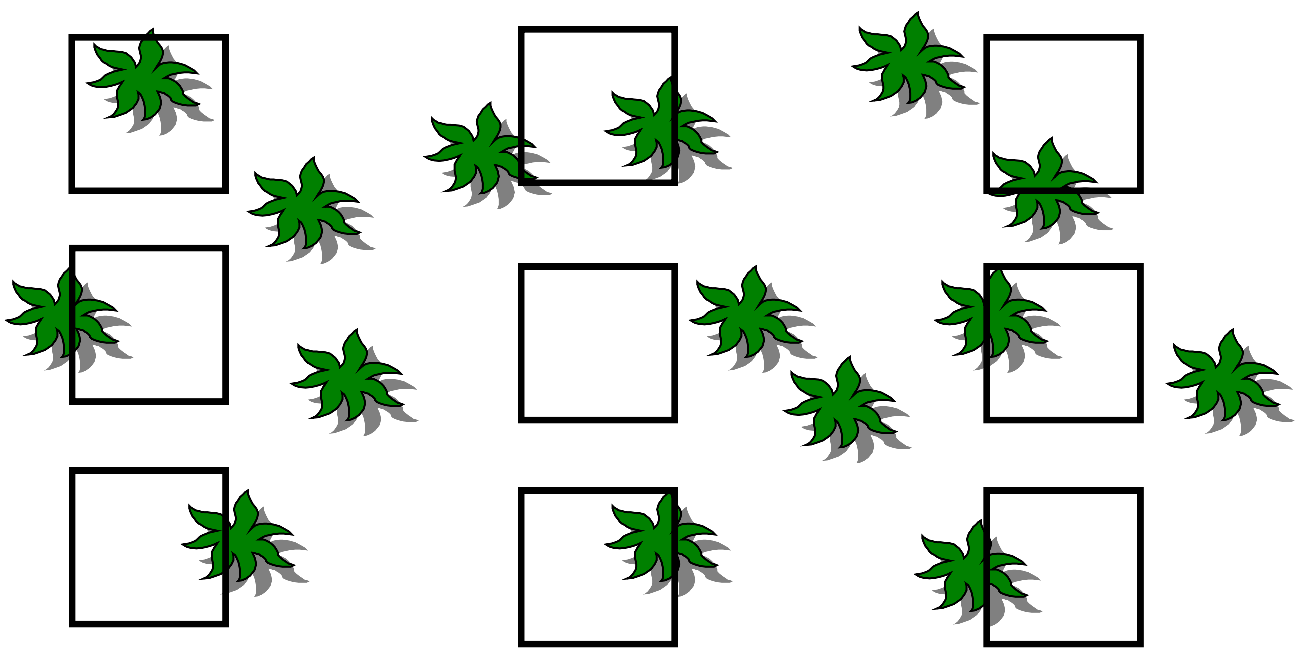


Figure 3-9. Diagrams showing effects of quadrat size on sampling efficiency and statistical distribution. The smaller quadrats show a value of zero for 75% of the sampling units - it would require a large sample to get a good estimate of the mean, and the assumption of a normal distribution (values equally distributed on both sides of the mean) is violated. The larger quadrat size would require a much smaller sample and comes closer to meeting the assumption of a normal distribution.

The second thing that can be done to reduce the number of sampling units required is to increase the desired width of the confidence interval. In other words, we can say we want to estimate forage production within 200 pounds per acre of the true value, rather than within 100 pounds per acre. This depends on what we want to use the data for. If a comparison between two areas or on one area over time is to be made, how big a difference would we consider important? The smaller the difference you want to detect, the narrower the confidence interval must be, and the larger the required sample size will be.

The third thing that can be done is to reduce the level of confidence that the true mean is within the desired confidence interval. For example, if we are willing to accept a probability of 80% that the confidence interval calculated includes the true mean of the population we can get by with substantially fewer sampling units than if we want a 95% probability (Figure 3-10). Probability levels in excess of 90% are usually used for research studies, but may be excessive for routine monitoring. SRM's Range Inventory Standardization Committee (Range Inventory Standardization Committee 1983) recommended a probability level of 80% unless there was demonstrated need for more precise results.

After all these considerations, if the required number of sampling units is too high to be practical in terms of the time and money required to measure that number of sampling units, there are two options. One option is to measure a different attribute that will provide repeatable data with less time and expense. For example, the main reason for using plant species frequency is that it provides an objective and repeatable sample with less time than sampling some other attributes.

The other option is to select an attribute that is easy and fast to measure that can be used to estimate or predict the attribute of interest. This is called regression sampling or double sampling, and is employed in several common range monitoring techniques. For example, in the calibrated weight estimate method, weight (production) is visually estimated in a large number of quadrats (see Chapter 32). In a subsample of those quadrats weight is both estimated and harvested for drying and weighing. The relationship between the clipped and estimated weights from the sub-sample can be used to adjust the estimated weights of the large sample, provided a consistent relationship exists. This allows a much larger sample than if every quadrat were weighed. Other examples are the use of height-weight (see Chapter 40) relationships of grasses so that the easily measured attribute of height can be used to estimate the utilization by weight (which is harder to measure directly). Using double sampling approaches can increase the precision of estimated means, but also introduces additional sources of error that should be accounted for. For example, mean weight obtained by weight estimate with double sampling has: (1) an error associated with variability in the main estimated sample, (2) an error associated with the difference in means of the estimated and clipped samples, and (3) an error associated with the consistency of the relationship between estimated and clipped samples. Utilization estimates based on height-weight relationships not only have error associated with the height measurements (sampling variation) but also have some error associated with the conversion factor used to convert percent height used to percent weight used.

The same concept is used in adopting methods that assign attributes to classes rather than estimating them in absolute terms. For example, the Daubenmire canopy cover method (see Chapter 33) involves assigning plants to cover classes rather than estimating the percentage cover directly (Daubenmire 1959). Daubenmire explained the purpose of this was to reduce the time spent on each quadrat to increase the total number of quadrats observed, even if some accuracy was sacrificed on each observation. He recognized that spatial variability was the main problem in sampling range vegetation and the solution to the problem is to increase sample size, not increase the accuracy of observation on each sampling unit. In other words, if you want to increase reliability of production estimates (see Chapter 32) you increase the number of quadrats weighed rather than using a more precise scale to weigh each quadrat (Figure 3-10).

Calculation of confidence intervals and other statistical calculations are based on the assumption that sampling units are selected at random. This assumption is often hard to meet in range monitoring. It is usually necessary to locate sampling units systematically or in some type of restricted random fashion. Statistical calculations can still be performed on the data but the basic assumption of randomness is compromised, which technically invalidates statistical tests.

Fetch				
	Location One		Location Two	
Obs #	Nearest 1/2"	Nearest 1"	Nearest 1/2"	Nearest 1"
1	1.5	2	1	1
2	3	3	1	1
3	2.5	2	3.5	4
4	1	1	1.5	1
5	2	2	1	1
6	0	0	2.5	3
7	5.5	6	0.5	0
8	2	2	3	3
9	0.5	0	2	2
10	3	3	0.5	1
11	2	2	1.5	1
12	0.5	1	0.5	1
13	3.5	3	2	2
14	1	1	3	3
15	6	6	0.5	0
16	2.5	3	0.5	1
17	0.5	0	1.5	1
18	2.5	3	1	1
19	1.5	1	1	1
20	1	1	2	2
21	5	5	1	1
22	0	0	2	2
23	4.5	5	3	3
24	1.5	2	2	2
25	2	2	0.5	1
Mean	**2.2**	**2.24**	**1.54**	**1.56**
Standard Deviation	**1.658**	**1.763**	**0.923**	**1.003**
Coefficient Variation (%)	**112%**	**118%**	**74%**	**80%**
Confidence Interval (5%)	**+/-0.65**	**+/-0.69**	**+/-0.72**	**+/-0.79**
Confidence Interval (20%)	**+/-0.42**	**+/-0.45**	**+/-0.24**	**+/-0.26**
Required Sample Size				
95% probability w/in +/- 1/4"	**176**	**199**	**55**	**64**
80% probability w/in +/-1/4"	**74**	**84**	**23**	**27**

Figure 3-10. Example of the effect of measurement accuracy on precision of the estimate of the mean and the effect of probability level for confidence interval on the required sample size.

Note:

1. Location 1 has a greater mean fetch distance than location 2 and the measurements are more variable, i.e. the CV is higher.
2. Measuring to the nearest 1/2 inch did not significantly affect the mean, the standard deviation, the confidence interval or required sample size for given level of precision compared to measuring to the nearest inch.
3. Using a probability level of 5% results in a much wider confidence interval than use of 20% level.
4. The estimated sample size required to measure mean fetch within + or - 1/4 inch is more than twice as great using a probability level of 95% compared to 80%.

Observations on different sampling units can be considered to meet the randomness requirement if each observation is independent of others. This means that a plant occurring in a quadrat is no more or less likely to occur in the next quadrat than if the quadrats were located at random throughout the entire area sampled, or that the yield of one quadrat cannot be predicted from a neighboring quadrat (Grieg-Smith 1964). If sampling units are separated enough, this requirement can be met. For example, successive points or quadrats (if these are the sampling units) should be located far enough apart so they don't fall into the same patch of vegetation. When quadrats or points are located along a line (either a tape or by pacing), as is often done in frequency sampling, the quadrats or points should be separated as much as feasible within the constraints of sampling logistics and the need to stay within a uniform stand of vegetation (Heywood and DeBacker 2007). This will: (1) help to meet the requirement of randomness (Grieg-Smith 1964) if each quadrat or point is considered the sampling unit (binomial distribution) or (2) reduce the variability among transect averages if transects are considered the sampling unit. There are ways to test whether observations in a series of sampling units are independent, but it is seldom feasible to check this in the field.

In the final analysis the most important thing is to locate sampling units in an unbiased way. If sampling units are objectively located in a systematic manner, they will usually provide an unbiased estimate of the sample mean even if the assumption of randomness is not fully met.

Another assumption of most statistical analysis is that data follow a normal distribution, i.e. a symmetrical, bell-shaped curve with the mean in the center of the observations. This assumption often is not met in range sampling. For example, there may be many small values and a few large ones, causing the calculated mean to be higher than most individual values. In a normal distribution the mean is the most likely value in the data set. Fortunately, the central limit theorem comes to the rescue. This theorem says that the means of a series of samples from a population will tend to be normally distributed even if the data are not. Therefore, confidence limits and statistical tests on means will usually meet the assumption of normality.

CHAPTER 15
Selection of Monitoring Areas

Unless complete inventories are possible (by mapping or remote sensing), monitoring and assessment data are usually collected in specific locations chosen to indicate a particular management situation. These areas are not randomly selected; they are chosen to be representative using professional judgment. Statistical analysis cannot be used to extend the results obtained to a larger area. Therefore, it is extremely important that selection of data collection locations should be made and agreed upon by all interested parties. Data may be collected in 3 types of situations: key areas, critical areas, or comparison areas (Range Inventory Standardization Committee 1983).

Key areas are selected to be representative of the effects of one or more management practices on the entire management unit. The key area is therefore specific to a particular use or management practice, e.g. livestock grazing, quail nesting cover, or a reseeding project. A key area for livestock grazing is one that represents a fairly typical ecological site or vegetation type, will receive substantial grazing use but is not a concentration area, and has the capacity to respond positively or negatively to livestock grazing management. Key areas for livestock grazing may or may not be key areas for other uses such as wildlife.

In some cases, especially in large pastures or diverse topography, several key areas may be selected to represent different situations. In this case all of the key areas should be used for interpreting monitoring data and making management decisions based on such data. It should be recognized that the key areas may be affected by grazing differently in different years due to factors such as season of use, water availability, weather patterns (temperature, wind, snow cover), or class of livestock (dry cows vs. cows with calves). Therefore, selecting only one of the key areas to base management decisions on is not generally warranted. If some of the key areas consistently show higher utilization or other livestock impact over a period of years, then all areas are not really representative key areas. In this case, the location of the key areas should be reconsidered, or measures should be taken to improve livestock distribution.

Key areas should not be changed without careful consideration (see Chapter 21). Since the length of the monitoring record is an important asset for interpreting the data, the monitoring should continue in the same key areas as long as those areas continue to serve the purpose for which they were selected. If a new key area is required due to changes in management practices or management objectives, a break in the continuity of the monitoring data is introduced. This is analogous to moving a weather station to a new location; the continuity of the record is compromised. How serious the problem is depends on how similar the new site is and whether similar data continue to be collected.

Critical areas for livestock grazing purposes may be key areas for certain wildlife species, or they may be areas with special resource concerns, such as endangered species or water quality issues. An example of a critical area could be a small riparian area within a large upland pasture grazed by livestock. The riparian area would have differing objectives which could only be addressed by specific management for that area. Therefore, monitoring carried out in critical areas will generally be done in selected portions of the critical area (at specific locations along a riparian corridor for example) just as monitoring is done in key areas within a larger management unit. To avoid confusion, we recommend these areas be called designated monitoring areas, rather than key areas. The difference is that the monitoring on designated monitoring areas represents the critical area, while the monitoring on key areas represents an entire pasture or management unit.

Comparison areas are those selected as a basis for establishing trends or interpreting the cause of trends measured on key or critical areas. Exclosures, lightly grazed areas, similar areas managed differently, or regional data sets may be used to separate the effects of management, weather, and other factors (see Chapter 20).

Since the terms key area, critical area and comparison area, are sometimes misunderstood, it may be wise to refer to any area monitored as a "designated monitoring area" and document the purpose for which each is established.

CHAPTER 16
Selection of Time of Monitoring

Time of year that data are collected can have important consequences. A major consideration is the stage of growth of vegetation. Most vegetation attributes, especially for herbaceous plants, are best measured when vegetation reaches its peak of maturity near the end of the growing season. This is usually the time when species identification is most accurate, a major factor in repeatability and completeness of data. Monitoring in pastures where grazing is rotated is best done in pastures that have been deferred from grazing in that year, or were grazed early in the grazing season, if possible. This avoids the necessity of trying to “reconstruct” the grazed plants for purposes of estimating cover or production, and also aids in species identification.

Litter cover also varies significantly depending on season of the year on southwestern rangelands due to differing rates of accumulation and decay. For example, in the Altar Valley of Arizona, litter cover averaged about 40% in June and declined to about 25-30% by October on the same area due to decomposition during the monsoon rains. Other soil parameters, such as infiltration rates and surface crusting also can vary seasonally (Simanton and Emmerich 1994).

SECTION 4
INTERPRETING DATA

What You Will Find in Section Four

- Why is it better to use single attributes than scores based on several factors?
- What is the problem with using "standards" as a basis of interpretation of inventory/monitoring data?
- How can comparison areas or exclosures be used to interpret data? Why is the detection and interpretation of trends better than standards or comparisons?
- Why is determination of causes for trends essential?
- Data needs and intensity, season, and frequency of use.

CHAPTER 17
What is Data Interpretation?

Section 3 dealt with guidelines to select appropriate attributes and methods to provide objective data relevant to management objectives. Section 4 focuses on considerations involved in making interpretations of the data as a basis for grazing management decisions. Interpretations are generally of two types. One is to compare data collected at a given time to some comparison area or to a standard. The other is to compare data collected over a period of time to detect and interpret trends that reflect the effects of current management. In some cases, the two are combined, as when repeated comparisons to reference areas or a standard are made.

Interpretation of the data basically involves two processes. One is to establish whether trends actually exist, or whether and how much the current resource condition differs from the desired or reference condition. The second is to determine, to the extent possible, the cause of trends and/or departure of present condition from desired condition. The latter is particularly important when condition or trend appears contrary to management objectives, because then a decision is needed about how and whether to change current grazing management or other practices.

CHAPTER 18
Single Attributes or Multiple Attributes and Scores?

Comparison of data on two different areas at one time, or on one area over time can be based on one attribute, or on several attributes each analyzed separately. Comparisons that are based on one attribute alone are fairly straightforward. For instance, the percentage of bare soil on a key area can be easily compared statistically to percentage bare soil in a comparison area, or a minimum standard for the ecological site. Likewise, the trend in bare soil on an area over time can be interpreted by statistical analysis or graphing. If several attributes are measured each can be analyzed and interpreted separately.

Sometimes several indicators are combined in some way to come up with a rating or score that is a more general indicator of resource conditions than use of separate indicators. Examples are the soil surface factor ratings formerly used by BLM (Bureau of Land Management 1973), the range condition scores used by the Forest Service in Region 3 (U.S.D.A. Forest Service 1979). that combine plant composition, vigor ratings and other factors into a range condition score, or "importance values" (sum of frequency, density and cover for each species) used by some ecologists (Whittaker 1970). The cover-frequency index (Uresk 1990) is another example (see Chapter 24).

When a number of attributes are rated or measured and then combined in some way to arrive at an overall rating interpretation of the rating is not straightforward. Questions arise as to whether the variables are all of equal importance or should be weighted, whether the variables are independent or interrelated (which builds in weighting), or whether positive change in some attributes compensates for negative change in others. In some cases, the full suite of indicators may not be appropriate for some ecological sites. For example, one of the indicators used for the soil surface factor is the extent of erosion pavement (surface gravel), but some soils may not contain enough gravel to form an erosion pavement due to surface erosion. Therefore, scores or ratings based on multiple attributes build in assumptions about relative values of different indicators and must be interpreted with caution. The Rangeland Health (Pellant et al. 2005) evaluation uses multiple (17) indicators but these should not be added or multiplied to achieve an overall numerical score; rather the indicators are used to assign a "preponderance of evidence" regarding three interrelated attributes of rangeland health. Each indicator may be used to evaluate more than one attribute. Since the indicators and attributes are related in complex ways, this approach is much preferable to a single score or rating based on addition or weighting of factors.

CHAPTER 19
Using Standards for Assessments

Use of standards to provide a one-point-time rating of current status versus some standard or goal has been widely employed in range management. Examples include, range condition or rangeland health ratings, similarity to desired conditions, proper functioning condition, or soil stability ratings. Such ratings suffer from several deficiencies.

Standards are often abstract or hypothesized. For example, the historic plant community composition on ecological site descriptions is an abstraction based on sampling of many locations within the same ecological site. As such, it represents a best estimate of what the site might have produced on the average. But no location within the area classified as one ecological site will have exactly that potential, so how closely the existing vegetation can approach the "standard" is unknown and will vary from one location to another.

Ecological sites usually contain a considerable amount of variability in site potential within the area classified as a given site. This variability may be due to differences in slope, aspect, precipitation, or land use history. For example, in southeastern Arizona, Loamy Upland ecological sites may occur in the 8-12, 12-16 or 16-20 inch precipitation zone. The general soil and topographic characteristics are similar in the three ecological sites, but vegetation composition and production is influenced by average precipitation and varies significantly not only between sites but within the upper and lower precipitation limits of each site described. In reality there is a continuum of vegetation characteristics related to average precipitation so that any division into distinct sites is arbitrary. When evaluating a location near the drier end of one precipitation zone, experienced observers will often consider the site description for the next lower precipitation zone in interpreting plant composition or production. Likewise, differences in vegetation on north or south slopes (due to differences in effective precipitation) can sometimes be interpreted by considering the site descriptions for the next higher or lower precipitation zone. Usually ecological site descriptions contain a range of values for plant composition or production to allow observers to select appropriate values based on their judgment about how the specific location being considered differs from the average for the site. This variability must be considered when establishing and using standards or reference areas for assessments of current "condition". Such considerations require considerable knowledge and experience in the local area.

Desired plant communities (DPC) represent another use of standards (see Chapter 7, 12). In this case, the species or life-form composition of the DPC may be derived from interpretation of the possible plant communities listed on the ecological site description, or by observation of actual communities known to exist on the site. In either case it represents a standard that may or may not be completely achievable on any given location within the site.

The rangeland health assessment procedure described in the interagency Technical Reference 1734-6 (Pellant et al. 2005) rates the estimated departure of each of 17 indicators of rangeland health to the expected status of that indicator under "reference" conditions as indicated on a reference sheet (see Chapter 24). This reference sheet constitutes a *de facto* standard of comparison. In this case the standard is developed by use of various sources of information including ecological site descriptions and opinion of experienced people. Ideally, the reference sheet should be accompanied by an Evaluation Matrix which provides detailed descriptions of what constitutes “slight”, “moderate” and “extreme” departure from reference conditions for each indicator on a site specific basis. Observers are supposed to take into consideration the spatial variability in soil, slope, precipitation and other factors in making these assessments. This is an example of an abstract or hypothesized standard (as described in a previous paragraph) and depends entirely on the experience and ecological understanding of the observer. The use of an abstract reference sheet replaced the use of Ecological Reference Areas (ERA) as standards in the previous version of this manual (Pellant et al. 2000). ERAs were actual locations chosen as a basis for comparison and rated using the same criteria used on evaluation sites.

Similarity indices are often used to compare the species composition, species production, or species cover of a community to that of the DPC or historic plant community from an ecological site description (see Chapter 24). The most commonly used formula to calculate percent similarity is Sorenson's index which is calculated as: Percent Similarity =2w/(a +b) X 100 where a = the sum of values measured for existing vegetation, b = the sum of values measured for potential or desired vegetation, and w = the sum of values common to both communities. (When percent composition is the measured value, the formula is simplified to Percent Similarity = w). (Note the similarity index used in the NRCS Range and Pasture Handbook is not the same formula). Similarity indices are convenient because they allow the two communities to be compared with a single number (%), rather than having to consider each species separately.

Similarity based on composition data is not likely to achieve 100%. There are several reasons for this:

1. The DPC (or the historical climax community) are abstractions developed as averages for the site. They are not actual communities.
2. There is variability within a site in terms of soil, aspect, slope, and climate. Therefore, the kind and amount of vegetation is also variable so that no two specific locations are identical.
3. The estimated composition percentages for each species or group of species contain sampling error. Depending on the sampling precision, repeated samples from the same actual community will not usually result in a calculated similarity above 75% except by chance.
4. The more detailed the estimate of species composition (the greater the number of individual species with an estimated percentage composition) the lower the expected similarity will be when compared to actual communities. This is because the measured composition on an actual community will vary from season to season and year to year due to differing plant growth and phenology.

Achieving a similarity percentage much above 75% is unlikely to occur, except by chance, due to any or all of the factors listed above. For example, Bray and Curtis sampled two pairs of forest stands seven times each, and found a maximum similarity of 82%. They concluded that about 80% similarity was approximately the maximum similarity to be achieved by repeated sampling of a given forest stand (Bray and Curtis 1952) cited in (Grieg-Smith 1964). Their acceptance of 80% similarity was based on repeated sampling of a given stand at one time, thus would not include the additional variability due to use of abstract comparisons (#1 above) or to seasonal/annual fluctuations in composition (#4 above). We have not found any comparable studies in grassland or shrublands, but it is reasonable to assume that the results would be similar.

The historically common practice of dividing similarity coefficients into classes (as in range condition classes) of 0-25%, 25-50%, 51 -75%, and 76-100% (Range Inventory Standardization Committee 1983) is misleading, since the upper class is not likely to be a realistic objective. It would be preferable to use only 3 classes of similarity, as the Forest Service in Region 3 does, or to normalize the values, that is, to divide the similarity values by 75%.

There are several other problems with the use of similarity indices as a basis for interpreting species composition data. One is that the percentage composition is a relative value. A change in one species will affect the composition of all others (see Chapter27). This problem can be avoided by using absolute values, such as pounds per acre or percent cover, rather than composition based on these values. However, production and cover vary considerably due to seasonal and annual effects, so that calculated similarity may be more affected using absolute values than using species composition.

Another problem for interpretation is that plant communities with the same calculated similarity to the standard (DPC or historic community) may be very different in terms of actual plant composition and other resource values.

In other words, the level of similarity is not correlated with forage values, habitat values, or other values. Finally, similarity indices may not be sensitive to change in some situations. For example, if the historic community is described as having 40% sagebrush the herbaceous component of the vegetation can be completely changed or removed, and the similarity index will still be at least 40%. This problem can be mitigated to some extent by using absolute production or cover values rather than percent composition. Similarity indexes are one tool for comparing plant communities to some standard or desired community, but they should be interpreted carefully (Figure 4-1).

Similarity Index							
Species	**Potential Community**	**Situation One**		**Situation Two**		**Situation Three**	
	% on ESD	**Actual %**	**Allow %**	**Actual %**	**Allow %**	**Actual %**	**Allow %**
Sideoats grama	45	30	30				
Hairy grama	20	15	15				
Lehmann's lovegrass	0					40	0
Threeawns	10	20	10	20	10	10	10
Annual grasses	5	10	5	10	5	5	5
Annual forbs	5	1	1	5	5		
False mesquite	6	4	4				
Burroweed	2	10	2	30	2	10	2
Cactus	5	5	5	5	5	5	5
Mesquite	2	5	2	30	2	30	2
Total/Similarity Index	**100%**	**100%**	**75%**	**100%**	**29%**	**100%**	**24%**

Figure 4-1. Calculation of similarity indexes based on percent composition by weight for three different situations on a hypothetical desert grassland site.

Situation one: a range in "excellent" condition with a SI of 75% indicating it is very similar to the "historic climax community." Native perennial grasses make up most of the composition and livestock forage production is high. Limited amounts of shrubs and cacti provide some structural diversity.
Situation two: a range where all the more desirable native perennial grasses have been eliminated and the relative amounts of shrubs, especially mesquite, have increased. The SI is 29%. This situation is undesirable for livestock forage and for soil protection, but may be better for some wildlife species than the "potential" community.
Situation three: a range where all the desirable native perennial grasses have been replaced by Lehmann's lovegrass and mesquite has increased compared to the potential. The SI is 24% which is not much different from Situation 2. However, this situation is much superior to Situation 2 in terms of livestock forage production and soil protection.

CHAPTER 20
Using Comparison or Reference Areas for Assessments

An alternative to the use of standards for making range assessment is to use comparison or reference areas (see Chapter 15). This has the advantage that comparisons are made against an actual plant community that exists on the ecological site and can be measured using the same procedures as the community being assessed. This was the procedure recommended for evaluation of Rangeland Health in an earlier version of the rangeland health manual (Pellant et al. 2000). Use of comparison areas as a basis for assessing certain resource attributes is basically the same process as use of artificial standards (PNC or historic plant community), but at least it represents a plant community that actually exists at present. However, selection of a comparison area and interpretation of the data collected from it must be done with careful consideration of how it relates to resource protection and management objectives. A primary consideration in selecting comparison or reference areas is to establish, to the extent possible, that the site potential of the reference area is equivalent to the location being assessed. Different locations within a particular ecological site may still vary considerably in site potential (see Chapter 19). Wilson (1989) suggested that multiple reference areas should be used to avoid the danger of selecting reference areas with higher or lower potential than the area being evaluated.

During the early days of range monitoring exclosures or other areas thought to have had little or no grazing were widely used as comparison areas. There were two main reasons for this. One is that heavy grazing during the open range days often meant that range vegetation and soil had been severely impacted and it was often unclear what the potential for different sites might be. The exclosures were established, and "relict" areas located, to provide insight on this subject, and they did provide valuable information. Second, the prevailing approach to assessing "range condition" was to compare present vegetation with the "climax" or undisturbed condition which represented "excellent condition." Exclosures and other ungrazed areas were seen as approximations to the climax or potential for the site. This approach has proved to be somewhat problematic.

Exclosures are often too small to give a good indication of protection from grazing, because they sometimes attract rodents or other animals from surrounding areas in numbers that are not typical of larger areas. Exclosures also do not represent what "would have been" in the absence of grazing, but only what happened after grazing was excluded. For all their shortcomings, long-term exclosures do provide some interesting information on vegetation and soil changes in the absence of grazing and they should be maintained. Exclosures can also provide the opportunity to separate effects of different animals. A common comparison is that of exclusion of elk and cattle, and/or cattle only with range grazed by both.

Changing concepts of plant succession have generally resulted in the recognition that plant communities in exclosures do not represent a desirable plant community for grazed ranges anymore than an unburned area would represent the management goal where prescribed fire is a management tool (Wilson et al. 1984). Grazing by livestock or wildlife will have some effect on species composition; therefore desired plant community descriptions should reflect what is possible under grazing. This reasoning should be, but has not always been, applied to comparisons of other attributes such as soil cover or other properties. For example, measuring litter cover in an exclosure does not provide a standard for areas that are grazed because that level of litter cover may not be required for soil protection, may reduce density of desirable plants, lead to weed invasion, and at any rate may not be achievable under grazing. Likewise, soil compaction or infiltration rates are often measured in exclosures, but that does not mean the values measured in an exclosure are necessarily the standard to be achieved.

For all the reasons outlined above, selection of a comparison area on the same ecological site in an area that is considered to in "good condition" and under well-managed grazing is preferable to use of exclosures or relict areas. This was succinctly stated by Wilson et al. (1984) "The traditional 'exclosure' is of little value as a reference area, because the composition of an ungrazed vegetation is not the object of management." Such areas need not be on the same ranch or allotment, provided the site potential is sufficiently similar.

CHAPTER 21
Trend

Advantages of Trend

An alternative to making one-time assessments based on standards or comparison areas is to concentrate on establishing trends on one area over time. This procedure eliminates the need for assumptions about similarity of site potential on comparison areas or for hypothetical standards. The baseline of comparison is the data collected on the first sampling date. Subsequent sampling is compared to initial sampling data to establish trends in one or more attributes. Deciding whether the trends observed are "up" or "down" is an interpretation based on management objectives. For example, if the management objective is to increase percentage of perennial grasses (or a specific group of perennial grasses), then an increase indicates an upward trend and a decrease is downward trend. In this case, no specific target level needs to be established. If the desired plants are not increasing, then one must decide whether that means management is not working, other factors (like drought) are preventing the increase, or whether the levels may have reached their maximum value. This approach avoids many of the pitfalls outlined in the use of one-time assessments and standards described above. Comparison areas can still be used to compare trends on other areas to help establish cause and effect.

Trends in assessment scores or indices can also be used. This is preferable to the one-time assessment based on standards or comparison areas described above. In this case, it is the change, or lack of change, that is important, not the score itself. For example, movement toward a DPC objective based on comparison of species composition to some DPC can be interpreted as positive, even though the DPC as defined may never be completely achieved because the site lacks the capability to do so. Lack of progress must be interpreted either as ineffective management, other influences, or an unrealistic DPC.

Detecting Trends

There are two basic ways to detect trends over time in data. One is to perform statistical tests to identify statistically significant differences from one date to another. This type of analysis can be carried out if the data meet the assumptions of randomness, normality, or other criteria for such analyses. The analysis can also be employed where systematic sampling is used, and where assumptions of normality have not been tested, but in doing so, it must be recognized that errors of interpretation can result that the statistical tests will not identify. Also, statistical significance has no necessary relation to practical significance. For example, sampling of sufficient intensity may identify a minor change in the abundance of perennial grass as statistically significant, but the magnitude of change may be of no practical use for guiding management. More commonly, a change is judged to be non-significant statistically because sampling intensity is inadequate, and therefore estimated means have large confidence intervals due to high variability (s), high probability levels, or insufficient sample size. Lack of statistical significance does not mean the changes observed are not real, only that the level of sampling is not adequate to have a certain level of confidence they are real. Statistical analysis is only a tool to detect trends and must be tempered with professional judgment.

Comparing mean values over time in tables or graphs can also be used to detect trends, whether the differences can be shown to be statistically significant or not. The greater the frequency of sampling and the longer the period of record, the better the ability to detect trends. For example if mean soil cover declines more or less steadily over a period of several years, this demonstrates a trend. Whether it is significant, or what caused it, is a matter of interpretation. Only two or three widely separated samples may not provide much evidence for a trend, just as only two or three random values of the Dow Jones average won't tell much about long-term trends in the economy (Figure 4-2).

Interpreting Cause and Effect

Detecting trends in vegetation or soil attributes may be easier than deciding why the trends are occurring. If the cause of trends is not known, there is little basis for knowing if or how management needs to be changed. If current livestock grazing is the cause of undesirable trends, then the stocking rate, the grazing system, or animal distribution needs to be altered. However, before making any grazing management decisions it should first be established whether factors other than grazing may be involved. On most rangelands, the most important of these is weather.

Weather, particularly precipitation, is the main environmental factor affecting rangeland vegetation. At light to moderate stocking rates, such as are common on most western rangeland today, it is likely more important than grazing pressure. Precipitation data can be used in two ways to help interpret monitoring data.

Precipitation data should always be analyzed when interpreting monitoring data. If no data are available for the monitoring site, the nearest station with a good record should be used, recognizing that rainfall amounts can vary greatly over short distances due to topography or elevation, especially in any given year. Annual totals are usually not very informative. It is better to summarize data by growing season. For example, in Arizona precipitation data should be summarized using the months of June through September as summer growing season and October through May as the cool season period. This division will not be the same where growing season precipitation is mainly in the spring and early summer (Figures 4-3, 4-4).

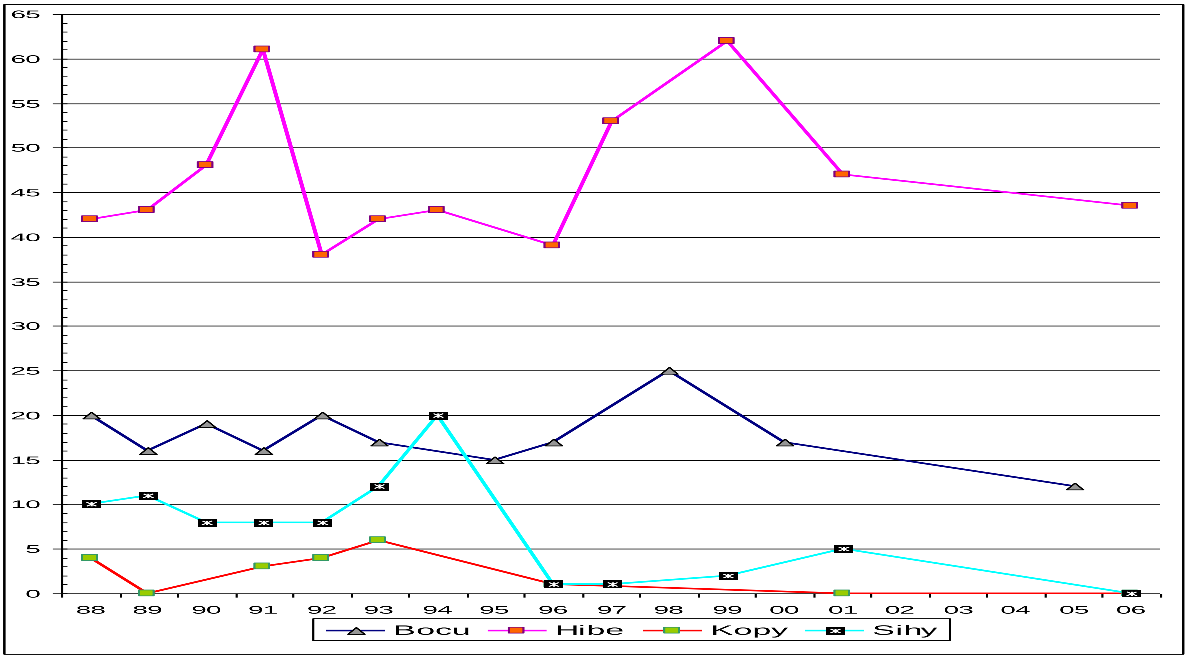


Figure 4-2. Frequency of four grass species over 28 years of monitoring. These data show a stable situation until about 2000,when there is a slight decline across all species, probably due to dry conditions during that time. Curly mesquite typically fluctuates more in response to short few dry/wet conditions than sideoats.

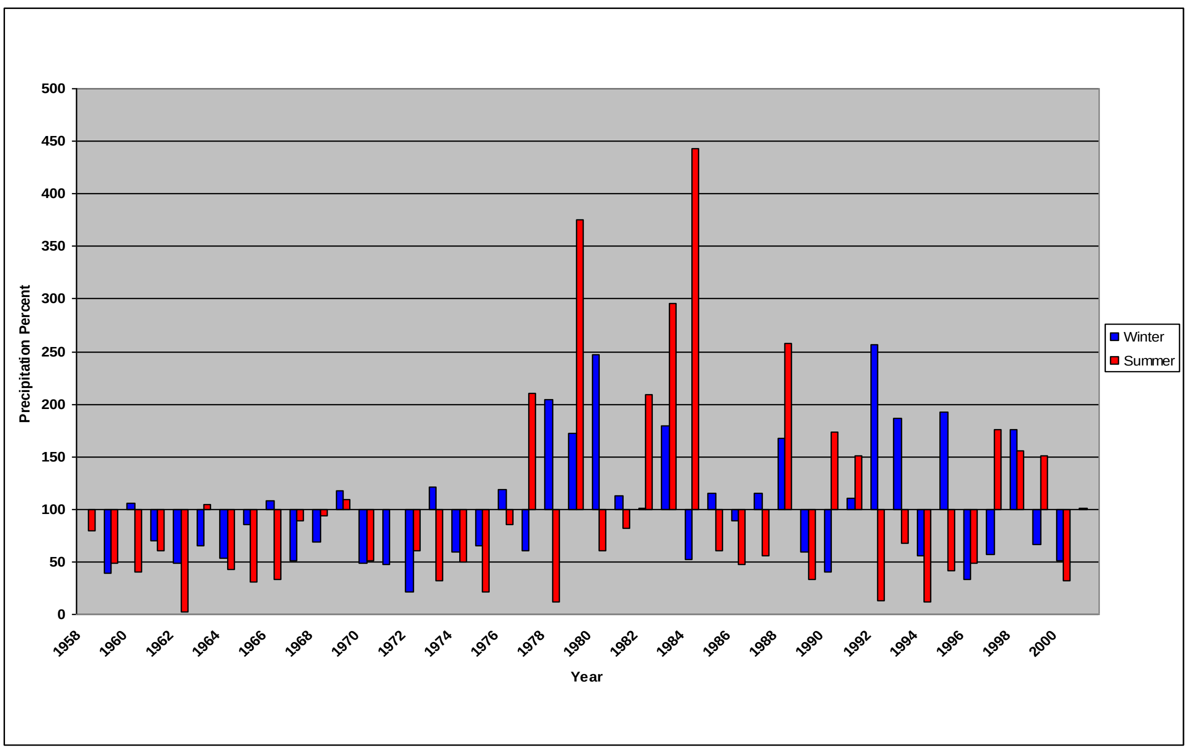


Figure 4-3. Analysis of winter and summer precipitation as percent of average for Mitchell Caverns State Park, California (Mojave Desert). Average precipitation over 42 years was 10.43 inches. BLM established monitoring locations (and reduced stocking rates) nearby in 1977 at the end of a very dry period from 1958 through 1977. From 1978 through 1985, when the next monitoring data were collected, was a very favorable period of rainfall. Since then, rainfall has been fairly "normal" with no long periods of either dry or wet conditions. Not surprisingly, the data showed a big increase in ground cover and plant cover from 1977 to 1985 and fairly stable conditions from 1985 to 2000. Although reduced stocking may have contributed to this, precipitation is no doubt the main driving force causing vegetation changes, illustrating the value of precipitation analysis and long-term monitoring data to support management conclusions.

Forage Year	Precipitation in Inches											
(Months)	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1998	2.5	0.31	3.89	0	0	2.63	0.59	0.3	0	2.2	1.2	0.95
1999	1.99	2.99	0.73	0.28	0.55	0.14	2.28	0	0.2	4.4	6.9	3.58
2000	0	0	0	0.32	0.36	3.6	0.41	0	2.9	0.7	3.7	0.02
2001	4.06	2.02	0.55	1.31	0.67	0.67	1.71	0.7	0.2	4.7	2.9	1.8
2002	0.25	0.28	0.69	0.46	0	0.17	0.63	0	0	2.5	2.4	1.91
2003	0.69	0.04	0.99	0.18	2.44	1.6	0.2	0	0.3	1.6	2.8	2.02
2004	1.05	1.99	0.81	1.26	0.6	0.25	2.07	0	0.2	1.5	1.2	1.55
2005	1.25	3.24	2.12	2.83	2.72	1.16	1.26	0.8	0.1	1.9	3	0.92
2006	1.32	0	0	0.27	0	2.58	0.72	0.1	0.8	4.9	5.3	1.03
2007	2.55	0.09	1.01	1.41	0.96	1.18	0.58	0.3	0.1	4.3	4.1	1.46
2008	0	0.23	5.57	1.61	2.1	0	0	1.1	0.4	2.1	4.7	1.21
1950-2008 AVG	**1.44**	**1.23**	**1.67**	**1.25**	**1.17**	**1.37**	**0.68**	**0.6**	**0.5**	**2.7**	**3.1**	**1.87**

Forage Year	Precipitation in Inches					
(Months)	Oct-May	O-M %	June-Sept	J-S %	Total	Tot. %
1998	10.26	108	4.36	**54**	14.62	83
1999	8.96	94	15.08	**188**	24.04	**137**
2000	4.69	**49**	7.36	92	12.05	**69**
2001	11.67	123	9.58	119	21.25	121
2002	2.48	**26**	6.83	85	9.31	**53**
2003	6.14	**65**	6.72	84	12.86	**73**
2004	8.03	84	4.4	**55**	12.43	**71**
2005	15.38	**162**	5.93	**74**	21.31	122
2006	4.99	**52**	12.03	**150**	17.02	97
2007	8.09	83	9.95	122	18.04	103
2008	10.57	112	8.35	103	18.92	108
1950-2008 AVG	**9.41**		**8.11**		**17.52**	

Figure 4-4. Forage year precipitation at Heber Ranger Station, Arizona, 1998-2008. A forage year is from October of the previous year to September of the current year. Here it is broken down by winter and summer seasons and expressed as inches and as a percent of average. The period from the winter of 2002 through the winter of 2006 was marked by below average in every summer and all but one winter period. This sequence indicates probable significant cumulative effects that are not readily apparent from consideration of the totals for the year. Annual monitoring started in 2002 following 4 years of more or less average rainfall.

Rainfall data can be used to adjust data to “average” conditions. This has been done with production and utilization data, although it might be possible with cover or other types of data. Cable (1975) developed a formula to adjust production data of warm season perennial grasses for rainfall based on 10 years of production data in semi desert grassland. The formula estimated percentage of average forage production based on the current and previous year’s growing season rainfall (June – Sept) expressed as a percentage of the long-term average. Current year’s rainfall was weighted heavier (.7) than previous (.3). The formula was: Current production = 0.7 (Current J-S ppt) X 0.3 (Previous J-S ppt); all values expressed as percentage of average. Ogden and Smith (1978) used the same data plus a few additional years and came up with basically the same relationship. However, when tested on a data set from a different time period, the formula did not predict forage production levels accurately. This may be because winter precipitation was ignored. Although warm season grasses respond mainly to summer rain, tillering and survival may be affected by winter precipitation as well. Reynolds (1954) also developed an approach for adjusting forage yields for drought in southern Arizona.

Holechek (1988) recommended that on “ranges dominated by perennial forages” standing crop at the end of the growing season could be reduced by 30% in years receiving 70% or less of average precipitation or increased by 30% in years receiving 125% or more of average precipitation to provide a satisfactory adjustment for purposes of estimating proper stocking or utilization. Based on work done in Oregon (Sneva and Hyder 1962), the BLM Manual 4400-7 (U.S.D.I .Bureau of Land Management 1985) describes the use of forage year precipitation to adjust production and utilization estimates for areas of the cold desert receiving mainly winter-spring moisture. Similar work has been reported for the Intermountain region(Hutchings and Stewart 1953) and for the sandhills of eastern Colorado where precipitation is mainly in early summer (Dahl 1963).

These various adjustments show the necessity of considering the proper seasonal precipitation to use in making adjustments. Data to support such adjustments in a quantitative way are scarce. They rely on monthly or seasonal amounts to make adjustments and ignore the intensity and spacing of rain events which are well known to have major effects on vegetative production. Therefore, such adjustments should be viewed as rough approximations and their possible error should be recognized when adjusting forage production and/or utilization estimates.

Drought can result in changes in species composition, reduced productivity, reduced ground cover, plant mortality, lack of reproduction and other responses that may result in unfavorable trends and reduced “range condition.” These responses may be similar to those produced by improper grazing and the two effects can interact, making it difficult to distinguish drought and overgrazing effects. On the one hand, it is easy to blame “overgrazing” anytime an undesirable trend occurs, and on the other, it is also easy to blame “drought” for all problems.

As pointed out above, adjustments can be made in forage estimates or utilization for high or low rainfall. However, the reliability of such adjustments may be questioned, and, at any rate, they do not apply to such things as ground cover, frequency, plant density, or recruitment. One way to try to separate the effects of drought from management is to make comparison across different pastures or ranches, including areas grazed at different intensities, and/or seasons and ungrazed areas. If sufficient data of a similar nature are available it should be possible to identify whether similar trends are occurring across a variety of different management scenarios, in which case drought or some other landscape level influence is involved (other factors could include extreme cold spells, invasion of weeds, spread of plant diseases). If trends on the area in question are down or static, but generally up elsewhere, then local management may be the reason. Making these determinations requires access to monitoring data taken over an entire landscape or region.

Utilization data taken at the monitoring locations may also help decide cause and effect. If utilization has been light to none, grazing is likely not the factor responsible for an observed downward trend. If it has been consistently heavy, then grazing may be the main cause of declines. Utilization data can also help distinguish between grazing effects of livestock and wildlife. In this case, seasonal utilization may be measured at different seasons, or seasonal effects estimated using cages put out at different times, to try to establish the relative contributions of livestock and wildlife that may use the area at different times. Seasonal utilization is not the same as utilization based on total production for the year, so interpretations of seasonal utilization must recognize the difference (Smith et al. 2007). If wildlife and livestock use the area at the same time, then exclosures may be necessary to compare effects. For example, cattle can be fenced out of some areas to see the effects of elk alone.

RELATING RANGELAND DATA TO "AVERAGE YEAR" BASED ON PRECIPITATION

Based on an analysis done by Dr. Phil R. Ogden contained in a report to the Governor of Arizona in 2001.
(Additional information and conclusions have been added.)

Biomass production on rangeland sites is known to vary greatly from year to year due to weather, especially precipitation. Range managers must interpret data and observations with knowledge of the annual variability that exists and, at least be able to say that the data were collected in a below average, average, or above average biomass production year.

Range managers can use analyses of precipitation data to help interpret data and observations relative to an "average year." Analyses of precipitation data from one or more representative weather stations supplemented with precipitation data and/or other supportive data from the management unit are needed. Average annual precipitation is usually not very useful in interpreting if growing conditions during a particular season are above or below average. Precipitation data should be analyzed taking into consideration the seasonal growth patterns of major plant species. Several studies in with different precipitation/growth patterns have been published illustrating this point.

Rangelands Where Summer Precipitation and Forage Production Predominate

* Cable, Dwight R. 1975. Influence of precipitation on perennial grass production in the semidesert southwest. Ecology 56:981-986. Cable concluded that current summer perennial grass production was an interaction effect of previous summer and current summer precipitation. The interaction product of current August precipitation and previous June-September precipitation accounted for 64% to 9l% of the annual variation in perennial grass production. Winter precipitation had no consistent effect on perennial grass production in the pastures studied on the Santa Rita Experimental Range in southern Arizona.

* Reynolds, Hudson G. 1954. Meeting drought on southern Arizona rangelands. Jour. Range Mgmt. 7:33-40.
Reynolds observed that successive years of summer rainfall (June through September) that were below normal resulted in a cumulative decrease in forage production. His conclusion was that drought severity is a combination of the amount of summer rainfall deficiency and the number of years in succession for which the summer rainfall remains below average.

Both of the studies above concluded that summer precipitation (June-Sept) in both the current and preceding years was the main determinant of perennial grass production in Southern Arizona where about 60% of the total precipitation comes during the summer monsoon. However, exceptionally dry winters may result in mortality or reduction in tillering of grasses that affects subsequent production in summer for one or more years.

Rangelands Where Spring and Early Summer Precipitation and Forage Production Predominate

*Dahl, B. E. 1963. Soil moisture as a predictive index to forage yield for the Sandhills range type. Jour. Range Mgmt. 16:128-132.

This study was conducted in the NE Colorado sandhillls where 70% of the precipitation comes in April-August. The growth period is May - August. Available soil moisture present at the beginning of the growing period and used during the growing period, precipitation during the growing period, and a carry-over effect of 2 previous years of precipitation explained most of the annual variation in the spring and summer growth of grasses at this location.

Rangelands Where Winter Precipitation and Spring Forage Production Predominate

*Hutchings, Selar S. and George Stewart. 1953. Increasing forage yields and sheep production on Intermountain winter ranges. U. S. Dept. of Agriculture Circular No. 925. These authors used data from the Desert Experimental Range (Utah) to predict October forage production based on the previous 12 months of precipitation. Eighty nine percent of the variability in herbage production was explained by the amount of the precipitation during the previous 12-month period, i.e. a "forage year."

*Sneva, Forrest A. and D. N. Hyder. 1962. Estimating herbage production on semiarid ranges in the Intermountain region. Jour. Range Mgmt. 15:88-93. This study predicted percentage of median forage production in October using precipitation from the previous Sept - June precipitation expressed as percentage of median. The equation accounted for 77% of the variability in forage production. The results may apply where summer precipitation is not a major factor determining forage production.

Recommendations

1. Analyze precipitation data using a "forage year" concept rather than annual averages. Definition of a forage year will vary depending on the location. In most of the southwest it is useful to look at a forage year as October (of the previous year) through September of the current year, and to break this down by winter (Oct - May) and summer (June - Sept) precipitation.
2. Equations to predict forage production or adjust production to "normal" years, or to predict end of year forage production based on mid-growing season observations, are subject to substantial error on a site specific basis for a particular year, especially in areas with mainly summer growing seasons. They should be used as a basis for helping interpret inventory and monitoring data, not as a basis for management decisions.
3. Analysis of the forage year and seasonal precipitation for the current year and several preceding years will aid in interpreting inventory or monitoring data.

“Early Warnings”

Some have criticized the use of trend monitoring as a basis for management decisions, arguing that by the time a trend is detected, the “damage has already been done.” To some extent that is true. However, the expressed need for “early warning” indicators also has shortcomings.

One of the reasons for monitoring utilization as an early warning is to identify where utilization is consistently heavier than we think is advisable for rangeland and watershed condition. Just because we measure utilization that exceeds our “guidelines” does not mean that unfavorable results have occurred, only that they might occur if this pattern is maintained.

Other indicators can be used as early warning signs that vegetation change, either positive or negative, may be occurring even though monitoring has not yet picked it up. Plant vigor or reproduction can be observed, and these have frequently been included as indicators of “apparent trend.” Such indicators are usually very subjective, and their interpretation is best made by people who have closely observed the area over a long period of time.

The concept of “early warning indicators” seems to be based on a paradigm that supposes a rather constant set of environmental conditions along with a fairly constant impact of grazing or other management actions. In this way, grazing management (for example) might not have immediate effects detectable by most monitoring, but there should be signs that can be observed that such effects are likely, so that management can be changed before they happen. This may occur in some situations, as where utilization is heavy and consistent over a period of years. The changes may not come until the heavy grazing interacts with drought, for example. However, many believe that vegetation and soil changes often occur through the occurrence of extreme events, or perhaps the co-occurrence of infrequent events (Noble 1986, Westoby et al. 1989). Examples would be an extreme cold spell or drought that alters species composition, sometimes for years after the event occurs. In some cases these impacts could possibly be mitigated by altering grazing before they occur. These events cannot be predicted, and there is nothing to observe on the ground in advance that would warn whether or when they are likely to occur. It seems our ability to foresee changes will likely continue to be limited. The alternative is to detect the change as early as possible so it can be corrected if possible.

CHAPTER 22
Changes in Grazing Management

Data Needs

What kinds of data are necessary for decisions regarding the need for change in intensity, season, frequency, or distribution of use by livestock, wildlife or people? These factors usually interact so it is difficult to separate them completely. For example the acceptable intensity of livestock grazing may differ depending on the season, frequency, or distribution of the grazing. The length of time animals spend in a pasture may be related to intensity and frequency of grazing on individual plants. Likewise, the various users (livestock, wildlife, people) may also interact.

Intensity of Use

Determination that preferred forage plants for livestock are declining in key areas for livestock, but not declining in selected comparison areas, may indicate that livestock grazing intensity is excessive under the current management system (see Chapter 20). The need for either a reduction in numbers or other management changes could be indicated by these observations. In the short-run, consistent documentation of utilization that exceeds recommended guidelines could indicate a need to reduce numbers or make other management adjustments. Holechek et al. (1998) stated: “Generally, management changes are needed if grazing intensity guidelines are exceeded on over 30% of the pasture or allotment for two consecutive years or in any two years out of 5.” Although that recommendation is based on professional judgment, it seems to be reasonable as a general guideline. It could, perhaps, be extended to wildlife and recreational uses as well. The converse should also be mentioned. For example, if utilization by livestock is at or below grazing intensity guidelines in most of the pasture or most of the key areas for a 5-year period, then increased stocking should be considered.

Season of Use

Determination that certain life forms or plant guilds are declining in relation to others could indicate that the season of grazing should be altered. For example, if the composition of cool season grasses is declining, and this decline is not apparently due to weather, then altering the season of grazing may be warranted. In the short-run, consistent heavy use, low vigor, or lack of reproduction of cool-season grasses are signs that could be used to instigate preventive measures.

Frequency of Use

Grazing frequency (how often individual plant may be defoliated), is dependent upon growing conditions and the length of time animals are in a particular pasture. Grazing frequency is related to intensity of use on individual plants. Determination of decline in preferred forage plants may indicate that rest periods are inadequate to provide for recovery and/or reproduction. In this case, the decline is likely due to shortened life spans and/or lack of recruitment. Longer rest periods (shorter grazing periods) may be desirable. In the short-run, low vigor or lack of reproduction may be indicators (see Chapter 24).

Distribution of Use

Differing vegetation trends in different key areas may indicate poor distribution. In the short-run, consistent differences in utilization among key areas may indicate poor distribution. Use pattern mapping is a good short-term tool to identify distribution problems (see Chapter 24).

SECTION 5
SELECTING APPROPRIATE ATTRIBUTES AND METHODS

What You Will Find in Section Five

- How does vegetation type influence attributes and methods selected for inventory and monitoring?
- How do objectives influence attributes and methods selected?
- What kinds of data are needed for point in time inventory/assessment as opposed to long term monitoring?
- Choosing what to measure and how.

CHAPTER 23
Attributes and Methods VS Objectives and Vegetation Type

This Section is a guide to matching rangeland attributes and data collection methods to management objectives for different vegetation types. The discussion has been divided into data needs for (1) one-time inventories or short-term objectives and (2) long-term monitoring of trends relative to management objectives. We recommend attributes and measurement techniques specific for assessing whether objectives are being met for particular types of vegetation. The attributes are described more fully in Section 6 and the methods in Section 7; after identifying the recommended attribute and method for a given objective the user can refer to these Sections for a discussion of both.

We also indicate when no practical procedure is available for a given vegetation type. In all cases, the emphasis is on quantitative or semi-quantitative procedures for determining whether objectives are being met. Although experienced practitioners can make range decisions based on qualitative descriptions or estimates, such informal observations do not usually provide data or records that can be objectively analyzed, especially by different people. Therefore, informal techniques are not recommended here for monitoring purposes.

Throughout this section vegetation will be described in terms of life form and "thickness", these categories are described in the following sidebar and illustrated in Figures 5-1 through 5-12.

Vegetation Type Classification for Selecting Appropriate Monitoring Attributes and Techniques

The variety and relative abundance of species and life forms that make up range and forest vegetation are exceedingly diverse over a landscape. Even "uniform" areas selected for monitoring exhibit significant spatial variability in kind and number of plants. These factors make it very difficult to generalize about proper attributes and techniques to use in rangeland inventory and monitoring.

Vegetation consists of layers that can be described in terms of life form, plant size, density, and cover, Some monitoring techniques work better in very dense vegetation (e.g. thick brush or riparian areas), and some work better in sparse vegetation (e.g. desert shrub types). We use the terms sparse, open, dense, and very dense to describe plant cover in the various layers. While there are no exact definitions for these modifiers, we offer clarification throughout the discussion of attributes and methods.

Most of the common rangeland monitoring techniques are best suited to open to dense herbaceous vegetation. Annuals are separated from perennials because the differences in growth patterns often make interpretation of data on annuals difficult. Where the focus is on collecting data to characterize shrub or tree different techniques or sampling schemes may be necessary to obtain accurate data.

Life form Layers	**"Thickness" Descriptors**
Annuals	Sparse
Perennial grass and forbs	Open
Low shrub	Dense
Tall shrub	Very Dense
Tree	

Classes of Layers

Annuals (grasses and forbs)- western rangelands probably have no native annual grasslands, but in many vegetation types annuals such as six weeks grama and annual threeawns may make up a significant portion of the herbaceous layer, at least in wet years. In some cases introduced annuals, such as red brome, cheatgrass, filaree, or Mediterranean grass, make up the bulk of the understory vegetation. Growth patterns of annuals often make it necessary to collect and/or interpret data differently than for perennials.

Perennial grass (and forbs)- perennial grasses, and some forbs, are the prominent life form in most grasslands. The perennial grass layer can be further subdivided into bunchgrass or sodformer; or shortgrass, midgrass, tallgrass. We have lumped these forms here, but we will point out where they require separate monitoring methods.

Low shrub- the low shrub layer is arbitrarily capped at 3-4 feet in height. This layer includes small shrubs and half-shrubs (e.g. snakeweed, burroweed, zinnia, shrubby buckwheat, false mesquite), cacti (prickly pear, cholla), and leaf succulents (yucca, beargrass, agave). Creosotebush and sagebrush are included in this layer, although these plants may exceed 4 feet in height. Shrubs in this layer may have single or multiple stems.

Tall shrub- the tall shrub layer is defined as 4-15 feet in height. It can be composed of one to many species in any given location. Tall shrubs may be single or multiple-stemmed, evergreen or deciduous. Examples are mesquite, catclaw, whitethorn, coyote willow, palo verde, ironwood, juniper, alder, manzanita, shinnery oak, mountain mahogany, cliffrose.

Tree- the tree layer includes woody plants greater than 15 feet in height and usually consists of species with a defined single trunk, although there are exceptions such as some species of oaks. Examples are pines, liveoak, fir, cottonwood, black willow, sycamore, and aspen. Some species, like mesquites and junipers, may be tall shrubs on some sites and trees on others.

Classes of Thickness

Vegetation "thickness" could refer either to density of stems or overall cover. Since cover is tied more closely to the size, production, or ecological importance of plants in a community than density, we use cover to separate the "thickness" classes.

Sparse – refers to a layer with plants very widely scattered. Generally, the total canopy cover of plants in a sparse layer will be less than 5%, and often much less. The perennial grass layer is usually "sparse" in some desert shrub, chaparral and forest types, or where it has been reduced by grazing or other disturbances.

Open – refers to a layer with plant cover between about 5% and 30%, Open spaces are visible between most individual plants or clumps. If seen from above, the "open" cover looks like a mosaic of plants across an area that is mostly bare ground, litter and/or rock. Most of the grassland vegetation types and many of the shrub or forest types have an open perennial grass/forb layer.

Dense – refers to a layer with cover of about 30%-70%. Many of the plants will have overlapping canopies. In shrub and tree layers the vegetation is thick enough to make it difficult to move in straight lines or see for long distances. A dense grass/forb layer may occur in some mountain grasslands, aspen forests, dry meadows and swales, sacaton bottoms, or other areas that receive substantial rainfall, runoff, or subirrigation, such as riparian areas.

Very Dense – refers to a layer with over 70% cover. "Very dense" is not common on most western rangelands, but some stands of chaparral, mixed conifer forest, wet meadow, or riparian forest or shrubland meet the 70% requirement. Very dense perennial grass layers are more common in sub-humid to humid grasslands (e.g. tallgrass prairie).

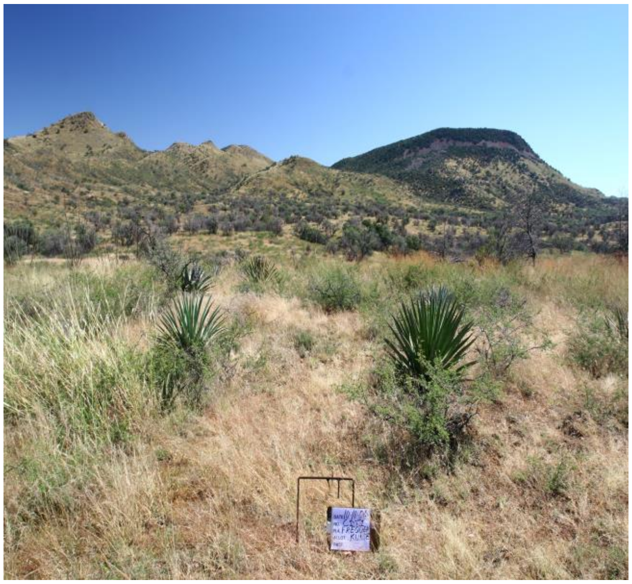


Figure 5-1. Open low shrub layer (catclaw, yucca, etc.) with open grass layer (mixed perennial grasses).

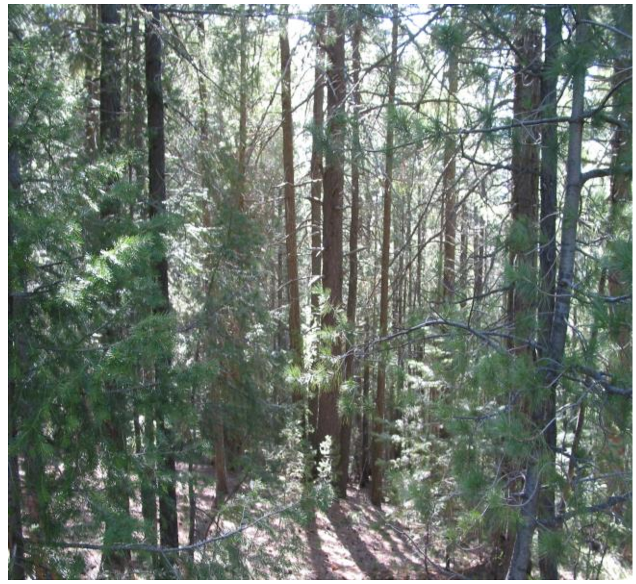


Figure 5-2. Very dense tree layer (mixed conifer) with sparse grass layer).

Figure 5-3. Dense tree layer (Ponderosa pine) with open grass layer (bunchgrass).

Figure 5-4. Dense tall shrub layer (Arizona chaparral) with sparse grass layer.

Figure 5-5. Open tall shrub layer (saguaro, paloverde), open low shrub layer (creosotebush, cactus), sparse perennial grass layer and sparse annual layer.

Figure 5-6. Open tall shrub layer (saguaro and paloverde), open low shrub layer (cactus, bursage) and open annual layer.

Figure 5-7. Dense tall shrub layer (cliffrose, pinyon, juniper) with sparse grass layer.

Figure 5-8. Open tall shrub layer (mesquite), sparse low shrub layer (cactus, burroweed) and open grass layer (perennial grasses).

Figure 5-9. Open low shrub layer (desert saltbush), with dense annual layer (cool season annuals).

Figure 5-10. Sparse tall shrub layer (juniper) with open low shrub layer (sagebrush) and sparse grass layer.

Figure 5-11. Sparse low shrub layer (Mormon tea, etc.) and sparse grass layer (galleta).

Figure 5-12. Very dense tall shrub layer (mesquite) with very dense annual layer (cool season grasses and forbs).

CHAPTER 24
Point-in-Time Inventories and Assessments

This chapter includes discussion and recommendations for data collection to support one-time inventory or assessment. One-time efforts can guide short-term management planning and decisions or identify needs for longer term monitoring. Point-in-time data collection can be repeated to provide trend information, although some techniques are too subjective and qualitative to provide good monitoring data.

Weather

- ✓ Purpose

A weather record helps interpret data on plant growth, utilization, species vigor, ground cover, livestock performance and behavior or other attribute that might vary from year to year. Weather patterns, especially precipitation amount and timing, can influence the annual growth of different species and ultimately, over the long term, plant species composition (see Chapter 22).

- ✓ Recommendations

Collect precipitation on a daily, monthly, or seasonal basis at each monitoring location, if possible, or in several representative locations scattered over the management unit. Other attributes, such as temperatures, humidity, or soil temperature and moisture may be useful but not essential.

Maps

Ecological sites

- ✓ Purpose

Mapping ecological sites over an entire ranch or grazing allotment provides the basic stratification of the landscape upon which to base management decisions and the collection and interpretation of monitoring or inventory data (see Figure 3-2, Chapters 9, 11)

- ✓ Recommendations

A map of ecological sites, or other classification of land capability (site potential), is a relatively stable and extremely important source for all aspects of management and assessment. Therefore, it should be based on the best available information and expertise. It is recommended that mapping be done by agency or other professional range and soil scientists. It is beyond the scope of this guidebook to describe the procedures for delineating ecological sites and mapping ecological units. These procedures are found in the NRCS National Range and Pasture Handbook (U.S.D.A. Natural Resources Conservation Service 2005). Ecological site maps are useful in all vegetation types.

Alternatively, most National Forests in Arizona have recent Terrestrial Ecological Unit Inventory (TEUI) information (maps and site data). Terrestrial ecological units are developed from data integrating climate, soils, landform and vegetation. Terrestrial ecological units and their descriptions are based on sampled sites and designed to reflect site potential. Procedures for Terrestrial Ecosystem Survey/Terrestrial Ecological Unit Inventory are consistent with the National Cooperative Soil Survey, and can be found in the Terrestrial Ecological Unit Inventory Technical Guide (Brohman and Bryant 2005).

Current vegetation types

- ✓ Purpose

A map of current vegetation can serve as a basis for developing desired plant community objectives, designing monitoring plans, mapping grazing patterns, identifying the need for vegetation treatments, or other management actions. Current vegetation maps are more dynamic than ecological site maps, therefore, they need to be updated periodically to reflect changes in the vegetation (see Chapters 5, 10).

✓ Recommendations

Vegetation maps are appropriate for all vegetation types. Attributes upon which vegetation maps are based are usually species composition or life-forms. Vegetation maps may be based on classification of plant communities based on species composition, or on other classification based on life-form, cover, density, or any number of attributes. See Section 3 for discussion on use of vegetation types. Methods of vegetation classification for mapping are beyond the scope of this guidebook. See Brown (1994), Shiflet (1994), Brohman and Bryant (2005), and Triepke et al. (2005) for examples.

Utilization patterns

✓ Purpose

Identification of grazing patterns of livestock and/or wildlife can guide management changes to improve distribution and grazing capacity, improve range conditions, or minimize conflicts among range uses (Figure 5-13).

✓ Recommendations

Grazing patterns can be identified by mapping utilization patterns over the entire management unit, or plotting observed utilization at a number of locations scattered over the unit. True utilization (based on total year's forage production) and seasonal utilization are both attributes that can be mapped or plotted and used to support decision making. The landscape appearance method is recommended for use pattern mapping since it can be used in almost any vegetation type and allows for rapid assessment over large areas. Where utilization is mainly being judged on perennial grasses other methods (e.g. height-weight, stubble height, percent grazed or grazed class) may be used for training or as checks on visual estimates (see Chapters 30, 40).

Resource Assessments

Range condition or Ecological status

✓ Purpose

Range condition/ecological status is the present status of the resource in relation to some reference condition or objective. The traditional procedure for assessing range condition previously used by NRCS, BLM, and other agencies was to compare species composition of the present plant community to the "climax" or "potential" plant community for the ecological site using an index of community similarity (see Chapter 19). Similarity percentages were arbitrarily assigned to four range condition "classes" or "seral stages." The concept of seral stages or successional classes is based on the predictable, linear model of plant succession which has largely been abandoned by range ecologists as a general explanation for vegetation change (see Chapter 5). NRCS still calculates percentage similarity to a reference plant community, generally the historic climax plant community or other vegetation state, but does not assign condition or succession classes. The similarities are only used to document similarity to the chosen reference plant community. NRCS is also using the estimated pounds per acre for plant species as a basis for calculating similarity indices as an alternative to using percentage composition of species based on dry weight.

Changing ecological theory has led to use of the desired plant community as a standard of comparison to measure degree of attainment of management objectives. In this case, the trend in similarity compared to a DPC can be used as a measure of progress toward or away from management objectives (see Chapter 7).

✓ Recommendations

For most general assessment purposes, especially where mixed life forms are present, species composition based on production by species or life forms using the dry weight rank method (DWR) is recommended for obtaining data to make "range condition" or "ecological status" interpretations. The annual production of a species is considered to be a better measure of its ecological importance in the plant community than species-specific cover. The demands of plants on site resources are probably more related to the production of dry matter than the canopy cover, especially in life forms with perennial aboveground stems and leaves. For example, a cactus or xeromorphic shrub may have considerable extent of aerial cover but produce very little biomass annually due to the necessity of maintaining existing living tissue. However, for some uses (such as hydrologic models) cover may be a more useful attribute than production.

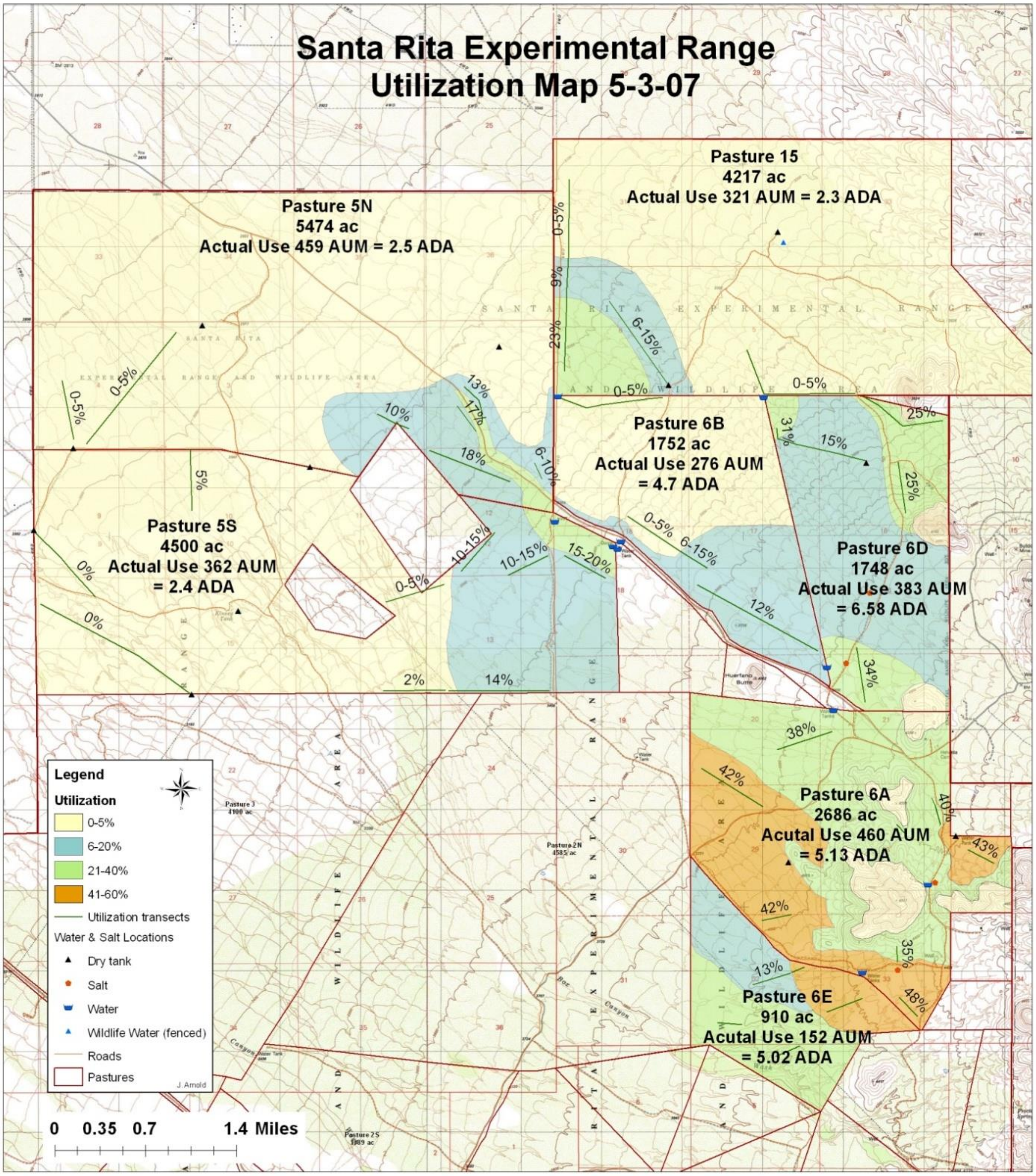


Figure 5-13. Forage utilization map developed on the Santa Rita Experiment Range.

Use of DWR to estimate composition (relative dry weight production) requires less time, less training, and is less subject to phenological or weather conditions than estimating dry weight production in pounds per acre by species. If production data are required, the DWR method can be combined with the Comparative Yield or other weight methods to provide the additional data (see Chapter 32).

We urge cautious use of similarity indices to assess range condition or ecological status. Using annual production or cover of species or life form to calculate similarity to a reference or desired condition constitutes data interpretation rather than data collection. Similarity to the DPC would be related to the mix of uses or values selected as the management goal for a particular site; however, similarity of present vegetation composition to the presumed potential or historic vegetation does not necessarily reflect the ecological "state" of the resource, the value of the vegetation for specific uses, or the tendency for vegetation to change in such a way as to increase the level of similarity. "Similarity" index calculators may be employed in any vegetation type. Species or life-form composition may be related to almost any attribute, but is most commonly based on current year's production or canopy cover because relative density or frequency have little interpretative value when different life-forms are included (see Chapter 19).

Forest Service desired vegetation status/ecological status determination

✓ Purpose

The Forest Service in Region 3 currently evaluates "desired vegetation status"(DVS) and "ecological status"(ES) as part of the process of interpreting rangeland inventory and monitoring data for management purposes (U.S. D. A. Forest Service 1997). This procedure is similar to that described in previous statement above except for two features: (1) data collection is based on TES units, which are analogous to ecological sites but not the same, and (2) interpretations are based on data obtained by the cover-frequency method or in $1/10^{th}$ acre plots which assess canopy cover rather than species composition by weight. ES is a measure of the similarity of present vegetation on a TES unit to the Potential Natural Vegetation (PNV) for that unit. DVS is the similarity of present vegetation to a desired plant community identified for the TES unit. Both ES and DVS are calculated using similarity indices that are the sum of the percentage of canopy cover of a species (as measured by the Daubenmire Canopy Cover Method) and canopy frequency of the species (the percentage of quadrats where the canopy of the species was observed). This method provides a cover-frequency index with a maximum possible value of 10,000 (100% frequency X 100% cover) and follows a procedure developed by (Uresk 1990) for use in the northern Great Plains.

The premise for the use of the canopy-frequency index by the Forest Service is that use of a combination of frequency and canopy cover provide a better measure of species importance than either one alone. Capturing the two attributes addresses several concerns with using only one attribute. Frequency has the benefit of being influenced less by weather and allows for greater repeatability. Frequency, by itself, is not very useful for expressing species composition and for use in vegetation classification. Canopy cover provides a more meaningful expression of species composition and is more useful for vegetation classification from inventory data. However, canopy cover can be greatly influenced by seasonal weather or plant phenology, especially in herbaceous species. The premise for using both, as the CFI (Cover-Frequency Index), is to mitigate disadvantages of either. Uresk (1990) thought that the CFI provided a better measure of species importance than cover or frequency alone, and this reasoning has been accepted by the Forest Service in Region 3 (U.S.D.A Forest Service 1997).

✓ Recommendations

The CFI is a method of interpreting data based on the collection of canopy cover and frequency data. Both of those techniques are discussed in Section 7. CFI was included in this section because it is a way of making an assessment of data. It may have value in certain types of inventory or classification of vegetation. The authors do not recommend the cover-frequency index as a method for interpreting monitoring data.

This negative recommendation is based on three main considerations. First, as pointed out earlier and by the Forest Service (USDA Forest Service 1997), the use of similarity indices, although appearing straightforward, may often be misleading in terms of attainment of resource objectives or management success. The degree of similarity may or may not be correlated with particular resource values or objectives (see Chapter 19). Similarity indices based on cover or production may relate to resource values or management objectives, but similarity based on density or frequency does not unless all plants are of similar growth form. Also, reference community conditions may mask variability within an ecological site or terrestrial ecosystem unit. Thus, similarity to specified reference conditions must be interpreted with caution.

Second, multiplying canopy cover and canopy frequency to provide a cover-frequency index obscures the interpretation of the data. Although both (Uresk 1990) and Forest Service Region 3 (U.S.D.A Forest Service 1997) state that using both canopy and frequency is a better indicator of species importance than either alone, there is no evidence that this is the case for most vegetation types. Uresk stated: "Canopy cover… is of greater ecological significance than density in the measurement of plant distribution…and gives a better indirect measure of plant biomass than the number of individuals. Cover values may change due to year differences, but multiplied with frequency to form an index, changes in an ecological stage are less likely when a change may not exist; frequency values are less likely to change abruptly on a yearly basis. However, if high frequency paired with low cover is equivalent to low frequency paired with high cover for a species, then the index is flawed."

He went on to say that the likelihood of such an occurrence was low in the vegetation where he worked (mainly perennial grass and forbs), but "it cannot be precluded for other plant species in other vegetation types." In contrast to the grassland vegetation where Uresk did his work, many types of range vegetation have a variety of plant growth forms which would render this procedure "flawed." For example: A shrub with a canopy cover of 25% and frequency of 4% has a CFI value of 100. A small bunchgrass with frequency of 50% and cover of 2% also has a CFI value of 100. Clearly, these two forms are not of equivalent importance in the plant community either in terms of ecological processes or resource values (such as soil protection or habitat value). If the attributes of canopy cover and frequency are determined to be impartial for an assessment it is better to interpret each independently than to create an index combining the two (see Chapter 18).

And third, this Guidebook is based on the premise that consistency of methodology and terminology among agencies is desirable as a basis for coordinated monitoring and management of land across ownership boundaries. The use of the CFI is unique to the Forest Service and, although the Forest Service may find it useful for certain applications, it is not consistent with methods used by other agencies and therefore is not recommended for monitoring in a coordinated management framework.

Grazing capacity

- ✓ Purpose

The purpose of estimating grazing capacity is to balance stocking rates of grazing animals with the ability of the rangeland to provide forage on a sustainable basis. Grazing capacity or stocking capacity are synonymous with carrying capacity, which is defined by the Society for Range Management as "the average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives for the unit. In addition to site characteristics, it is a function of management goals and management intensity" (Glossary Update Task Group 1998). Carrying or grazing capacity is generally considered to be the average number of animals that a particular range will sustain over time (Holechek et al. 2000). We use "grazing capacity" in this book, which is not the same as "stocking rate." Stocking rate is defined by the Society for Range Management (Glossary Update Task Group 1998) as "the relationship between the number of animals and the grazing management unit utilized over a specified time period." Stocking rate may be higher or lower than grazing capacity. The proper stocking rate may approach grazing capacity, depending upon management objectives, but is a subjective, moving target.

Grazing capacity for livestock (or proper stocking rate) is not an intrinsic biological characteristic of an ecosystem that can be directly measured. Grazing capacity is a function of the kind and amount of vegetation produced on the range, topographic characteristics of the landscape, and availability of water resources. However, it is also affected by management goals and management intensity. The amount of money and time spent on regulating and managing livestock use (e.g. fences, water developments, trails, herding) significantly affects grazing capacity. In addition, goals for wildlife or recreational use may constrain livestock use and thus reduce grazing capacity. Determination of grazing capacity is therefore a complex process that needs to explicitly consider all these components (Rangeland Technical Advisory Council 2001).

- ✓ Description

Several approaches can be used to estimate grazing capacity (or proper stocking rate).

- ✓ Guidelines or comparisons

One way to estimate the grazing capacity of a ranch or allotment is to compare it with similar areas where stocking rates are known to be in balance with land capability. Since no two areas are identical in terms of vegetation, topography, rainfall, or available water, adjustments based on experience or professional judgment are necessary. Most ranchers and many range specialists estimate grazing capacity using a comparison method, which may provide reasonable estimates if based on adequate local experience

The NRCS ecological site guides sometimes include recommended “initial stocking rates” for specific ecological sites. These guidelines are rough approximations because they cannot take into account the management intensity, range improvements (water and fences) or the overall pattern of ecological sites in a specific pasture or ranch. They are intended as an initial, conservative stocking rate for use until more site-specific information can be developed.

- ✓ Forage inventory or model approach

Probably the earliest formal inventory method for estimating grazing capacity was the Ocular Reconnaissance Method which was developed by the Forest Service and later used in the Interagency Range Survey on both National Forest and public domain lands (BLM). This method involved mapping range types in a pasture or management unit. For each map delineation, the estimated percent composition by species based on cover was ocularly (visually) estimated along with the total canopy cover (then called density) of all species. The percent cover of each species was multiplied by the proper use factor for that species to give a forage value factor (FVF) for the species. A proper use factor (PUF) was the percent utilization that would be achieved for that species when the range was properly stocked. The PUF reflects the relative preference or palatability of each species and is dependent on the kind of animal, season of year, associated species, and other factors. The FVFs for each species were summed to provide a type FVF, which is the percentage of the total plant production that is forage when the range is properly grazed. The type FVF was multiplied by the total plant cover percentage to give a Forage Acre Factor (FAF) which is a percentage relating the amount of forage per acre on the range to a hypothetical Forage Acre (FA), which is one acre covered by vegetation 100% usable and 100% cover. These factors assumed full use of the range, so reductions were made using professional judgment to compensate for steepness of slope, distance to water, and other factors restricting full livestock use. The number of FAs was converted to a stocking rate by using a Forage Acre Requirement (FAR) determined by a survey of vegetation on a similar type of range where the proper stocking rate was known. This method was widely used in the early days of range management to adjudicate grazing privileges among grazing permittees or to establish “initial stocking rates” in the absence of other information, including general lack of adequate actual stocking records (see Brown 1954 or Smith 1984 for further discussion).

The Ocular Reconnaissance Method served a useful purpose in the early 1900s but was generally abandoned in favor of monitoring range condition and trend in the 1950s and 60s. However, resurgence in the use of forage inventory techniques (this time based on forage production estimates) occurred in the 1980s and continues in some agencies. Apparently this return to use of forage inventories was the result of several factors. One was the concept of “forage allocation” that allocates vegetation to various uses, including livestock grazing. BLM was a major proponent of this approach. Another probable reason was the support for a forage inventory approach provided by Holechek (1988 and 2000) for “setting the stocking rate” which has been widely cited by the land management agencies. Another was probably the growing use of computer models used to simulate or predict forage production over landscapes, which eliminated the tedious work of measuring forage production on the ground.

These forage inventory methods involve estimating forage production and applying a number of assumptions or corrections to arrive at an estimated proper stocking rate. Exact methods vary but the general process is as follows. Total annual production of vegetation is estimated. The percentage of the annual production that is forage for livestock is estimated. This amounts to setting proper use factors on each species. Multiplying the pounds of vegetation produced by PUFs for each species and summing provides the amount of forage available if the range were uniformly properly utilized. However, because livestock grazing distribution is affected by distance from water and steepness of slopes, a correction must be introduced to adjust for these factors. Finally, an allocation of forage to wildlife is often made which further reduces the amount of forage available for livestock. The net pounds of forage available to livestock are then divided by the animal unit month (AUM) requirement on a monthly basis to estimate the AUMs of forage available for “allocation” to livestock.

If sufficient information were available, and if the process were properly applied, the forage inventory method could provide a reasonable estimate of proper stocking rate. However, all of the various estimates and correction factors used in the process are subject to errors. For example, annual plant production is subject to error due to sampling variability and possible bias due to techniques used. If the production is modeled based on research studies, the degree to which the equations can be extrapolated to other ecological sites is seldom known or validated. Assigning proper use factors is also subject to error since the effects of season of year, vegetation type, and other influences on the factor are seldom known or adequately considered. Corrections for slope and distance from water are usually based on relationships that have general validity but may not be valid for specific situations (i.e. landscape pattern, season of year, age or source of livestock, fencing, etc.). Finally, the forage requirement per AU is also based on general relationships and can vary by significant amounts depending on season of year, type of livestock, and other factors. When all the figures and correction factors (each having an error component) are multiplied together the result will have a large, but unknown, error associated with it. For example if six factors are used, each with an error of +/- 20% (not an unreasonable estimate), then the probable error in the result may approximate +/-50%. That level of accuracy does not inspire confidence in the usefulness of forage inventories for setting the stocking rate (Rangeland Technical Advisory Council 2001).

In addition to the problem of accuracy described above, forage may be "allocated" to wildlife from the amount of forage calculated as available to livestock with no regard for differences in the types of plants used by wildlife or the differences in grazing patterns with respect to vegetation types, topography, or water availability (Rangeland Technical Advisory Council 2001).

Finally, there is an issue of scale. Herbage production is extrapolated to a pasture or an allotment by assigning production values to the various mapping units within the management unit. These mapping units may be ecological sites or vegetation types. The problem is that mapping units generally contain a mixture of soil, site or vegetation taxonomic units and may contain inclusions of other types up to about 15% of the area. Production values are generally assigned to the dominant type within the mapping unit. These can result in substantial errors when the bulk of the forage is produced on inclusions of other types within the mapping unit. For example, on many forested rangelands in Arizona most of the forage for livestock and other large grazers is produced in relatively small openings within the forest. These may be along streams, on south slopes, in old burns, or dry meadows with deep soils. At the scale of mapping usually employed for allotment planning (1:25,000 or smaller) these openings may not be mapped unless they exceed about 40 acres. Therefore, the model approach to estimation of forage production will completely ignore these inclusions where the bulk of the forage is produced.

- ✓ Utilization

Estimated grazing capacity or proper stocking rate can be calculated using forage utilization and actual stocking data compared to the desired or "proper" level of utilization. The simplest formula is:

Proper Stocking Rate (AUMs) = Actual Stocking (AUMs) X Proper Utilization (%)/Actual Utilization (%).

Utilization is usually measured on key species in key areas. In that case, it is assumed that utilization on key species in key areas is proportional to the stocking in the pasture. In other words, if stocking is increased by 25%, the utilization on key species in key areas will also increase by 25%. If there are several key species and/or several key areas the results will vary depending on which of the key area or key species is used. BLM (Bureau of Land Management 1985) specifies that only one key area (the Key Management Area) should be analyzed, i.e. utilization should not be averaged across key areas or key species.

In general, it is not recommended that utilization be averaged across key areas or key species, unless site-specific information is available to show that averaging is justified (Smith et al. 2007). If utilization is measured in several key areas or on several key species in a pasture over a period of years and there is no consistent pattern of heavy or lighter than average use in any one area or species, then it would be appropriate to average use over key species or key areas. Otherwise, there would be little point in collecting data in more than one area or on more than species. However, if one or two key areas or key species consistently have higher or lower than average utilization over a period of years, this would indicate that the selection of key areas or key species should be re-evaluated because not all of them are actually representative of grazing effects in the pasture. If this occurs it may indicate a livestock distribution problem (although it is not the purpose of key areas to identify use patterns) or the need to select a key area that is more representative of livestock use in the pasture. However, the practice of "floating" key areas, or using only the key area or key species with the heaviest utilization in each year to calculate a grazing capacity for that year, then averaging calculated capacity over a period of years is not justified (McKinney 1997, Laycock 1998).

Variations on this procedure involve mapping use patterns and/or forage production patterns in the pasture and assigning desired utilization percentages to each zone of the pasture. A weighted average utilization value for the pasture can then be calculated and compared to a weighted average desired utilization rate and the ratio of the two values used to adjust actual stocking to desired or proper stocking. (Bureau of Land Management 1985, Forest Service 1997). This approach does not depend on the assumption that key areas are representative of utilization levels, but it does require making adjustments of “proper use” levels to reflect differences in vegetation type, slope, distance from water and other factors. If possible, these adjustments should be based on actual observation of differences in utilization based on use pattern mapping.

Utilization monitoring may be misapplied in grazing administration resulting in excessive restrictions on stocking rates and reduced flexibility in implementing adaptive management on government grazing leases and permits. Some of the potential misapplications of utilization guidelines are:

1. Establishing a specific level of utilization as the objective of management, rather than as a guide to achieving an objective.
2. Establishing utilization “standards” that are lower than supported by research and experience in range management without site specific information to support lower values.
3. Establishing utilization standards to benefit wildlife, endangered species, or other special values by reducing utilization on key species and key areas for livestock grazing without establishing the link between such use and the values to be protected.
4. Requiring that livestock be moved from a pasture or allotment when the specified utilization level is reached in each and every year, rather than recognizing that utilization guidelines are intended to be averages over a period of years.
5. Applying utilization guidelines on pastures grazed during the growing season based on only a percentage of the total year’s forage production on pastures grazed during the growing season; this is the failure to distinguish between utilization and seasonal utilization.
6. Arbitrarily selecting key species and key areas that represent the heaviest use in a pasture in a given year and ignoring key areas or key species in the rest of the pasture, as previously mentioned.
7. Failure to account for the variability in utilization data by making decisions based on a few percentage points well within the error of estimation.
8. Selecting “key areas” that are not good indicators of the overall utilization in the pasture or management unit.
9. Failure to adhere to ground rules and procedures in collecting data.
10. Basing decisions on unsupported assumptions and interpretations of utilization data.

- ✓ Stock and monitor

The stock and monitor approach involves measuring the effects of actual stocking levels over time (either short-term or long-term) on utilization and utilization patterns, composition of vegetation, vigor, soil cover, and other factors (including wildlife) to see if changes in stocking and/or management are needed. The stock and monitor approach, therefore, relies on careful observation of actual impacts of animal use on the landscape and adapting management, including possibly stocking rates, to insure that landscape management goals are being met. This approach is commonly called “adaptive management.” It is generally recognized that this approach is sounder than the forage inventory and allocation approach to grazing capacity estimation (described above) because of the numerous assumptions made in the inventory and allocation process. As with all models, the forage allocation model is a simplified representation without all of the mechanisms that occur in the system that is represented (Innis 1984). The stock and monitor approach, on the other hand, can be more objective in that it requires actual observation of the landscape over time. Unbiased interpretation of these observations requires a high level of professional experience and knowledge to provide the objectivity available in this approach. The stock and monitor approach to estimate grazing capacity as the preferred method is well established in the range management profession.

✓ Recommendations

The stock and monitor approach is recommended for establishing proper livestock stocking rates on ranches and grazing allotments. It is adaptive management i.e. continually reviewing and revising as necessary to meet changes in weather or other environmental factors as well as changes in management objectives. Utilization data can guide stocking when combined with other data or observations that indicate a change either up or down is probably needed.

Forage inventory data and models can be used to approximate stocking rates where actual stocking and trend data are lacking (which is seldom the case on either public or private lands). The principal use of forage inventory methods (and also of utilization pattern maps) should be to analyze potential effects of changes in management such as water developments, new fences, changes in kind of livestock, etc. Since we are predicting what would happen under a different pattern of grazing use in these situations, there is no prior information on levels of utilization, vegetation trends or actual stocking.

Plant diversity

✓ Definition

Like composition, plant diversity is a calculated or derived attribute of vegetation based on observation of other attributes such as presence, density, cover or biomass. Plant species diversity is most simply defined as "plant species richness," meaning the number of plant species occurring in a given plant community or landscape, but may also consider the "evenness" or relative abundance of plants in each species. Plant diversity can also be expressed in terms of the number of life forms or guilds rather than species.

✓ Description

Species diversity can be addressed at various scales. Community diversity may describe the number of species found (species richness) in a particular stand of vegetation on a uniform ecological site. This is sometimes called "alpha-diversity" or "intra-stand" diversity. West (1993) defined a stand as "an area of sufficient homogeneity with regard to vegetation, soils, topography, micro-climate, and past disturbance history to be treated as a single unit." The number of species found may be related to diversity of ecological niches supported by the site or to factors that alter the competitive relations among different species or life form groups, such as fire, herbivory, flooding, or other "disturbances."

Species richness (number of species found in a particular area) does not tell us anything about the number of individuals (or the amount of cover or biomass)

Professional Viewpoints on Estimating Livestock Carrying Capacity

"Forage production is the current growth of browse and herbaceous plants that is both palatable and available to all herbivores. Forage may vary with season of use and kind of livestock. Forage production estimates are primarily an inventory procedure. Forage production measurements can also be an important part of monitoring if the observer recognizes the limitations. Forage production fluctuates greatly with changes in climatic conditions. Reliable information can only be obtained from many years of production monitoring spanning climatic cycles. **Estimating forage production alone is a poor method of determining stocking rates on allotments with a history of livestock use.** (emphasis added) On existing allotments, stocking rates should be determined by a combination of forage production, livestock use patterns, wildlife, and trend determinations. All herbivores should be taken into consideration. **There is some value, however, in using forage production estimates as a factor in establishing initial grazing capacity on areas without a history of grazing use."** (emphasis added) (Forest Service 1997).

"Regardless of the technique used, all methods thus far developed based on vegetation analyses yield only an estimate of grazing capacity. **True grazing capacity can be determined only by stocking with an estimated number of animals and watching the range trend."** (emphasis added) (Stoddart et al. 1975).

"The processes on rangelands are dynamic thus making it impossible to directly measure grazing capacity for herbivores. Carrying capacity is dependent on the characteristics of the range resource, management intensity, management objectives and related variables. In the absence of other information, rangeland inventories done at one point in time can be used to provide general estimates of present or potential grazing capacity of management units. Such estimates are based on many attributes including topography, ecological sites, present vegetation, water distribution and other measurable factors. These estimates should be combined with animal intake, diet preference, animal distribution and other similar attributes to evaluate grazing capacity. **Carrying capacity estimates based upon one-point-in-time rangeland inventories do not produce results of sufficient accuracy to be the sole basis for adjusting time of grazing or stocking rates on specific grazing units.** (emphasis added) Carrying capacity should instead be based on impacts of historical and current stocking rates, grazing management, and weather. **Adjustments in carrying capacity should be made through monitoring over time to ensure progress toward desired resource conditions."** (emphasis added) (Society for Range Management).

represented by each species. Therefore, the concept of species “evenness” also may enter into the consideration of plant diversity. A plant community with a number of species each having a significant number of plants (or biomass or cover) would be more diverse than a community with the same number of species with only one or two species making up most of the vegetation.

Plant diversity can also be considered at the stand or site scale in terms of guilds, life forms, or structural groups instead of species. West (1993) concluded that species have probably been overemphasized from an ecological sustainability standpoint and that functional groups (guilds or life forms) may be more useful. For example, NRCS classifies species into functional groups on ecological site descriptions.

Species diversity for an ecological site can also include the complete list of all plants known to occur on the site over its entire extent and over a period of years. This is considered “inter-community” or “beta diversity.” The species list for the ecological site description would approximate this value, although not all species lists are complete for many sites. A list for the entire extent of an ecological site would generally contain more species than would ever be found in a single stand on the site as it would represent not only the variability in site variables within the concept of the site, but also the varying history of grazing, drought, fire and other influences on the vegetation.

Diversity may also be considered at a landscape level. In this case, diversity is affected by the various combinations of topography, parent materials, geomorphic history and weather patterns occurring in the landscape (i.e. the pattern of ecological sites) as well as the differing impacts of factors such as grazing and fire across the landscape. This is called “gamma -diversity.” The designations of alpha, beta, and gamma diversity are based mainly on difference in the scale at which diversity is considered.

Obviously, diversity can have many meanings and interpretations depending on which attributes it is based on, the spatial and temporal scale employed in collecting the data, ant the method of synthesizing the data. For the term to have any meaning in terms of a management objective, all of these factors must be carefully identified. However, diversity is often stated as a management goal/objective without such clarification, leading to arbitrary interpretations and conflict.

West (1993) summed it up when he said: “Thus, the only reliable means of knowing what people really mean when they use the term biodiversity is to ask what and how they would measure. Their answer must clearly spell out which levels of integration and temporal and spatial scales they favor. Furthermore, without a tightly stated purpose for estimating diversity, we cannot decide on the most relevant measure(s) of biodiversity. Failure to make objectives explicit insures continued frustration because what constitutes ecological good remains as much a matter of human opinion as it is a subject of science.”

- ✓ Necessary Ground Rules

There are no ground rules associated with plant species diversity since diversity is a calculated or synthesized value, not a directly observable attribute of vegetation.

- ✓ Recommended Ground Rules

The ground rules should be appropriate to the attribute upon which a calculation of diversity is based – presence, density, frequency, cover, or biomass.

- ✓ Methods of Measurement

Diversity is not measured directly, but is a value calculated from data collected on other attributes such as presence or density. Diversity may be expressed simply as the number of species found in a particular area (species list), which gives a measure of species richness. Species composition (based on density, cover, biomass or frequency) gives a measure of species evenness that will vary greatly depending on which of these attributes is used to calculate it (see Figure 6-5, Chapter 27). A number of different indices have been proposed or used to express species diversity that combine both species richness and species evenness (or equitability). West (1993) stated that over 90 proposed indices of community diversity based on richness and equitability have been published, but the possible number is infinite.

“There is no such thing as an ‘objective’ index of biodiversity. The numerical values produced are dependent on human choices of the area to be sampled, how often it was sampled, any selection of variable(s) to express presence or dominance and the particular formulae used to synthesize the data” (West 1993). Because of the variety of methods used to calculate indices of diversity, we will not discuss these methods in detail, but offer only some observations on the methods in general.

West (1993) pointed out that there are two basic approaches to calculation of diversity indices that combine richness and equitability (which he calls a heterogeneity index): those based on probability theory and those based on information theory. The information theory-derived indices are based on measures that treat all species equally. This gives more emphasis to rare species in the community. Probability based indices place more emphasis on common species. The latter have advantages for environmental assessment since they give more weight to the species that are most important in most ecological processes.

- ✓ Uses/Interpretations

Species diversity is often stated as a desirable goal or management objective because it is presumed to be indicative of stability, sustainability, or health of ecosystems. For example, the National Forest Management Act requires the U.S. Forest Service to consider natural diversity as a requirement, criterion, and output of good wildland management (West 1993). The problem is that “diversity” is often not defined in terms that provide guidance on exactly how it should be measured, and also the assumed links to ecological processes and/or desired outcomes of management are not elaborated. It is not possible to provide a recommended definition for diversity for rangeland monitoring. The paragraphs below will discuss some of the possible relationships of diversity to rangeland management objectives, with emphasis on plant rather than animal diversity.

In any given stand of vegetation (as defined above) the species diversity may be related to several factors. Heterogeneity of the site affects the number of ecological niches present. Variability in soil depth, gravel content, permeability of substrate, micro-topography, and even plant life forms may affect moisture, nutrients, rooting depth, wind, light, and other drivers of plant growth. The diversity of species, guilds, and/or life forms present in any location would be expected to be greater on spatially heterogeneous sites than on uniform ones.

Species diversity can also be affected by disturbances including weather patterns (drought, wet years), fire, grazing by livestock or wildlife, disease and other factors. Disturbance may increase diversity by reducing the ability of some species to competitively exclude others. For example, death of large trees due to fire or disease may open up resources for plants that could not successfully compete for them when the tree was alive. Diversity could be decreased by elimination of species that cannot tolerate the disturbance, or preventing them from reproducing. For example, species intolerant of fire would be removed from a community subjected to fire at critical intervals, which could increase the dominance of fire-tolerant species. Effects of grazing as a “disturbance” may vary widely across the landscape depending on topography, location of water points, and other factors, so that the effects of grazing are different across an ecological site, and also differ from one site to another. Grazing effects may vary from none to extreme over short distances. West (1993) suggests grazing at moderate intensities will increase plant diversity over a landscape.

It is often stated in environmental impact statements, biological opinions and other documents that livestock grazing reduces diversity. At the stand level that is certainly possible, as is evidenced by the effects of livestock grazing and trampling around water holes or other extreme concentration areas. However, the effects of grazing on diversity are, like fire, drought or floods, a function of intensity, frequency, and duration. Oliveira (1979) sampled moderately grazed, heavily grazed, and long-term protected locations on the same ecological sites at the Santa Rita Experimental Range and concluded that differences in ecological site had more effect on species composition than grazing did. Since present stocking rates on most rangelands, especially public lands, tend to be conservative it seems likely that this conclusion is relevant to much of the western rangelands.

Is Species Diversity a Useful Management Goal?

The factors discussed elsewhere in this section support the importance of defining the temporal and spatial scale at which diversity will be analyzed and the method of synthesizing the data. But there is still the question of why species diversity should be so frequently used as a stated or implied management goal, as was done in the National Forest Management Act. What is the ecological "good" that plant species diversity represents?

Most of the concern over diversity seems to relate to endangered species (or those in risk of becoming endangered). Extinction of species can have both ecological and economic consequences in the future whether those benefits can be currently documented or not. Therefore the objective of maintaining diversity in this case is to maintain the full range of existing plant and animal species to the extent possible as provided in the Endangered Species Act. Such an objective obviously applies over an entire landscape or region since only by examining the full range of a species can we know if it is being maintained or not. Such an objective does not provide a rationale for monitoring the full range of species diversity at a stand level, or even a local landscape level.

Concern over endangered native species is often intertwined with concern about the invasion of non-native species. One assumption appears to be that invasion of non-native species will lead to lower species diversity on a regional scale; in other words, the non-natives will crowd out the natives. Johnson and Mayeux (1992) indicated that California has added approximately 1000 new taxa of non-native plants while only 6 native plants have become extinct since settlement— species richness actually increased. California may not be typical because of the scale of exotic introductions there, and the situation elsewhere remains to be quantified.

The other assumption is that reduction in species diversity in native vegetation will facilitate invasion by exotic plants. "Overgrazing" is frequently cited as a main cause for invasion of exotic plants. At a stand or local landscape scale, grazing might open up niches that could be filled by exotics having greater grazing tolerance than the natives that disappeared. It seems likely however that open niches (increased availability of water, nutrients, light or space) would probably result more from a reduction in cover or vigor of the more common species rather than a reduction in the number of species present. If so, then establishing objectives for maintaining cover or productivity of the dominant species may be more relevant than species diversity.

If a diverse ecosystem is more resilient and productive than a less diverse system then we have a reason to set diversity as a management goal and to monitor it on local landscapes at the stand level. However, there seems to be scant evidence that species richness at a local level is necessarily correlated with either ecosystem productivity or resilience. Species are taxonomic, not functional, groupings of plants. According to West (1993) and Johnson and Mayeux (1992) ecosystem productivity and sustainability are probably more related to the presence of different functional groups than to species richness.

Plant species diversity is often emphasized as an objective because it is assumed higher diversity means a better mix of food and cover for wildlife, and therefore higher wildlife species diversity. That relationship may hold if all species of "wildlife" are considered (including insects and smaller organisms). However, most evidence indicates that life forms and structural characteristics of vegetation are more important than plant species diversity for most vertebrate species.

At the community level, the full geographical range of an ecological site will have more habitat variability than a single stand; thus one would expect a wider range of species and community types due solely to differences in site factors. The same logic applies across a landscape composed of varying proportions of different ecological sites. The diversity of sites and their distribution on the landscape will determine to a great extent the diversity of species and species groups found.

As stated in Chapter 3 sustainability of the productive capacity of rangeland ecosystems is a primary goal in range resource management. On a local level, interest centers on protecting the soil against irreversible loss or degradation and maintaining ecological processes such as energy capture and nutrient cycling (West 1993; Johnson and Mayeux 1992). Soil protection and ecological processes depend mainly on the type and balance of functional groups (life forms, guilds) of plant species rather than the taxonomic classification or number of species. For this reason, range monitoring has generally characterized vegetation in terms of relative abundance of species and/or functional groups, rather than species richness. This approach seems to have more relevance to land management objectives and has been emphasized in this guidebook.

✓ Appropriate Vegetation Types

Species or life form diversity can be calculated in any vegetation type.

✓ Time of Measurement

Time of measurement can be extremely important if the data are to be used to express species diversity. If diversity is expressed on a species basis it is important to be able to identify all the species that occur in the area considered. This means that data collection should occur when species are present in a phenological stage that will allow correct identification. In many vegetation types this may be difficult to accomplish if sampling only takes place during one season. For example, sampling in the late summer or early fall may result in some cool-season species (especially annuals) being overlooked or misidentified.

✓ Recommendations

Plant species diversity is best applied as a measurement that can be related to a resource objective such as ecosystem productivity or stability. (In this sense it is comparable to measuring utilization, not because a certain level of utilization is the management goal, but because it is assumed to be related to maintenance or improvement of range condition or soil stability.) No specific recommendations can be made with respect to whether or how plant species diversity should be measured or expressed. If plant species diversity is to be monitored, two questions should be answered in every situation: (1) What is the true objective for which plant species diversity is considered an index or indicator? (2) How is plant species (or life form) diversity to be determined? In other words at what spatial scale and taxonomic level will the data be collected, and how will an index of diversity be calculated? The answers to the second set of questions depend on the answer to the first.

As a general recommendation we suggest a simple plant species list which is as complete as possible. If some indication of the importance of species in a community is desired, then species composition by weight or species frequency are probably the most useful measures. These are described in more detail in Chapters 27, 32 and 35.

Vigor, form class, age class

- ✓ Purpose

The purpose of rating vigor, form class, and age structure is to assess the “health” of an individual plant or of a stand of vegetation. “Vigor” refers to a subjective evaluation of plant health based on growth form, height, color, or other features. Vigor of grasses has often been based on comparing leaf lengths and/or height and number of seedstalks on grazed areas versus ungrazed. Woody plants may be described by form classes based on the degree of apparent hedging, “decadence” as evidenced by dead branches, and/or leader length. Such assessments depend mainly on subjective opinion of the observer. They can be useful in some cases, especially where “vigor” can be compared on two nearby areas. However, “vigor” can be influenced by many factors, including site potential, weather, insects, and genetic variability in plants (ecotypes), and thus must be interpreted with caution. For example, dead centers of bunchgrasses have been interpreted to reflect poor vigor of the plants due to overgrazing (Figure 5-14). In most cases they are likely due to the way bunchgrasses produce new tillers on the outside of the “bunch” while old tillers in the center die out, which leads to splitting up of the bunch and creation of several distinct “new” plants (Bureau of Land Management 1973).

Figure 5-14. Alkali sacaton plant showing "dead center" which reflects growth pattern of the plant, not a decline in vigor due to grazing. The plant shown occurs on an ungrazed area.

In addition to browsing, "form class" of shrubs can also be influenced by site conditions or weather. For example, drought or extreme cold temperatures can result in die-back of branches and apparent "decadence" in the absence of grazing. The appearance of hedging can remain long after the causal agent has been removed and may even represent higher production of annual above ground biomass than non-hedged shrubs (Roundy et al. 1989).

"Age structure" is another subjective type of assessment made to indicate plants are maintaining themselves. In this case, the assumption is that a species should have individuals in different age classes (or size classes), from seedlings to mature if the stand is "healthy" and reproducing itself. This type of assessment is mainly applied to shrubs and trees since, except for seedlings, the age of herbaceous plants may not be related to the observed size of the plants. The assumption that an all-age stand is a prerequisite to a "healthy" situation cannot be extended to all species of plants, woody or herbaceous, because it assumes that the species must regularly recruit new plants into the population. However, many plants reproduce only episodically when favorable conditions occur. Some trees, such as lodgepole pine or aspen, typically form even-aged stands because they only reproduce after fire. Likewise, cottonwood or willow trees only reproduce when favorable seed bed conditions occur after flooding and sufficient time elapses before another flood to allow establishment. For example, Stromberg (1998) found that cohorts of Fremont cottonwood on the San Pedro River began to establish mainly after a record flood in 1926 that downcut the bed of the river and created unstable conditions in the channel. Recruitment events since then occurred in response to years with good winter/spring streamflow (El Nino events). Thus the age structure of cottonwood stands is related more to geomorphological and climatic events than to land management. A complete range of age or size classes is not to be expected for every species or in every environment.

The interagency technical reference on rangeland health (Pellant et al. 2005) includes two indicators related to plant vigor and reproduction: plant mortality/decadence and reproductive capability of perennial plants. Rating of these indicators implies that a mixture of age classes is desirable at least for native plants, and that mortality and decadence should be balanced by recruitment of new plants. If some plant species are presently less abundant than desired (for the reference or desired plant community), then low mortality and abundant recruitment would indicate a positive trend. On the other hand, if some plant species are more abundant than desired, then mortality and/or lack of recruitment would be a positive indicator. Therefore the statement in the manual that "a healthy range has mixture of many age classes of plants relative to site potential and climatic conditions" must be tempered against the desired condition of the site.

- ✓ Recommendations

Ratings or classification of vigor, form class, or age class are generally not quantitative enough to serve for monitoring purposes, although they can serve to help explain results of monitoring quantitative attributes. Interpretation of vigor or reproductive status of either individual plants or plant populations should carefully consider site conditions, past and present weather conditions, fire, insects, and other factors that may affect the present "condition" of plants or stands, as well as the reproductive requirements of the species involved.

Soil erosion

- ✓ Purpose

Assessing the apparent amount of soil erosion on a site at a given point in time identifies the need for vegetation treatments, reseeding, changes in grazing management, or other management actions. It can apply to all vegetation types.

- ✓ Recommendations

Assessing soil erosion is based on qualitative erosion indicators, not direct observation of erosion. Several methods have been developed that use soil erosion indicators in rating or scoring systems. A few of these systems include: Soil Surface Factor (Bureau of Land Management 1973), the soil portion of the Rangeland Health checksheet (Pellant et al. 2005); the current erosion part of Parker 3 step Method (U.S. D. A. Forest Service 1979)**;** and ratings of bank stability used in riparian areas (Platts 1987, Burton et al. 2009). These methods can be useful for assessments or monitoring, but their dependence on professional judgment must be recognized.

Rangeland health

- ✓ Purpose

Assessing the present condition or ecologic function of upland range ecosystems provides a basis for management planning, communication, and/or deciding where additional studies are required.

- ✓ Recommendations

The procedure for assessing rangeland health is described fully in "Interpreting Indicators of Rangeland Health Version 4" (Pellant et al. 2005). This document currently is available on-line at www.blm.gov/nstc/library/techref.htm. The procedure is a qualitative, multiple-attribute approach designed for relatively rapid assessment of overall range condition or health at the site level. The conceptual basis for this procedure was derived from a National Research Council publication (Committee on Rangeland Classification 1994).

The "fundamentals of rangeland health" described in BLM's grazing regulations are broader than the procedures outlined in the technical reference cited above. These fundamentals include consideration of state water quality standards and habitat for endangered species in addition to the assessment of vegetation, soil and hydrologic processes covered in the technical reference. The grazing regulations are the guiding authority for BLM's policies and programs for assessing "rangeland health". However, it is the position of the authors of this guidebook that state water quality standards and acceptable habitat for endangered species are legal mandates that BLM must follow rather than fundamental determinants of ecological function or health on rangelands, and they are therefore only incidentally treated in this guidebook.

The rangeland health assessment procedure involves qualitative assessment of the degree of departure of each indicator from "reference conditions" for a specific ecological site. For this reason it should only be used by those with extensive training and experience with local ecological sites. It is intended to be used for management planning, communication among interested parties, and indicating the need for additional, quantitative data collection to establish trends and causal factors for problems identified. It is not a method for monitoring, decision making, or reporting of range conditions and should not be used for those purposes (Pellant et al. 2005).

Satisfactory rangeland health may be achieved with vegetation and soil conditions that differ significantly from the historic plant community or the desired plant community as described on ecological site guides. The rangeland health determination refers to basic ecological functions such as soil erosion rates, nutrient cycling and biomass productivity, not to desired uses or values. Thus, a "healthy" and sustainable ecological condition may be realized without achieving the goals defined by the desired plant community. For example, many types of grassland in Arizona have been invaded by Lehmann lovegrass. Such plant communities are different from the "original" vegetation and may not represent "desired" conditions, at least for some resource values. However, these plant communities may be healthy rangelands in the sense that ecological processes are generating sustainable resources.

Proper functioning condition

- ✓ Purpose

Proper functioning condition (PFC) is a tool to assess hydrologic function of riparian systems as a basis for management planning, communication, and/or deciding where additional study and observation are needed.

- ✓ Recommendations

The procedures for assessing PFC are outlined fully in Prichard (1998) and Prichard (2003). Like rangeland health, this procedure is a qualitative, subjective assessment based on professional judgment and experience. This procedure should not be used in ephemeral "dry riparian" or "xero-riparian" areas. It is designed to be used where there is surface or near-surface water available during a substantial part of the year, or for natural lakes or ponds, where obligate riparian species of plants occur or can occur.

PFC evaluation is not a method for establishing trends (monitoring) or cause and effect. The evaluation is qualitative and should not be used to establish numerical scores or guidelines. It can identify where monitoring studies are needed and help in devising a monitoring strategy for riparian areas. Hydrologic and vegetation conditions considered in rating PFC are related to the physical properties of the stream. Values for wildlife or fish habitat, forage for livestock or other values are not relevant to this evaluation. Thus, a stream may be determined to be in PFC although it does not meet all management objectives. Thus, as is the case for rangeland health(see above), any desired plant community for a riparian area should provide for PFC, but some vegetation that provides for PFC may not be the desired plant community.

The method is not described further in this guidebook since the aforementioned manuals are complete and readily available.

Forage Production

- ✓ Purpose

Forage production estimates are used to characterize the amount of forage available in a pasture before stocking or to compare different areas, for example to quantify effects of a fire, a brush treatment, fertilizer, or difference in soil.

- ✓ Recommendations

Forage production is difficult to estimate accurately on most rangelands because of spatial and temporal variability and the wide variety of plant life forms that may furnish forage. Forage production estimates with a high degree of accuracy are expensive because they take a lot of time, and forage production estimates with lower time investment are not likely to be of sufficient accuracy to be very useful (Rangeland Technical Advisory Council 2001).

In annual or perennial grass layers with more than 50 pounds dry weight/acre production or standing crop, the comparative yield method is recommended where quantitative data of reasonable precision are needed. Minor amounts of low shrubs or tall shrubs can be included in the estimates with this method, but data on these life forms will be less reliable. If species composition is desired, the dry-weight-rank method can easily be combined with the comparative yield method. The calibrated weight estimate method may be used if the required intensive training and calibration are warranted (see Chapter 32).

In vegetation where much of the forage (browse) is furnished by low shrubs, tall shrubs, or trees, the methods available to estimate production by weight rest on assumptions that are not verifiable or regression sampling procedures requiring substantial supporting studies. Thus, these techniques are not recommended for general range work.

We recommend measuring density or canopy cover of shrubs and trees as **indices** of forage production. For open to moderately dense stands of low shrubs, tall shrubs or trees, the belt transect method is recommended for estimating density. In dense or very dense stands, the abundance rating method or distance measurement methods are recommended. Canopy cover provides a better index of forage production than density, but it can only feasibly be measured in sparse to moderately dense stands of low or tall shrubs. The line intercept method or point methods are recommended for estimating canopy cover for open to dense stands of low shrubs and open stands of high shrubs and trees (see Chapters 33, 34).

Forage Utilization/Residual Measurements

- ✓ Purpose

Forage utilization or the amount of residual vegetation remaining is estimated to document the degree of livestock and/or wildlife grazing that has occurred in key areas or critical management areas. These measurements provide a check on attainment of grazing guidelines, help explain trends in other monitoring data, or assist in adjusting stocking rates for the next year. Although, utilization and residual measurements are listed here under “short term” methods, results may fluctuate considerably from one year to another due to weather and other factors. We recommend that for most situations utilization or residual measurements should be interpreted for management decisions based on data collected over a number of years. (Rangeland Technical Advisory Council 2001, Smith et al. 2007).

- ✓ Recommendations

Since appropriate attributes and methods vary considerably for different vegetation forms, recommendations are made separately below.

✓ Annuals

Since annual plants live only one year, the percentage of current growth removed by or remaining after grazing has no physiological significance to the survival or subsequent growth of the plant. Grazing affects how much biomass remains on the ground and, in some cases, seed production. Therefore, residual biomass provides better information in annual vegetation than stubble height or utilization (unless the purpose is to estimate the amount of forage consumed by animals). Residual biomass cannot be satisfactorily measured in sparse stands of annuals. The comparative yield method is the preferred method (see Chapter 32).

✓ Perennial grass (key species)

If perennial grasses are key species, estimate utilization or stubble height. Selection of perennial grass as the key species is appropriate where perennial grass stands are sparse (in some cases) to very dense, either as the dominant life form or in association with shrub or tree overstory (see Chapter 40).

To estimate utilization of perennial grasses, we prefer the landscape appearance method, height/weight method or the grazed class method. The percent grazed plants method can be used as an index of utilization but does not provide an estimate of percent use by weight unless site-specific studies to establish that relationship are available. The weight-estimate method or the harvest method (grazed/ungrazed comparisons) are not recommended for general range monitoring due to the time and training required to obtain reasonable precision.

To measure residual height, the stubble height method is used. Stubble height measurement does not require as much training or calibration as utilization measurement, and may be done at any time of year (Holechek and Galt 2004).

✓ Low shrub/Tall shrub (key species)

If shrub species are considered the key species for indicating grazing (browsing) use, direct measurement of utilization is difficult and neither residual biomass or stubble height are appropriate concepts. The percentage of twigs browsed method is recommended for an indirect estimate of utilization on many shrubs if a quantitative measure is desired. As with the percent of grass plants grazed, percent twigs browsed only provides an index of grazing use. If a relative or qualitative measure will suffice, the landscape appearance method can be used, especially to provide an overall utilization estimate in mixed-form vegetation (see Chapter 40).

✓ Trees

Tree species may be browsed when in the seedling to sapling stage. In this case, the same recommendations apply as for shrubs. Foliage and buds of mature trees are generally out of the reach of livestock or native ungulates. Considerable forage may be derived by consumption of seeds and/or leaves that fall on the ground, but no established procedures are available for estimating utilization on these fallen leaves and seeds.

Residual Wildlife Cover/Structure

✓ Purpose

Habitat monitoring may require assessing residual cover or structure available for wildlife hiding or nesting cover. Cover for wildlife might not be defined the same way it is for vegetation measurements for two reasons. First, cover may be defined as occurring at certain heights above the ground, as for bird habitat or thermal cover for large animals. “Cover” may also refer to “hiding cover” for ground nesting birds, fawns, or small animals. In this case, the height and thickness of the foliage and pattern of its distribution may be more important than the portion of the ground covered by vegetation. This attribute is probably more correctly described as vegetation structure, rather than cover.

The proper criteria for defining wildlife cover or structure, and the appropriate technique for measuring them, depend on the habitat requirements of specific animals and the type of vegetation (Morrison 2008).

✓ Recommendations

Monitoring wildlife cover and structure often involves species-specific studies rather than the general monitoring methods described in this guide. Visual obstruction using the Robel pole method (Robel et al. 1970) and foliage density method (Anderson and Ohmart 1986) are briefly described in Chapter 38. For more detailed methods, consult wildlife management literature.

When seeking an appropriate attribute and method, keep in mind the following: (1) For management interpretations, information is needed to establish a relationship between the habitat attribute measured and the response of the target animal(s). For example, if visual obstruction is measured because it is thought to be related to nesting cover for quail, there must be some evidence of how and whether the measurements taken are related to nesting success of quail. This would require actual determination of nesting success rates in areas with varying levels of visual obstruction measured by the technique used. Without this essential background information, there is no scientific basis for the relationship between visual obstruction ratings (VOR) and nesting success. A trend in visual obstruction may correlate with a trend in value of nesting cover for quail, but it is not justified to just assume that beneficial effects of cover on nesting success are linear. In other words an increase in VOR at low levels of cover may be correlated with a higher degree of nesting success than when average VOR levels are high. (2) Forage utilization by livestock or stubble height measured as an indicator of livestock grazing intensity does not necessarily correlate well with residual cover for wildlife. Utilization measurement conducted for the purposes of evaluating livestock grazing intensity usually targets key forage species for livestock in key areas (Smith et al. 2007) selected to be representative of livestock grazing intensity in a pasture or grazing allotment. Cover for wildlife may be provided by plants that are not key forage plants for livestock and that occur in areas that are not key areas for livestock (riparian areas for example). Consequently, the relationship between livestock use and remaining wildlife cover, if any, is highly variable from one situation to the next.

Plant Establishment/Mortality

Vegetation treatments

- ✓ Purpose

Establishment and mortality studies assess how tree, shrub or weed control treatments (herbicide, fire, mechanical, etc) affect mortality of target and/or non-target species.

- ✓ Recommendations

Vegetation treatments may be aimed at killing undesirable plants or reducing the level of competition between target species and other plants. Attributes measured to determine efficacy may be different in each case. Vegetation treatments may be aimed at woody plants or herbaceous species (e.g. weeds). Density or cover of live and dead plants can be estimated separately, or biomass of live and dead plants can be compared on the same plots before and after treatment, or on treated versus untreated areas.

To evaluate the effectiveness of a treatment in killing target species, density of live/dead plants is the appropriate attribute (see Chapter 27). The percentage of dead/live plants can be visually estimated in plots or by a reconnaissance estimate. If density is needed in quantitative terms, use the belt transect method. This approach can be used for perennial herbs or shrubs/trees with appropriate modification of sample unit size. In dense stands of small individuals, small quadrats may be more efficient than belt transects (see Chapter 34).

To evaluate the effectiveness of a treatment in reducing competition for light, space, or moisture between the target species and a more desirable species, cover is a more suitable indicator than density (see Chapter 27). For perennial grasses or forbs the cover estimation using quadrats (a variation of this method is the Daubenmire canopy cover method) or a point method is recommended for measuring either canopy cover or basal cover. For bunchgrasses, the line intercept method can be used to quantify either basal cover or canopy cover. If the target species are annual grasses and forbs, production is a better measure of competition than cover. The comparative yield method is appropriate for annual production. If the target species is a shrub(s), canopy cover, but not basal area, should be measured using the line intercept method in low or tall shrub stands where the live canopy is open to moderately dense, and the remaining dead stems and canopies are not too dense to allow stretching a line. Otherwise, it may be necessary to use qualitative estimates or use vertical photographic methods (see Chapter 32, 33, 39).

Drought effects

- ✓ Purpose

We assess effects of drought on plant survival (mortality) by characterizing live versus dead plants. Methods differ from the assessment of plant treatments described above in that it is not usually possible to make comparisons to unaffected areas.

- ✓ Recommendations

In annual grassland, drought is likely expressed as lower production rather than mortality. For perennial grasses, the effects may be expressed on amount of live cover, density of dead/live plants, or production. To measure live canopy cover or basal area, use point methods, cover estimation in quadrat methods, or line intercept method (for bunchgrasses) (see Chapter 33). To estimate production, use the comparative yield method with dry-weight-rank method to estimate species composition if desired (see Chapter 32). The density of live/dead plants can be estimated with the belt transect method if individual plants can be reliably distinguished (see Chapter 34). For shrubs, use the same methods described for vegetation treatments above.

Plant establishment

- ✓ Purpose

Plant establishment studies assess the success of reseeding or replanting projects, or compare various seedbed or planting techniques.

- ✓ Recommendations

The establishment success or relative effectiveness of different techniques of seeding or planting is best measured by counting seedlings or surviving young plants to get at differential densities. Production or cover has little meaning for this purpose since the plants are generally immature and have not reached full size when the evaluation is made. Density should be measured using the belt transect method for sparser stands of plants and quadrats of appropriate size in denser stands. Alternatively, qualitative estimates may be obtained by the abundance rating method (see Chapter 34).

Grazing Response Index (GRI)

- ✓ Purpose

The Grazing Response Index (GRI) was developed by Colorado State University and the U.S. Forest Service in Colorado. It has been successfully used on summer ranges in parts of Colorado. The method is described in detail in (Reed et al. 1999), and that is the basis for the description presented here.

The purpose of the method was described as follows:

“The Grazing Response Index (GRI) was developed to assess the effects of grazing during the current year, and aid in planning the grazing for the following year. The GRI is based on general assessment of grazing use that occurs during the current growing season. It is necessary to understand plant physiology and plant responses to grazing to use the GRI. The GRI considers three concepts related to plant health in evaluating the impacts of grazing – frequency of defoliation, intensity of defoliation, and opportunity of the plant to grow or regrow”(Reed et al. 1999). Although the authors make reference to the need for “monitoring”, this procedure is not designed for obtaining quantitative data over time; it is a qualitative, one-point-in time assessment based on observation and professional judgment and therefore does not qualify as a monitoring method. GRI is not a compliance objective; it has been presented as a tool to be used primarily by the livestock producer, working in conjunction with their local range specialist, in planning next year’s management. The method has not been promoted for, and should not be used for, regulatory purposes.

✓ Procedure

The procedure involves making evaluations of three aspects of grazing applied in the current year – frequency, intensity, and opportunity.

(a)Frequency – "Frequency refers to the number of times forage plants are defoliated during the growing period" (Reed et al. 1999). This depends on the length of time plants are exposed to grazing (grazing period). It is assumed that plants will regrow in 7-10 days after being grazed once, and thus be subject to regrazing if animals are still present. The authors cite research suggesting that three or more successive defoliations during a growing season were detrimental to the plant. Therefore, the rating of frequency of grazing is based on the length of the grazing period and assumes that plants will regrow in 7-10 days after being grazed. A grazing period long enough to allow for only one defoliation is given a rating of +1, grazing period allowing time for two defoliations is given a rating of 0, and a grazing period allowing time for three or more defoliations is given a rating of -1.

(b)Intensity – "Intensity is a description of the amount of leaf material removed during the grazing period. This is not an estimate of forage utilization. The primary concern is the amount of photosynthetically active material remaining for the plant to recover from defoliation." (Reed et al. 1999) The GRI use the following values for describing intensity of grazing: Light (<40%) = +1; Moderate (41-55%) = 0; Heavy (>56%) = -1.

(c)Opportunity – "Opportunity is the amount of time plants have to grow prior to grazing or to regrow after grazing has taken place….Since this factor is so important in sustaining healthy plants, the relative rankings are doubled in value."(Reed et al. 1999) The rankings of opportunity to grow/regrow are as follows: Full season = +2; Most of season = +1; Some chance = 0; Little chance = -1; No chance = -2

The ratings of the three factors are added together. A positive value indicates a beneficial effect of management; zero is neutral; and a negative value is harmful. The authors give an example of how the GRI can be used to rate each pasture used during the current year to provide a basis for adjusting management in the following year. For example, if a pasture gets a low rating for frequency, the time of grazing in that pasture could be shortened next year. If a pasture did not get adequate time to grow or regrow in one year, then additional rest could be allocated to that pasture in the next year. And so on. The example shown was for an allotment with eight pastures and a grazing season from June 16 to October 15.

When adapting the GRI to any grazing planning process the following observations should be considered.

(a) The physiological responses to grazing upon which the GRI is based relate to perennial grasses. Other responses may be obtained where annuals and shrubs are major components of the forage.

(b) The assumptions that grasses will regrow in 7-10 days and that substantial amounts of time are needed to replenish carbohydrate reserves does not seem consistent with current theory. When growing points are removed by grazing, regrowth may be slower because it must come from new basal tillers. With the short periods of favorable growth conditions on many ranges, especially in the Southwest, grasses grazed at a critical phenological stage may not produce much regrowth until the following year. Carbohydrate reserves are now considered to be relatively unimportant for regrowth of grasses.

(c) Many ranges in the Southwest are grazed yearlong. These rangelands may have two growing seasons. In addition, animal diets shift seasonally throughout the year, so the frequency of regrazing and opportunity for growth/regrowth may vary markedly depending on the forage species and erratic weather patterns.

(d) Although "intensity" is claimed not to be the same thing as "utilization", that is how it is described. It would seem that if the amount of photosynthetic material remaining is the important factor, then that is what should be observed. Like "seasonal utilization," intensity is observed at the end of the grazing period, not the end of the growing season.

(e) If all of the premises involved in the GRI are accepted, it is mathematically certain that achieving a neutral to beneficial overall rating requires a large number of pastures (or other management units) and pasture moves. Frequency cannot be rated positive unless the grazing period in a pasture is only 7-10 days. Opportunity cannot be rated positively unless the rest period extends over all or most of the growing season, which can only happen with a large number of pastures, or by other means such as herding or controlling water points. The three or four pasture systems that are generally used in the Southwest provide ample "opportunity" but will be rated low on "frequency;" yet they have proven to have positive results. Increasing number of pastures may not be feasible due to cost, topography, water, size of the ranch, or other factors.

(f) Negative ratings for one or more of the three factors may indicate that a change in management in the next grazing season may be desirable. However, the rationale for adding up the scores to come out with a total rating and meaning of that rating are not clear (see Chapter 18).

✓ Recommendations

We believe that GRI is useful as a planning tool, but it does not eliminate the need for quantitative monitoring data, and it should not be used or reported as a management objective or a regulatory threshold.

CHAPTER 25
Long-term Trend Monitoring

The objectives listed below are those mainly aimed at long-term monitoring to document progress, or lack of progress, toward specific management objectives and provide information for plan revisions. Obviously, most of the data described below can be used for one-point-in-time documentation or interpretation, but they are most valuable when collected over a period of time along with collateral data to help interpret cause and effect of any changes.

Vegetation

Species or life-form composition

✓ Purpose

Documenting changes in species composition or life-form composition on key areas, critical management areas, or comparison (reference) areas can help evaluate (1) drought effects, (2) changes in species diversity, (3) increase in weeds, and (4) whether current management practices are leading to desired outcomes (see Chapter 15). When composition data are compared to reference areas or desired plant communities, trends in range condition or rangeland health may be interpreted (see Chapter 19, 20).

✓ Recommendations

When a quantitative estimate of species composition is the desired attribute, we recommend the dry-weight-rank method for open to dense annual or perennial grass layers (Ruyle 1991, Smith and Despain 1997). This method also can be used for low shrubs or tall shrubs, but the disparity in size and difficulty of identifying current growth of these plants introduces significant possible bias of results. Therefore, if shrubs are the principal ones of interest, this method may not be appropriate. Other methods depending on identification of current growth also suffer from this limitation. For species composition of open to dense low shrub layers, canopy cover estimated by quadrat methods, the line-intercept method, or point methods may be better than weight-based methods (see Chapter 33). These methods can also be used on open to dense perennial grass layers. None of the canopy cover methods are adapted to species composition estimates in very sparse vegetation because of excessive size of sampling units required. They are also not useful in annuals or very dense perennial grass, low shrub, or tall shrub layers because of the difficulty of unbiased placement of sampling units and difficulty of identifying canopy boundaries of species.

In dense trees, species composition based on canopy cover can be estimated from large scale vertical aerial photos if species or species groups can be distinguished (see Chapter 33, 34). Relative density of tree species based on quadrat counts or distance measure methods have been used to characterize forest stands.

Species composition of dense to very dense stands of low shrubs and/or tall shrubs is very difficult to estimate quantitatively based on weight, cover or density. Relative abundance or prominence ratings have been used in this type of vegetation. These provide semi-quantitative data, but depend on training and bias of observers (see Chapter 39).

Biomass or forage production

✓ Purpose

In some cases, it may be useful to establish trends in productivity of vegetation including all species, or just forage species. Such trends can help establish changes in carrying capacity, effects of shrub or weed increases, relationships of production to rainfall, or other environmental factors. However, these needs are more related to research studies than to routine monitoring for management purposes.

✓ Recommendation

No specific method is recommended for measuring changes in plant production because direct measurement generally results in data too variable for detecting trends, even in grasslands where the available techniques work best. In shrubs and trees, estimation of current production is very difficult and time consuming. We do not recommend use of production data for routine monitoring (see Chapter 28).

Wildlife cover/structure

✓ Purpose

Monitoring trend in plant cover or structure available for wildlife in designated wildlife habitats locations may be useful for evaluating habitat quality objectives.

✓ Recommendations

If wildlife cover requirements are related to canopy cover of certain species or life forms, the methods outlined above for species/life-form estimation of canopy cover are appropriate (see Chapter 33).

When wildlife cover requirements are related more to plant height than to canopy or ground cover, height is the attribute to measure. Plant height methods are straightforward (see Chapter 27).

If wildlife cover requirements have been related to the amount or pattern of residual biomass, the stubble height or production methods may be appropriate. In this case, these methods would be employed for all plant species in the community, not just livestock forage species. See discussions above for suitability to different vegetation types (see Chapter 40).

Wildlife cover requirements can also be a function of vegetation structure (pattern of height and foliage density of vegetation) which can be related to species/life form composition, drought effects, and/or grazing by animals. Vegetation structure can be quantified using visual obstruction ratings (see Chapter 38). The Robel pole method (Robel et al. 1970) for visual obstruction has been tested in open to dense or very dense perennial grass and may be appropriate in annual grass. It has not been used extensively in shrub types and appears to be unsuited to sparse grasslands or dense to very dense shrub and tree layers. Target boards have been used to measure visual obstruction at various levels in tree or shrub canopies (Anderson and Ohmart 1986, Bureau of Land Management 1996).

Community types

✓ Purpose

In riparian wet meadows species composition and production is highly variable on a small scale due to site variability and also to grazing effects (see Chapter 11, Figure 3-4, 3-5, 3-6). The complex pattern of vegetation makes it difficult to obtain data on species composition or production by usual monitoring techniques. Documenting changes in relative abundance of different plant communities within the riparian area over time can provide information on management effects and riparian function. Similar issues apply in dense to very dense stands of low or tall shrubs.

✓ Recommendations

For monitoring changes in relative abundance of vegetation types (i.e. species/life form composition) in wet meadows, the community type method is recommended (Winward 2000). Using this technique requires a classification of riparian community types useful for the specific area in question (see Chapter 37).

In dense to very dense shrub stands on uplands, a similar approach can be used. In this case, the most prominent shrub species are rated across a series of observation points. The prominence method can be used to quantify changes in relative prominence over time in these species. The method could also be used in annual or perennial grass layers.

Soil

Soil or ground cover

- ✓ Purpose

Soil or ground cover is monitored because it is related to the protection of the soil surface from overland flow and the hazard of erosion by water (see Chapter 28). Ground cover may reduce water erosion hazard by increasing soil infiltration rates (thus reducing runoff), by protection from raindrop impact, and by increasing soil aggregate stability. Ground cover may also reduce the ability of water moving over the surface to detach soil material. The latter effect is also important in reducing the availability of soil material for erosion by wind.

- ✓ Recommendations

Measure ground cover using a point method in sparse to dense vegetation of all types (see Chapter 33). In some dense to very dense vegetation, ground cover is usually 100% or nearly so and thus not a very useful thing to measure.

Pattern of ground cover

- ✓ Purpose

Although ground cover is highly correlated with erosion hazard, the pattern, or patchiness, of cover is also important because it is related to the distance water can move over the soil without encountering an obstruction. The pattern of vegetation is also a factor influencing susceptibility to wind erosion. Vegetation reduces wind velocity near the ground. This effect is related to the height, spacing and growth form of plants. Such relationships are well-established for windbreak plantings, for example. Therefore, some measure of pattern is desirable.

- ✓ Recommendations

Fetch is the easiest attribute to measure that is an index to the pattern of ground cover of plants (Tongway 1994). The fetch method is adapted for sparse to dense perennial grass cover, and for sparse to open low shrub or tall shrub cover. In dense to very dense shrubs, fetch can be measured, but may have doubtful relationship to soil protection. Fetch is not useful in annuals or tree layers, or where there is extensive litter and/or rock cover (see Chapter 38).

The gap intercept method can also be used to characterize pattern of ground cover (Herrick et al. 2005), as well as some variations of that process also described in this manual. The method is adapted to similar conditions as the fetch method (see Chapter 38).

Biological soil crusts
(also referred to as cryptogamic, cryptobiotic, microbiotic or microphytic crusts)

- ✓ Purpose

Biological soil crusts are composed of a mosaic of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria. Biological crusts are not the same thing as physical soil crusts resulting from deterioration of soil surface structure due to raindrop impact or other factors (see Chapter 28). Biological soil crusts have received increased attention in recent years and are believed to influence several ecological processes, especially in arid and semi arid rangelands where vascular plant cover is fairly sparse. Biological crusts have been found to influence soil infiltration rates either positively or negatively. These crusts have also been found to fix nitrogen and to add carbon (organic matter) to the soil (as do all types of plants). Other effects include positive or negative effects on establishment of higher plants, effects on microclimate by changing soil albedo, and protection of the soil surface from erosion by wind or water. Evaluation of the species composition and/or extent of biological crusts may be useful in interpreting rates of recovery from disturbance (such as fire, grazing, or recreational uses).

- ✓ Recommendations

Detailed description of techniques for monitoring biological soil crusts are given in Technical Reference 1730-2 (Belnap et al. 2001). In general, the techniques for measuring cover of biological soil crusts are the same as for other attributes of ground cover, including use of quadrat, point, or line intercept methods (see Chapter 33). Biological crusts may be recorded by individual taxa (e.g. species) or morphological groups (Belnap et al. 2001).

At present, we do not recommend including biological soil crusts as a category of ground cover (along with bare soil, plant litter, gravel, rock) for routine monitoring unless biological crust data are recorded so that they can be either used or ignored for interpretation. The reasons for this recommendation are:

1. Identification of species, or morphological groups, is often difficult to do in the field and may require knowledge not generally possessed by many resource managers and ranchers. Correct and consistent species identification is a major problem with monitoring vascular plants, and this problem is likely to be much worse with identification of the organisms making up biological crusts.

2. Adding another component to ground cover measurement or estimation will make interpretation of long-term trends more difficult. Ground cover measurement and interpretation are complicated by the difficulty of making consistent distinctions among categories (bare soil and gravel for example) because such distinctions not usually guided by quantitative boundaries (see Chapter 28). This problem leads to lack of consistency among observers and/or times of observation. Another problem of interpretation is that percentage cover of components are interrelated, for example if litter increases, then either bare soil, litter or both must decrease. These problems are increased if biological crust is added as a component. Biological crusts are usually found on what would otherwise be called bare soil. They are not usually found underneath low growing higher plants or litter cover. Therefore, crusts may decrease either because bare soil increases or because either higher plants or litter increase. Crusts may also be highly sensitive to short term disturbance (as is litter or annual plant cover) such as current grazing, fire, or sediment deposition, thus complicating interpretation of long-term trends.

3. The ecological significance of biological crusts is incompletely known and appears to be highly site specific (Belnap et al. 2001). As pointed out earlier, crusts have been found to have variable effects on soil infiltration and plant establishment. Although some organisms comprising crusts have been shown to fix nitrogen and carbon, there is little evidence that the overall composition or productivity of plant communities is significantly affected by this process. Biological crusts do provide some soil protection from erosion, but we know little regarding their overall effect on watersheds on a landscape basis. Therefore, interpretation of data on biological soil crusts may be highly subject to erroneous or biased interpretation if based on generalities.

Soil compaction

- ✓ Purpose

Soil compaction (increase in bulk density) is related to infiltration and/or permeability rates of the soil as well as moisture holding capacity (see Chapter 28).

- ✓ Recommendations

Routine monitoring of soil compaction for range management purposes is not recommended because of the difficulty of obtaining repeatable data and interpreting the results.

Soil infiltration rates

- ✓ Purpose

Soil infiltration rates can be reduced by compaction or breakdown of surface soil structure due to reduced ground cover, trampling, or other factors. Infiltration rates are inversely related to surface runoff and erosion hazard (see Chapter 28).

✓ Recommendation

Direct measurement of soil infiltration rate for routine monitoring is not recommended due to sampling variability and time required (see discussion in Section 6). Measuring ground cover or fetch may provide an index to protection of the surface soil that affects infiltration. Surface soil aggregate stability can be measured using the slake method to characterize the tendency of soil structure to break down under raindrop impact, which affects infiltration. The slake test can be used in any vegetation type, but the results would likely have more relevance in sparse to moderately dense vegetation types.

Water

Water quality

✓ Purpose

Assessing water quality can provide baseline values for attributes of interest and/or document effects of management on them. Attributes include, but are not limited to turbidity, dissolved oxygen, microbial contamination, pH, temperature, and mineral content (see Chapter 29).

✓ Recommendations

Evaluating water quality is difficult due to spatial and temporal variability in many attributes, and the need for sophisticated and properly calibrated equipment. These methods are beyond the scope of this guidebook. The quality of water in any given stream reach may be influenced by man-caused and/or natural factors that may be independent of the management applied on adjacent lands. Water quality issues often need to be addressed on a scale very different from the factors monitored to guide management of ranches, grazing allotments, or even small watersheds. Aside from measurements of vegetation and surface soil attributes, these issues are not addressed in this guidebook.

Water quantity (runoff)

✓ Purpose

The amount and or trend in water yield from a watershed, or the amount of overland flow may be related to soil erosion, sediment yield, flooding, and other factors, which, in turn, may be affected by land use practices (see Chapter 29).

✓ Recommendations

Runoff or water yield cannot be measured on specific sites without extensive instrumentation and long-term studies that are not feasible for routine rangeland monitoring. Measures of ground cover or canopy cover, and observations of soil erosion indicators are used to draw conclusions about runoff or erosion.

SECTION 6
ATTRIBUTES

What You Will Find in Section Six

- What is an attribute?
- What are common attributes of vegetation and soil that can be observed or monitored?
- What is the value of these attributes for management decisions?
- What ground rules are necessary to allow interpretation of these attributes?
- What are some techniques for measuring these attributes?
- What are the vegetation types appropriate for use of these attributes?

CHAPTER 26
What Are Attributes?

Section 6 outlines attributes of vegetation, soil and other rangeland resource values and common techniques used in their evaluation. An attribute is a characteristic or quality that can be observed, measured or described. There are many identifiable attributes of natural resources but not all can be characterized objectively, cost effectively, and in ways useful for interpretation. This Section introduces attributes of vegetation, soils, water, and animal impact. Where attributes can be defined in different ways, we may offer several definitions. We discuss indicator value, ease of definition and/or measurement, variability in space and/or time, and other factors determining attribute value for monitoring or inventory. Common methods or techniques for characterizing particular attributes are contained in Section 7.

CHAPTER 27
Vegetation Attributes

Vegetation refers to all the plants growing in one place. Vegetation is likely composed of a number of species that come in a variety of sizes, growth forms, numbers, spacing, and phenology.

Presence

- ✓ *Definition*

Plant presence means the plant species (or sometimes species group) is found in a particular plant community.

- ✓ *Description*

Plant presence only indicates the plant species was found in a particular plant community on a given date. It does not give any indication of the abundance either in absolute or relative terms.

- ✓ *Uses/Interpretations*

Presence/absence data have been used to classify plant communities or to provide information on species/habitat relationships. Such data can provide a rough basis for comparison of plant communities (for example inside and outside of an exclosure) when time does not permit more detailed analysis.

A species list can provide an indication of species richness (diversity) provided it is complete and plants are correctly identified (see Chapter 24). Otherwise the number of species listed in a given stand may be related mainly to search time and the identification skills of the observer.

- ✓ *Necessary Ground Rules*

Since the number of species generally increases with the size of the area searched, it is necessary to define or limit that area. Determine which growth forms will make the list-- for example, will cryptogams be included?

- ✓ *Recommended Ground Rules*

Confine the species counted to one ecological site.

- ✓ *Methods of Measurement*

Measurement of presence simply involves a species list (see Chapter 31).

- ✓ *Appropriate Vegetation Types*

Any vegetation type is appropriate.

- ✓ *Time of Measurement*

Season of the year will affect ability to identify species, and also the occurrence of some species such as annuals. Conduct repeat surveys during the same season.

Cover

Cover refers to the extent of vegetation in relation to ground area. It is usually expressed as the percentage of the ground covered by vegetation. Cover can be a valuable indicator of species importance (composition) in the plant community, soil protection from raindrop impact or overland flow, and shelter from the elements or predators for wildlife. Cover comes in several forms: canopy cover, foliar cover, leaf area index, or basal area. Each cover type has different interpretive value and suitability for rangeland evaluation, as well as different techniques and ground rules for measurement (Fehmi 2010), and we discuss them separately below.

Canopy cover

- ✓ *Definition*

Canopy cover is the total area covered by plant canopies in relation to the ground surface. It is usually expressed as percent.

- ✓ *Description*

Canopy boundaries are simply defined as a polygon drawn around the outer extent of the canopy (Figure 6-1). Small irregularities or open spaces within the canopy of a given plant are usually ignored. Canopies of individual plants may overlap when small plants grow underneath larger plants, or the canopies of adjacent plants are intertwined. Overlap of canopies of different plants may or may not be ignored depending on desired interpretation of the data.

In dense vegetation, canopy cover can exceed 100%, and open areas can still exist. If the purpose of quantifying canopy is to document the portion of the soil surface exposed to raindrop impact, then measure total area under plant canopy, and ignore multiple layers.

Canopy cover is easier to define for some growth forms (e.g. many shrubs, bunchgrasses, trees) than others such as diffuse shrubs, vines, sodforming grasses.

- ✓ *Uses/Interpretations*

Species composition based on canopy cover is a good measure of relative importance of plants in the community. Canopy cover may also be related to the degree of protection of the soil from raindrop impact and the amount of rainfall or snow intercepted by plants.

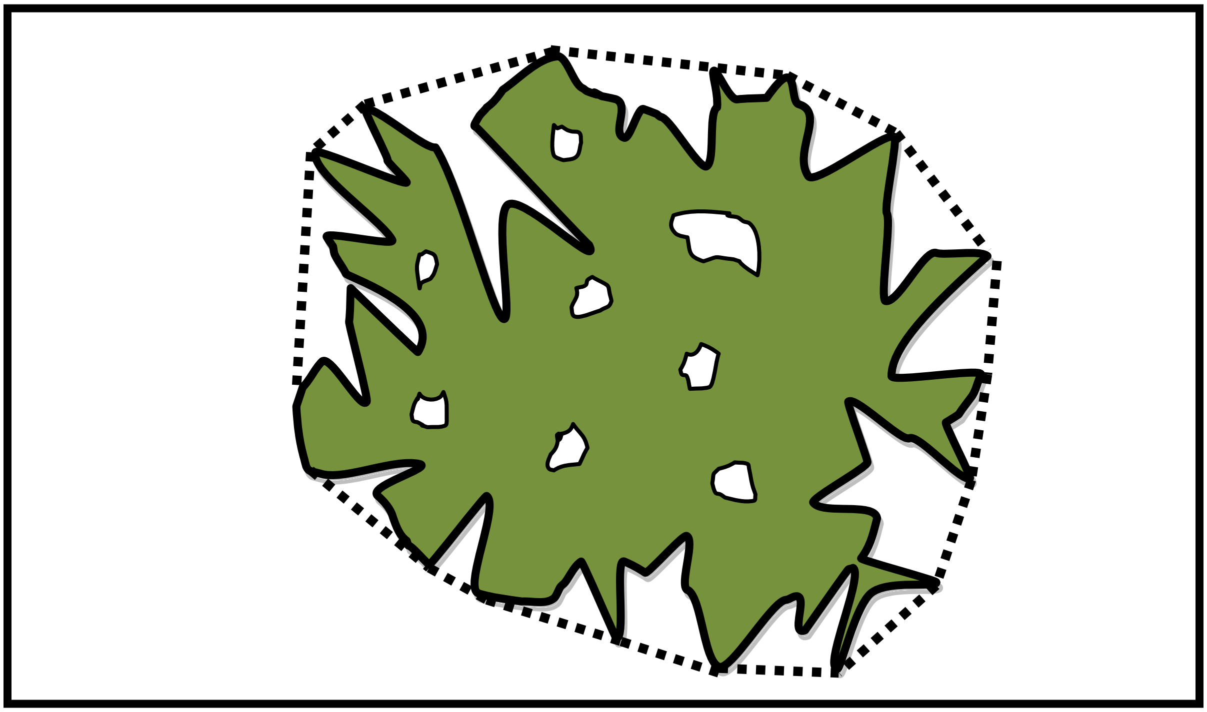


Figure 6-1. Diagram illustrating canopy cover. All the area within the dashed lines is included as canopy cover, ignoring irregularities and "holes" within the canopy.

Canopy cover of trees and shrubs can be an index of competition for light, moisture or space experienced by understory plants (herbs and smaller woody plants). Canopy cover may indicate thermal protection for wildlife or livestock.

Canopy cover of grasses and forbs may be significantly and differentially affected by grazing, growth stage, or weather, which limits its usefulness for trend monitoring. Woody plants are less affected by these factors. Canopy cover is bested suited to measuring trend on shrubs and trees.

✓ *Necessary Ground Rules*

It is necessary to determine:

- How is the edge of the canopy defined?
- How will "holes" in the canopy (areas where leaves are missing that allow light or raindrops to reach the ground unimpeded) be defined?
- How will overlapping canopies of the plants of the same or different species be recorded?

✓ *Recommended Ground Rules*

Canopy edge should be defined as a polygon connecting the extremities of the plant canopy (Figure 6-1). This procedure is recommended because (a) it tends to reduce variability in interpretation of different observers or the same observer over time, and (b) this definition is more related to importance of the plant in terms of above-ground ecological processes, since the occupation of the soil by roots under the plant doesn't necessarily follow the indentations of the canopy (Daubenmire 1959).

Ignore holes in the canopy for the same reason that indentations in the canopy perimeter are ignored if the purpose of measuring cover is to estimate species or life form composition of the vegetation or competition of overstory canopy with understory production, which are the most common uses of this attribute in rangeland monitoring. If canopy cover data are intended as input for hydrologic models or other special purposes, the definition of canopy should be specific to the requirements of the model.

The general rule for rangeland monitoring, where the main interest is to characterize the species or life form composition of the vegetation, is to ignore overlap of canopy of the same species (both multiple layers on the same plant or intertwined canopy of other plants of the same species). If multiple canopy layers consist of different species, then the cover of each species is usually considered separately. In this case, it is possible for total canopy cover to exceed 100%. Failure to account for overlap of canopies would bias the results for smaller plants that tend to occur as understory. For example, in Figure 6-2 the portion of species A under the canopy of adjacent plant of species A would not be counted, but all of species B and C would be counted. If the purpose of the cover measurement is to indicate the amount of soil protection, then overlap should be ignored altogether to avoid inflating the apparent cover provided by vegetation, i.e. the dashed area in Figure 6-2 would be ignored in this case.

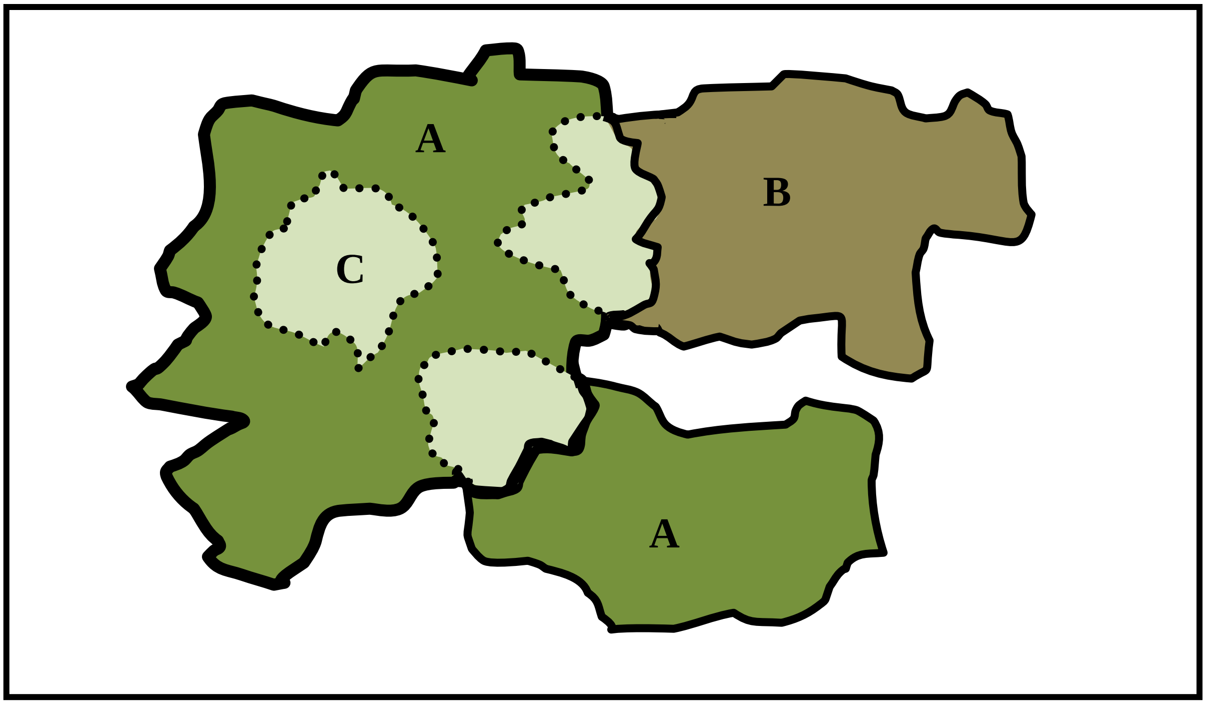


Figure 6-2. Diagram illustrating treatment of over lapping canopy of different species of plants (A, B & C). Dashed lines indicate understory canopy.

✓ *Methods of Measurement*

Ocular estimates, vertical photos, point sampling, line intercept, Daubenmire Method, mapping, and the Parker Loop Method all can be used to provide an estimate of canopy cover (see Chapter 33).

✓ *Appropriate Vegetation Types*

Canopy cover can be measured in any type of vegetation where individual plant canopies can be readily identified. It is best adapted to open to moderately dense perennial grass layers and open to dense low or tall shrub or tree layers. Canopy cover is difficult to define in annual vegetation, especially where data on species composition is also desired. Canopy cover is difficult to sample in sparse stands of any vegetation type because of small amounts and high variability. Canopy cover of individual plants is difficult to define in dense to very dense stands of perennial grasses, low shrubs, tall shrubs, or trees (see Chapter 23).

✓ *Time of Measurement*

Canopy cover may vary seasonally and annually and is affected by grazing and other disturbances (trampling, wind, etc), thus making interpretation of trends difficult. Herbaceous plants are particularly problematic, and canopy cover of these plants should be measured near the end of the growing season, preferably in situations with little or no current grazing use. Canopy cover is a more stable attribute of woody plants and may provide good trend data for these life forms.

Foliar cover

✓ *Definition*

Foliar cover is a vertical projection of leaf cover expressed as a percentage of the ground covered. It is the percentage of the ground surface that would be shaded by a vertical projection of light through the plant canopy (Figure 6-3).

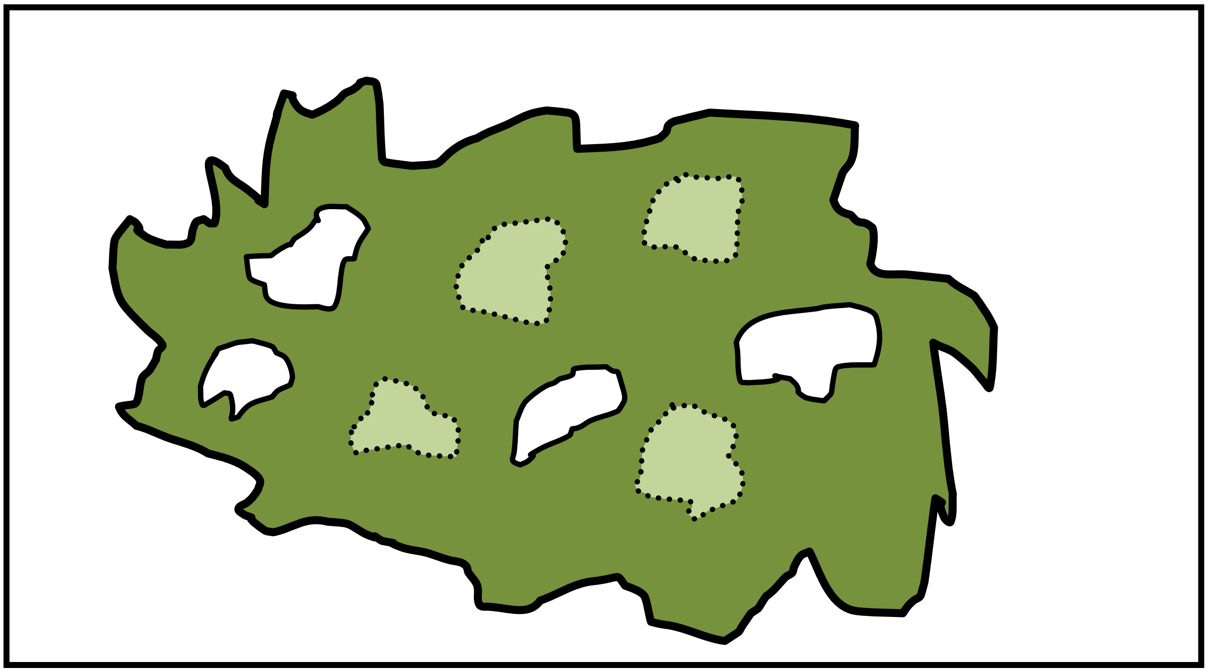


Figure 6-3. Schematic illustration of foliar cover and leaf area index. Foliar cover includes all the area covered by leaves ignoring open spaces (white patches) and multiple coverage (dashed lines). LAI adds area inside dashed lines to the foliar cover.

✓ *Description*

Foliar cover is usually less than canopy cover; it will equal canopy cover when the entire area within the canopy is covered by leaves.

✓ *Uses/Interpretations*

Foliar cover may be more correlated to soil protection from raindrop impact or interception of precipitation than canopy cover. It is probably less related to the relative overall importance of the plant in the ecological processes taking place in the community than is canopy cover.

✓ *Necessary Ground Rules*

The definition implies that overlap of leaves will be ignored; however it may be desirable to document that. It should be noted whether dead leaves are recorded as cover.

✓ *Recommended Ground Rules*

Leaf overlap should be ignored. Count only live leaves or senescent leaves produced in current year.

✓ *Methods of Measurement*

Foliar cover is usually measured using point methods (see Chapter 33).

✓ *Appropriate Vegetation Types*

Foliar cover could be measured in any vegetation type. In taller layers, it is difficult or impossible to use point methods. Foliar cover is not a recommended attribute for routine rangeland monitoring purposes; canopy cover is easier to measure and probably is more ecologically significant.

✓ *Time of Measurement*

Measure anytime when leaves are fully developed. Measurement of forage plants after grazing will affect the results.

Basal area

✓ *Definition*

Basal area, or basal cover, is the area covered by a plant, or plants, at the soil surface.

✓ *Description*

Unlike other plant cover measures, basal area cannot have overlap. Basal area measured along with other attributes of soil cover (e.g. litter, rock, and bare soil) will add to 100% cover.

✓ *Uses/Interpretations*

Basal area is related to the amount of protection from or obstruction to overland flow on the soil surface and to protection of the soil from raindrop impact. Thus, it is a measure of soil protection or erosion hazard. Basal area can also be related to plant production by developing appropriate relationships (regression equations) between basal area and production. For example, basal area of timber trees is used to estimate wood volume in trees. Basal area of some shrubs and bunchgrasses has been used to estimate plant volume or production (see Chapter 32).

✓ *Necessary Ground Rules*

It is necessary to determine:

- Where will basal area be measured--at ground level, or some higher point?
- How will the basal area of bunchgrasses be defined?
- How will basal area of multi-stemmed shrubs be defined?
- How will basal area of single-stemmed forbs and grasses be defined?

✓ *Recommended Ground Rules*

Basal area should be measured as close to the soil surface as possible. Exceptions may be in forestry applications (eg. diameter at breast height). Basal area of bunchgrasses should be defined by the outside boundary of the connected portion of the grass clump at the soil surface, ignoring small areas lacking living tillers within the base. Consistent application of this rule can be difficult in species that tend to spread by tillering on the outside of plant bases and thus divide into separate clumps (Figure 6-4).

Multi-stemmed shrubs usually should be measured at ground surface around the outer stems for an estimate of the gross basal area, rather than measuring each individual stem.

Single-stemmed annuals, forbs, or perennial grasses, while technically having a “basal area,” may cover such a small area where they enter the ground that measuring basal area is impractical. In these cases, the standard practice is to assign an arbitrary minimal area (for example, a square centimeter or half-square inch) to each plant and multiply by the number of stems counted.

✓ *Methods of Measurement*

Point methods are the most practical way to measure basal area for routine monitoring. For more intensive studies, line intercept, caliper measurements, chart quadrats or other methods can be used (see Chapter 33).

✓ *Appropriate Vegetation Types*

Basal area is most appropriate for open to dense perennial grasslands dominated by bunchgrasses. Very sparse grass cover is difficult to sample. Basal cover in very dense (especially sod-forming) grasses may be difficult to measure. Basal area is not a very useful attribute to measure in shrub or tree types unless the interest is in predicting plant production as described above. Basal area is not useful for monitoring annual vegetation (see Chapter 23).

✓ *Time of Measurement*

Basal area of perennial grasses is relatively unaffected by season of the year or current grazing impact. This characteristic makes it a more desirable attribute than canopy cover for monitoring perennial grasses, provided that consistent ground rules can be developed and applied(Joint Committee of the American Society of Range Management and the Agricultural Board 1962).

Figure 6-4. Some grass plants may break up into several clumps leaving bare patches between them. This can make measurement of basal area somewhat arbitrary without strict rules on allowable size of holes within the basal area.

- ✓ *Definition*

Leaf area index (LAI) is the relationship of total leaf area to the ground surface. It may exceed 100% in dense vegetation. LAI is always greater than foliar cover because it includes leaf overlap and is not affected by leaf orientation (Figure 6-3)..

- ✓ *Description*

Leaf area index is a measure of the total leaf area available for photosynthesis and may be related also to amount of rainfall intercepted by vegetation.

- ✓ *Uses/Interpretations*

Leaf area index is used in some agronomic research to estimate photosynthetic rates. In denser vegetation such as forests or improved pastures there is an optimum leaf area to maximize light interception. It is not very useful for most rangeland monitoring where water tends to be a more limiting factor than light.

- ✓ *Necessary Ground Rules*

It is necessary to define whether one or both sides of the leaf will be measured. In some cases it may be necessary to define whether the area will be a vertical projection of the leaf surface or the actual surface. This would result in different values for horizontal leaves compared to vertically oriented leaves. Standard practice is to ignore leaf orientation and express as one side.

- ✓ *Recommended Ground Rules*

Adopt ground rules to fit the purpose of measurement and type of vegetation.

✓ *Methods of Measurement*

Leaf area can be measured with point methods (Bonham 1989). Other methods are available in research applications (see Chapter 33).

✓ *Appropriate Vegetation Types*

Leaf area is sometimes used in very dense annual or perennial grassland to estimate species composition. It also has forest research applications.

✓ *Time of Measurement*

Measure leaf area when leaves are fully grown. Measurements are highly affected by grazing or season.

Density

✓ *Definition*

Density is the number of plants per unit area.

✓ *Description*

Density may be expressed as plants per acre, per hectare, per square meter, or other unit of area. "Density" was used in some of the earlier range management literature to refer to cover, especially basal cover (e.g. the square-foot-density method)(Joint Committee of the American Society of Range Management and the Agricultural Board 1962).

✓ *Uses/Interpretations*

Density can be used to express the composition of plants in a community (relative density) but this description is less ecologically useful than composition based on production or cover. Differences in plant size are not accounted for by density. For example, a small grass species may have high density, but account for much less production or cover than a large shrub occurring at low density. Therefore, density is mainly used for applications where all plants are about the same size such as seedling counts on range seedings or counting live/dead plants in vegetation treatments. It may be used in some dense to very dense stands of shrubs or trees because other methods are not feasible. It can be used to document trends in shrub occurrence (see Chapter 24).

✓ *Necessary Ground Rules*

How is one individual plant defined? This rule is very important especially for multi-stemmed plants, including many shrubs and rhizomatous or stoloniferous plants.

✓ *Recommended Ground Rules*

Develop and record definitions of what constitutes an individual plant for each specific mix of plant types on a monitoring location.

✓ *Methods of Measurement*

Density is usually measured in plant count quadrats or belt transects. Distance measure methods are sometimes used in dense to very dense shrub or tree types where quadrats are difficult to use (see Chapter 34).

✓ *Appropriate Vegetation Types*

Density is recommended for monitoring shrub occurrence if individual shrubs can be reliably defined and recognized. It does not work well where multiple stems arise from one root crown (as with turbinella oak or jojoba) or with sod-forming grasses (such as western wheatgrass). In such cases it may be feasible to use clumps of plants for estimating density rather than individual stems (see Figure 6-5).

✓ *Time of Measurement*

Density of perennial grasses and shrubs is relatively little affected by season or grazing.

Figure 6-5. Multi-stemmed clumps of "sand dune" mesquite - it is not feasible to count plants since one clump may consist of one or more plants that are indistinguishable without excavating.

Weight (productivity, biomass, standing crop)

✓ *Definition*

Productivity can be defined as the rate of production of plant dry matter per unit area (e.g. pounds/acre/year or kilos/hectare/year). It may include both above and below ground production, but usually is restricted to above ground production because that is easier to measure. Biomass is the total weight of plant material present at a given time, without reference to rate of production or whether it was produced in the current year. Standing crop may refer either to the weight of total biomass or the weight of current year's production present at a given time. Usually, the latter is of most interest in range monitoring and assessment.

✓ *Description*

Measuring weight is used to estimate annual productivity, which is difficult in range vegetation for two reasons. One is that above -ground biomass may include current and previous year's growth. Shrub standing biomass will normally include both woody and herbaceous material produced in previous years. Previous year growth of grasses may exist as residual biomass or, in some cases, through the persistence of perennial culms. The second reason is that the rate of plant growth, and the rate of disappearance of plant growth by senescence, decay, herbivory or other factors, varies throughout the year, and the pattern is different for different species or growth forms. This variability is particularly apparent in the Southwest with its diversity of life forms and with growth taking place during different seasons. Some species may have growth periods in both spring and fall. To measure the actual biomass productivity requires sampling at several dates during the year, which is usually not feasible (Haile 1981). Therefore, the best estimate comes from measuring productivity when the current year's production reaches the "peak standing crop," i.e. the maximum for the year. This peak occurs near the end of the growing season (late summer, early fall), after which the standing crop starts to decline. Peak standing crop will always underestimate actual productivity.

✓ *Uses/Interpretations*

Productivity is a useful measure of importance of plant species or life forms in a community. It reflects their importance in ecological processes such as use of water, light, and nutrients. Most ecologists agree that plant productivity is a better measure of relative ecological importance than cover or other attributes, especially where different life forms are concerned. The relationship of cover (canopy or foliar) to annual biomass production (energy capture and water use) may vary considerably among life forms such as annuals, herbaceous perennials, deciduous or evergreen shrubs and trees, leaf or stem succulents, or vines. Productivity of palatable plants is related to forage available for livestock and wildlife. Productivity trends can indicate long-term sustainability of soil fertility and moisture-supplying capability.

- ✓ *Necessary Ground Rules*

To estimate productivity it is necessary to decide:

- Is total biomass or current year's production to be estimated?
- How will current year's production be identified for each species or life-form in the community?
- If sampling after summer growing season, will litter of cool-season annuals lying on the ground be included?

- ✓ *Recommended Ground Rules*

Annuals: By definition, all of the growth of annuals is current year's production. Annual plants produced in a previous year, if present, are usually weathered and occur mostly as litter. However, cool season annuals produced in the current year may also be on the ground or fairly weathered if sampling takes place in autumn. The decision whether to include these annuals, or to pick up the litter and include that as current year's production, depends on the purpose of the sampling and the confidence it can be accomplished objectively. Another alternative is to sample twice – once after annuals are mature and again after the growing season for perennials.

Perennial grasses: The distinction between current year's and previous year's production is easier when the stems and leaves die in winter and are subjected to rain and snowfall, then re-grow new leaves in a short period of spring, and summer (as in higher mountains and northern rangelands). However, at lower elevations in the southwest, growth may occur at several times during the year, and this makes identification of current growth less obvious.

While not foolproof, determination of current year's production or previous year's production may be based on coloration and texture. Current growth, when cured, will often have a straw colored appearance, while previous year's growth, if still present, is often gray or light gray in color. Growth that occurred in the spring and weathered during the summer monsoons may also be gray in coloration, so caution should be used when applying this distinction. If the area was grazed in previous years, but has not yet been grazed during or since the current growth cycles, last year's growth may consist of stubble or leaves with ragged edges.

There are some southwestern (and tropical) grasses that have perennial stems (bush muhly, Arizona cottontop). These stems will produce new growth on the existing stem, complicating the determination of what is current year's growth versus previous year's growth.

Accurately capturing current year's growth, even when obvious, is complicated by several items. (1) Weathering of plant material occurs rapidly in the warm moist condition of the growing season and thus in some cases, relatively little of the previous year's growth survives and/or standing dead material may have been produced in the spring of the current year, (2) standing crop at the end of the growing season already reflects losses from current year's production, particularly growth that may have occurred in the spring, and (3) attempting to meticulously separate current and previous growth may greatly increase sampling time with little or no increase in "accuracy" of the result. Therefore, measuring biomass changes is not recommended for routine monitoring but may be useful for inventory or assessment purposes.

(Haile 1981) found that net annual production was 186% of that measured by a one-time measurement of standing crop due to growth and conversion to dead biomass during the season, plus identification of recent dead herbage as part of the old dead component. He also found that sampling at least four times during one year was necessary to estimate net production with reasonable accuracy. His findings support the conclusion that biomass is not routinely measurable with any degree of accuracy.

Deciduous shrubs and trees: On shrubs that lose all of their leaves each year, the leaves, pedicels, flowers, fruits, seeds, seedpods, and current twig growth should be considered current growth. Of course, parts that have been shed will not be considered. New twig growth is easy to identify on some species and difficult on others.

Evergreen shrubs and trees: On shrubs that retain some of their leaves from year to year (sagebrush, juniper) discerning current year's growth is difficult. Considerable experience observing growth on these plants is necessary to make reasonable decisions, and some plants may defy any consistent determination of current versus previous growth.

Succulents: There does not seem to be any reliable way to estimate or clip weight of current growth on succulents (cactus, yucca, agave). Fortunately, these species usually do not make up a large percentage of the productivity of the plant community and even less of the forage supply.

- ✓ *Methods of Measurement*

The comparative yield method combined with dry weight rank method is an efficient way to estimate standing crop by species or life-form (Ruyle 1991, Despain and Smith 1997). Weight estimate and harvest methods require more training and/or time to achieve comparable reliability (see Chapter 32).

- ✓ *Appropriate Vegetation Types*

Productivity based on weight can be estimated with several techniques as described above in open to very dense stands of annuals or perennial grasses. Low shrubs, tall shrubs, or trees can be accommodated in these methods, but estimates on these plants will be less reliable (see Chapter 23).

If shrubs, trees, or succulents are the primary species of interest or make up a large percentage of the total community, productivity estimates based on weight are impractical for routine monitoring purposes.

- ✓ *Time of Measurement*

On most rangelands, productivity (standing crop) is best measured in late summer to early fall after most of the perennial grass has reached maturity, but before frost or start of winter rains. This period will vary but usually runs mid-August to the end of October. If grazing has occurred, it will be necessary to correct for utilization. The best time to measure productivity will range in different climatic types.

Residual biomass

- ✓ *Definition*

Residual biomass is the amount of plant material that exists at any given point in time. It is equivalent to standing crop (see above).

- ✓ *Description*

Residual biomass may include the total amount of biomass or only current year's production depending on the purpose of measurement. It is usually expressed as pounds per acre or kilos per hectare.

- ✓ *Uses/Interpretations*

Residual biomass may provide:

1. A measure of grazing intensity on forage plants (i.e. a substitute for utilization). In this case, only the residual amount of forage plants should be measured.
2. A measure of soil protection and/or seedbed environment. In this case, all plant material in contact with or close to the soil surface should be included.
3. A measure of residual biomass available for wildlife cover or forage. In this case the species included should be specific to the needs of wildlife whether or not they are grazed by livestock.
4. A measure of residual biomass available for wildlife forage. In this case, the species included should be specific to the needs of wildlife.
5. A measure of fuel for predicting fire intensity. In this case, all plant biomass and litter should be included, not just current year's production.

- ✓ *Necessary Ground Rules*

It is necessary to specify which species and or components of production (current growth vs. previous; living or dead) should be included?

- ✓ *Recommended Ground Rules*

Rules will vary depending on the purpose of measurement.

- ✓ *Methods of Measurement*

Methods are the same as for measuring productivity by weight.

- ✓ *Appropriate Vegetation Types*

Residual biomass is best applied in open to very dense annuals or grass layers. It has limited usefulness for shrubs or trees, except for estimation of fuel loading (see Chapter 23).

- ✓ *Time of Measurement*

The time of measurement of residual biomass is governed by the purpose. For evaluating grazing intensity it should be at the end of the grazing period in a pasture, the end of the growing season, or the end of the grazing season, depending on how it will be interpreted.

For seedbed/environment (e.g. in annual grasslands) it should be measured just prior to beginning of the growing season.

For soil protection it should be measured just before the period of highest erosion hazard, or before the summer monsoons in most of the Southwest. On mountain ranges or higher altitude floodplains the best time may be in early spring before snow melts and runs off.

Height

Discussion of plant height measurement is incorporated into discussions of stubble height, structure, and utilization.

Frequency

- ✓ *Definition*

Frequency is the probability that a particular plant species or form will occur in a random placement of a quadrat of a given size. It is usually expressed as a percentage of quadrats occupied.

- ✓ *Description*

Frequency is not an attribute of vegetation that can be observed or described independently of the technique used to measure it, namely quadrat size. It is a function both of the density and the spatial distribution of individuals of a given species (or life-form).

- ✓ *Uses/Interpretations*

Frequency data can be used to monitor changes in the number and/or distribution of plants (Hyder et al. 1963, Hyder et al. 1966, Despain et al. 1997). Each species is measured independently and must be interpreted individually. Frequencies for different species should not be added together. If total frequency of grasses (or other life form) is desired, the data must be recorded individually for each quadrat so that the number of quadrats containing at least one species of grass can be totaled, or a "total grass" category added to the species list. Likewise, although Mosley, Bunting and Hironaka (Mosley et al. 1986) described the use of frequency data to calculate "range condition," we do not recommend that composition based on frequency (relative frequency) be used to compare one plant community with another (e.g. using a similarity index). Rooted frequency, like density, is not related to production or cover of plant species unless all species are about the same size (see Chapter 24). Because of this, relative frequency has little ecological or practical meaning (Figure 6-6).

- ✓ *Necessary Ground Rules*

It must be decided which plants are counted as inside the quadrat. In other words, for each species will rooted frequency or canopy frequency be used? What is the required quadrat size for each species? Will seedlings and mature plants be recorded separately?

- ✓ *Recommended Ground Rules*

Herbaceous plants should be counted inside the plot if any portion of the plant where it enters the soil is inside (rooted frequency). For canopy frequency, count the plant "in" if any part of the general outline of the canopy overlaps a vertical projection of the quadrat (canopy frequency).

For shrubs and trees rooted frequency will usually not provide an adequate sample unless quadrats are very large. Use of canopy frequency will improve the usefulness of frequency data on these plants. In this case, frequency is related to cover rather than density.

For abundant low shrubs or half shrubs, like snakeweed, burroweed, zinnia, either rule (rooted or canopy) may be used, but apply the same one in subsequent measurements to make comparisons valid. Therefore, it must be well-documented whether rooted frequency, canopy frequency, or both was used for each species.

Generally it is better to record seedlings separately from established plants. Seedlings may be abundant in a given year but may not persist. Failure to distinguish seedlings from established plants may result in apparent "trends" that do not reflect any real change on the site.

✓ *Methods of Measurement*

Use of quadrats is required because, by definition, frequency is defined by occurrence in quadrats of a given size. Although various names are sometimes applied to frequency (quadrat frequency, pace frequency, etc) these names only refer to the method of selecting quadrat locations and its effect on statistical treatment (see Chapter 35).

✓ *Appropriate Vegetation Types*

Frequency can be used in open to very dense stands of annuals and/or perennial grasses. It is also appropriate in open to dense stands of low shrubs. It becomes less useful for tall shrubs and trees because of the need for large quadrats and the difficulty of locating them in dense stands of these plant types. Frequency can also be problematic in sparse stands of vegetation due to plot size requirements (see Chapter 23).

✓ *Time of Measurement*

Collection of rooted frequency data is relatively insensitive to time of year (compared to weight or cover-based methods) because it does not depend on plants having achieved or retained full size. However, plants can be identified more consistently near the end of the growing season. Rooted frequency is not affected by grazing (unless plants are pulled up) as long as reliable identification can be made. Since canopy frequency is related to canopy cover, it will be affected to some extent by season of year, weather, grazing, or other short-term influences. However, since canopy frequency is usually applies only to shrubs and trees where the general canopy outline is insensitive to such short-term influences, this problem is minimized.

SPECIES	PERCENT COMPOSITION DRY WEIGHT BASIS	PERCENT COMPOSITION FREQUENCY BASIS
Blue grama	59.9	33
Wolftail	1.9	3
Sand dropseed	6	12
Threeawns	4	3
Sedges	0.2	0
Annual Grasses	0.3	1
Annual Forbs	15.7	34
Perennial Forbs	0.5	2
Shrubby buckwheat	1.2	2
Fringed sage	0.5	1
Mat buckwheat	0.3	1
Snakeweed	0.2	0
Rabbitbrush	7.5	6
Juniper	1.8	2
Ponderosa pine	0	0
Total	**100**	**100**

Figure 6-6. Comparison of species composition based on relative dry weight to species composition based on relative frequency, illustrating lack of agreement in species importance.

Species or life form composition

✓ *Definition*

Composition is the relative amount of different species or life-forms in a plant community expressed as a percentage (Figure 6-6). Composition is not a physical attribute of vegetation like cover, biomass, or density, but a calculated value or derived attribute.

✓ *Description*

Composition may be based on dry weight, cover, or density. Composition based on density has little interpretive value unless all species are about the same size. Relative frequency also has little meaning (see Chapter 24). Composition can be calculated based on all species in a community or only on selected categories such as perennials, forage species for livestock, or growth forms.

✓ *Uses/ Interpretations*

Composition enables comparing the relative contributions of different species or life forms to overall plant productivity or cover. Composition is used to compare different plant communities, to analyze changes in a community over time, or to compare a plant community to some objective (e.g. desired plant communities).

Composition data must be interpreted with care because an increase in one species will necessarily cause decreases in other species (since the total of all species will be 100%). Or if some species are present at one sampling date and absent the next (or if the observer fails to record a species at one date) the composition of other species will be affected even though no real change has occurred in the other species. For example, if annuals are absent in a dry year, the composition of perennial species may increase compared to a wet year in which annuals made up a substantial part of the vegetation. In this case, composition can be calculated without annuals to allow a better comparison of the perennial species.

✓ *Necessary Ground Rules*

Decide which species will be included in the calculation of composition.

✓ *Recommended Ground Rules*

For interpretation of trend where perennial species are the main objective of management, exclude annuals from the calculation. If general characterization of the plant community at one point in time is the objective, include annuals.

✓ *Methods of Measurement*

Composition is a calculated value that may result from various measurement methods.

✓ *Appropriate Vegetation Types*

Composition can be used for all vegetation types.

✓ *Time of Measurement*

Composition can be calculated from data collected at any time, but the season may affect values obtained due differences in plant growth, species identification, grazing, drought, or other environmental factors. Therefore for long-term trend measurement it is advisable to measure composition at the same time of year, preferably when identification is likely to be most accurate.

Fetch (plant spacing)

✓ *Definition*

Fetch, as used here, is the distance from a given point to the base of the nearest plant. (Fetch may also be defined as the distance between various types of obstructions to water flow along a line (Tongway 1994), although Tongway now uses the term “interpatch width” instead of fetch (Tongway and Hindley 2004).

✓ *Description*

Fetch does not measure the distance between plants, but from a point to the nearest plant in any direction around the point.

✓ *Uses/Interpretations*

Fetch is a nautical term meaning the distance waves can travel without obstruction. It was adapted by Tongway (1994) for use in evaluating the pattern of soil cover and relates to the distance that water might travel unimpeded by vegetation. Fetch thus can be an index to size of openings between plants. Fetch measured in conjunction with other monitoring attributes can determine trend in the fragmentation of ground cover (Kuehl et al. 2001).

✓ *Necessary Ground Rules*

Decisions required include:

- Which plants are to be considered?
- How is the “base” of the plant defined?

✓ *Recommended Ground Rules*

Fetch should be measured only on perennial plants. Including annuals in the measurement will result in drastic fluctuations in the measurement seasonally and annually that make comparisons difficult.

Fetch should be measured to the nearest part of the perennial stem for single-stemmed plants or live plant base for bunchgrasses or multi stemmed shrubs. Because some single-stemmed plants probably do not provide any appreciable barrier to water flow, it may be desirable to exclude plants with less than a minimum basal area.

✓ *Methods of Measurement*

The “fetch method” listed under distance measurement methods (see Chapter 38) is recommended for monitoring pattern of plant cover. A line intercept method was suggested by Tongway and Hindley (2004) for characterizing barriers to water movement, and the “gap method” is used by Herrick et al. (2005) for the same purpose. These methods require more time than the “fetch method” as described in Chapter 38.

✓ *Appropriate Vegetation Types*

Fetch is best measured in open to dense perennial grass and shrub vegetation (see Chapter 23). Measuring fetch in very sparse vegetation may have little value for interpreting soil protection, since vegetation would have an insignificant effect on pattern of bare soil in such a situation. Likewise, in very dense vegetation plant spacing is minimal and fetch is probably not a sensitive indicator of trend in soil protection. Fetch may also be of limited value where the soil surface has a heavy cover of gravel or rock as vegetation cover may have less importance for soil protection in such situations.

✓ *Time of Measurement*

Since fetch is measured to the stem or basal area of plants, it is relatively insensitive to either plant growth stage or grazing. Therefore, the time of measurement is flexible in most cases.

Visual obstruction (structure)

✓ *Definition*

Visual obstruction is the ability to see a target through the vegetation canopy at a prescribed height or distance.

✓ *Description*

Depending on how it is measured, visual obstruction may refer to the height, thickness of canopy, or spacing of plant canopies. It may be affected by the amount of vegetation, the species or life-form composition, and other effects such as grazing and plant maturity. Visual obstruction is sometimes referred to as “vegetation structure.” However, although it may relate to one aspect of structure, it is not synonymous with the term “structure” as generally employed in plant ecology.

✓ *Uses/Interpretations*

Visual obstruction ratings (VOR) are used as an indicator of wildlife habitat characteristics. Examples are nesting cover for certain ground nesting birds, amount of habitat for birds preferring to nest at different heights above ground, or hiding cover for pronghorn antelope fawns.

The Robel Pole technique (Robel et al. 1970, Bureau of Land Management 1996) has been used in grasslands to estimate production based on VOR. To do so requires development of a relationship between pole readings (VOR) and production based on another method of estimating production. This relationship must be derived for every different vegetation type of interest. The relationship may change depending upon growing conditions, species composition, vegetation patterns, or other factors. This need for calibration limits its use for estimating production for general range assessment and monitoring purposes.

The Robel Pole can be used as an index of visual obstruction to compare different areas or trends over time. In particular, VOR readings have been used to characterize vegetation in relation to wildlife needs such as nesting cover. Additional studies would be required to develop a relationship between the average of frequency distribution of readings and certain resource outputs or values. For example, in order to interpret VOR data in terms of quality of nesting habitat for quail requires studies that relate various VOR levels to abundance of nests or nesting success. Lacking such information, there is no way to establish standards or thresholds of VOR data in relation to quality of nesting habitat. The VOR readings can only be used as an index or to compare two areas. For example, it could be assumed that an increase in VOR is good for nesting and a decline is not. But there is no basis to say at what VOR level the quality of habitat is impaired or eliminated.

Since the necessary knowledge of the relationship between VOR readings and forage production or wildlife values for specific situations are often lacking, the procedure may have limited application for routine rangeland monitoring.

✓ *Necessary Ground Rules*

The ground rules are generally a function of the technique employed.

✓ *Recommended Ground Rules*

These depend on method used.

✓ *Methods of Measurement*

The Robel pole method is the most commonly used for rangeland applications (see Chapter 38).

✓ *Appropriate Vegetation Types*

Visual obstruction can be rated in a variety of vegetation types. The Robel (see Chapter 23) method is best suited to herbaceous and/or low shrub vegetation types ranging from open to dense. Its sensitivity to effects of livestock or wildlife utilization may be reduced where substantial shrubs or succulents are present. Methods designed to measure obstruction at various heights in the canopy are mainly used in open to very dense tall shrub or tree vegetation, such as occurs in some riparian areas.(Anderson and Ohmart 1986)

✓ *Time of Measurement*

The time of measurement may vary depending on the purpose of measurement. If characterizing nesting habitat is the objective, then measurement should occur at the time nesting is initiated. In herbaceous vegetation where grazing may affect cover available before plant growth occurs the following year, measurements may be taken in fall if data are available to show a consistent relationship of fall measurements to residual values the following spring.

CHAPTER 28
Soil Attributes

Ground Cover

✓ *Definition*

Ground cover is a measure of the percentage of the soil surface occupied by different types of cover.

✓ *Description*

The types of ground cover may vary but are usually divided into basal vegetation, litter, gravel, rock, and bare ground (lack of cover). These categories total to 100% (Figure 6-7).

✓ *Uses/Interpretations*

Ground cover, or lack of it, is an important indicator of the risk of soil erosion, although cover alone does not account for the connectedness of bare soil which affects soil erosion hazard. Ground cover affects the rate of overland flow of water (see Chapter 24). It also affects the impact of raindrops on the soil surface that result in surface crusting, which influences infiltration rate, and raindrop splash (saltation) which re-distributes soil particles on the surface. Ground cover also reduces the ability of running water to pick up and transport soil particles. The amount and distribution of ground cover is the attribute most correlated with soil surface erosion (Pellant et al. 2005). Biological crusts may occur on otherwise bare soil. Whether these crusts are a positive, negative or neutral factor in terms of soil erosion hazard appears to vary in different areas (Belnap et al. 2001). Making generalizations about their value questionable.

Figure 6-7. Example of ground cover components (basal vegetation, litter, gravel and bare soil) which total 100%.

Interpretation of ground cover trends can be complicated since an increase in the percentage cover of one category necessarily requires a decrease in another category. For example, the percentage cover of bare ground may appear to increase from one time to the next, but the increase may be due to inconsistency in defining the difference between bare ground and gravel. In other words the increase in bare ground is accompanied by a decrease in recorded gravel cover. Litter may also vary considerably from one sampling date to another due to time of year, weather, grazing, fire, wind or other factors. Thus an increase in bare soil or gravel may be due to a short-term decrease in litter, or to a change in the amount of litter required as a basis for recording a hit.

✓ *Necessary Ground Rules*

What are the categories of ground cover to be estimated or measured and how are they defined?

✓ *Recommended Ground Rules*

For reasons discussed above, strict rules are exceedingly important for ground cover if repeatable results are to be obtained among observers and over time. Basal vegetation should be defined as the area of the stem where it enters the ground on single-stemmed herbaceous or woody species. The outside perimeter of the basal tuft of bunchgrasses should be used (see Figure 6-4).

Gravel is defined by soil scientists as particles in excess of 2 mm (smaller particles are considered sand). However, the Range Inventory Standardization Committee (Range Inventory Standardization Committee 1983) recommended that gravel be considered as mineral particles with a diameter of 5 mm (about ¼ inch) or more and particles with diameter less than 5 mm be considered bare soil This group believed that consistent classification of the surface as bare soil or gravel would be more likely with the larger size break.

Rock is defined as any mineral particle with average diameter greater than 3 inches. Soil scientists subdivide the rock category further (cobbles, boulders) but this is rarely done for range monitoring.

Litter is defined as any identifiable plant material lying on the soil surface, regardless of size of particle or composition (i.e. woody or herbaceous). Some definitions require that litter be detached from the plant and count any dead material still standing or attached as plant canopy (Herrick et al. 2005). Some references or agency procedures have defined litter as having a certain minimum thickness (assumed to be necessary for effective soil protection) and/or persistence (litter which is likely to persist beyond the current season, persistent litter, rather than decompose in a short time, non-persistent litter). These definitions are based on valid concerns, but introduce possible differences in interpretation depending on the perception and/or training of observers that is undesirable for trend monitoring. Ground rules for defining litter must be clearly established because differences in interpretation from one sampling date to the next reduce the value of monitoring data.

Biological soil crusts are not recommended as components of ground cover due to the difficulty of recognizing or characterizing them consistently and their lack of demonstrated interpretive significance. Clubmoss cover is easily recognized and may be used as a category where present.

Bare soil is recorded whenever one of the other categories of ground cover is not present.

- ✓ *Methods of Measurement*

Ground cover is usually measured using point methods (see Chapter 33). It can also be visually estimated with adequate training. Other quantitative methods, like line intercept, can be quite time consuming. Measuring distribution of bare ground is less straightforward. Generally measurements are made of the distance between covered soil (plants or litter) to calculate an index of patch size as is done in the fetch method or gap method (although both those methods measure distance between perennial plant cover, not litter or other soil cover attributes) (see Chapter 38).

- ✓ *Appropriate Vegetation Types*

Ground cover can be measured and may be of interest in almost any kind of vegetation (see Chapter 23). In very sparse vegetation, the main indicator of soil protection may be gravel rather than vegetation or litter; as such it is more of a site variable than an indicator of management effects. In very dense vegetation, ground cover is at or very near 100% and may not be sensitive to management impacts until major changes in plant composition and/or production have occurred.

- ✓ *Time of Measurement*

The best time to measure ground cover is just before the expected time of maximum erosion risk. As a practical matter, ground cover is usually measured at the time of other data collection on vegetation. Litter cover can be significantly affected by the time of year it is measured on some southwestern rangelands. For example, litter cover measured in June in southern Arizona had declined by about 10% in actual cover when the same area was re-measured in October due to decomposition during the late summer “monsoon” season. It is likely that similar patterns occur elsewhere. Litter usually reaches minimum levels at the end of the growing season (summer rainy season) because new growth is still erect and much of the existing litter decays during the wet season. Litter then increases through the dry and cold parts of the year and may reach a maximum (at least under ungrazed conditions) some time before the advent of the next summer growing season. For this reason, it is desirable to measure ground cover at the same time each year.

Indicators of soil erosion

✓ *Definition*

Indicators of soil erosion are qualitative attributes that can be observed on a site that are related to loss of surface soil by wind or water erosion.

✓ *Description*

Indicators may include the amount, degree, pattern, or activity of rills, water flow patterns, litter movement, soil movement or deposition, erosion pavement, plant pedestaling, coppice dune deposition, presence or activity of gullies, or other factors. Good descriptions of these attributes are given in Pellant et al. (2005) as indicators of rangeland health.

✓ *Uses/Interpretations*

Erosion indicators are used to describe the apparent rates or risk of soil erosion on a site (Bureau of Land Management 1973, U.S. D.A. Forest Service 1997, Pellant et al. 2005). Erosion cannot be measured directly without long term studies and rarely can be observed because it occurs only at unpredictable times. Various models of soil erosion (such as the Universal Soil Loss Equation) have been developed to predict soil erosion rates based on site factors. However, the validity of such models for specific situations may be questionable. Therefore, qualitative indicators are widely used to approximate soil erosion rates and/or hazard. The most difficult aspect of interpreting soil erosion indicators is to distinguish between the erosion that is "natural" to the site, i.e. a function of climate, soil, topography and vegetation type, and that which is "accelerated", i.e. increased by land use. It also may be difficult to distinguish between current and historic erosion. Because erosion indicators are qualitative and subjective, they must be interpreted with caution for establishing trends. Actual measurement of ground cover and/or pattern is preferable for trend measurement.

Pedestals have been used to indicate soil erosion in several different methods for assessing soil surface condition, including the current rangeland health assessment method (Pellant et al. 2005). This reference defines pedestals as rocks or plants that appear elevated as a result of soil loss by wind or water erosion (Figure 6-8). The manual goes on to point out that pedestals can be caused by non-erosional processes such as frost heaving or through deposition of soil or litter on and around plants. Thus, the assumption that the top of pedestals represents a former soil surface and the height of the pedestal indicates the amount of sheet erosion that has occurred is not always correct.

Figure 6-8. Photo on the left shows grass plants on pedestals which may indicate soil loss on intervening areas. The photo on the right shows shrubs occupying soil hummocks which may be the result of erosion on surrounding areas, or buildup of soil under the shrub due to wind deposition and leaf fall, or both. Interpretations of cause and effect are not always easy. Photo on left by Quinton Barr.

Terracettes also may be either the result of soil deposition behind obstacles by water movement or the effect of livestock or wildlife movement along hillsides (Pellant et al. 2005). Thus, caution is advised in assuming terracettes indicate soil erosion. It should be noted that the term "terracettes" has also been defined to mean small erosional scarps along the contour of a slope (Tongway and Hindley 2004).

A number of erosion indicators may be added together, and possibly weighted by importance, to arrive at an overall rating as was done in the Soil Surface Factor Rating approach formerly used by BLM. Such a process should be carefully considered because various indicators may be relevant on only certain sites, indicators are often not independent of each other, and indicators are not all of equal importance or equally observable. (see Chapter 18).

- ✓ *Necessary Ground Rules*

How is each indicator defined and ranked or evaluated?

- ✓ *Recommended Ground Rules*

No blanket ground rules are offered. The number of indicators and their description may vary depending on the site.

- ✓ *Methods of Measurement*

These indicators are visually observed or ranked, not measured.

- ✓ *Appropriate Vegetation Types*

Indicators can be used in any vegetation type where bare soil patches can be observed.

- ✓ *Time of Measurement*

Time of measurement is not critical since the indicators relate to processes that have occurred over a period of time. Observation after rain events (or windstorms) may provide more insight than after a long period without such events.

Biological soil crusts (cryptogamic crusts)

- ✓ *Definition*

Biological soil crusts are a mosaic of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria. Biological crusts are not the same thing as physical soil crusts resulting from deterioration of soil surface structure due to raindrop impact or other factors (Figures 6-9, 6-10).

- ✓ *Description (based mainly on Technical Reference 1320-2 (Belnap et al. 2001)*

Biological crusts occur on the surface and within the top few millimeters of the soil. They occur in all hot, cool, and cold arid and semi-arid regions. Crusts may form on soil of almost any texture except coarse sandy soils containing little silt and clay. Soils especially susceptible to development of crusts are those with low organic matter and high silt, sodium, or calcium carbonate content. These characteristics are all related to soils with low structural and aggregate stability. In general biological crusts tend to increase with decreasing vascular plant cover, decreasing elevation, decreasing loose rock cover, increasing embedded rock cover, decreasing soil depth, and increasing silt/clay fractions in the soil.

Structurally crusts are a rough, uneven carpet or skin of low stature (1-10 cm) in height. Below ground, lichen and moss rhizines, fungal hyphae, and cyanobacterial filaments form a matrix that binds soil particles together. Soil crusts occupy the nutrient-poor zones between vegetation clumps in many types of arid land vegetation. Compositionally, biological soil crusts are diverse. In many arid and semi-arid communities there are often many more species associated with biological soil crusts at a given site than there are vascular plants.

- ✓ *Uses/Interpretation*

Biological soil crusts can be used as indicators of ecological health of rangelands as key indicator vascular plants have been used in evaluating range condition and trend. Unlike vascular plants, crustal organisms, particularly lichens, are not greatly influenced by short-term climatic conditions. Just as plants increase or decrease with livestock grazing, many biological soil crust components are good indicators of physical disturbance, such as by livestock, human foot traffic, or motorized vehicles. Land managers have been slow to use biological crusts in range assessment partly because of perceived difficulty with identification. This problem can be reduced by grouping organisms by function or morphological groups (Belnap et al. 2001).

Figure 6-9. Strongly developed biological crust indicating a stable soil surface.

Figure 6-10. Physical surface soil crust resulting from raindrop impact.

Biological soil crusts may have a number of effects on ecological processes. Biological crusts add carbon to interspaces between vascular plants, thus increasing nutrient supply for soil organisms. Some types of crust organisms fix atmospheric nitrogen which can improve the nitrogen balance of soils and increase nitrogen content of vascular plants. Biological crusts are generally dark in color and therefore can decrease the albedo of soils, resulting in warmer soil temperatures which can have effects on microbial activity, soil water loss, plant nutrient uptake rates, seedling growth and other factors, some of them beneficial and some detrimental to vascular plants. Biological crusts may have effects on seed germination and establishment of vascular plants by altering the germination environment and water availability.

These effects depend on the soil type, species of vascular plants, etc. Biological crusts may either enhance or inhibit infiltration of water into the soil surface. In general, studies have shown benefits to infiltration in cool deserts (where crusts tend to occupy rough surfaces due to frost heaving) and detriment in hot deserts (where crusts tend to occupy flat surfaces not subject to frost heaving). The effects of crusts on both water infiltration and soil moisture are highly variable depending on site factors. Biological soil crusts are "unambiguously effective in reducing wind and water erosion of soil surfaces" because of binding of soil particles that contributes to greater aggregate size of the surface soil (Belnap et al. 2001).

Further, according to Belnap et al. (2001) the degree of development and taxonomic composition of crusts develops after disturbance in a manner analogous to the successional pathways of vascular plant communities. Thus study of such microphytic "communities" can provide information about the degree of disturbance and the rate of recovery after disturbance.

The above discussion outlines the major rationale for including biological soil crusts in monitoring rangeland health and trends in rangeland health. Biological crusts are now included in some assessment protocols. However, at present, we do not recommend including biological soil crusts as a category of ground cover (along with bare soil, plant litter, gravel, rock, etc) for routine monitoring unless biological crust data are recorded so that they can be either used or ignored for interpretation. The reasons for this recommendation are:

1. Identification of species, or morphological groups, is often difficult to do in the field and may require knowledge not generally possessed by many resource managers and ranchers. Correct and consistent species identification is a major problem with monitoring vascular plants, and this identification problem is likely to be much worse of the organisms making up biological crusts.

2. Adding another component to ground cover measurement or estimation will make interpretation of long-term trends more difficult. Ground cover measurement and interpretation is complicated by the difficulty of making consistent distinctions among categories or ground cover (bare soil and gravel for example) because such distinctions are usually arbitrary and the minimum size to be counted is often not specified. This problem leads to lack of consistency among observers and/or times of observation. Another problem of interpretation is that percentages of cover components are interrelated, for example if litter increases, then either bare soil, litter or both must decrease. These problems are increased if biological crust is added as a component. Biological crusts are usually found on what would otherwise be called bare soil. They are not usually found underneath low growing higher plants or litter cover. Therefore, crusts may decrease either because bare soil increases or because either higher plants or litter increase. Crusts may also be highly subject to short term disturbance (as is litter or annual plant cover) such as current grazing, fire, or sediment deposition, thus complicating interpretation of long-term trends.

3. Because biological crusts are disturbed to some extent by such factors as grazing animals (livestock or wildlife), fire, vehicular or human traffic, their value for establishing long term trends is reduced. In other words, just as in measuring utilization or other indicators of animal impacts, the values obtained at a given time may be highly affected by the degree of disturbance and/or length of time since the disturbance occurred. Only if one considers that biological soil crusts play such an important role in the ecosystem that any reduction in their development or extent is to be considered an indicator of "unhealthy" conditions would they be useful as long term indicators. Although some might make this claim, there seems to be little scientific basis for such an assertion.

4. The ecological significance of biological crusts is incompletely known and appears to be highly site specific, as pointed out by Belnap et al. (2001). As indicated earlier, crusts have been found to have variable effects on soil infiltration and plant establishment. Although some organisms comprising crusts have been shown to fix nitrogen and carbon, there is little evidence that the overall composition or productivity of plant communities is significantly affected by this process. Biological crusts do provide some soil protection from erosion, but, again, we have little insight regarding their overall effect on watersheds on a large scale. Therefore, we could easily misinterpret data on biological soil crusts

✓ *Necessary ground rules*

A decision must be made whether to use a taxonomic or functional/morphological approach to recording data. Also, consideration of how a "hit" on biological crusts will be defined. In other words, is a certain minimum area or degree of development required. If so what is it?

✓ *Recommended ground rules*

Selection of ground rules has to be made on a site-specific basis depending on the nature of the crusts to be measured, the time available, experience of the observers, and the availability of studies to support interpretation. For example, if the research relied upon for interpretation is based on species composition, then a taxonomic approach may be indicated.

✓ *Methods of measurement*

Methods are described in some detail in Technical Reference 1320-2. In general, the methods are similar to those used for other attributes making up ground cover (see Chapter 33).

✓ Appropriate vegetation types

Biological soil crusts could be assessed in any type of vegetation but are more likely to be of importance in sparse to open grassland and shrublands.

✓ *Time of measurement*

The season for measuring or observing biological crusts is fairly insensitive to time of year or weather conditions. Algal crusts are generally more obvious during moist conditions.

Aggregate stability

✓ *Definition*

Aggregate stability is the tendency for soil aggregates to remain intact when wet or impacted by raindrops or animals.

✓ *Description*

Soil structure is the result of the cohesion of soil particles to form larger units. Structure is promoted by physical processes (shrinking and swelling, freezing and thawing), chemical processes (adhesion of particles by electrical charges), or biological processes (addition of humus, activity of soil organisms). It can be destroyed by raindrop impact, trampling, increase of salts such as sodium, or loss of organic matter by oxidation. The kind and degree of aggregate development and stability are related also to the texture of the soil, type of vegetation, and climate, so sites will vary in the potential aggregate stability of their soils.

✓ *Uses/Interpretations*

The type and degree of soil aggregation and the ability of those aggregates to hold together, are important factors related to infiltration rates and the ability of surface water to detach and erode soil. Aggregate stability therefore is a factor that helps evaluate soil condition.

As yet, little research is available to support how aggregate stability should be sampled or measured and how results can be translated into realistic, site-specific decision making. Tongway and Smith (1989) employed a slake test as an quantitative index of soil surface "condition" and found it was correlated with site productivity. The slake test has also been tested and incorporated into recommended monitoring procedures in Australia (Tongway 1994, Tongway and Hindley 2004) and the southwestern U.S. (Herrick et al. 2005).

The slake test provides a semi-quantitative measure of soil stability. The rate of slaking may vary considerably within a site due to influences of vegetation or biological crusts and will also vary among ecological sites. Therefore, unless there is adequate sampling and site specific data to correlate slake rates with ecological processes, the data can only be considered useful for documenting changes over time or comparing two or more areas at one time.

- ✓ *Necessary Ground Rules*

Ground rules depend on the method used to measure.

- ✓ *Recommended Ground Rules*

Recommended rules depend on method used to measure.

- ✓ *Methods of Measurement*

The "slake test" has been employed to a limited degree on rangelands as a simple test of aggregate stability (Tongway and Hindley 2004, Herrick et al. 2005).

- ✓ *Appropriate Vegetation Types*

Aggregate stability can be measured in soil associated with any vegetation type.

- ✓ *Time of Measurement*

Aggregate stability should be independent of season when used to represent soil condition or trend in soil condition, but studies that demonstrate this independence are not abundant. Slake tests should be conducted on soils that have been dried (not moist soils) (Tongway and Hindley 2004).

Infiltration rate

- ✓ *Definition*

Infiltration rate is the rate at which water enters the soil at the surface, and is often expressed as inches per hour. Infiltration rate is not a constant – it will decrease over time during a rainfall event as the moisture content of the soil increases.

- ✓ *Description*

Infiltration rate is highly related to surface runoff and consequently to risk of erosion. Infiltration rate varies significantly with changes in slope, soil texture and structure, ground cover, surface roughness, bulk density, moisture content, as well as with changes in vegetation or soil impact due to land use.

- ✓ *Time of Measurement*

Infiltration rates may vary significantly depending on the season of measurement (Achouri and Gifford 1984). Soil surface conditions may change due to frost action, rainfall impact, amount of litter present, or antecedent moisture conditions.

- ✓ *Uses/Interpretations*

Infiltration rates are used as inputs to runoff models and erosion prediction equations. Trends in infiltration rates could be a valuable indicator of watershed condition from a hydrological standpoint. However, field measurement of infiltration is time consuming and highly subject to variation in time (seasonal effects and antecedent moisture conditions) and space, which limits its usefulness for routine monitoring purposes. For example, with a sample size of 70, coefficients of variation were found to range from 33 to 73 % in a Utah study (Achouri and Gifford 1984). Therefore, other attributes such as ground cover are more practical as surrogates for infiltration measurements.

Soil compaction

- ✓ *Definition*

Soil compaction is an increase in bulk density, that is a increase in the weight per unit volume of soil, or a decrease in the air and water holding capacity of the soil.

- ✓ *Description*

An increase in bulk density reduces plant available moisture storage and permeability of soil which can lead to increased surface runoff and erosion. Reduced pore space decreases soil aeration and may affect respiration of plant roots and microbial activity. Soil compaction may be caused by physical impact of animals, machinery, or raindrops (Simanton and Emmerich 1994) or by changes in plant production characteristics (especially rooting habits). Compaction may occur at the surface or in deeper horizons (described as plow pans in cultivated soils). Natural processes (freezing and thawing, wetting and drying, and the action of plants and animals) restore structure and decrease bulk density.

A platy soil structure may indicate soil compaction. Raindrops that impact a soil surface unprotected by plants, litter, gravel or biological crust can destroy soil aggregates and cause them to clog the pores of the surface soil, resulting in lower infiltration rates (Figure 6-10). When the surface dries a hard physical crust can form that inhibits covering of plant seeds, or emergence of seeds that germinate. Platy structure and clogging of surface pores is most common in silty/clayey soils and where silt/clay particles are deposited by runoff.

Compaction of the subsoil may also result in a platy structure due to the re-arrangement of soil particles from weight placed on the soil. Subsoil compaction is also more common in silty/clayey soils.

Platy structure is not necessarily the result of soil compaction. In some cases, it can be inherited from the parent material of the soil or occur as a result of deposition of sediment on the surface. Platy structure can also form in eluvial subsurface horizons when organic matter and/or iron/aluminum silicate that promote aggregation into granular or blocky structure are leached from that horizon.

- ✓ *Uses/Interpretations*

Monitoring of soil compaction can reveal trend in “soil condition” if measurements are carried out with sufficient precision to detect change over time. Such precision can be difficult to obtain given the spatial variability in most rangeland soils and the time required to measure bulk density quantitatively.

- ✓ *Necessary Ground Rules*

It is necessary to document the sampling and measurement method used.

- ✓ *Recommended Ground Rules*

Recommended rules depend upon the method used.

- ✓ *Methods of Measurement*

Measurement of bulk density involves weighing dry soil from a known volume of naturally occurring soil at a given depth. The resistance of soil to penetration by a probe of given size can be used to indicate relative resistance of two soils or the same soil over time (Herrick et al. 2005). Such measurements may be related to bulk density, but are considerably affected not only by spatial variability in soil properties such as texture and coarse fragments but also moisture content. These limitations reduce the feasibility of direct measurement of bulk density and the use of soil penetrometers for routine range soil monitoring.

- ✓ *Appropriate Vegetation Types*

Soil compaction can be measured in any vegetation type.

- ✓ *Time of Measurement*

Time of measurement of bulk density in subsurface horizons should not affect results provided soil is dried before weighing. Bulk density of the soil surface may vary seasonally depending on frost action, swelling, soil organisms or raindrop impact. Penetrometer readings can also be affected by seasonally varying moisture content.

Other soil attributes

Many other physical and chemical properties of soils that are related to effects of management on soil productivity and/or stability could be monitored or studied. Examples are pH and organic matter content. Some of these properties can be determined by field tests, and others require laboratory analysis. In any case, the procedures are generally too time consuming, or require too much calibration, for routine rangeland monitoring. For example, there is current interest in managing rangelands for the sequestration of carbon which would, presumably, be of benefit in mitigating global climate change due to increased atmospheric CO_2. However, it is not practical to monitor soil carbon directly because of the need for a large number of samples and the high costs of obtaining and analyzing the samples. Therefore, surrogate measures are used (Herrick et al. 2005).

CHAPTER 29
Water Attributes

Water quality

Rangeland management objectives generally aim at meeting water quality standards for designated uses. Water quality attributes include turbidity, sediment, pH, temperature, dissolved oxygen, salts, metallic ions, bacteria and other micro organisms, and micro invertebrates. Procedures exist for monitoring these and other water quality parameters. However, water quality monitoring involves considerations of timing, sampling, and methods that make it a specialized project not readily adapted to most rangeland monitoring programs. For the most part, the effects of rangeland management practices on water quality are related to the kind and amount of vegetation present on the watershed and the degree of soil protection offered by that vegetation. Rangeland monitoring concentrates on causes of water quality issues, rather than the water itself.

Water quality standards adopted by the Environmental Protection Agency and/or State Departments of Environmental Quality may or may not be related to the ecological processes and issues of sustainability that are usually monitored to guide livestock grazing or other management actions. Most of the impacts of land use are “non-point source” effects on water quality, i.e. those that are difficult to tie to a specific source such as a feedlot, industrial plant, or septic tank discharge.

It may not be possible to establish whether observed effects in a particular stream reach (or well) result from a given management unit or a larger landscape. For this reason, the Arizona Dept of Environmental Quality (ADEQ) has taken the approach that land management activities, such as livestock grazing, should adhere to a prescribed set of “best management practices.” If the rancher or other responsible person is applying these practices, it is assumed that the activity is in compliance with the standards. This shifts the emphasis on monitoring to monitor the implementation of the best management practices rather than the water quality itself. ADEQ may still need to monitor water quality to identify other problems (see Chapter 25).

Water quantity

Rangeland management practices may affect vegetation and soil and ultimately the water yield from rangeland watersheds. In most arid to semi arid rangelands the objective of management is to increase infiltration rates and reduce runoff to reduce the hazard of soil erosion. Meeting these objectives through maintenance of vegetative cover usually reduces flooding and water yield downstream. In some cases, however, rangelands can be treated to increase water yield by brush removal. Water yield and runoff are difficult to measure directly, so the attributes that can be monitored related to water runoff and yield are mainly amount and type of vegetation and ground cover, and those are the attributes emphasized in this guidebook (see Chapter 25).

CHAPTER 30
Attributes Related to Animal Impact

Utilization

✓ *Definition*

Utilization is the proportion or degree of current year's forage production that is consumed or destroyed by animals (including insects). Utilization may refer either to a single plant species, a group of species, or the vegetation as a whole (Interagency Technical Team 1996b).

"Seasonal utilization" is the percentage of the forage produced in the current growing season up to the date of measurement that is removed by grazing (Smith et al. 2007).

✓ *Description*

The impact of grazing on individual plants is considered related to the percentage weight removed, and the percentage of the forage by weight in a vegetation type is related to the animal unit months of grazing that has occurred. Thus, utilization is based on percentage of the dry weight of plant production rather than height or cover.

✓ *Uses/Interpretations*

Utilization is a check on the intensity of grazing by livestock and/or wildlife at the end of a grazing season. When combined with other information, utilization can indicate the need for adjusting stocking rates, especially when measured over a period of years (see Chapter 24).

Utilization can also be used as a basis for mapping distribution patterns within a management unit to identify need for management changes and/or range improvements to improve distribution, or to identify possible conflicts with other uses.

Utilization can help interpret trends observed in other vegetation attributes such as species composition, ground cover, or plant species frequency (see Chapter 21).

Seasonal utilization can be used for some of the same purposes with the caution that the level of utilization observed part way through the growing season may be quite different from the situation at the end of the growing season.

✓ *Necessary Ground Rules*

Ground rules depend on the purpose and method of measuring utilization.

✓ *Recommended Ground Rules*

Ground rules depend on the purpose and method of measuring utilization.

✓ *Methods of Measurement*

Utilization can be measured by the landscape appearance, height-weight, percent plants or twigs grazed, grazed class, and harvest methods (see Chapter 40).

✓ *Appropriate Vegetation Types*

Most utilization methods are best adapted to sparse to very dense perennial grass vegetation (see Chapter 23). Utilization is less useful in annual vegetation because the physiological impacts of grazing on the individual plant are of minor concern. Residual vegetation is more commonly used for annuals. Shrubs and trees present difficulties for measuring and interpreting utilization directly because (1) current year's growth may be difficult to identify (and utilization can exceed 100% of current growth), (2) portions of the plant may be too tall and/or dense for grazing animals to reach, and (3) grazing effects on some shrubs may be more related to the time of grazing in relation to bud formation than to amount removed. Twig count methods or the landscape appearance methods are most commonly used for shrubs.

✓ *Time of Measurement*

Utilization requires an estimate of total current year's production, thus it cannot be measured prior to the end of the growing season. On ranges where the grazing season is approximately the same as the growing season (i.e. on summer ranges in the higher mountains) utilization should be measured at the end of the grazing season in the fall. When the grazing season starts after the growing season, as on winter ranges, utilization should be measured at the end of the grazing season in the spring. In this case, utilization is being measured on the forage produced in the previous year. On the year-round ranges common in the Southwest it is much more difficult to identify current year's production, since growth may occur during more than one season. Also, complications of interpretation due to regrowth are greater than for seasonal ranges. Generally, the best time to measure utilization on year-round ranges is before the main growing season begins. That will be in spring where the growing season is spring - early summer, or summer where the main growing season occurs in the late summer "monsoon".

Seasonal utilization is measured before the growing season ends, usually when grazing in one pasture is completed.

Stubble height

✓ *Definition*

Stubble height is a measure of the height of forage plants after grazing by livestock or wildlife.

✓ *Description*

As the definition says, stubble height is measured on forage plants for specific animal(s) and season of use. If other plants are considered, then residual vegetation should be measured as described in Chapter 27. The term "stubble" refers to the parts of a plant remaining after grazing (or mowing). Stubble height measurements cover all plants of the selected forage species such that some of the data will represent ungrazed plants, not actual stubble.

✓ *Uses/Interpretations*

Stubble height is used as a measure of grazing intensity in both upland and riparian areas. It differs from utilization in that it only refers the amount of plant material remaining after grazing, not the amount removed. This attribute may relate better to the ability of the grazed plant to produce new growth or survive dormant periods than the amount of foliage removed, and it requires less training and meeting of fewer assumptions than utilization. Stubble height can reflect the average height of vegetation that traps sediment in floodplains where the majority of the vegetation is composed of forage species. If the riparian vegetation is not primarily made up of forage species, then stubble height on the forage plants may have little value as an indicator of sediment capture.

✓ *Necessary Ground Rules*

- Which plant species will be measured?
- How will stubble height be defined on partially grazed plants?
- How precise will measurements be, i.e. to nearest inch, half inch, etc?

✓ *Recommended Ground Rules*

If monitoring to check on stocking rates, only forage species should be measured. One or more key species may be selected. If the interest is in plant residue for sediment trapping or wildlife cover, then all species should be measured.

On bunchgrasses that are partially grazed, stubble height is usually expressed as the weighted average of grazed and ungrazed stems. This combination introduces a subjective element in the measurement but is a better measure of actual grazing effects. On single-stemmed grasses, or in dense swards where individual plants are hard to identify, only an individual tiller is measured.

Measure stubble height to the nearest inch or half-inch (specify which). Finer resolution does not improve the precision of the average as much as a larger sample size. Therefore, aim to measure more plants rather than measure each more accurately (see Chapter 14).

✓ *Methods of Measurement*

The stubble height method is appropriate (see Chapter 30).

✓ *Appropriate Vegetation Types*

Stubble height is appropriate for perennial grass vegetation ranging from sparse to very dense (see Chapter 23).

✓ *Time of Measurement*

Stubble height can be measured at any time since there is no need to estimate total growth as in utilization. Therefore, measure stubble height when the data best shed light on the objective of the sampling. For example, if sediment trapping is the objective, then take measurements just before overbank flow is most likely (e.g. spring runoff). If impact on key perennial grasses is the objective, then measurement should occur at the end of the growing season. If litter for soil protection is the main objective (although stubble height may not be the best indicator of soil protection) then just before the onset of additional growth would be the logical time to measure it.

Soil disturbance (trampling)

✓ *Definition*

Soil disturbance is the amount of soil that has been visibly disturbed by animals or machines.

✓ *Description*

Soil disturbance can be caused by trampling of livestock, wildlife, or humans. It can also be caused by vehicle traffic or vegetation treatment with machinery.

✓ *Uses/Interpretations*

Measuring soil disturbance can be used to estimate the location and/or degree of impact of grazing or herded animals or other land uses. It is often used to characterize impacts to stream banks in riparian areas. Like utilization, soil disturbance is a tool to document amount of disturbance, not a management objective in itself. The management objective is to maintain stable stream banks, avoid excessive erosion, limit weed invasion, or other resource effects that may be related to the amount of soil disturbance. To interpret soil disturbance relative to these management objectives requires knowledge of how the intensity, amount, frequency, and seasonal timing of soil disturbance affects management objectives. We prefer the monitoring of bank stability based on vegetation composition described by Winward (2000) to a one-time assessment of bank disturbance.

✓ *Necessary Ground Rules*

How is disturbed soil defined?
How are differences in the intensity of disturbance accounted for? (For example how does the depth of a cow track relate to its impact?)

✓ *Recommended Ground Rules*

Ground rules specific to the type of disturbance and management objectives have to be established and documented to reduce subjectivity.

✓ *Methods of Measurement*

Specific methods have been developed but will not be presented in detail in this guidebook. The multiple Indicator Monitoring or the MIM Protocol is "an efficient" and effective approach to monitoring stream banks, stream channels, and riparian vegetation" (Burton et al 2008). The MIM protocol is being tested in various ecosystems and is at this time in a developmental state.

✓ *Appropriate Vegetation Types*

Soil disturbance can be measured in any type of vegetation.

✓ *Time of Measurement*

The best time of measurement will depend on what kind of disturbance is involved and what the objectives are. For stream bank disturbance, the logical time would be just before high stream flows are expected. If upland erosion is the concern, then soil disturbance should be measured just before maximum likelihood of runoff or high winds. It does not necessarily make sense to measure soil disturbance just after disturbance pulses, because though highly visible at that time, the effects may be short-lived and appear much different later in the growing season.

Signs and indicators

Some indicators of animal presence, relative distribution, and travel routes can be observed, counted, or mapped. Some examples are fecal deposits and trails. Such information can help document relative use by livestock and wildlife and provide indices to the amount of animal use (or human use). These methods are not described in this guidebook.

Documentation of signs and indicators can be very valuable when interpreting monitoring data. Such documentation may simply consist of field notes and/or photographs.

SECTION 7
METHODS

What You Will Find in Section Seven

- ✓ What are common methods for measuring or observing vegetation and soil attributes?
- ✓ In which types of vegetation are these methods useful?
- ✓ What are the general procedures for each method?
- ✓ What are the necessary and recommended ground rules for each method?
- ✓ What are the statistical characteristics of the methods?
- ✓ How does the method compare to alternative methods for measuring the same or similar attributes?

Section seven describes several methods commonly used for rangeland monitoring or assessment. The intent is not to provide a detailed "how-to-do-it" for these methods – that is adequately described in existing manuals that are referenced in Appendix C. Our purpose is to help the reader understand which methods are appropriate for particular situations.

The methods are grouped by the general attribute measured, e.g. production, cover, density. Some methods, like photos, may indicate more than one attribute. For each method there is a brief description of what it measures (attribute), the procedure used and identification of sampling units, advantages and disadvantages compared to other methods, appropriate vegetation types for use, recommended ground rules, and type of statistical analysis. This discussion focuses on the methods. Before selecting a given method, consult Section 6 for more information on the attribute measured by the method, including its interpretive value for different vegetation types or monitoring objectives.

CHAPTER 31
Species List

✓ *Brief Description*

A species list is a complete list of plant species occurring on a particular area which can be a stand, an ecological site, a more general ecological zone, or a management unit at any scale (ranch, National Forest). A species list may be used to indicate species diversity (see Chapters 24, 27).

✓ *Appropriate Vegetation Types*

Species lists are appropriate for any type of vegetation.

✓ *Procedures*

Species lists are usually based on careful observation of vegetation in a specified area. Unless sampling is very intense, most transect or quadrat based methods will not record every species present. Therefore, additional inspection is necessary to try to come up with a complete list.

It may not be possible to obtain a complete list on only one sampling date due to seasonal or annual differences in the occurrence of the species or the ability of the observer to detect or identify it due to its phenological stage.

The number of species encountered will tend to increase as the total area examined increases even if the observations are confined to one ecological site. The number of species found may tend to level out when the "minimal area" is reached, (the area that has to be examined to characterize a "community"). Both plant communities and the minimal area are based on the concept of plant communities as discrete entities rather than gradually changing over time and space in response to site variability and disturbance gradients.

Although the minimal area has no objective definition for a given area the concept is still useful. The area selected for a species list should be large enough to make it likely that most species present on a local area will be found, but for comparisons over time the area should remain the same at each sampling date.

- ✓ *Recommended Ground Rules*

None

- ✓ *Statistical Analysis*

Usually no statistical analysis is feasible since there are no quantities attached to the list other than presence of a species. Tests of presence/absence have been developed for comparing plant communities over time or space, but these are not usually employed in rangeland monitoring.

- ✓ *Advantages/Disadvantages - Competing Techniques*

For most range management purposes a species list has value mainly as supporting information for the monitoring program. It is useful to make as complete a list of species on a monitoring site as possible no matter what kind of monitoring is being employed. For example, with photo monitoring a species list will provide some information that may be useful in interpreting the photo. If frequency, cover, or biomass is being monitored by species, not all species will be found. A complete species list can document species not encountered on transects or in quadrats and can help observers in the future know what to look for. It must be recognized that a species list is seldom complete.

- ✓ *Other Observations*

Species lists provide a measure of species diversity (species richness).

CHAPTER 32
Vegetation Weight (Production)

The following methods all are used to estimate the amount of standing crop of plant material on a dry weight basis. Usually only the current year's production is estimated; however the methods can also be used to estimate all standing crop including previous year's production on woody plants (see Chapter 27).

Harvest Method

- ✓ *Brief Description*

As the name implies, this method involves cutting all the above-ground plant material (standing crop - either current year's growth or total) in a quadrat and weighing it. This method is the only direct, quantitative measurement of production. It is usually considered the most accurate method of estimating production for a given quadrat. Achieving a precise estimate of mean production for a given area may, however, require a large sample size (see Chapter 27).

- ✓ *Appropriate Vegetation Types*

The harvest method is best suited for open to very dense stands of annuals and perennial grass (see Chapter 23). The required quadrat size and/or number of quadrats in sparse vegetation are prohibitive. The method can be used for low shrubs, although difficulty of separating current and older growth make it time consuming and introduces possible errors. Use of the harvest method on cactus, yucca, agave and other succulents is problematical because of the difficulty of ascertaining current year's growth. Use for tall shrubs and trees is usually confined to research studies because of the time required to harvest large plants

- ✓ *Procedures*

Quadrat size – Proper quadrat size and shape are important for achieve sampling efficiency, reducing bias, and meeting assumptions for statistical analysis (see Chapter 14). If more than 5% of the quadrats do not contain any plants, a larger quadrat should be used, and the average weight per quadrat should be at least 5-10 grams. If the production per acre is 50 pounds, there will be an average of 5 grams in a 9.6 square-foot plot, which is about a square yard or square meter in size. Production lower than about 50 pounds per acre is not really measurable using this method. Errors of measurement, that is, errors due to difference in clipping height or scale accuracy, expressed as a percent of the weight, decrease as the weight of observations increases. For example, weighing to the nearest gram produces a relative measurement error of +/- 20% on a sample of 5 grams, but only +/- 5% on a sample of 20 grams. For this reason, mean plot weights of around 20-40 grams are desirable. Usually, the number of quadrats required for a given confidence level also decreases as plot yields increase, up to a point. As a rule, increasing average plot yields beyond about 20-40 grams only increases the time required to clip the plot and does not decrease the number of quadrats required.

Locating quadrats: Quadrats are the sampling unit for the harvest method (see Chapter 14). They should be located objectively and preferably with some kind of randomization. As a practical matter, they are usually located systematically at paced intervals along a straight line, or at given intervals along a tape. If the quadrats are spaced at sufficient intervals, they may meet the assumption of independence.

Clipping: Herbaceous plants should be clipped as near ground level as possible. The clipping height must be consistent because it can have major effects on the amount of material clipped and on differences among species. In some cases it is easier and more accurate to remove current growth on shrubs by picking it off by hand, than by clipping.

Separating species: If species composition by weight is required, then species must be weighed separately. In range vegetation it is usually better to clip species separately in the field and place each in a separate bag for weighing. In very dense annual or perennial grass vegetation, it is sometimes easier to clip bulk samples, then separate the species by hand in the laboratory. That is a very laborious process, but it may be less painful in the office than trying to do it in the field. It may be advisable to select a subsample for separation, then apply the composition estimates to the whole sample.

Separating current growth: Current growth may be separated from older growth either in the field or in the laboratory. Usually, it is done in the field, and only the current growth is clipped. On some perennial grasses, especially bunchgrasses, clipping at ground level will also remove older growth within the clump. Clumps can usually be roughly separated in the field by picking out the older material. Failure to remove all old material is probably not a major error, unless it is very abundant, because it may offset failure to include some current growth that has already died (see Chapter 27).

Weighing: Production is generally expressed on a dry weight basis. There is no reason to weigh the samples until after they are dry unless you use a subsample to determine a dry-weight correction factor. In that case, weigh all samples in the field immediately after clipping. Field weighing usually employs hand-held scales that read to the nearest 1, 2, or 5 grams, depending on the capacity of the scale. The capacity of the scale required depends on the average weight of samples being measured, and a scale should be used that will result in acceptable relative errors of measurement. For example, a scale calibrated in grams will provide a relative error of +/- 2% on a sample weighing 100 grams, but +/- 20% on a sample weighing 10 grams. Lab scales that weigh to 0.1-0.5 grams should be adequate.

Drying- correction factors: Moisture content of plants can vary widely (from 15-90%) depending on the stage of growth, soil moisture conditions, and even the time of day. Plants may wilt (lose moisture) in the afternoon and recover moisture content during the night. These differences have large effects on the field weight of plants, which is why production is expressed on a dry weight basis. Different species also vary widely in moisture content on any given sampling date due to differences in growth form, growth stage, and microhabitats (rooting depth, etc). When using the harvest method it is usually best to bring in all samples for drying. If that is not possible, a representative subsample can be brought in for drying and a correction factor developed to correct field weights of the larger sample. In this case, care must be taken that the subsample is representative of the species composition. In other words, either a separate correction factors is developed for each species or species group, or the subsample must have the same species composition as the field sample. A different correction factor is needed each time the moisture conditions change. When sampling during dry conditions after plants have matured this correction is less critical than when sampling during the growing season when moisture conditions change rapidly in response to changes in soil moisture and even time of day.

In arid and semi-arid conditions where humidity is low, and especially where plants are relatively dry when harvested, air-drying is often used. Place plant samples in dry locations with the sacks open to allow moisture to escape as soon as possible after clipping. Otherwise plant samples may become moldy and actually lose weight by decomposition if stored moist. Use paper bags rather than plastic, because the paper will allow passage of moisture and air. Samples should be air dried until they reach a more or less constant weight. That state may take days or weeks to attain depending on the humidity and the original moisture content of the samples. Air-dried samples will contain more moisture than oven-dried samples. Oven drying requires placing samples in an oven, preferably one with forced air circulation, until they reach a constant weight. ”Constant” weight will vary depending on oven temperature. The usual standard is about 100 degrees centigrade (about 200 degrees F). Care must be taken not to use too much heat or samples may burn. Oven drying is recommended for research studies and may be necessary with very wet samples or high humidity as may be encountered when sampling in wet meadows in summer. In the Southwest, air drying is generally sufficient for most range monitoring work.

- ✓ *Recommended Ground Rules*

Clipping height: Clip herbaceous plants as near ground level as possible and record any deviation. Criteria for selecting current growth of shrubs should also be described.

Plot boundaries: All current growth of plants should be clipped within a vertical extension of the plot boundaries, regardless of where the plants are rooted. In other words, include material hanging over the plot from a plant rooted outside and exclude material hanging outside the plot. Be sure to adjust canopies back to their normal position when the quadrat is placed on the ground. An alternative is to clip all plants rooted within the quadrat and ignore those not rooted without regard to whether canopies are inside or outside the plot. This procedure will, however, increase the variability of the sample if plants of different sizes and life forms are involved, which is often the case on rangelands. For example, if only rooted plants are clipped when sampling large shrubs, very few quadrats might contain a rooted shrub, but when a rooted shrub is encountered it would be necessary to clip the entire plant, not just the part overhanging the quadrat. Obviously this procedure would both increase the variability among quadrats (thus resulting in a wider confidence interval on the mean) and increase the amount of time required to clip the samples.

Weighing and drying samples: Carefully document which of the procedures is being used.

Selection of species for clipping: If the data are to be used to estimate forage for livestock or other grazing animals, some practitioners advocate only clipping those plants considered forage for that animal. We caution that such data cannot be used to characterize site productivity or the species composition of the vegetation. We believe such an approach will likely underestimate forage for a given animal (given the variability in animal diets), and the data are not appropriate for interpretation relative to forage for animals with different grazing preference.

- ✓ *Statistical Analysis*

Statistical treatment of production data is straightforward as long as quadrats are large enough to provide data that are approximately normally distributed. Quadrats are the sampling unit, and analysis is usually based on dry weights. If a moisture correction factor has been used, any systematic error (bias) resulting from the correction factor will not be detected by statistical analysis. Fairly large sample sizes (20-50 quadrats) may be required to achieve desired levels of precision (see Chapter 14).

- ✓ *Advantages/Disadvantages - Competing Techniques*

The main advantage of the harvest method is that it does not depend on visual estimates or calibrations as do many other methods of estimating production. Despite this greater objectivity, errors still arise through differences in experience of observers or application of techniques. Example sources of error are differences in clipping heights, identification of current growth, decisions about whether material lies in or out of the plot, and weighing or drying procedures. The main disadvantage of the method is the field time required to achieve an adequate sampling. Even if the time is expended to obtain accurate data, the information has limited value for management purposes. For these reasons, the harvest method is generally not recommended for routine monitoring, although it can be used for studies or research.

✓ *Other Observations*

When the harvest method is used where grazing has occurred, either measure only the residual vegetation or apply a correction to adjust clipped weights to an ungrazed condition. Correct by combining an estimate of utilization on grazed species and adjusting back to an ungrazed condition. The utilization estimate, however, introduces another source of error Sampling conducted before the end of the growing season or peak standing crop is sometimes adjusted for the stage of growth when the sampling occurs. In other words, weights are adjusted upward to reflect end of season production (Natural Resource Conservation Service, 2005). This adjustment imposes an additional source of error, since it cannot be easily predicted how much additional growth will occur.

Weight-Estimate Method

✓ *Brief Description*

The weight-estimate method is basically the same as the harvest method, except that the field weight of current growth is visually estimated rather than clipped, dried, and weighed. Extensive and repeated training is required to achieve accurate estimates.

✓ *Appropriate Vegetation Types*

Same as for harvest method.

✓ *Procedures*

The general procedure in terms of selecting quadrat size, quadrat location, and definition of current year's growth is basically the same as for the harvest method. The difference is that the weight-estimate method involves estimating weight rather than clipping and weighing.

The training required to make this technique reliable involves repeatedly estimating, then clipping and weighing samples of the vegetation in a particular area. If all the vegetation is similar in growth form or if only similar plants are estimated (e.g. perennial grasses) the estimates may be of total plot yield. However, if information is required on species of different growth forms, "weight units" are usually identified for each species. A weight unit is a convenient plant size or portion of a plant selected as a basis for estimation. The training is continued until the observer can consistently come close to the actual weight of the weight unit for each species of interest. The estimation procedure then involves counting the number of weight units in a quadrat as a basis for estimating the weight of a species in a quadrat (Natural Resource Conservation Service, 2005).

The species encountered and the current growth conditions may vary depending on sampling time. Also, the observer usually must estimate weight in the field (green or wet weight) rather than use dry weight. Repeat training is needed to cover different sets of species, different growth stages, or different moisture contents. In some cases such variation may involve retraining even from one day to the next.

Experienced observers may develop great skill in estimating weights as they vary with growth form just as some people working around sale barns become very proficient in estimating livestock weights. However, even experienced people should check themselves every time they use this method.

Field estimates are based on "green" weights, and therefore a sample must be collected for drying to correct for moisture content. For the weight-estimate method, the samples are collected to represent each species of interest at a single point in time when moisture content is assumed to be constant. Otherwise, the procedures for drying and weighing are the same as for the harvest method. It is possible to train observers to estimate dry weights directly but that is seldom done due to increased time required to dry training materials before conducting the field sampling (Tadmor et al. 1975).

✓ *Recommended Ground Rules*

Ground rules for quadrat size, defining current growth and for inclusion or exclusion of material along the quadrat edges are the same as for the harvest method. Describing weight units for different species or groupings of similar species is useful but does not eliminate the need for training at each sampling date.

✓ *Statistical Analysis*

Weight-estimate data can be analyzed in the same way as clipped weights. Statistical analysis does not detect lack of accuracy of the estimates due to consistent high or low estimates. However, estimating one species high and another low will distort species composition, and estimating high on one date and low on the next will affect trend measurement. Random errors in estimation will contribute to the variability in the sample (see Chapter 14).

✓ *Advantages/Disadvantages - Competing Techniques*

The main advantage of the weight-estimate method compared to the harvest method is that more observationst can be made in a given period of time. The advantage is reduced by the amount of training required to have confidence in the method. Variability can be introduced due to changing conditions of the vegetation and differences among observers in making estimates. It is difficult to quantify the reliability of the estimates or proficiency of the observer. For this reason, weight estimate is acceptable for rough estimates of species composition or total production, but we recommend against its use for trend monitoring.

✓ *Other Observations*

As with the harvest method, weight estimates where grazing has occurred will include only residual vegetation can be estimated. Weight estimates are adjusted to ungrazed condition using utilization estimates.

Calibrated Weight Estimate Method

✓ *Brief Description*

The calibrated weight estimate method or "doubling sampling" method combines the harvest and the weight-estimate methods. It increases sample size by using weight estimates for the main sample. Estimates are adjusted (or calibrated) using correction factors based on a subsample of quadrats that are both estimated and harvested. This correction can take the form of a linear regression or ratio, and has been widely used for research purposes and for ecological site inventories. For a good analysis of this method see Tadmor et al. (1975); also Natural Resource Conservation Service (2005).

✓ *Appropriate Vegetation Types*

This method is suited to the same types of vegetation as the harvest method. It works best where the vegetation is composed of species with similar growth habits.

✓ *Procedures*

This method follows similar procedures to the harvest method as far as selection of proper quadrat size and location, identification of current growth, deciding what to include or exclude, and other criteria.

The first step in applying the calibrated weight estimate method is to train the observers to estimate weights for the specific growth forms and moisture conditions. These procedures are the same as outlined for the weight-estimate procedure above. After training, the data are collected by selecting a number of quadrats and estimating weight in each as for the weight-estimate method. A representative subsample of quadrats is selected for clipping and weighing. Usually the subsample is selected systematically; for example, targeting every 10^{th} plot in the main sample for both estimation and clipping (Mannetje and Haydock 1963).

The clipped weights obtained in the subsample are used to develop a correction factor that relates estimated to clipped weights. This correction can take the form of a best-fit linear regression using the formula $Y = a + bX$, where the clipped weights are the Y values and the corresponding estimates are the X values. A simple ratio ($Y = bX$) may also be used. It implies a linear relationship, but the regression line is assumed to go through the origin ($a = 0$). Each of the estimated values is adjusted using the derived ratio or regression to provide a corrected estimate. This correction is based on a consistent tendency of the observer to overestimate or underestimate. If the observer is inconsistent, no reliable correction can be made. Therefore, the regression equation developed should be tested for “goodness of fit” before it is used (Figure 7-1).

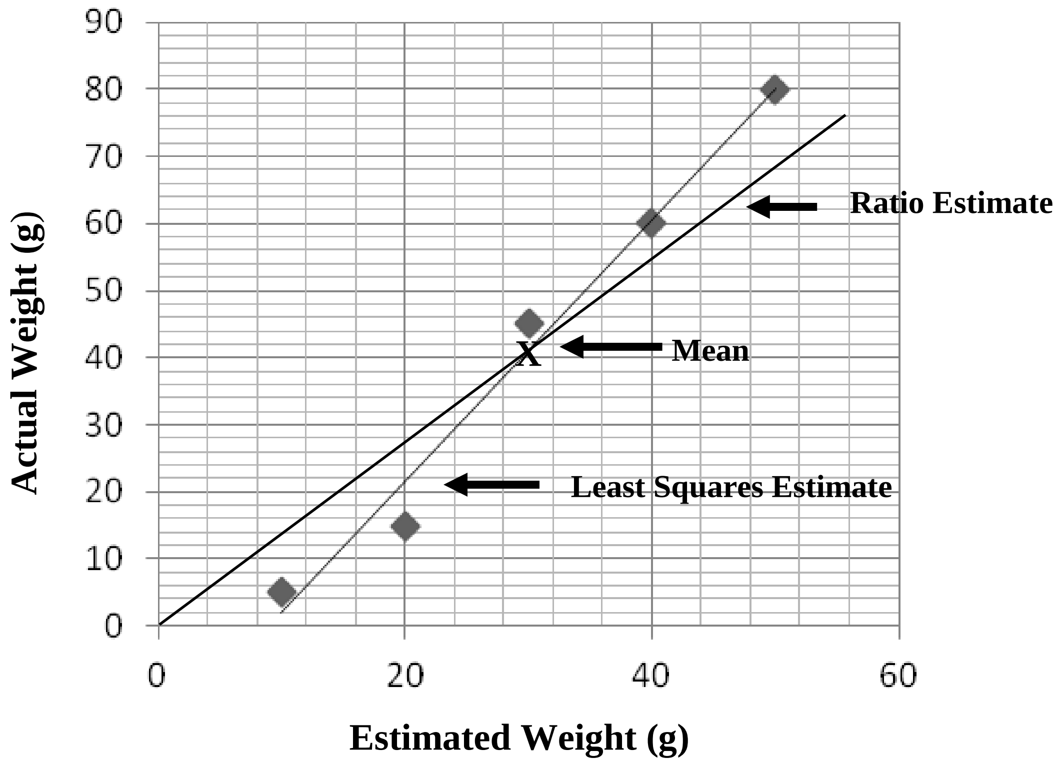


Figure 7-1. Comparison of use of ratio estimates to least squares. Ratio estimates would tend to overestimate actual weights for values below the mean and underestimate above the mean. The least squares or regression estimate provides the best correction on a linear basis.

Another (frequently violated) rule requires the estimator to not revise his estimates once training is complete and sampling has begun. If the estimator sees that estimates are higher or lower than the clipped weights there is a tendency to correct subsequent estimates to compensate. This compensation makes the correction factor (regression) meaningless. Therefore, one person should do the estimating and let another do the clipping and weighing. Another solution is to clip the plots but to defer weighing them until the sampling is complete. This approach can introduce error if samples dry out too much before being weighed.

The correction factor is only valid as long as plant growth and moisture conditions match those present during the training period. Any change requires a new training period and development of a new correction factor.

The calibrated weight-estimate approach works best across similar growth form and stage (i.e. where the plants are perennial grasses or only the perennial grasses are estimated). In that case correction factors can be used for total plot yields. For plants with different growth habits, weight units will be different for each species or life form group. Consequently, the relationship between estimated and clipped weights will be different for each species. Estimates then have to be made and corrected separately for each species.

Since training is based on “field weights” or “green weights,” the uncorrected main sample will also represent those weights. The calibration can be based either on field weights or on dry weights. If calibration is on field weights a moisture correction is developed by drying the clipped samples to make a further adjustment of the estimated weights to a dry-weight basis. Alternatively, the calibration can be developed by drying the clipped material and developing the calibration factor to adjust estimated “green” weight to weighed dry weight. Using correction for different species requires the moisture content of each to be determined.

✓ *Recommended Ground Rules*

Rules are basically the same as for the harvest method and weight-estimate.

✓ *Statistical Analysis*

Statistical analysis is complicated by introduction of several sources of variability. First, there is variability among the estimated quadrat yields in the main sample. Second, there is variability due to any difference in the mean of the subsample compared to the main sample. Third, there is variation introduced by the error of the correction factor, which can be measured if actual regression equations are developed. In practice, the latter two sources are seldom considered, although their errors may be substantial.

✓ *Advantages/Disadvantages - Competing Techniques*

The main advantage of this method compared to the harvest method is the larger main sample size that can be obtained in a given time. The main advantage over the weight-estimate method is that some measure of the reliability of the estimates is available. However, this method is still very time consuming in the field because of the training prior to sampling and the clipping and weighing required for proper subsampling.

Because of the time involved, these requirements are often subject to shortcuts that cause substantial and unrecognized errors. For example, a main sample of only 10 quadrats with a subsample of 2 quadrats has often been used for ecological site inventory work. This sample size is totally inadequate. This procedure can be useful where extensive sampling is to be done in a particular area for studies or research. Although this method is used by NRCS (U.S.D.A. Natural Resources Conservation Service 2005) and recommended by the Agricultural Research Service (Herrick et al. 2005), for routine range work, the results have to be considered only general approximations and not sufficiently precise to use for monitoring.

✓ *Other Observations*

As with the previous methods, estimating production in grazed situations may require adjustment for utilization if ungrazed production estimates are desired.

Comparative Yield Method (CYM)

✓ *Brief Description*

The comparative yield method (Haydock and Shaw 1975, Despain and Smith 1997) is similar to the calibrated weight-estimate method in that it is a double sampling approach. Instead of estimating plot yields in grams, CYM merely involves assigning a rank from 1 to 5 to each quadrat representing yield classes. The weights for each class are determined by clipping a subsample. CYM estimates total plot yields, not individual species. Total plot yields are generally less variable than yields of individual species, so fewer plots are required for an adequate sample.

✓ *Appropriate Vegetation Types*

CYM works best in open to dense annual or perennial grass (see Chapter 23). As is true with the weight methods above, it can be used for shrub types, but is much more subject to error due to differences in definitions of current growth.

✓ *Procedures*

Before establishing the main sample it is necessary to establish a set of reference quadrats that will be used to rank the main sample quadrats on a scale of 1 (low) to 5 (high). To do this, the observer selects 5 quadrats that represent the expected range in quadrat yield that will be encountered in the vegetation type. The goal is to represent equal increments of weight, e.g. 5, 10, 15, 20, 25 grams/quadrat. The increment in grams depends on the production of the vegetation and the size of quadrat used (Figure 7-2).

The quadrats should be large enough to allow enough difference in yield among them such that an observer can consistently assign ranks. For example, if only 1 or 2 grams differentiate rank 1 from rank 2, it is unlikely that an observer can consistently rank them. On the other hand, if quadrats are too large, they may also be difficult to rank since the relative difference among them may be diminished.

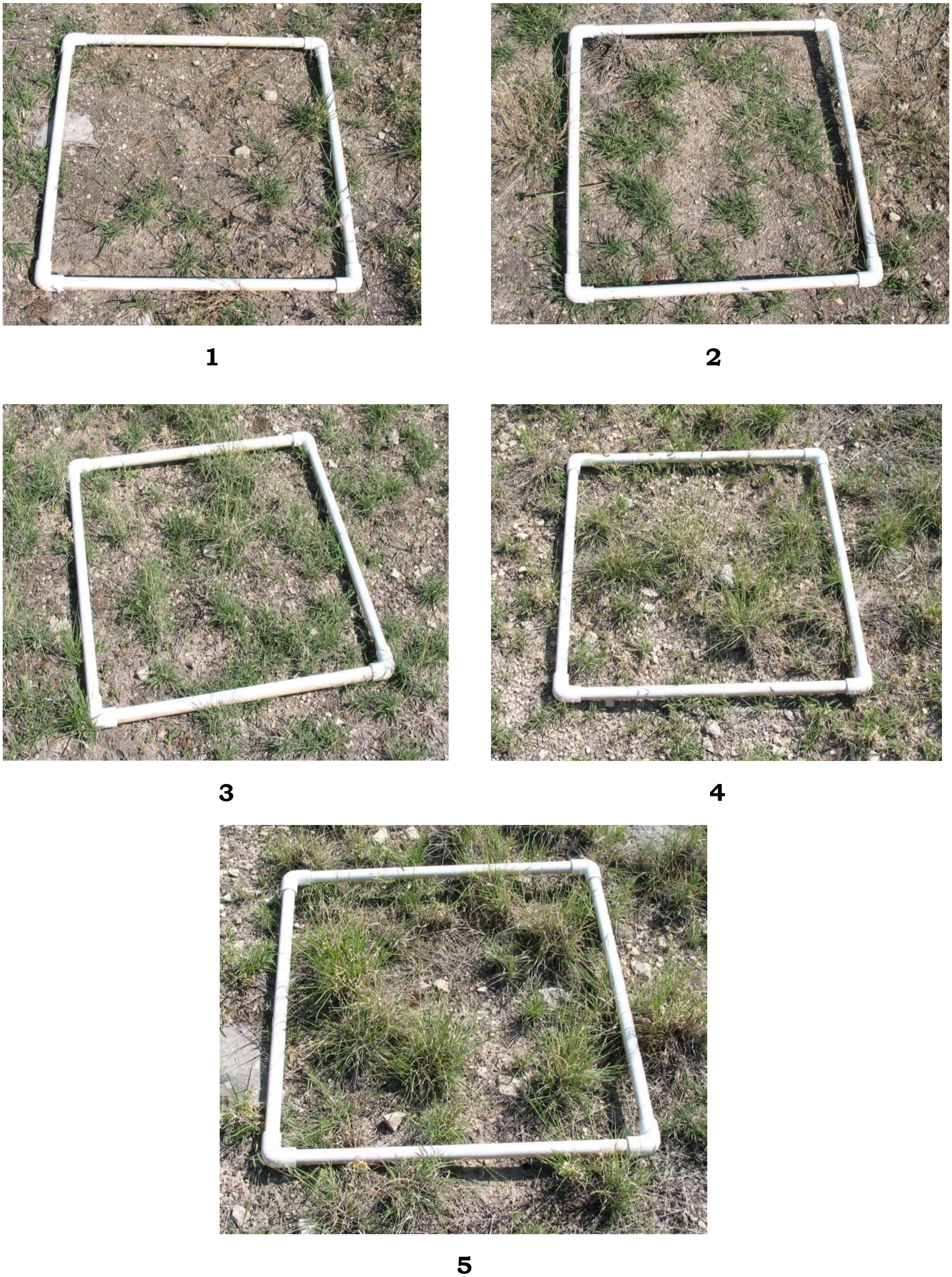


Figure 7-2. Set of five reference quadrats for comparative yield method. The quadrats represent approximately five gram increments in green weight, i.e. 1=5g, 2=10g, 3=15g, 4=20g, 5=25g.

Experience has shown that in typical rangeland types in Arizona, a quadrat size between 25 cm (10 inches) to 50 cm (20 inches) square will be adequate (Despain and Smith 1997). It is recommended to use only herbaceous vegetation for the reference samples, because of ease in ranking and estimation.

Once a set of reference quadrats is selected, the current growth in each should be clipped and weighed to confirm uniform increments in weight. Repeat this process several times if necessary to obtain a reasonable set of standards. When the observer is satisfied with his ability to identify a good set of standards, an additional set should be established as a reference for the main sample.

The main sample consists of selecting a number of quadrats and ranking each on the scale of 1 to 5 according to their correspondence with the reference samples. Where there is doubt between two ranks, half ranks may be used. Likewise if a plot is empty it is assigned a rank of 0; if an occasional plot yield exceeds the reference for a rank of 5, an estimated higher rank (e.g. 7 or 8) can be assigned. It is acceptable to refer to the reference quadrats if needed. After the main sample is completed, clip and bag the reference quadrats. The clipped samples should then be dried and the dry weights used to establish a dry weight for each rank. It is advisable to clip an additional set or several sets of reference quadrats to provide a better basis for this conversion. Ideally, the clipped weights should follow a straight line when plotted against plot rank, which indicates the weight increments among ranks are about equal. If the relationship is curvilinear, then a bias is introduced into the calculations that follow.

The conversion factor can be determined by developing a relationship between plot rank and plot yield. If several sets of reference quadrats are available, a linear regression equation can be used ($Y = a + bX$, where Y = weight and X = rank). Or a ratio estimate can be used where the average of weight (Y) = b (average rank X), and b is the ratio. Since the average rank of the reference quadrats is 3, this will give the average weight for a rank of 3. Then the average plot weight of the main sample can be estimated by using a ratio and proportion calculation as follows:

$$\text{Ave wt main sample} = \text{Ave rank of main sample} \times \frac{\text{Ave wt reference sample}}{3}$$

There are other ways to select reference quadrats, and some may be more statistically valid. For example, as in the calibrated weight estimate, a certain percentage of the plots in the main sample could be ranked and clipped to develop the correction factor. This will involve more clipping than the method outlined above.

- ✓ *Recommended Ground Rules*

Ground rules for comparative yield are basically the same as for other methods of estimating and clipping production in quadrats.

- ✓ *Statistical Analysis*

Statistical analysis can be carried out on the set of ranks obtained in the main sample to calculate an average rank and place a confidence interval around it. This analysis does not measure how well the reference quadrats estimate weights for each rank.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of the comparative yield method is that each observation only requires a small amount of time, and thus a large main sample is possible with minimal field time. The large sample makes it more representative and more repeatable. The amount of time required in training and establishing reference quadrats is usually much less than in weight-estimate methods. It is easier to rank quadrats by weight than to estimate the actual grams of weight in each quadrat, and rankings are less affected by differences in moisture content. Comparative yield is not very reliable if it is important to estimate shrub production.

- ✓ *Other Observations*

The comparative yield method can easily be combined with other techniques such as frequency or dry-weight-rank.

Dimension Analysis

✓ *Brief Description*

Dimension analysis is another regression sampling approach used to estimate plant yield by measuring stem diameter, height, or canopy volume and predicting weight from that measurement. It requires studies to develop the regression relationship and test its application for different sites or seasons. A variation would be to determine average production per plant, then just count the plants.

✓ *Appropriate Vegetation Types*

Dimension analysis has mainly been used for trees and shrubs. For example, diameter at breast height (DBH) is used to estimate wood volume in trees. It has also been used for shrubs to relate stem diameter to total biomass or average productivity and for bunchgrasses, where basal area is used to predict production(Shipley et al. 1942).

✓ *Procedures*

The procedure involves a study to develop a relationship between a relatively easily measured attribute of plants such as stem diameter or height and the total biomass or average annual production for a certain species of plant, usually trees and shrubs. Once the relationship is developed and tested, sampling involves measuring the independent variable (diameter or height) and predicting biomass.

✓ *Recommended Ground Rules*

Rules vary depending on variable measured.

✓ *Statistical Analysis*

As in any regression sampling approach there is a component of variance related to the variability of the overall sample, and also in the goodness of fit of the regression to the data used to predict biomass.

✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of dimension analysis is to acquire a larger sample with less time. The method also allows non-destructive sampling for the main sample. For example, you can estimate wood volume in trees without having to climb the tree or cut it down. Disadvantages are the time and effort required to develop acceptable quantitative relationships and how generally those can be applied to other sites or other years from those in which they were developed.

Direct Estimation of Species/Life Form Composition Based on Dry Weight Production

Composition (relative amount) by species, species groups, or life forms based on weight can be visually estimated directly either on a reconnaissance (i.e. landscape) basis or in quadrats. The procedure is similar to that described under direct estimates of species composition based on cover in Chapter 33. The main difference is use of weight rather than cover as a basis for estimation. Refer to Chapter 33 for further description.

Dry-Weight-Rank (DWR)

✓ *Brief Description*

Dry Weight Rank (DWR) is a quadrat technique to estimate percent composition of species based on dry weight (Mannetje and Haydock 1963, Smith and Despain 1997) .

✓ *Appropriate Vegetation Types*

DWR is best suited for open to very dense annuals or perennial grass since sparse vegetation requires quadrats too large to be practical to meet the assumptions for this method (see Chapter 23). DWR can be used in open to dense low shrubs or tall shrubs. However, shrubs are more difficult to rank because identification of current growth is more difficult. The assumptions of the method regarding association of certain species with high yielding quadrats are more apt to be violated, which usually means that shrub weights are underestimated relative to grasses.

- ✓ *Procedures*

DWR uses quadrats, and the number required depends on species diversity and spatial pattern. The composition of the major species can usually be estimated with 25-50 quadrats. Obtaining estimates of uncommon species would require more quadrats because such species may only occur in a small subset of the overall sample.

Locate quadrats along transects or by pacing. In each quadrat the first three species are ranked according to dry weight. The species contributing the most amount of dry weight to the plot yield is ranked 1, the second is given a 2, and the third a 3. Any other species present are ignored (although they may be tallied for frequency).

After rating all the quadrats, apply a weighting factor to the number of each rank received by a species and sum across all plots. The total weighted ranks for all species are divided into the weighted rank for each species to obtain an estimate of percent composition.

The weighting factors can be derived for specific situations. However, experienced practitioners find that weighting factors tend to be consistent across a variety of situations: 1=70%, 2=20%, and 3 = 10%. Where quadrats contains only 2 species, one species may be given two ranks, i.e. 1 and 3 (80%), 1 and 2 (90%) or 2 and 3 (30%). If the quadrat only contains one species it is given all 3 ranks (100%).

A significant bias in the estimated composition is introduced when particular species occur in plots with higher or lower than average production. In this case, the species ranked mainly in heavy plots will be underestimated, and the species ranked mainly in light plots will be overestimated. Examples of this situation are where shrubs occur in heavy plots and herbaceous plants in lighter plots, or where a large bunchgrass is intermixed with lightweight annuals or short grasses (Figure 7-3). The bias introduced can be considerable.

The bias described above can be corrected by estimating the total weight of each plot and making a second weighting of composition scores based on this weight. However, estimating weight largely eliminates the main value of the DWR method, which allows for quick estimates and generation of large sample sizes. The Comparative Yield Method can provide for weighting of DWR scores and can be easily combined with DWR. In either case, the data must be recorded for each quadrat individually.

DWR requires very little training, although experience in weight estimation helps provide the judgment required to rank species.

Ideally, the quadrat size selected for DWR should generally capture at least three species and is thus a function of species richness and density of vegetation. In practice, the number of species encountered in a given quadrat tends not to be highly sensitive to quadrat size within a general range from about 0.2 to 1.0 square meters. Using the multiple rank procedure seems to compensate for quadrats with fewer than 3 species (Despain and Smith, 1997).

- ✓ *Recommended Ground Rules*

Estimate current year’s growth on all species and the portion of plants within a vertical projection of the quadrat boundary, regardless of where the plant is rooted. If some plants are estimated as a group (e.g. annual grasses or forbs) make a note of this. Assign ranks for grazed plants as if they were ungrazed; in other words, mentally reconstruct the plants to an ungrazed condition.

- ✓ *Statistical Analysis*

A set of quadrats constitutes a sampling unit; no data can be obtained on a single quadrat. If, for example, the quadrats are located along paced or line transects, one estimation of species composition results from that set of quadrats. DWR data can be analyzed statistically to compare different areas or trends for each species over time. Percentage data are often transformed to make them better fit the assumption of normal distribution (Bonham 1989).

Figure 7-3. Stand composed of big sacaton (large bunchgrass) with shorter grasses in interspaces. DWR will tend to underestimate big sacaton composition and overestimate the short grasses.

✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of the DWR method is that it allows a large sample size in a short period of time and requires very little training or calibration compared to other techniques. It is easily combined with frequency and/or comparative yield to provide added information. For example, DWR may not provide precise measures of plants making up minor portions of the composition by weight. Frequency can document these species quantitatively for trend interpretation if that is desired. DWR alone does not provide an estimate of production, but the use of comparative yield along with DWR can provide this information. The disadvantages of DWR are mainly the tendency to underestimate shrub composition in mixed shrub/grass range and its limited use in sparse vegetation.

✓ *Other Observations*

Species composition by weight has been widely used for comparing current vegetation to a desired state (for example range condition, ecological status, and range health). DWR is probably the most practical way to obtain good, repeatable estimates of composition on a weight basis in a wide variety of vegetation types.

CHAPTER 33
Vegetation Cover and Ground Cover

Ocular Reconnaissance/Square Foot Density

✓ *Brief Description*

The "Ocular Reconnaissance" method was developed early in the 20^{th} century for range inventories designed to adjudicate grazing allotments on federal range. It was used in the Interagency Range Survey during the 1930s and formed the basis for grazing capacity estimates called the Range Survey Method. The "Square-Foot Density Method" was a method also used in the Range Survey that relied on estimating species cover in ¼ square foot increments in a 100 square foot plot (Brown 1954).

Species or life form composition based on absolute cover or percent ground cover can be estimated either for an entire community or on a series of quadrats. Such estimates can be used as a check for vegetation maps or to help explain other data collected. For example, it may be useful to estimate composition or ground cover together with taking monitoring photos (either general or close-up) to help interpret what is in the photo.

✓ *Appropriate Vegetation Types*

Composition based on cover can be estimated in sparse to very dense annual, perennial grass, low shrub, or tall shrub vegetation. It is more difficult to estimate in dense to very dense shrub stands. It is less useful in dense or very dense stands of tall shrubs or trees because it is difficult to get a perspective of cover that is above head height (see Chapter 23).

✓ *Procedures*

List the species, species groups, or life forms that will be included. For a long list of species, it is helpful to group species and estimate composition by life form first. Composition always adds up to 100%, so the process is basically one of allocating the percentages among groups of species, then among the species within the group. It is easier to estimate the percentage of the total production made up by species than to estimate the actual cover of the species. The same procedure is used for the various categories of ground cover; basal vegetation, litter, gravel, and bare ground.

The procedure is basically the same whether an estimate is made for a key area or for quadrats. The main problems with estimating on a landscape basis are that the area is not well defined and there is a tendency to emphasize species near the observer at the expense of those farther away. This bias can be lessened by cruising through the type before making the estimates. Using quadrats strictly defines the area to be considered and reduces the number of species. The estimate in each quadrat is more accurate and repeatable than a landscape level estimate, and experienced observers working with quadrats over a sampling area can provide a good overall estimate of species composition. However, Reid and Pickford found that a reconnaissance estimate by trained observers was more repeatable among observers than the use of quadrats due to the high variability among quadrats (Reid and Pickford 1944).

✓ *Recommended Ground Rules*

Quadrats should be large enough such that most contain some of the species of interest— no more than 5% of quadrats should be empty. Large quadrats may simply increase estimation time without decreasing required sample size (see Chapter 14).

The Range Survey Method limited the cover estimates to cover within 4.5 feet of the ground because anything higher was not considered available to livestock. However, if the purpose is to estimate total vegetation composition, this rule is not appropriate. (See the discussion of ground cover in Section 6 for rules on ground cover.)

✓ *Statistical Analysis*

Species composition or ground cover estimated in quadrats could be analyzed statistically using quadrats as sampling units. Statistical analysis would allow setting confidence limits or comparing species composition to another area or to another sampling date. A statistical analysis is only concerned with the differences among quadrats; it makes no difference whether the quadrat data are visual estimates or weights from an analytical balance. If the visual estimates are reliable the data will be reliable.

✓ *Advantages/Disadvantages - Competing Techniques*

Direct estimation of species composition or ground cover is much faster than most other methods, and it can provide valuable information. Its main disadvantage is that its accuracy is totally dependent on the skill and integrity of the observer, and there is no way to establish how well the observer did.

✓ *Other Observations*

Given the uncertainties regarding observer skills and training, this method is probably better suited to "training the eye" for reconnaissance surveys or mapping or for providing supplementary information for photo monitoring, rather than for quantitative monitoring.

Daubenmire Canopy Cover Method

✓ *Brief Description*

The Daubenmire canopy cover method was developed by Rexford Daubenmire in the Palouse Prairie area of the Pacific Northwest and has been widely used elsewhere to estimate canopy cover (Canfield 1941, Daubenmire 1959, Bureau of Land Management 1996). The Daubenmire method involves assigning each species to a cover class, rather than estimating the percentage cover directly. This procedure sacrifices some accuracy on the estimate of each plot, but improves overall sampling precision by increasing number of plots that can be read in a given time period.

✓ *Appropriate Vegetation Types*

The Daubenmire canopy cover method is best suited to open to dense grassland or shrub-steppe vegetation, because it is necessary to look down on the quadrat to make reasonable estimates. Its use in sparse desert shrub, or for sparse understory in woodlands requires an impractically large quadrat. Use in chaparral or other dense shrub cover is complicated by the difficulty of locating quadrats in an unbiased manner (see Chapter 23).

✓ *Procedures*

Calculation of the estimated cover percentage requires a reasonable number of quadrats, rather than one or a few quadrats. The sampling unit therefore is a set of quadrats, usually located along a paced or line transect. Daubenmire found that a set of 40-50 quadrats provided reasonable precision (Daubenmire 1959). However, several of these sampling units are required to set confidence limits and perform statistical tests. Cover is estimated in each quadrat by assigning a cover class for each species. Daubenmire proposed 6 classes based on percent cover: <1-5, 6-25, 26-50, 51-75, 76-95, and 96-100 (a 7^{th} class could be 0). Note that these classes are not equal. Daubenmire subdivided the high and low ends of the scale to avoid overestimating species with low cover, or underestimating those with very high cover. Some workers have proposed subdividing the middle classes also to increase the number of classes used. This suggestion was based on the idea that narrowing the class intervals would make the result more precise. However, we believe that increasing the number of quadrats is more effective in increasing precision of the estimate. Using extra classes in the middle of the range will make it more difficult to decide which class to assign and slow the estimation process, thus offsetting the main advantage of this method.

Only the portion of the canopy included within a vertical projection of the quadrat frame is included in the estimates, regardless of whether the plant is rooted in the frame or not. Daubenmire recommended defining “canopy” as a polygon connecting the outside limits of the crown, and ignoring holes within the crown or indentations in the perimeter of the crown. He reasoned that this definition was easier to apply consistently and better represented the importance of the plant in the community since the intervening spaces were occupied by roots of the plant (see Chapter 27, Figure 6-1).

Cover estimates are based on an average of species occurrence weighted by the mid-point value of each class. (For example, the number of quadrats in which species X occurs in the 26-50 class would be weighted by 37.5.)

Daubenmire used a 20 X 50 cm quadrat in the shrub-steppe Palouse region. That size was convenient for that vegetation type and is suitable for much of the semi-arid to subhumid grasslands. However, a quadrat size of 20 X 50 cm is not a requirement for the method. The appropriate quadrat size should accommodate the vegetation being sampled and will likely be larger in arid areas and smaller in meadow applications.

✓ *Recommended Ground Rules*

Canopy cover is defined by the outside perimeter of the plant canopy. Only the portions included within a vertical projection of the quadrat are included regardless of where the plant is rooted.

✓ *Statistical Analysis*

The sampling unit is a set of quadrats. For example, if 20 quadrats are located along a transect, the cover estimates calculated from the 20 quadrats are one observation. The number of observations (n) used for statistical analysis is the number of transects. Therefore, from a statistical standpoint it is desirable to have more transects than to increase the number of quadrats per transect. For statistical analysis we would recommend at least 10 transects of about 20 quadrats each. Statistical analysis does not account for any consistent tendency of the observer to overestimate or underestimate cover of any given species or life form (see Chapter 14).

✓ *Advantages/Disadvantages - Competing Techniques*

This method is an objective and quantitative way to estimate canopy cover. Use of classes rather than actual cover estimates speeds up observations for each quadrat, thus allowing more quadrats, transects, and ultimately a larger sample size for the time spent. Daubenmire found it more efficient than the line intercept method (Daubenmire 1959). It requires less training and experience than direct cover estimates. Canopy cover, however, is highly subject to influence of season of the year, annual growing conditions, and grazing or other disturbance. (Forest Service n.d.) Therefore, its usefulness for range monitoring is reduced compared to basal cover (Grelen 1958).

✓ *Other Observations*

If canopy cover is the desired attribute to measure, then the Daubenmire canopy cover method is recommended in appropriate vegetation types. It is not very useful in sparse vegetation because an impractically large quadrat size would be necessary. It is not very useful in dense vegetation because the overlap and intermingling of canopies makes consistent estimates arbitrary and time consuming. In general, we prefer to characterize vegetation composition based on annual dry matter production rather than canopy cover.

Line Intercept Method

✓ *Brief Description*

Line intercept involves stretching a tape or wire between two points and measuring the distance intercepted by each plant or component of ground cover. The total intercept distance of all plants, or each species of plants, divided by the total length of the line provides an unbiased estimate of percentage cover. The method may be used either for canopy cover or ground cover.

The line intercept method was developed by Canfield (1941) for use in desert grassland vegetation. It has been widely used in arid and semiarid rangelands, including grassland and shrub-steppe vegetation.

✓ *Appropriate Vegetation Types*

Line intercept is best suited to vegetation with species of interest having canopy cover of about 5-40%. Species with less than 5-10% cover will not be efficiently measured because a very long total length of line must be measured to obtain a reliable estimate. Vegetation with extensive cover (over 50%) can be measured with line intercept, but the process may be slow due to the need to distinguish between overlapping canopies of different species.

The line intercept technique is therefore suited to open to dense perennial grass or low shrub vegetation (where the line can be stretched over the canopy). It is not suited to annual vegetation or sparse perennial grass. It works in open stands of tall shrubs (where the line can be run under the canopy). Dense stands of tall shrubs or trees are difficult to run a straight line through and estimating cover at some distance above the line leads to possible errors (see Chapter 23).

✓ *Procedures*

Stretch a line between two stakes or pins. The line may be a steel or cloth tape, or just a wire of known length that does not need to be graduated. Steel lines are preferred to cloth since they can be stretched tighter and do not blow around in the wind as much. The line should be located in an objective way. A typical way is to locate transects along one or both sides of a baseline. Transects can be either randomly or systematically located. The line should be straight and located as near to the ground as feasible. Where low shrubs are common, it is usually necessary to stretch the line above the canopies of the shrubs. As the line gets higher above the cover being measured, opportunity for error in defining the cover grows.

For each plant species, species group, life form, or ground cover type the length of intercept is recorded each time it occurs along the line. Each observation is totaled for the whole line. The total length of intercept for a species or other feature (e.g. inches) is divided by the length of the line (in inches) and multiplied by 100 to estimate percentage cover for that species or feature. If the line is graduated (i.e. a measuring tape) then the intercept can be read directly from the tape by subtraction.

It is usually more convenient and less subject to possible error to measure intercept using a retractable steel tape or measuring stick graduated in inches or centimeters. Readings are usually taken to the nearest ½- 1 inch or the nearest centimeter. Greater precision will be achieved from more short lines than a few long ones. However lines should be long enough to cut across a number of plants or patches of plants, capturing the vegetation “mosaic” and reducing variability among lines. In most open to dense perennial grass, 25-50 foot lines are effective. Canfield (Canfield 1941) recommended 50-foot lines where basal cover is 5-15%, and 100-foot lines where cover is less than 5%. In open stands of low shrubs, lines generally need to be 100 feet long. In sparse to open stands of larger shrubs, lines can be up to 300 feet long. Orient lines parallel with one another or end to end to cut across any expected gradients in plant cover or composition. For example, lines should usually run up and down hill rather than on the contour or radiating from a central point.

- ✓ *Recommended Ground Rules*

Measure plant cover around the outside perimeter of the canopy (see Figure 1-1, Chapter 27). Holes in the canopy are usually ignored; if not, record the criteria for deciding how to account for holes Overlapping canopy of the same species is usually ignored, but overlapping canopy of different species is measured. Application of this rule depends on the purpose of measurement. The usual attributes for recording ground cover are basal area, litter, gravel, rock, and bare soil.

- ✓ *Statistical Analysis*

There is only one estimate of cover for each line, and thus each line is a sampling unit. To capture the range of cover conditions across a site it is necessary to run multiple lines. As with quadrat size and number, there is a trade-off between the length of each line and the number of lines. Data from very short lines will be highly variable, and thus more lines will be required for the same precision. Very long lines will usually yield less variability but take longer to run, and may result in wide confidence intervals because of the high t values that occur when n is <10. It is time consuming to determine optimum length and number of lines for every sampling situation.

Lines should be randomly located within the sampling area. A common approach is to randomize transect spacing along a base line. Lines located systematically provide an unbiased estimate of cover, but calculation of confidence intervals violates the basic statistical assumption of random sampling. Since cover data are expressed in percent, an arc-sine transformation is sometimes used before calculating statistics.

The number of lines required to obtain reasonable precision is often surprisingly high and may require considerable time of sampling. Cover of the vegetation is perhaps the most important factor influencing sampling variability of transects samples (Larson 1958). Whitman and Siggeirsson (1954) found that 15 10-meter line transects gave a standard error of +/-5% where total cover averaged 20.7%. To get estimates of equal precision where cover averaged about 5%, 60 to 85 transects were needed, and for western wheatgrass, which averaged only 1.28 % cover, more than 400 transects would be needed.

- ✓ *Advantages/Disadvantages - Competing Techniques*

Line intercept is an objective and quantitative method for estimating cover. The method requires little specialized knowledge and minimal training. It is fairly rapid to use for low shrubs or for open stands of bunchgrasses. In denser vegetation, it can become time consuming. It is difficult to use in taller shrubs or trees because it is hard to stretch a straight line. Point methods are generally faster and easier to use in denser herbaceous vegetation.

- ✓ *Other Observations*

The line intercept method is mainly useful for monitoring cover of low shrubs.

Point Methods

- ✓ *Brief Description*

Point methods are used to estimate cover of vegetation and/or ground cover. Vegetation cover may be recorded as canopy cover, foliar cover, basal cover, or leaf area.

There are a number of point methods that go by different names. Pace transects locate points at each pace along an unmarked transect. Line points are located systematically at intervals along a tape or wire. The point frame method locates sets of points in a rigid frame located either at random or along a line. The wheel point method locates points on one or more of the spokes of a wheel that is rolled across the sampling area (Tidmarsh and Havenga 1955).

There are also various methods of locating the points: on the toe, on quadrats, with hand-held pins, frame-held pins, sighting devices with cross hairs, lasers or even on photographs taken from directly above. All of these methods and sampling devices have the same basic characteristics; they vary mainly in convenience, speed, adaptability to different vegetation types, and the manner they are analyzed statistically.

In contrast to data obtained from quadrats or lines, point data are binomial, as the observation of a cover attribute for a given point is either "yes" or "no." Thus, the percentage cover estimated is the proportion or percentage of points that gave a positive hit on that cover component. Point cover is sometimes called point frequency. A set of points is required to estimate cover. Data estimate the probability of hitting that cover attribute by randomly placing one point.

- ✓ *Appropriate Vegetation Types*

Point methods are applicable to any vegetation type or amount of ground cover. Where vegetation or ground cover is very sparse, very large sample sizes may be required to measure the cover (although bare ground hits may require fewer points), and the data may not be very sensitive to change. In dense stands of tall shrubs or trees, it is difficult to physically locate points on the ground in an unbiased way. Point methods are best suited to open to dense stands of annuals, perennial grasses, and low shrubs (see Chapter 23).

- ✓ *Procedures*

All point methods involve the observation of "hits" on vegetation cover or ground cover using some method to define the exact point where the hit is recorded. To be an unbiased estimate of cover, the point must be dimensionless. That is, its diameter is zero. In practice, this requirement is difficult to achieve, so that some positive bias is usually present, in other words the point actually covers a small area of surface. The larger the point, the greater the chance of encountering vegetation or litter, and thus the estimated cover value is positively biased.

Cover cannot be estimated from only one point; it requires a set of points. Therefore, the set of points constitute the sampling unit. Different point methods vary in how the sets of points are established.

When sampling ground cover, only one attribute is recorded at each hit; the point will hit bare ground, litter, rock, gravel, or basal vegetation. Therefore consistent rules to define these attributes are essential. When sampling canopy cover, the points can be recorded for the first hit only (i.e. the first one encountered as a pin is lowered through the canopy) or on all hits in the case of multiple layers of canopy. It is possible to combine canopy cover hits and ground cover hits by appropriate data collection.

- ✓ *Recommended Ground Rules*

Ground rules for defining cover and ground cover were given in Chapter 27.

- ✓ *Statistical Analysis*

There are two ways to analyze point data. If points are assumed to be located at random, then the data follow a binomial distribution. Confidence levels may be established from a binomial table for a given confidence level, since the confidence interval is a function only of the confidence level and the estimated cover percentage. Statistical comparisons are made using chi-square analyses. The number of points required for given level of precision is a function of the number of "hits" on the attribute of interest. Therefore the number required for a given level of precision is different for bare soil (for example) than it is for basal cover on an individual species.

It is rare that point data are collected at random due to the time required to randomly locate the number of points required. Data collected systematically can be considered to meet the randomness requirement if the data points are independent, i.e. if a positive hit on one point is neither more or less likely to result in a positive hit on the next point in the sample (Grieg-Smith 1964). Each species must be considered separately because one species may be independent and another not with the same point spacing. Spacing systematic points farther apart will increase the likelihood of independence, but it is seldom feasible to check this assumption for routine range work.

Point data can also be analyzed by considering different sets of points as sampling units. In this case, normal statistics can be used, as only the sampling units need to be randomly located. For example, 100 points collected at 1-foot intervals along a 100-foot tape would be one observation of cover for each component measured. In this case, the transect is the sampling unit. The transects should be randomly located, and the reliability of the sample will depend on how many transects are measured. The same rules apply for points located by pace transects, wheel point transects, or for point frames where the point frames are individually located. Point frames located at systematic intervals along a transect constitute a subsample of the transect, where transects are the primary sampling unit and frames are the subsample. Use of point frames requires substantially more points for a given level of precision than use of individual points (Grieg-Smith 1964). Technically, the use of several points on each frequency quadrat along a transect is similar to use of a point frame, i.e. the points are not independent of each other and should be considered a subsample. In practice, all the points usually are considered to be randomly located.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of point methods is that no ranking or estimating is required. The only decision to make is defining the hit (for example gravel or bare ground). Therefore, point methods are usually fairly rapid to use. The disadvantages are several. First, a large number of points may be required for statistical reliability (although from a practical standpoint, fewer points may give fairly repeatable results). Second, the objectivity of the method is only as good as the consistency of ground rules used to establish the categories of cover to be recorded. This issue is particularly true for ground cover where personal differences in how to interpret hits on litter, bare soil, gravel, or basal vegetation can lead to major differences in results. Such inconsistency is not desirable for monitoring. Use of point methods to measure canopy cover in herbaceous vegetation is subject to considerable bias or variability under windy conditions.

The "line-point" method (Pellant et al. 2005) is similar to other point methods and most of the discussion above applies. Points are located systematically along a line transect. The transect can be located in approximately the same position for subsequent measurements. Three transects of 50 meters with starting points 5 meters from a central point and radiating out at 0, 120, and 240 degrees are recommended. Points are located at 1-meter intervals, giving a total of 50 points per transect or a total of 150 points. This technique calls for recording multiple pin hits as the pin is lowered through intercepted vegetation to the ground. Lack of repeatability of pin-hit data is a problem with the line-point method, and 150 points are very likely to be insufficient for monitoring purposes.

- ✓ *Other Observations*

Step point transects (i.e. points located by pacing) have long been used for range monitoring and for checking range inventory maps. The procedure involves observing a point, usually a mark on the toe of the boot, to record ground cover, including basal vegetation. Although basal vegetation may be recorded by species, the number of hits on basal vegetation in most range vegetation types will be inadequate to provide a good estimate of species composition. For example, in vegetation with basal cover of 5%, there will only be 5 hits on basal vegetation on a 100 point transect, a number completely inadequate to estimate species composition. For that reason, the "nearest plant" may be recorded by species at each point, thus providing 100 observations on a 100-point transect as a basis for calculating species composition. This technique works fairly well in vegetation where most of the plants are of similar size and life form. However, the nearest plant may be considered as the nearest part of the canopy or the nearest part of the basal area or stem. One attribute is related to cover and the other to density. Therefore, species composition results may vary considerably depending on which definition is used. For example, measuring to the nearest stem or basal area will inflate the percentage of annuals or perennial grasses compared to shrubs. Therefore, the definition of "nearest plant" must be explicit.

Parker Loop Method

The Parker loop method (Parker 1954), used in the Parker 3-Step procedure of the U.S. Forest Service (Parker and Harris 1958, Forest Service 1997), is a variation of the pace point or line point methods described above. It was developed by Kenneth Parker and has been widely used by the Forest Service both for allotment analysis and trend monitoring on permanent transects.

The loop method employs a ¾ inch-diameter loop instead of a point. A plant "hit" is recorded if the plant or any part of it is rooted within the loop. If not, whatever other soil ground cover attribute (litter, gravel, rock or bare ground) is predominant in the loop is recorded. Canopy cover is usually recorded also. Since the loop is not dimensionless it results in an index to cover not a precise estimate as true points do. Parker thought, probably with justification, that the loop gave more consistent results than points (Parker and Harris 1958).

Pace or temporary transects usually consisted of 100 loop readings. These were not intended to be re-measured but only to serve as a check on visual estimates and mapping of range types and condition in allotment analysis. The method lays out a different setup for long-term monitoring—1-3 transects with permanent markers so that transects can be re-located in the same place for re-reading. The number of sample points observed is not sufficient for a reliable one-time characterization, but the relocation of the samples in the same place allows a fairly reliable indication of change over time.

Both pace and permanent Parker transects rely on "nearest plant" for estimates of species "composition," which produces an estimate of composition that is not comparable to composition based on either production or cover (see under discussion of point methods above).

The measurements taken using the Parker Loop Method were used to calculate a vegetation condition score and a soil condition score. The vegetation score was based on hits on basal vegetation, composition of "forage species," "vigor" derived from height measures on key species, and sometimes an adjustment for hits on cool-season species. The different categories were weighted by various factors depending on a scorecard developed for major vegetation types, such a pinyon-juniper, or pine-bunchgrass. These scorecards did not reflect differences in site factors such as soil type, slope, or precipitation zone. A similar process was used to calculate a soil condition score based on hits on bare ground and subjective scoring of erosion indicators. Because these scores do not reflect site differences, and because they involve factor weightings that are complex and subjective, we do not recommend using the scoring system to arrive at a range condition score (see Chapter 18). Parker data are reasonably useful for evaluating trends if only the actual loop hits and nearest plant tallies are presented without modification

Plotless (Bitterlich) Method

The Bitterlich Method (Bonham 1989) was developed to measure basal area of forest trees. It uses an angle gage or prism calibrated for different cover classes. The observer merely counts all tree stems that exceed the angle of sight of the angle gage. The number of trees counted multiplied by a factor will give basal area in square feet/acre or other units.

The method has been used to some extent for basal area of grasses and canopy cover of shrubs (Cooper 1957). However, the difficulty of accurately defining the canopy borders has limited its use in shrublands and there are less time consuming methods that estimate basal cover in grasses. This method has not been shown to be useful for long-term range monitoring.

Mapping Methods

Vegetative cover can be mapped in quadrats or larger plots by use of diagrams, pantograph (for smaller plots), or plane table mapping (for large plants in large plots). These maps are very useful in that not only the cover of individual species is measured, but also the location and size of individual plants. Thus, information on the demography of plants and spatial arrangement can be obtained.

The Forest Service protocols called for mapping of a 3X3-foot plot on each of the Parker trend transects. BLM also used mapping of 3X3 or 5X5 foot plots for trend monitoring. The data provided by these maps is excellent, but drawing conclusions about a larger area is limited by the very small sample size. In other words, there may be excellent documentation of changes in a very small area, but no basis for concluding these changes represent even a local area much less an entire pasture or allotment. However, the maps or photos made of these plots may provide a long-term record that should not be ignored or discarded, and it may be worthwhile to continue data collection (Figure 7-4).

Figure 7-4. Photo of permanent BLM trend plot measuring 3X3 feet in size. Using only 1 or 2 plots of this size at a monitoring location clearly does not represent the entire plant community.

Aerial Photos

Aerial photos (or video imagery) can be used to estimate cover. Since cover is expressed in terms of percentage of the ground surface covered, measurement of cover does not require a determination of scale of the photo as would estimates of density, production, or other attributes.

Ability to discern cover of individual plants depends on the scale and type of imagery, and also on the time of year that photos are taken. Obviously, the larger the scale the more likely it is to be able to identify individual plants by species. Photos taken at large scale (e.g. 1:400 up to 1:1000) may allow fairly accurate identification of grasses or small shrubs, especially in sparse vegetation. Such photos generally must be taken by helicopters or slow moving fixed wing planes. In some cases, radio-controlled unmanned planes or balloons have been used. Groundtruthing of large scale photos can be difficult because of the difficulty of locating the photographed area on the ground, but global positioning system (GPS) technology has now has improved this situation. Photos at scales of 1:10,000 down to 1:40,000 generally only allow identification of individual shrubs or trees that have crown diameters of 5 feet or more, which excludes smaller individuals or smaller species from cover measurements.

Color photos or color infrared photos can help to identify individual plants and differentiate among species. Season of the year when photos are taken can also help identify different species due to differences in growth patterns as in deciduous versus evergreen species.

Aerial photography has practical application for documenting changes in cover of larger shrubs and trees. Continuing development of new technology may increase the value of aerial photography for rangeland management purposes. Satellite and small-scale aerial photography can often show landscape-level patterns of vegetation, weather, fire occurrence, disease outbreaks, or invasive species that allow management decisions at a broader scale than the pasture or ranch.

Vertical Ground Photos

Photographs can be taken on the ground for the purpose of estimating cover. In order to estimate cover accurately, the photographs must be vertical. Vertical photos are difficult to take when standing on the ground. Usually it is necessary to stand on a ladder or suspend the camera over the plot to be photographed using some other device. Various platforms have been devised, including the use of balloons or radio controlled small airplanes. Because of these technical problems, other methods are usually preferable for estimating cover on small areas.

Other considerations in using vertical ground photos are similar to the discussion of aerial photos above, or to the use of photos for other purposes, discussed under the section on Photographs below.

Gigapan Technology

Very high resolution panoramic photography can be used in capturing images of large areas, such as landscapes, while retaining the ability to zoom in and reveal details within the scene. In general, equipment to automate the process of taking a large number of images is expensive. Recently, a new technology for photographing very high resolution landscapes was developed by Carnegie Mellon University and Charmed Labs, LLC in collaboration with NASA Ames Intelligent Robotics Group and with support from Google (Nichols et al. 2009). The system called Gigapan consists of three technological developments: a robotic camera mount for capturing very high-resolution (gigapixel and up) panoramic images using a standard digital camera; custom software for constructing very high-resolution gigapixel panoramas; and, a new type of website for exploring, sharing and commenting on gigapixel panoramas (www.gigapan.com).

Use of the robotic mount for taking photos follows protocols developed for single photo monitoring documentation. A global positioning system (GPS) can be used to determine photo point coordinates. This information should be recorded in a notebook along with date, location, compass bearing, name of photographer and other information sufficient to support re-photographing the site.

This technology offers the unique ability to simultaneously collect landscape panoramas and highly detailed photos of individual plants. In addition, the system uses a standard off the shelf digital camera. Currently the primary uses of Gigapan images are qualitative. Research is ongoing to integrate this technology with rangeland research and management datasets as well as established monitoring programs to improve our ability to manage watersheds and riparian areas, restoration efforts, and livestock grazing.

CHAPTER 34
Density

Abundance Ratings

Density, defined as individuals per unit area, can be rated into classes rather than measured quantitatively. Generally such classes are referred to as “abundance” rather than density, because the exact numbers of plants per unit area are not estimated. Examples of abundance classes would be: absent, rare, occasional, common, abundant, etc. Usually 3-7 classes of abundance are used.

Abundance ratings are useful for general characterization of most vegetation types (for example as notes to accompany photographs) but are not suitable for monitoring.

Quadrats

- ✓ *Brief Description*

The most common way to estimate density is to count the number of individual plants in a sample of quadrats.

✓ *Appropriate Vegetation Types*

Density can be counted in any type of vegetation where individual plants can be distinguished. This requirement limits its use in sod-forming grasses, trailing forbs, and many shrubs that have multiple stems or spread by root sprouts (see Chapter 27, Figure 6-5). In very sparse vegetation the required quadrat size may make this method impractical. In very dense perennial grass (e.g. wet meadows) distinguishing individual plants may be difficult. In that case individual stems or tillers may be counted rather than individual plants. Counting density in dense to very dense tall shrubs or trees is hampered by difficulty of establishing plots objectively. Density is best suited to open to dense stands of single-stemmed low or tall shrubs, like juniper or big sagebrush stands (see Chapter 23).

✓ *Procedures*

Quadrats are usually located by pacing or by placing them at intervals along a line. The number of individual plants (or sometimes stems if plants cannot be identified) rooted within the plot is counted and recorded. Results are expressed as number per unit area (for example plants/square meter or plants/acre).

Selection of proper quadrat size involves questions of sampling efficiency and assumptions for statistical analysis. The proper quadrat size varies with the density of plants. The denser the vegetation, the smaller the quadrat required. If quadrats are small relative to the vegetation density, there will be many quadrats containing no plants or only 1 or 2 plants, and relatively few containing higher numbers. If the number of quadrats containing 0, 1, 2, 3, etc. plants is plotted on a graph, the data will show a distribution highly skewed to the left and tapering off to the right.

This “Poisson distribution” does not meet the assumption of normality required for setting confidence limits or making statistical tests using normal statistics. Selecting a larger quadrat will cause the distribution to become closer to normal with the peak in the middle. If the quadrat is large, there will be many plants in each quadrat, resulting in increased counting time. A quadrat (or belt transect) that contains on average about 7-10 plants will produce a frequency distribution that approximates the normal (Grieg-Smith 1964), and thus we recommend this size or larger.

Each species in a plant community will have a different optimum quadrat size because densities are different. For example, the same quadrat size will not work well for juniper trees and annual grasses. Either select the size to fit the species of main interest or use several different quadrat sizes.

✓ *Recommended Ground Rules*

Count plants as inside the plot if they are rooted within the boundaries. For plants that occur on the edge of the quadrat, count them in if more than half the basal area is inside the plot, and exclude them if more than half is outside. Decisions will have to be made and recorded on how individual plants are defined. For example, bunchgrasses often break into several more or less separate clumps (see Figure 6-4). How much separation must there be before each clump is counted as a separate plant? Similar problems are encountered with some shrubs. How will grasses with stolons or rhizomes be counted? No general rules can be made, but specific rules must be made, recorded and followed when using density for monitoring or comparisons.

✓ *Statistical Analysis*

As indicated above, density data often do not follow a normal distribution and must be transformed before analysis. Taking the square root of each observation reduces the effects of less abundant higher values and makes the distribution more normal in shape. Quadrats may be the sampling unit if they are located randomly. If quadrats are located systematically along several lines, then each set of quadrats may be used as the sampling unit.

✓ *Advantages/Disadvantages - Competing Techniques*

Counting density in quadrats provides a quantitative estimate that requires little training or calibration other than adequate ground rules for defining an individual plant. However, distinguishing individual plants may be difficult to do consistently in many vegetation types.

✓ *Other Observations*

Density counts in quadrats have limited application for most rangeland monitoring.

Belt Transects

Belt transects are nothing more than long, narrow quadrats. All the considerations of quadrat sampling for density apply to belt transects. Since the required quadrat size may be large for counting sparse to moderate stands of shrubs, belt transects offer a fairly easy way to count these plants. Belt transects are usually established by laying out a line of a certain length and then counting all the plants of interest within a certain distance either side (or on one side) of the line. Just walk down the line and use a tape or stick to decide whether plants are within the prescribed distance from the line. Data can be collected quickly and easily if the plants being counted are not too dense. The belt transect can also be used for less dense plants and quadrats along the line for counting the denser ones. The entire transect is the sampling unit, as it is equivalent to a quadrat.

One can make a rough estimate of density by pacing through a stand of shrubs and counting the number judged to be within a certain distance from the paced line. Such density estimates can be useful for mapping or general description, but not for monitoring.

Distance Measurement

Because of the difficulty of laying out large quadrats or belt transects in dense to very dense tall shrubs or trees, distance measurement methods have been developed and used to estimate density. These techniques involve measuring the distance between plants as a basis for calculating density. Density is the number of plants per unit area, so the reciprocal is the mean area per plant. If the average spacing between plants can be estimated, the mean area per plant can be calculated, and from that the density can be derived. For example, if one wanted to know the density of trees in an orchard, you could simply measure the distance between rows and the spacing within the row and calculate the area for each tree. You could then estimate the total number of trees in the orchard if you know its dimensions.

In natural vegetation plants are not regularly distributed as in an orchard. If plants are randomly distributed, distance between plants can still be used to estimate mean area. The formula varies depending on how the distance is measured. Some techniques measure from a point to the nearest plant, some measure the distance to the nearest plant in each quadrant around a point, some measure the distance from the plant nearest a point to its nearest neighbor. The problem is that most of these methods assume plants are randomly distributed. They usually are not, and each species may be distributed differently. Thus the estimate of density may be biased up or down for each species (Bonham 1989).

Even if plant distributions are not normal, one can use density estimates based on distance measurements as an index of density that can be compared across two stands of vegetation or to measure trend over time.

Aerial Photos

It is possible to count some kinds of plants and measure density using aerial photos of known scale. It is necessary to know the scale of the photo in order to relate the number of plants counted to a specific area on the ground. The size of plants that can be identified, and the ability to distinguish different species, depends on the scale of photo, type of image, season, growth form, and spatial distribution of the species, and other features.

Density measurement using aerial photos is generally limited to trees or larger shrubs where individual plants can be readily determined. Using images that pick up different wave-lengths of reflected light (e.g. color IR film) can often help to distinguish different species of plants.

Large scale aerial photos (up to about 1:20000 scale) can be very useful in documenting invasion of coniferous trees or mesquite into grasslands.

CHAPTER 35
Frequency

✓ *Brief Description*

Frequency is the number of quadrats in which a given plant species (or other target) occurs divided by the number of quadrats observed. It is usually expressed as a percentage. It may also be thought of as the probability that a given species will occur in a randomly placed quadrat of a specific size. Like point data, frequency is binomial, as each observation is either a yes or no. Frequency does not exist as an independent attribute that can be measured by several methods as is the case with cover, production or density. Frequency is defined by the method used.

✓ *Appropriate Vegetation Types*

Frequency is not well suited to sparse vegetation of any kind because the required quadrat size is too large to be practical. Nor is it well suited to dense or very dense stands of tall shrubs or trees due to the difficulty of locating quadrats objectively in such vegetation. Frequency has some limitations in very dense annual or perennial grass vegetation (e.g. wet meadows) because it may be difficult to accurately identify all the plants in the quadrat. The measurement is best suited to open to dense stands of annuals, perennial grasses, or low shrubs.

✓ *Procedures*

Selection of proper quadrat size is the most important consideration in using frequency. Frequency is a function of quadrat size for any given species in any given vegetation type. Frequency of a plant species cannot be compared on two areas or over time unless the same quadrat size is used.

Larger quadrats result in higher probability of a species being encountered in a random placement. However, there is no simple linear relationship of frequency to quadrat size. Frequency is related to the number of plants present (density) and their spacing. If plants were located completely at random, frequency could be used to calculate density (Grieg-Smith 1964). Since plants usually occur nonrandomly, frequency is not directly related to density alone. For example, increasing quadrat size from 50X50 cm to 1 meter square will often not increase frequency values significantly (Despain et al. 1997). Quadrats larger than 1 square meter become difficult to use in the field. If a 1 square meter quadrat does not furnish acceptable frequency values for species of interest, it is advisable to use a different monitoring technique (Figure 7-5).

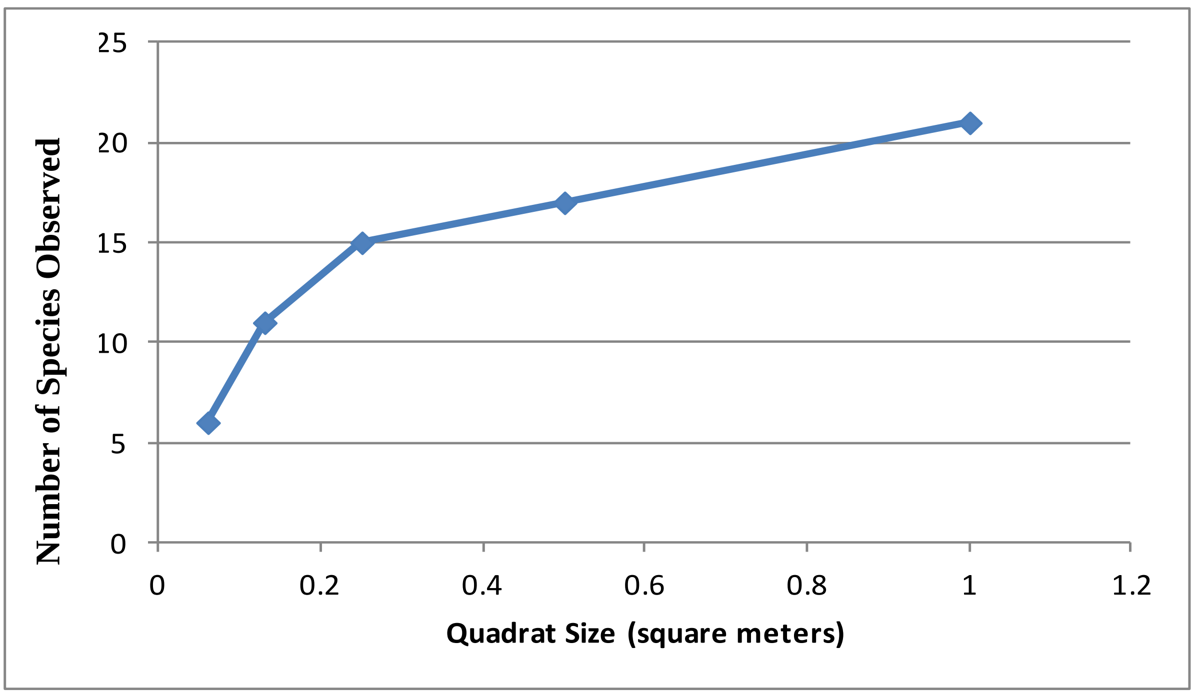


Figure 7-5. The number of species encountered increases as frequency quadrat size increases. However increasing quadrat size beyond .2 square meters (45 X 45 cm) results in relatively few new species. The relationship between quadrat size and number of species encountered will be different in each plant community.

Each species has a different optimum quadrat size, depending on its spatial distribution. Therefore, quadrat size has to be selected to provide reasonable frequency values for the most important species (usually the most abundant or dominant herbaceous plants). If one quadrat size will not furnish desired frequency values for all species of interest, two or more quadrat sizes may be used in a nested fashion (nested frequency). This situation is usually encountered where one or two species are very abundant in relation to others. For example, a quadrat of 10 X 10 cm may provide reasonable frequency values for blue grama, but very low values for all other species. Therefore, a larger quadrat (40 X 40 cm) can be used for all other species. Nested quadrats may be used for sampling in new situations where information on proper quadrat size is lacking. In this case, each species is measured in several quadrat sizes simultaneously and the optimum size can be selected for each species. Recording nested frequency is not difficult since species that occur in the smaller quadrat also occur in each of the larger ones. It is rarely necessary to use more than 2 sizes of nested quadrats. See Interagency Technical Team (1996a) for a good description and a form for recording nested frequency.

Rooted frequency is normally recorded for all herbaceous plants. Canopy frequency may be recorded for shrubs because rooted frequency for these species is often very low. Canopy frequency may be more related to species importance in the community and provide better data on trends in both number and cover of shrubs. For small shrubs or half-shrubs either rooted or canopy frequency or both can be used, but the same procedure must be used each time.

Frequency is only useful for comparing one species on different areas or over time on the same area (trend). Comparing frequency among species, especially where they are of different size, does not provide useful information (see discussion on density above). Also, the frequency of several species should not be added together or used to calculate composition (relative frequency) for comparison to a standard or reference area. If information on different age or size classes within a species (e.g. seedlings vs. mature) is desired each must be treated as a separate species. The two classes cannot be added together later to arrive at total frequency for that species unless the data are recorded separately for each quadrat observed. An alternative is to record seedlings, mature, and total to start with.

Rooted frequency is related to density and distribution of plants, and canopy frequency is related to amount and distribution of canopy cover. Frequency is not directly related to cover, production, or other attributes of vegetation in the sense that if frequency doubles from 20% to 40% it cannot be assumed that cover, production, or density of plants has also doubled. All of these attributes have probably increased, but it cannot be assumed that they have doubled.

- ✓ *Recommended Ground Rules*

Rooted frequency is recorded if any part of the basal area of the plant falls within the quadrat. Canopy frequency is recorded if any part of the outline of the canopy of a plant overhangs the quadrat, regardless of where it is rooted. The appropriate quadrat size for a given species should result in average frequency estimates between 5% and 95% or, preferably, between 20% and 80% for statistical reasons. Frequency values of less than 5 or more than 95% are of little value for making comparisons or detecting change (Despain et al. 1997). If one quadrat size will not provide such estimates for all species of interest, use multiple quadrat sizes (nested quadrats) and select an appropriate quadrat size for each species.

- ✓ *Statistical Analysis*

Frequency data follow a binomial distribution because the data recorded involve a yes or no decision on each quadrat. If all quadrats are located at random, statistical tests and confidence intervals may be based on binomial tables. The confidence interval is a function of the percentage frequency, the sample size, and the desired probability level. The optimum frequency value for statistical comparisons is between 20% and 80% frequency. Confidence intervals for values higher or lower than this may be questionable because the frequency distribution about the mean value is skewed to one side or the other (because frequency cannot have values < 0 or > 100). Values below 5% or above 95% are not suitable for statistical tests.

Frequency may also be determined by transects composed of several quadrats. In this case, each transect provides one estimate of frequency, and the transects, therefore, are the sampling units. If the transects are located at random, normal statistics may be used for statistical tests. Since frequency data are percentages, arc-sine transformation may be desirable (Grieg-Smith 1964, Bonham 1989).

Theoretically, the optimum number of transects and number of quadrats per transect can be established to provide the best precision of the estimate of frequency. In Nevada, a recommended number of transects and quadrats per transect was recommended for each major vegetation type (Swanson 2006). However, since each species in a plant community differs in both density and spatial distribution, it seems that each species would have a different optimum combination of numbers of transects and quadrats and therefore we do not think it is useful to make recommendations for each vegetation type.

Since it is practically impossible to locate all quadrats completely at random (as the use of binomial statistics requires), two methods have been used to establish quadrats. One, sometimes called the "quadrat frequency method" (Interagency Technical Team 1996a), is to establish a baseline with a measuring tape and lay out transects perpendicular to the base line. In this case the transect locations can be randomized, but the quadrats are located (usually by pacing) systematically along each transect. Typically 10 transects of 20 quadrats are used to provide a total of 200 quadrats. If the data are analyzed using transects as the sampling unit, there will be a sample size of 10. Precision of the sample would probably be increased by using 20 transects of 10 quadrats, although the time required may be increased. Further reduction in the number of quadrats per transect would not be desirable because the variability among transects would be increased.

The second way, sometimes called the "pace frequency method" (Interagency Technical Team 1996a) is to establish a baseline and run several transects parallel to it on one or both sides. In this case, transects are located a set distance apart and the quadrats located at set pacing intervals along the transect. Typically, 4 transects of 50 quadrats have been used, producing a total of 200 quadrats. In this case, neither the transects or the quadrats are located at random. Using transects as the sampling unit would not be appropriate due to lack of randomization, and also because 4 transects is a completely inadequate sample size. Usually, the binomial tables are used to set confidence limits and perform statistical tests when this layout is used.

If it is important to strictly meet statistical assumptions in the analysis and interpretation of frequency data, we recommend the first approach, establishing transects at random along a baseline and analyzing the data with normal statistics using transect values as sampling units. However, in our experience usually 25-30 transects (number of quadrats has little effect) per sample are required to obtain the same level of precision as using 200 quadrats and applying binomial statistics (Despain 2008).

Therefore, we recommend using the total number of quadrats in the sample as the sampling unit and applying confidence intervals and statistical tests using the appropriate table of binomial statistics. In this case the confidence interval around the estimate depends only on the frequency value and the sample size. This approach assumes that each quadrat is selected at random. Although the randomness assumption is not necessarily met in either of the sampling schemes described above, it can be met if quadrats are selected so that the occurrence of a species in a given quadrat is independent of its occurrence in the adjacent quadrats (Grieg-Smith 1964, Yavitt 1979).

If quadrats are located close together successive quadrats may land in the same clump of vegetation. In that situation it is more likely for the same species to occur in successive quadrats than if the quadrats are located entirely at random. The assumption of randomness (or independence of observation) is not met and the quadrats need to be more widely spaced. For example, plains bristlegrass tends to occur mainly under the canopy of mesquite on the Santa Rita Experimental Range, therefore placing 2 consecutive quadrats under the same mesquite tree will be more apt to result in 2 occurrences of plains bristlegrass than if the quadrats were placed at random in the community. In this case, quadrat spacing should exceed the canopy diameter of mesquite. Of course, every species has its own spatial pattern of distribution so it is practically impossible to arrive at a spacing that is optimum for all species.

We recommend that quadrats and transects be spaced as widely as practical while recognizing the need to confine the sampling to a uniform area (Heywood and DeBacker 2007). A general guide would be to space transects 10-20 feet apart and quadrats 5-10 feet apart as a minimum. This spacing would probably meet an assumption of randomness for most species in most vegetation types, unless very large patches of vegetation are apparent. By following this procedure, there is a good chance of meeting the assumption of randomness that will justify the use of binomial tables for the statistical analysis.

Finally, if statistical tests are important, we recommend the use of 200 quadrats at a sample location to achieve statistically valid precision. Our practical experience has shown that good repeatability can be achieved with 100 quadrats, but the statistical power to detect change will be reduced. If monitoring is to assist management decisions in a non-litigious environment, it may be preferable to sample more locations and only 100 quadrats apiece.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The main advantages of frequency for monitoring are its objectivity and repeatability. All that is required is the ability to identify species and decide whether it is in the plot or not. No estimates or measurements requiring training are necessary. Because observations on an individual plot take a short amount of time, it is possible to sample a large number of plots that cover a large total amount of ground. Thus, frequency measurements are repeatable and relatively lacking in observer bias. These characteristics are important for methods designed to detect change over time with successive measurements often taken by different observers.

In most plant communities a few species (usually about 5-10) will make up a majority (85-95%) of the plant cover or production, even though 25-40 species may actually be present. Individual plants of these "minor" species may be fairly abundant in the community but due to small size their collective contribution to cover or production is small. In this case, cover and production estimation methods will not provide a reliable measure of these minor species unless very large samples are taken. However, frequency is related to density, and these species may have frequency values that are adequate for performing statistical tests. If the minor species are rare in the community, i.e. only a few plants occur in the sampling area, then most methods, including frequency, will not provide meaningful data on their occurrence unless samples are extremely large.

Frequency values for different species cannot be added or combined to arrive at a "score" for the community. Some consider it a disadvantage that each species has to be separately considered. But it can also be an advantage since such composite scores (such as similarity indices) often obscure the nature of changes that occur.

Frequency does not measure cover, production, or density, and it should not be used to try to make inferences about these or other vegetation attributes. Frequency sampling can easily be adapted to include point data for ground cover, dry-weight-rank for weight-based species composition, and/or comparative yield for standing crop estimates if this information is needed. The quadrat size appropriate for frequency will also serve for dry-weight-rank and comparative yield.

- ✓ *Other Observations*

Some have stated that frequency is sensitive to increases in species, but it is not sensitive to declines. They reason that the value of frequency monitoring in the early detection of undesirable change is reduced. Rooted frequency is related to both density and distribution of plants of a given species. Frequency would therefore increase if new plants become established, especially if those new plants resulted in more even spatial distribution. Likewise, frequency will decline if mortality occurs, especially when it results in a patchier distribution of the remaining plants. Rooted frequency is less sensitive to changes of the basal area of plants than in the number of plants. Critics claim that plant size and productivity can decrease due to overgrazing with little change in frequency, and monitoring frequency does not provide an early warning of decline in range condition or health.

While it is true that basal area or productivity of individual plants can change without affecting its frequency, we believe this argument overlooks several other considerations.

First, this concern would apply only to those plants where a change in basal area of individual plants is relevant, for example bunchgrasses, rather than forbs, annuals, some sod-forming grasses and shrubs measured by canopy frequency.

Second, resistance to change due to seasonal or short-term weather cycles is an advantage for long-term monitoring. Canopy cover and production are susceptible to these short-term cycles (which is why basal area is generally preferred over those attributes for monitoring), but basal area can also be affected. For example, reduction in the number of live tillers (reduced basal area) of a perennial grass due to weather can be reversed quickly when favorable conditions return and does not necessarily indicate range degradation.

Third, the recognition that increases in plant distribution will be better reflected by frequency data than by cover or production is important. Frequency measurements detect increased distribution of all plants and can detect potentially increased cover and production of undesirable as well as desirable species.

Finally, the frequency for plants with good watershed protection value can be a useful indicator of both improvement and deterioration of soil protection, since data describe the spatial pattern of occurrence of these species.

No one attribute, including frequency, can meet all needs for rangeland monitoring equally well. The advantages of objectivity, rapidity, and repeatability make frequency a desirable method for routine monitoring of rangeland trends in many types of vegetation, particularly where annual or perennial grasses, forbs, and low shrubs are the main species of interest. It does not work well in very sparse vegetation and may be time consuming in very dense vegetation where species identification is difficult.

CHAPTER 36
Community Type Method

Application of many of the quantitative vegetation sampling methods used in upland plant communities is difficult in some riparian meadows. Riparian vegetation often forms a complex mosaic of small communities that result from the interaction of biotic and physical factors such as depth to moisture, age and pattern of sediment deposition, extent of flood disturbance, and time since the last disturbance (see Chapter 11). This heterogeneity makes it difficult to locate line transects or pace transects within a uniform type. Also, dense vegetation that usually grows in riparian types makes some of the upland procedures time consuming and subject to error. It is difficult to differentiate cover or density of individual species among close growing, often rhizomatous grasses and sedges, and it is also easy to overlook certain species.

Rather than attempt to describe a “community” that is in fact a mosaic of vegetation, another approach is to characterize the proportions of the large area composed of each community type (Winward 2000). Community types are classified based on prominent species and/or life forms. In this approach, a transect is run by pacing or placing a line across the area to be monitored. At selected intervals the community type is noted based on the most prominent species in the community. Data on community types are summarized as the percentage of each community type in the location. Trends can then be determined by measuring differences in these proportions over time or in comparing two areas at one time. The management objective may be to encourage certain community types (e.g. those composed of species with good soil binding capability) or to maintain a high diversity of types if that state is thought to have ecological or resource value.

This method requires developing a community classification system; community types have to be identified before their occurrence can be documented (Figure 7-6). This exercise is fairly easy for a local area using *ad hoc* observation. Community types can be documented with photographs or species lists, but it is more desirable to have community type classifications developed and published for standardized use over a larger area which allows for the development of guidelines or resource information linked to the various types or proportions of types that will facilitate setting objectives and interpreting results. Such classifications have been developed in some areas, but are not common everywhere (Youngblood et al. 1985, Manning and Padgett 1995). This approach is rapid to apply and will give repeatable results.

Type #	Community Type	Ungrazed	Elk Only	Cattle & Elk
1	Kentucky Bluegrass Sod	6.3%	43.3%	34%
2	Kentucky Bluegrass & Mixed Grass & Sedges	13.2%	30.7%	52.5%
3	Tufted Hairgrass & Mixed Grass & Sedges	22.2%	20.7%	10.6%
4	Sedges Dominant	58.3%	5.3%	2.9%
Total		100%	100%	100%

Figure 7-6. Example of a simple community type classification used to compare community composition in an exclosure ungrazed by cattle or elk for 10 years, a cattle exclosure grazed by elk, and a pasture open to both cattle and elk in a mountain meadow in Arizona. The data are percentages of each type occurring in quadrats (40 X 40 cm) observed in pace transects run perpendicular to the stream with about 200 quadrats in each area..

CHAPTER 37
Prominence Rating Method

Prominence rating is a method for characterizing vegetation where other methods are too tedious and time consuming (see Chapter 23). This procedure can be used for an entire stand of vegetation, or it can be applied to a series of locations within a vegetation type or mapping unit. Data obtained are qualitative, but may suffice for general vegetation description. This approach was developed by Charles Poulton and his graduate students (Schrumpf et al. 1973). He used “prominence” rather than “dominance” because it avoids the implication that the species are necessarily dominant in an ecological sense (Grieg-Smith 1964). The rating scale he used was:

5 = the most prominent species in the stand. Only one species can receive a 5.

4 = assigned to two or more species that are equally most prominent. If 4 is assigned, there will be no species that receives a 5

3 = species that are common and easily observable, but not the most prominent. Any number of species can receive a 3

2 = species that are not prominent in the vegetation but can be observed by careful observation from a given point.

1= species that are rare and usually cannot be seen from a given point, i.e. the observer may have to walk around through the area to detect these species.

These ratings can be applied to all species in a vegetation type regardless of life form. However, our experience has shown that it may be better to rate each vegetation layer separately. Since shrubs are generally more “prominent” due to larger size, the interpretation of prominence is more complicated when greatly different life forms are present. The most useful application of this method may be to rate shrub prominence in dense to very dense shrub stands where other methods of measuring species composition are difficult to carry out.

Prominence rating is not a monitoring method, but it can be used to help stratify sampling, map vegetation, or describe vegetation at a photograph station.

CHAPTER 38
Structure/Pattern

Fetch Method

✓ *Brief Description*

An index to the pattern of ground cover can be provided by measuring fetch (Tongway 1994). This term is used to describe the distance between plant bases or the distance from a point to the nearest plant base. The average distance is an index of plant spacing, while the frequency distribution of different fetch lengths indicates variability in plant spacing (Kuehl and McClaran 2001). Information about plant spacing helps determine effectiveness of ground cover in protecting soil from erosion due to overland flow.

✓ *Appropriate Vegetation Types*

Fetch can be measured in almost any type of vegetation, but is most amenable to interpretation in open to dense perennial grass or low shrubs. Fetch may not have much meaning in sparse vegetation because plant cover is not great enough to have much effect on water flow. In very dense perennial grass or shrubs, plant basal cover also may not have much relevance to site stability.

✓ *Procedures*

Fetch (or interpatch distance) may be measured as the distance between patches of plant basal cover along a line intercept transect (Tongway and Hindley 2004). In this case, refer to description of the line intercept method .

Fetch is more commonly measured as the distance from a point to the nearest plant base (see Chapter 27). The point may be located by pacing, or by selection of a point on a quadrat used for frequency or other data collection. The distance can be measured in any direction from the point, or only within a 180 degree arc along the line of travel. Distance is measured to the nearest rooted stem of small, single-stemmed plants or to the nearest portion of the basal area of a perennial plant (Figure 7-7). Annual plants are not generally included since their presence varies greatly seasonally or annually, and therefore annuals are not very reliable indicators for trends where perennial plants are important species.

✓ *Recommended Ground Rules*

Measure distance to the nearest portion of the rooted base of the plant. This rule means that bunchgrasses are measured to the edge of the bunch, not to the center, and sodformers to the edge of a patch of grass. The rule adopted for direction of the measurement from the sample point should also be recorded.

✓ *Statistical Analysis*

Fetch distances can be analyzed by computing means and confidence intervals. The frequency distribution of fetchlengths may yield more information regarding plant pattern (Kuehl, McClaran and Van Zee, 2001).

✓ *Advantages/Disadvantages - Competing Techniques*

The fetch method provides an objective and quantitative indicator of size of areas between plants and can be used to distinguish randomness and fragmentation of basal cover in a community (Kuehl , McClaran and Van Zee, 2001). It is nothing more than an index that may be used to compare two communities or the same community over time unless research studies have established site-specific standards or thresholds for interpretation purposes. In this regard, fetch is not different from the gap intercept method (Herrick et al. 2005) or the interpatch measurement (Tongway and Hindley 2004). However, fetch measurement is much faster than either of the other techniques and can be combined with quadrat or line methods used to characterize other attributes.

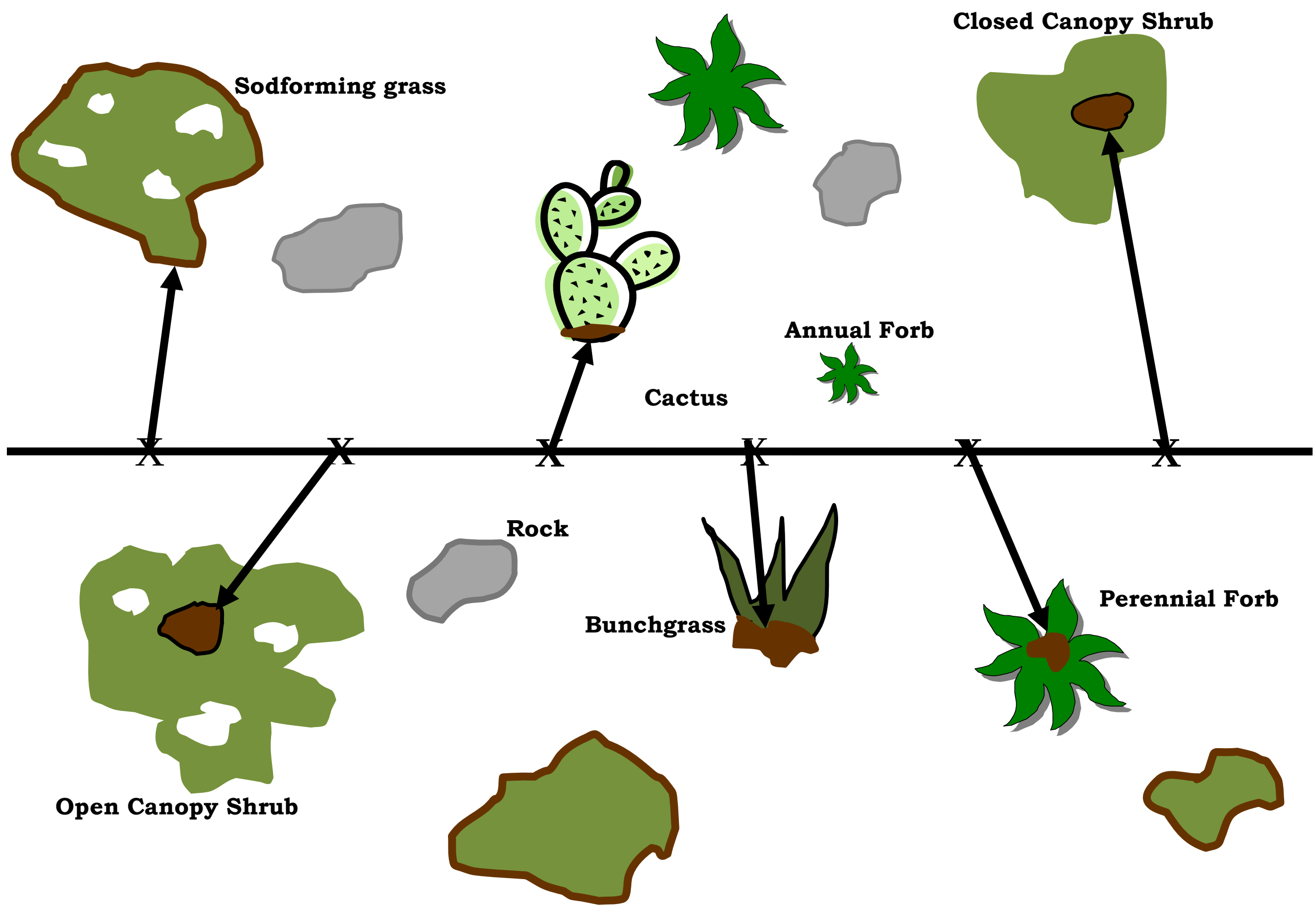


Figure 7-7. Fetch is measured from a sample point (X) to the basal area (outlined in brown) of the nearest perennial plant in any direction. Rocks and annual plants are not considered.

Gap Intercept Method

✓ *Description*

The gap intercept method is included in the monitoring manual developed by the Agricultural Research Service (Herrick et al. 2005) and recommended for collecting quantitative data to evaluate several rangeland health indicators (Pellant et al. 2005). This procedure involves measuring the distance between the bases of perennial plants along a 50-meter line intercept transect. Only distances in excess of 20 cm are measured (although that requirement may be modified for specific situations). The total length of gap intercept is expressed as a percentage of the line length for each of three transects on a monitoring site. The ARS manual provides detailed instructions for ground rules, data recording and analysis.

✓ *Advantages/Disadvantages – Competing Techniques*

Agricultural Research Service says this method needs only 0.4 hours per location. Our experience indicates it takes considerably more time. Time required may vary depending on vegetation type, especially where the presence of gaps >20 cm is low, or where very large gaps are present. The direction to measure only gaps >20 cm seems somewhat arbitrary; although it is reasonable that smaller gaps would not have much effect on water flow over the surface. The manual provides that this rule can be modified if desired. This method appears to provide an objective and quantitative measurement of gap size and/or percentage of larger gaps and thus provides an index to soil protection. As is the case with fetch (see above) it is only an index that can be used to compare two sites or the same site over time unless research has provided site-specific guidelines for assessing the value of different levels of gap size. The fetch method described above seems to be faster and equally useful.

Visual Obstruction Rating (VOR)

- ✓ *Brief Description*

The most commonly used technique to measure visual obstruction is the Robel Pole (Robel et al. 1970, Bureau of Land Management 1996, Interagency Technical Team 1996a). This technique involves observing a graduated pole from a standard distance and height above the ground. The lowest graduation (poles are generally graduated in inches or centimeters) that can be seen is recorded as an index of the height, thickness, and spacing of vegetation. With this method, the shorter the vegetation, the less dense the canopy, and the wider the spacing (on average), the closer to the ground the observer can see graduations on the pole. The method has been used to estimate total above ground biomass in some grassland types. Biomass estimation involves developing a regression equation that predicts biomass from the pole reading (see Chapter 27).

- ✓ *Appropriate Vegetation Types*

Robel Pole appears to have value mainly in open to dense annual or perennial grasslands, and possibly in grassland with a low shrub component (see Chapter 23). It is questionable whether VOR measurements can be used to estimate production on rangelands where there is considerable cover of shrubs, cactus, and rocks as is the case on many western ranges, because the relationship of biomass to pole readings would be highly variable among different growth forms.

- ✓ *Procedures*

Within the area to be sampled, locate poles systematically or randomly. The usual practice is to place poles systematically along a straight line transect. The beginning point of the transect and the direction of travel can be randomized. At each pole location take one or more readings at pre-determined distance, height, and direction from the pole. Often two readings are made on opposite sides of the pole, or four readings on each quadrant of the pole.

- ✓ *Recommended Ground Rules*

It is essential to specify both the height of the observer's eye and the distance from the observer's eye to the pole, since these distances determine the readings obtained. Interpretation of change over time as well as any correlation with plant production or wildlife habitat values depends on these relationships being constant. Also, it is important to note whether the height recorded on the pole refers to the first full segment that can be seen or the first segment that is partially obscured.

- ✓ *Statistical Analysis*

Each pole reading can be considered a sampling unit if only one reading is made per pole. Technically, the pole locations should be randomized but, as explained for some other pace transect procedures, this requirement is often not followed for practical reasons. If several transects run through a sampling area, the mean pole reading for each transect could be considered the sampling unit. In this case the transect locations should be randomized. Several readings taken on each pole constitute subsamples, because the different readings on one pole are not independent.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of the Robel pole technique is that it requires little training and can provide a large number of readings in a short time. The main disadvantage of the method is that the data have little meaning without studies that correlate the readings with some value of interest such as biomass production, nesting cover for quail, or other resource values. With proper adherence to ground rules this method should provide repeatable results over time and among observers, although we found no studies of such repeatability.

- ✓ *Other Observations*

The Robel Pole method can provide a quantitative index to vegetation structure, at least in grassland types. Like frequency, the results are dependent on the protocol adopted and the values obtained cannot be interpreted directly into resource values without site-specific studies to establish such relationships. Pole readings can provide an index for comparison in time or space.

Foliage Density

Another type of visual obstruction measurement is to record the distance a target can be seen through vegetation canopy at various distances above the ground. This technique has been used in riparian forest vegetation to evaluate bird habitat. It is not a routinely used range monitoring technique (Anderson and Ohmart 1986, Bureau of Land Management 1996)

Age or Form Classes

Distribution of age classes is an indicator of the age structure of plant populations. Age class distribution can indicate whether, or how often, reproduction is occurring for a given species (see Chapter 24).

Age class cannot be reliably determined for herbaceous plants because, by definition, the above ground portions of these plants remain live only one season. Age class of some woody species can be determined by evaluation of annual rings. However, age class of woody species generally is subjectively estimated based on plant size. For example, trees may be classified as seedling, sapling, young, mature, decadent, or dead. Data on cover, density or other attributes may be collected by age or size classes if the additional time is considered to be worth the effort.

Management decisions based on age or size class data should be made cautiously, since the distribution of classes may relate more to the ecology of the species or the episodic nature of reproduction than to management influences.

CHAPTER 39
Photographs

- ✓ *Brief Description*

Photographs are commonly used to document resource conditions, to supplement other data, and/or to show changes over time. Unless taken from vertically above it is difficult to make quantitative measurements on photos. However, photos can indicate cover, density, height or other attributes of vegetation and may provide qualitative evidence of species changes. This discussion will focus on repeat photography intended to show trends in vegetation.

- ✓ *Appropriate Vegetation Types*

Use photographs in any vegetation type. Their effectiveness is limited in dense to very dense stands of tall shrubs or trees because it is difficult to obtain a general view perspective in this type of vegetation. They are a particularly helpful tool for documenting increases or decreases in shrubs or trees in grasslands.

- ✓ *Procedures*

Photos are now nearly always taken with digital cameras. For long-term records hard copy may be less subject to loss or corruption than images stored on computer disks. Images should be stored in both hard copy and digital formats. Color film is almost always more useful than black and white.

General views taken to document the vegetation type and appearance are the most common type of repeat photos. Record the location and direction of the photo using GPS coordinates and other data. If possible mark the location on the ground also by driving a stake or making a pile of rocks. It is also helpful to record the compass bearing of the direction of the photo. General view photos should include a recognizable feature in the landscape if possible—a distinctive hill on the skyline, a large rock, or a prominent tree (see Figure 7-8). These features are useful not only for relocating the photo point but also to prove that the photo was taken in the same place. Riparian areas are tricky because shrubs and trees can grow up in a short time and completely obscure any landmarks in the photo. The possibility of losing a reference point should be considered when photographing relatively open riparian types that have the potential to become very dense (see Figure 7-9).

Close-up photos show ground cover and sometimes allow identification of herbaceous species. Close-up photos show only a small area on the ground and therefore are of little value for monitoring unless they can be re-located accurately. Therefore, it is desirable to use a plot frame or string to define the area photographed, and to mark the corners of the plot with stakes so that the frame can be re-located.

Figure 7-8. The peak on the horizon and large rocks at beginning of transect help re-locate this photo.

Figure 7-9. This photo documents the current condition of this riparian area but if the young willows grow 20 feet high they will obscure everything else in the photo.

Ability to distinguish plant species in photos will vary greatly depending on the type of vegetation, time of year, and amount of grazing that has occurred. We recommend taking notes on the species composition and/or ground cover. A list of species present, an estimate of the composition by species or life forms, an estimate of ground cover, or other comments may help someone interpret the photo at later date and compare changes over time. If the photos are taken in conjunction with collection of monitoring data, then the data provide good information on what the photo shows.

Each photo should show a board with the location and date of the photo on it. The writing should be large enough to be legible in the photo. Some cameras have the date imprinted on the image, and these are recommended for monitoring purposes. It is also useful to document the type of lens, film type, resolution for digital cameras, and time of day the photos were taken. This information will help provide comparable repeat photos.

- ✓ *Recommended Ground Rules*

The ground rules consist of documenting the procedures (location, direction, film type, etc.) described above.

- ✓ *Statistical Analysis*

Photos do not usually provide quantitative data suitable for statistical analysis. Change in area over time should be detectable in photos taken from above.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The main advantages of photographs are that they require very little time and expense and provide a record of conditions on a specific date and place. Photos are not necessarily unbiased because one can select locations or views that may give a distorted view of the general situation. However, bias and lack of integrity will invalidate any type of monitoring. The main disadvantage of photos is lack of quantitative data that can be analyzed statistically to detect trends. Photos are highly recommended as a minimal level of monitoring when used alone, and as a valuable addition to almost any other type of data collection.

- ✓ *Other Observations*

Despain (2010) analyzed a large set of monitoring data, including repeat photography, collected by the Bureau of Land Management in the Arizona Strip over a period of 30 years or more. He observed that repeat photography often gave a very misleading impression of actual vegetation change when compared to the quantitative measurements of species frequency or cover. The photography was highly influenced by current weather (wet and dry years), time of year (growth stage), and current grazing levels. His observations do not discount the value of photographs but only serve as a warning that photos must be interpreted with caution.

CHAPTER 40
Utilization

Harvest Method

- ✓ *Brief Description*

The harvest method involves estimating the standing crop of annual production of forage plants in grazed and ungrazed plots. The difference in weight divided by the weight of the ungrazed plots is the estimate of utilization.

- ✓ *Appropriate Vegetation Types*

The harvest method is suited for dense to very dense annual or perennial grass vegetation. It is not suited to sparse herbaceous vegetation or for shrubs and trees (see Chapter 23).

- ✓ *Procedures*

The procedures followed are the same as for the harvest method described in Chapter 32. In this case a set of quadrats is clipped, dried, and weighed in an ungrazed area, and the estimated mean compared to another sample in a grazed area. The ungrazed area must be comparable to the grazed area, and should not have been excluded from grazing for more than the current year. In other words, a long-term exclosure or other protected area cannot be used, because these areas do not reflect the expected annual or seasonal production on the grazed area.

Cages or temporary exclosures may be used to establish the ungrazed situation. Cages have been found to affect the growth of plants (Cowlishaw 1951, Heady 1957, Owensby 1969). The effect is usually positive but has been negative in some situations. This "cage effect" can affect the calculation of utilization (Figure 7-10).

Since production sampling in quadrats is highly variable, it is often not possible to obtain sufficient sampling units of both grazed and ungrazed situations to make valid comparisons. In other words the sampling variation may obscure any difference due to grazing. For this reason, when cages are placed prior to the growing season, the caged plot can be paired with another plot chosen to have similar species composition and plant cover. Several unprotected plots may be selected for each protected one. This paired-plot approach provides a better comparison of grazed and ungrazed plots. It does not necessarily provide a good estimate of production since paired plots may not provide a representative sample of the stand.

Sampling before and after grazing is another way to make grazed versus ungrazed comparisons. This method works only if the current year's growth is complete when grazing starts, or where grazing periods are so short that growth during the grazing period can be considered negligible. This approach is usually not feasible in most rangeland situations.

- ✓ *Recommended Ground Rules*

See harvest method under estimating weight for ground rules.

- ✓ *Statistical Analysis*

Statistical analysis involves a comparison of the ungrazed mean with the grazed mean standing crop. If paired plots (grazed and ungrazed) are used to facilitate comparison, statistical analysis must recognize that randomness has been compromised.

Figure 7-10. Example of a utilization cage. There is no utilization outside the cage and it appears that plant growth is better inside the cage. Cages should be sturdy as animals will rub on them.

✓ *Advantages/Disadvantages - Competing Techniques*

The harvest method provides a direct measurement of utilization by weight, so it does not require estimation or calibration as many other utilization methods do. However, its disadvantage is that the necessary sample size for making valid comparisons is rarely feasible to attain. Usually caged plot comparisons will require 10-30 quadrats in both grazed and ungrazed situations which means an excessive number of cages and extensive sampling time. Therefore, this method is not recommended for most range monitoring situations.

✓ *Other Observations*

With small samples and light levels of utilization, especially where small plots are used, it is entirely possible to obtain "negative" utilization. In other words the sampling lacks sufficient precision to detect the level of utilization that has occurred.

Visual Estimation

✓ *Brief Description*

Visual estimation involves clipping and weighing individual plants until the observer gains some proficiency in estimating percentage utilization by weight, then estimating utilization based on visual observations only.

✓ *Appropriate Vegetation Types*

This approach is suitable for perennial grass and for shrubs where the current growth is easy to identify.

✓ *Procedures*

The key to this method is training. The observer estimates the percent utilization by weight on a clipped plant of a certain species and then checks the estimate by weighing the clipped portion and the remaining portion of the plant and calculating the percent utilization. This procedure is continued until the observer feels confident of his ability to estimate use on each species of interest. The estimates are based on field weights, not dry weights. Therefore, the training has to be repeated whenever the moisture conditions change. This may not be a major problem if utilization is estimated after the end of the growing season when forage is fairly dry (see Chapters 27, 30).

Once the training is complete, utilization on each species in a series of quadrats may be estimated to provide an overall utilization figure for the area. More commonly, this method is used only to train the eye for utilization mapping purposes, or for correcting production estimates for utilization. In the latter case, the objective is to estimate total production as if it had not been grazed. If grazing has occurred, then the observer can estimate percentage utilization and use the estimate to adjust forage weights.

✓ *Recommended Ground Rules*

Same as for weight-estimate method of forage production (see Chapter 32).

✓ *Statistical Analysis*

The sampling units are either individual plants of one species, or the average of one species within a quadrat, depending on how the estimates are made. Statistical analysis can account for variability in the sample, but cannot describe bias (consistent errors) on the part of the observer.

✓ *Advantages/Disadvantages - Competing Techniques*

With adequate training, this method may help improve forage production estimates. It is also useful to train people to estimate utilization. It is not recommended as a quantitative utilization method because there is no check on the skill of the observer.

✓ *Other Observations*

Experienced people can often make remarkably consistent estimates with sufficient preliminary clipping and weighing to calibrate estimates. Such estimates are adequate for documenting the general level of utilization or mapping use patterns.

Residual Biomass

Estimating residual biomass is the same as estimating standing crop, and similar techniques may be used such as the harvest, calibrated weight estimate, or comparative yield. In this case, the standing crop is the plant material remaining after grazing. Either all plants or only forage plants can be estimated. As with any estimates of standing crop, a fairly large sample is usually required (see Chapter 32).

Stubble Height Method (Residual Height)

✓ *Brief Description*

The stubble height method is another approach to measuring residual plant material as an alternative to utilization. It involves measuring the average height of grazed and ungrazed plants on a key area or other area. The method probably should be called "residual height after grazing" since both grazed stubble and ungrazed plant heights are measured.

✓ *Appropriate Vegetation Types*

Stubble height is used in perennial grass and annual vegetation types. It is not suitable for shrubs and trees.

✓ *Procedures*

Measure height on a sample of plants from a single key species, several key species, or all forage species. Plants to be measured are usually selected by pacing a straight line and choosing the plant closest to the toe. Measure plant height on all individual plants encountered of the chosen species–on both the grazed stubble and ungrazed plants.

Height can be measured in several ways. On ungrazed grasses height of the tallest seedhead or height of the tallest basal leaves may be measured. On grazed plants the height is usually recorded as the average leaf height (average of both grazed and ungrazed leaves on the plant). The height is usually measured to the nearest ½-1 inch or the nearest centimeter.

If stubble height is being measured as an index of grazing effects on the physiology of key forage plants, then only the forage plants of interest should be measured. If the interest is to provide an index of remaining soil cover, plants available for wildlife forage or habitat, or sediment trapping potential on floodplains, then measure all plants useful for those purposes, whether they are forage plants or not. The plant species measured and the reasons those were chosen should be well documented.

✓ *Recommended Ground Rules*

Since some plants may not produce seedheads (depending on species, site, weather) measuring tallest seedheads may produce data that vary in ways that are not necessarily related to grazing pressure. If height of tallest leaf is used, specify whether leaves located on flowering culms are considered or only basal leaves. Using leaves on flowering culms may have the same limitation as measuring height of seedheads, therefore use of basal leaves is recommended. On a given grazed site, leaf height measurements should include grazed and ungrazed leaves (if any exist). For bunchgrasses where a portion of the plant is grazed and part is ungrazed, this determination requires the observer to make an estimate of average leaf height remaining. This estimate is straightforward on grasses where individual plants are easily identified, but may be more complex on sodformers or some bunchgrasses (such a blue grama) where individual plants may be difficult to consistently discern. In this case, an additional rule is needed to specify how an "individual" plant will be defined for the purpose of averaging grazed/ungrazed-area leaf heights. Leaf heights should be measured to the nearest ½ inch on leaves less than 10 inches off the ground, but may be measured to the nearest inch on taller leaves. More detailed measurement does not provide "better" averages because it is not possible to consistently define the attribute measured more precisely. Improved precision of the estimated average value should be obtained by measuring more plants, not by measuring to the nearest 1/8 or ¼ inch on each plant (see Figure 3-10).

✓ *Statistical Analysis*

The sampling unit is normally the individual plant measured. While usually not random observations, they are often treated as such for statistical calculations.

✓ *Advantages/Disadvantages - Competing Techniques*

The main advantage of stubble height measurement is that it involves measuring only what can be seen (as opposed to what is not there anymore). It does not require assumptions about growth forms or relationships of measured values to utilization. Stubble height in any given year is affected not only by utilization but by the amount of growth produced in that year. For example, in a dry year, the stubble height may be lower in an ungrazed situation than it would be in a wet year with grazing. This factor must be considered in interpreting the data.

✓ *Other Observations*

Provided adequate ground rules are established, the stubble height or average leaf height method is probably the most objective one to use in a variety of situations. It requires neither calibration nor validation of assumptions about converting measurements to estimates of utilization by weight. Documenting stubble height at the end of grazing periods or the end of the grazing season can be useful to plan future grazing use. Guidelines to acceptable stubble heights have been developed for specific situations (Holechek and Galt 2004).

Height/Weight Methods

✓ *Brief Description*

Height/weight methods are based on development for a given forage species of a relationship between the percentage of height removed and the percentage of weight removed (utilization). The relationship of height to weight of grasses is curvilinear, and a given height increment will contain more weight on the lower portion of the plant than on the top part. Height/weight relationships can be described by a formula, a graph, or a table (see Figure 7-11). Measuring utilization in the field involves measuring the height of grazed and ungrazed plants and conversion of the percentage height removed to percentage weight removed for each plant measured using the height/weight relationship for that species. The same approach has been used for some shrubs where percentage of the length of current twig growth is related to percentage of the weight removed.

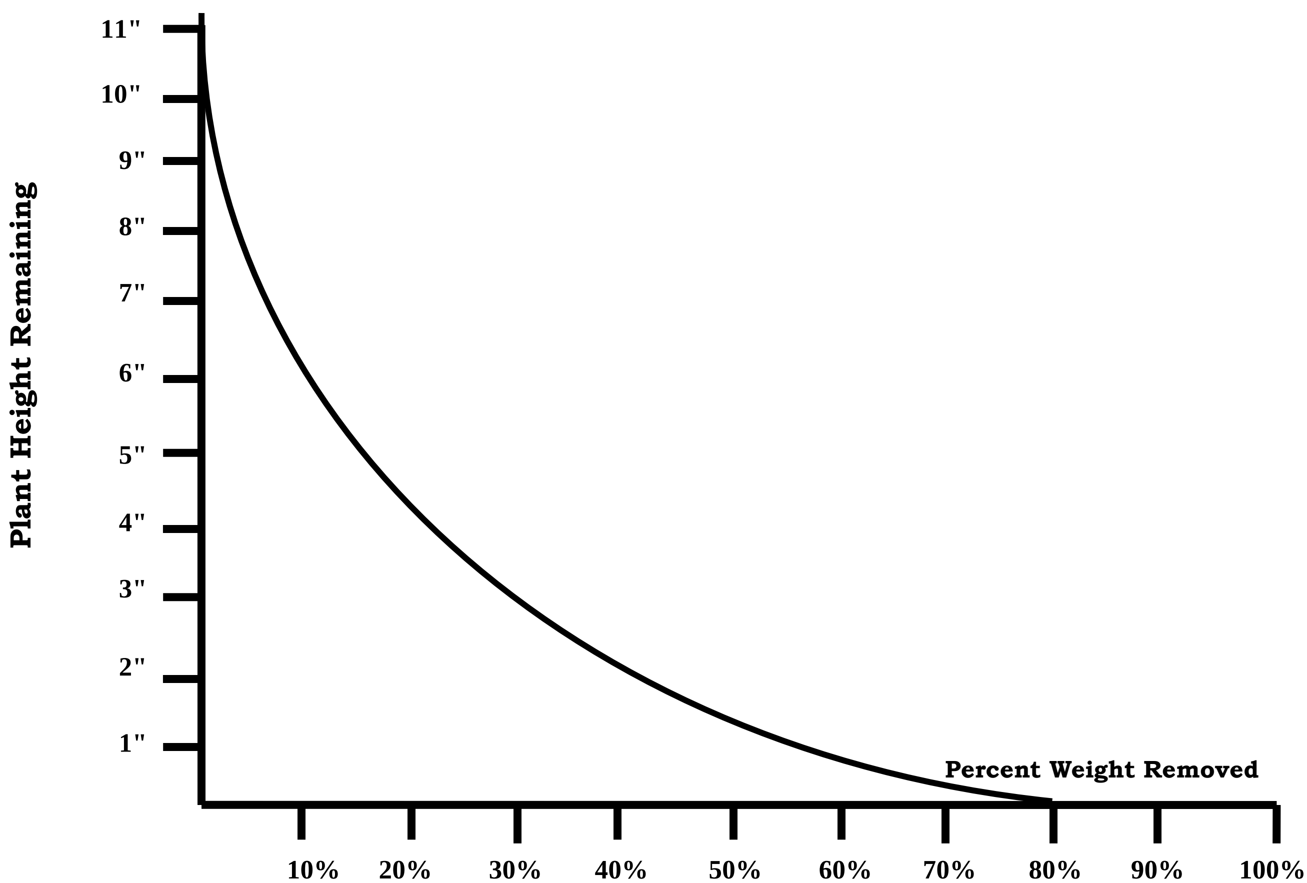


Figure 7-11. Height-weight curve for a grass plant with an ungrazed height of 11 inches. Inches remaining can be converted to % remaining to use for other plant heights for same species.

- ✓ *Appropriate Vegetation Types*

The height/weight method has been widely used for perennial grasses, and height/weight relationships have been developed for many species and presented in graphical or tabular form. The “Utilization Gauge” developed by the Forest Service is a convenient device used to calculate percent utilization by weight for different species based on the measured height of ungrazed plants compared to grazed height of individual plants. The method can be used for shrubs that have easily identifiable current twig growth, like mountain mahogany and bitterbrush.

- ✓ *Procedures*

Sample vegetation running one or more pace transects at selected pace intervals across a key area. At each pace (or multiple paces), identify and measure the nearest individual of the key species to the toe. If the plant is ungrazed, the height is measured either to the tallest seedhead (culmed height), or to the tallest leaf present (culmless height), depending on how the height/weight relationship was developed. If the plant is uniformly grazed, the average height of the remaining leaves is measured. When only parts of the plant are grazed, estimate an average height of grazed and ungrazed portions. Usually a minimum of 25 plants are measured on the transect. Two or more key species can be measured on the same transect, but record data separately.

After collecting the data, determine the average ungrazed height. In situations where the number of ungrazed plants encountered on a transect is inadequate to calculate a good average for ungrazed height (<5 plants), measure additional ungrazed plants. These additional plants do not enter into the calculation of utilization but serve only to establish ungrazed height. Select additional ungrazed plants only on the site being sampled. Plants growing in protected areas, road right of ways, adjacent pastures, or different ecological sites should not be used because they may reflect more or less favorable growing conditions than the key area. Cages can be used to establish ungrazed heights provided the cages have not been left in place over more than one season. The possibility of taller heights in cages due to microclimate should be considered.

Using the average ungrazed height, the grazed height of each plant is used to estimate the percentage utilization for that plant based on the appropriate height/weight relationship. The average percentage utilization for all plants, including the ungrazed ones found on the transect, is calculated and is the estimate of utilization by weight for the key species.

Using this method, the observer must carefully determine whether the plant is actually grazed or not. This determination is not always easy. When grazing occurs over a long period, plants may regrow. In this case, the plant may at first appear ungrazed, but with close examination signs of grazing appear (square ended leaves, grazed culms). Also, in cases where plants fail to produce seedheads, there may be a tendency to consider them grazed. Close inspection will show no evidence of grazing. Failure to recognize these culmless plants as ungrazed will bias the estimated utilization upward. Ungrazed culmless plants should not be averaged with ungrazed culmed plants on the same transect.

Height/weight relationships vary considerably among species of plants. There is some controversy as to whether these height/weight relationships also vary on different sites, in different years, or even between different ecotypes of some species. Some maintain that the basic form of the plant (including the relation of height to weight) does not change appreciably under different growth conditions (Schmutz 1971). Others claim it does (Clark 1945). Some species of perennial grass, especially those that grow over a wide range of environmental conditions (wide ecological amplitude), may exhibit marked differences in growth form due to genetic variability. Such differences may show up in leaf length, culm height, leaf/culm ratios, color and other attributes. Clearly such variability would affect the validity of height/weight relationships. We have observed significant variation in growth form within a species on different sites, when growth occurs in different seasons on the same site, and sometimes from what appears to be ecotypic variability on the same site.

- ✓ *Recommended Ground Rules*

Height/weight relationships have been developed using both culm heights and leaf heights. The average height of ungrazed plants can be based on either the tallest seedhead (culmed height) or the tallest basal leaf (culmless), depending on the growth form of the plant and how the available height/weight curves were developed. Most of the available curves are based on culmed heights. The height of grazed plants is based on the average remaining height of leaves and/or culms on the plant.

In some cases not all plants of a grass species will produce seedheads in a given year, depending on weather, site, and effects from previous grazing periods. This lack of seedheads may result in these culmless plants being erroneously identified as grazed, and thus an overestimate of utilization. Therefore, plants should not be identified as grazed unless actual evidence of grazing (clipped leaves or culms) are present. If some ungrazed plants are culmless and some are culmed, the two growth forms cannot be combined to obtain an ungrazed height – use either one or the other. Utilization can only be measured after the current year's growing season. However, when grazing occurs very early in the growing season and substantial regrowth occurs, it may be difficult or impossible to accurately distinguish grazed and ungrazed plants, especially if ungrazed plants are culmless.

Measure leaf or culm height to the nearest ½ inch or 1 cm. If improved precision is needed it should be obtained by measuring more plants rather than attempting to measure plant heights to 1/8 or ¼ inch (see Chapter 14).

✓ *Statistical Analysis*

Confidence intervals can be calculated on the mean utilization based on individual plants as sampling units. The calculated percentage utilization for each plant is used to generate the average and the standard deviation. The relationship between percent height removed and percent weight removed is assumed to be without error. In practice, that assumption may not be true because ecotypic variation, site, or weather conditions may cause differences.

✓ *Advantages/Disadvantages - Competing Techniques*

The advantage of this method is that it uses an attribute that is fairly easy and quick to measure (height) to estimate one that is not (weight) (see Chapter 14). It requires less training than methods that are based on visual estimates and less time than those requiring clipping. The disadvantage is that the method depends on the existence of a developed relationship of height to weight and the validity of that relationship across a range of sites and weather conditions. Height/weight relationships can fairly easily be derived by clipping in height increments and weighing the segments for a number of plants, and it is recommended that height/weight relationships be validated for site-specific use.

✓ *Other Observations*

The height/weight method has been widely used by agencies and consultants because it can provide repeatable results over time and among observers with a reasonable expenditure of time, provided consistent ground rules are followed. It can, therefore, provide a good way to document utilization differences among pastures in a given year or over a period of years. However, the estimated percentage of current year's growth removed (which is the definition of utilization) should be interpreted with caution due to the problems of: (1) variability in the height/weight relationship due to genetic and/or environmental factors, and (2) possible errors in identification of grazed plants where seedheads are not produced or grazing is obscured by regrowth.

Grazed Class Methods

✓ *Brief Description*

Grazed class methods involve observing the utilization of a number of plants of a given forage species and assigning each to a utilization class. Several methods can be used to make this determination.

✓ *Appropriate Vegetation Types*

These methods are mainly useful for perennial grasses.

✓ *Procedures*

Select a number of individual plants of a key forage species, usually by pacing and using the nearest plant to the toe of the boot. Assign each to a utilization class. Utilization classes usually are: 0, <5%, 6-20%, 21-40%, 41-60%, 61-80%, 81-95%, 95%+. However, different classes can be used. The estimated percent utilization for the sample is based on a weighted average derived by multiplying the number of plants in each class by the mid-point value for the class(Anderson and Currier 1973). The reason for breaking the first 20% increment into smaller increments is to provide more sensitivity on ranges where many plants are lightly grazed, as is commonly the case. The same reasoning applies to the upper 20% increment, but in practice it is rare to find plants utilized more than 80%.

Each plant can be assigned to a utilization class based on visual observation alone by experienced observers. To assign species to utilization classes consistently requires experience with the species in question based on measuring utilization using other techniques (for example, by clipping and weighing). Visual estimates are adequate if done by unbiased and experienced observers. However, if a more objective way of assigning plants to utilization classes is desired, photo guides or height/weight charts may be used for this purpose.

The photo guide method (Schmutz 1971) uses photographs to aide in assigning plants to the correct utilization class. Photo guides illustrating the appearance of different species when grazed to given levels of utilization by weight are developed by clipping studies based on height-weight relationships. Photo guides are required for each species considered.

Another check on the assignment of utilization to the proper class is to combine this method with height/weight using the utilization gage or graphs for the species. In this case, measure ungrazed height on several plants prior to beginning the sampling. Then the height limits for each of the utilization classes can be determined and noted on the data sheet. If there is any doubt about the proper class, the stubble height of the plant can be quickly measured to establish which class it goes in.

- ✓ *Recommended Ground Rules*

Since this method relies on the appearance of plants grazed to different levels, it is important for the observer to recognize the appearance of ungrazed plants and plants grazed to different levels. As was discussed under height/weight methods above, the presence and/or absence of flowering culms on ungrazed plants may be confusing, and regrowth obscuring earlier utilization may complicate accurate placement of plants in grazed classes. Therefore, when encountered, the observer should make notes on how such situations are resolved.

- ✓ *Statistical Analysis*

Confidence limits or statistics cannot be calculated using this method as there is no individual measurement for each plant. Though not common practice, a transect could be the sampling unit when multiple transects are used. Then a confidence interval could be established around the mean transect value.

- ✓ *Advantages/Disadvantages - Competing Techniques*

Grazed class methods are more rapid to use than most other quantitative or semi-quantitative methods. However, accuracy depends on the ability of the observer to correctly classify utilization on a weight basis. This ability usually requires experience with other methods that incorporate the appearance of various species used to a given level. Photo guides help provide consistency and are highly recommended. Measuring heights of plants to check on classes is also recommended as an alternative to photo guides, although the potential inaccuracy resulting from dependence on height/weight relationships (discussed above) should be considered. Inexperienced people will generally overestimate utilization.

- ✓ *Other Observations*

Grazed class methods train the eye for use pattern mapping and provide a good record of annual or seasonal utilization in different pastures or key areas as an aid to management planning and interpreting trend data.

Percent Plants or Twigs Grazed Methods

- ✓ *Brief Description*

Percent grazed methods are based on counting grazed and ungrazed plants, (Roach 1950) or browsed and unbrowsed twigs, and using this percentage to estimate utilization by weight. In some cases, the percent grazed is simply used as an index to grazing pressure.

- ✓ *Appropriate Vegetation Types*

The percent grazed plants method is mainly adapted to perennial bunchgrasses. For sodforming grasses percentage grazed plants may be replaced by the percentage of tillers grazed. Percentage twigs grazed can be used on shrubs where current growth twigs are identifiable and where use on those twigs can be seen. On some shrubs, like mesquite, animals tend to take off the leaves rather than bite off the twigs and thus often leave little evidence of browsing that can be easily seen (Sundt and McClaran 1993).

✓ *Procedures*

Select forage plants of one or more species along a paced transect. The plant closest to the toe is recorded either as grazed or ungrazed. Several plants of different species can be recorded. The percentage of plants grazed can then be calculated when an adequate number of plants are measured. When estimating use on shrubs as percentages of grazed twigs, a method for selecting the individual shrubs, then the stems to be observed on those shrubs, must be established.

The percentage of plants grazed or ungrazed can be used to estimate percentage of that species or group of species utilized by weight by conducting a study to measure various levels of utilization by a weight-based method to percent grazed or ungrazed. Studies of this relationship must be extrapolated to different vegetation types or ecological sites with extreme caution (Roach 1950, Arizona Interagency Range Committee 1972).

With these methods it is not necessary to estimate percentage utilization by weight. The percent plants or twigs grazed or ungrazed can simply be used as an index to grazing use to compare two areas or to provide a record over time. The percentage of plants grazed may not be very sensitive to grazing pressure at higher levels of grazing. Obviously, once all plants or most of them are grazed the percentage grazed cannot change very much even though the average intensity of grazing continues to increase. However, on lightly to moderately grazed ranges, this method is reasonably sensitive.

✓ *Recommended Ground Rules*

The main decision that must be made is how to distinguish grazed from ungrazed plants. We advise recording a plant as grazed if there is any evidence at all of grazing, even when barely noticeable.

✓ *Statistical Analysis*

The percentage grazed or ungrazed constitute binomial data similar to frequency or point data. Thus confidence intervals for given levels of probability could be established using the estimated percentage of either grazed or ungrazed plants and the sample size.

✓ *Advantages/Disadvantages - Competing Techniques*

The main advantage of this method is that a large number of plants can be observed and classed rapidly. It may provide a repeatable index if observers are consistent in identifying plants as grazed. The disadvantage is that studies to predict utilization by weight based on percent plants grazed may be lacking or of unknown applicability to a given situation.

✓ *Other Observations*

We recommend this method especially if the percent of plants or twigs grazed is simply used as an index to grazing rather than trying to estimate utilization by weight.

Landscape Appearance Method

✓ *Brief Description*

The landscape appearance method consists of classifying the utilization of a given area into one of several classes based on visual observation and descriptions of the appearance of each class (Interagency Technical Team 1996b). This method can be used as a tool for qualitatively assessing utilization or seasonal utilization (see Figure 7-12).

✓ *Appropriate Vegetation Types*

This method works for any type of vegetation and is one of the few that can be used to arrive at a general rating even when there is mixture of life forms among the forage plants, or where the species composition varies considerably across the range.

✓ *Procedures*

The landscape appearance method uses descriptions of utilization classes based on the general appearance of the range and on the relative amounts of grazing on more preferred to less preferred forage species. The number of classes that have been used ranges from 3 to 9. The most commonly used are none (0-5%); slight (6-20%); light (21-40%); moderate (41-60%); heavy (51-80%) and severe (>80%). The modifiers are not intended to indicate whether use is “proper” or not. “Moderate” use is not necessarily the desired level for a specific situation.

Use Class	Class Interval	Description
None	**0-5%**	Rangeland shows no evidence of grazing or negligible use.
Slight	**6-20%**	Rangeland has the appearance of very light grazing. Herbaceous forgage plants may be topped or slightly used.
Light	**21-40%**	Rangeland may be topped, skinned, or grazed in patches.
Moderate	**41-60%**	Rangeland appears entirely covered as uniformly as natural features and facilities will allow. Fifteen to 25% of the number of current seed stalks of herbaceous species remain intact.
Heavy	**61-80%**	Rangeland has the appearance of complete search. Herbaceous species are almost completely utilized, with less than 10% of the current seed stalks remaining.
Severe	**81-94%**	Rangeland has a mowed appearance and there are indications of repeated coverage. There is no evidence of reproduction or current seed stalks of herbaceous species.
Extreme	**95-100%**	Rangeland appears to have been completely utilized.

Figure 7-12. Classes and description of utilization for Landscape Appearance Method. In practice, the categories of severe and extreme are seldom encountered except in concentration areas, e.g. very close to water or salt grounds.

The utilization percentages in parentheses are general estimates of approximately how much utilization is present on key forage plants. The determination of the proper utilization class should be based more on the overall appearance of the range than on estimates of percent utilization for key species.

The landscape appearance method can be applied in two ways. One is to map zones of utilization or use pattern mapping (Anderson and Currier 1973). In this procedure, the observer travels through the pasture and maps zones that have similar amounts of utilization based solely on observation and experience. The amount of utilization each mapped area represents relates to the descriptions on the landscape appearance worksheet. Observers develop the maps based on observation and experience with the way livestock or wildlife use the ecological sites and topography on a given area. The aim of this method is to identify areas that are heavily used or unused as a basis for planning range improvements or grazing management to improve distribution. The amount of utilization is less important than the pattern.

Landscape appearance can also be applied by selecting a number of observation points within a key area or a mapping unit. At each location, classify the utilization using the landscape appearance descriptors. The area represented by each observation should be defined. The area selected may depend on the vegetation type – in grassland a radius of about 20 feet is commonly used. Results from a number of observations can be summarized and a weighted average utilization can be calculated using the number of observations in each class weighted by the mid-point of the utilization values shown for each class.

Use this procedure cautiously. It appears to generate a quantitative estimate of percentage utilization. However, two points should be recognized. One is that the area considered at each point is subjective and different observers may look at it differently. Second is that the utilization percentages for each utilization class are not based on any site specific information, but they are assumed to approximate expected utilization for a given description of appearance. In other words, the percentage utilization by weight assigned to the mid-point of each utilization class is not site specific and could vary considerably among sites, years, or seasons of the year. Therefore, using landscape appearance in this way may give a false impression that this method is quantitative.

- ✓ *Recommended Ground Rules*

This method depends on observing utilization on key forage species and also how much use may occur on other species occurring within the plant community. Make notes on each data sheet that identify key species and include comments on the other species that occur in the community. If repeated observations of small areas within a key area are used, then it is recommended to note the approximate area considered for each observation. For example, the rating applies to an area of 50 foot radius around the observer. In that case, the distance between successive observations should be at least 100 feet.

- ✓ *Statistical Analysis*

Statistical analysis is not feasible for this method unless several transects are compared, which is not usually done.

- ✓ *Advantages/Disadvantages - Competing Techniques*

The landscape appearance method is about the only method, other than simple observation, that can be practically used for mapping utilization patterns. Since use pattern mapping is probably the main reason for looking at utilization, it becomes an important method. It is also one of the few methods that can accommodate differences in life-form or species composition over the range to come up with one utilization class. The disadvantage is that the method is dependent on the experience and integrity of the observer and does not provide quantitative data for trend evaluation.

- ✓ *Other Observations*

Landscape appearance is recommended for routine range monitoring of utilization as a basis for use pattern mapping or interpreting range trend data.

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APPENDIX A
GLOSSARY OF TERMS

NOTE: Definitions of terms follow the Society for Range Management Glossary in most cases. Other sources are used where the SRM Glossary does not contain the listed term, or where an alternative definition was considered to be better. Definitions lacking a citation were developed by the authors.

Abbreviations: cf – confer, compare this definition with the definition of words that follow.
Syn. - synonym
Abbr. - abbreviation

Actual use
A report of the actual livestock grazing use. Actual use may be expressed in terms of animal unit months or animal months. A record of actual use contains dates and numbers of livestock gathered or moved, notes about partial removals and death losses, and it may also include information about grazing problems involving water or livestock distribution, salting records, or forage conditions.

Abundance
A qualitative estimate of the number of individual plants by species in an area usually employing descriptive classes (e.g rare, common, etc).

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. (Glossary Update Task Group 1998)

Adaptive management
(1) A formal, systematic, and rigorous approach to learning from the outcomes of management actions, accommodating change and improving management. (Nyberg 1998).
(2) A process of monitoring outcomes and adjusting management as needed to achieve desired outcomes; e.g stock and monitor.

Age-class.
(1) A descriptive term to indicate the relative age of plants. *or*
(2) Refers to age and class of animal. (Glossary Update Task Group 1998)

Air-dry-weight
The weight of plant material after it has been allowed to dry to equilibrium with the atmosphere. (Glossary Update Task Group 1998)

Allotment management plan
A long-term operating plan for a grazing allotment on federal public land prepared and agreed to by the permittee and appropriate agency.(Glossary Update Task Group 1998)

Animal month
A month's tenure upon range by one animal. Must specify kind and class of animal. Not synonymous with animal-unit-month. (Glossary Update Task Group 1998)

Animal unit
Considered to be one mature cow of about 1,000 pounds (450kg), either dry or with calf up to 6 months of age, or their equivalent, consuming about 26 pounds (12 kg) of forage on an oven-dry basis. Abbr. AU, cf. animal-unit-equivalent.(Glossary Update Task Group 1998)

Animal-unit-day
The forage demand (amount of forage) on an oven-dry basis required by one animal unit for a period of one day. Abbr. AUD. (Glossary Update Task Group 1998)
Animal unit month
The amount of oven-dry forage (forage demand) required by one animal unit for a standardized period of 30 animal-unit-days. Not synonymous with animal-month. Abbr. AUM. The term AUM is commonly used in three ways: (a) stocking rate, as in "X acres per AUM"; (b) forage allocations, as in "X AUMs in Allotment A"; (c) utilization, as in "X AUMs taken from Unit B." (Glossary Update Task Group 1998)

Apparent trend
An interpretation of trend based on observation and professional judgment at a single point in time. (Glossary Update Task Group 1998)

Aspect
(1) The visual first impression of vegetation or a landscape at a particular time or as seen from a specific point. *or*
(2) The predominant direction of slope of the land. *or*
(3) The seasonal changes in the appearance of vegetation.(Glossary Update Task Group 1998)

Assess
To estimate or determine the significance, importance, or value of; evaluate. (Webster's New World Dictionary, Third College Edition.).

Assessment
An evaluation or analysis that assigns values, importance or significance.

Available forage
That portion of the forage production that is accessible for use by a specified kind or class of grazing animal. (Range Inventory Standardization Committee 1983)

Bare ground
All land surface not covered by vegetation, rock, or litter. cf. ground cover. (Glossary Update Task Group 1998)

Basal area
The cross section 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 height or other designated height. Syn. Basal cover. (Glossary Update Task Group 1998)

Basal cover
Syn. Basal area. (Glossary Update Task Group 1998)

Belt transect
A long, narrow quadrat along one or both sides of a line transect.

Biomass
The total amount of living plants and animals above and below ground in an area at a given time. (Glossary Update Task Group 1998)

Browse
(n) The part of shrubs, woody vines and trees available for animal consumption. (v.) To search for or consume browse. (Glossary Update Task Group 1998)

Bulk density
(1) The mass of dry soil per unit of bulk volume, including the air space. (Brady and Weil 1999) *or*
(2) Soil bulk density of a sample is the ratio of the mass of solids to the total or bulk volume. This total volume includes the volume of both solids and pore space. Bulk density may be highly dependent on soil conditions at the

time of sampling. Changes in soil volume due to changes in water content will alter bulk density. Bulk density, as a soil characteristic, is actually a function rather than a single value. (Natural Resources Conservation Service 2004)

Bunch grass
A grass having the characteristic growth habit of forming a bunch, lacking stolons or rhizomes, cf. sod grass. (Glossary Update Task Group 1998)

Canopy
(1) The vertical projection downward of the aerial portion of vegetation, usually expressed as a percent of the ground so occupied. *or*
(2) The aerial portion of the overstory of vegetation. Cf. canopy cover. (Glossary Update Task Group 1998)

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. It may exceed 100%. Syn. Crown cover. (Glossary Update Task Group 1998)

Carrying capacity
The average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives for the unit. In addition to site characteristics, it is a function of management goals and management intensity.syn grazing capacity. (Glossary Update Task Group 1998)

Climax
The final or stable biotic community in a successional series; it is self-perpetuating and in equilibrium with the physical habitat. (Odum 1971) (Glossary Update Task Group 1998)

Cobble – see Gravel, Cobble, Stones

Community
A general term for an assemblage of plants and/or animals living together and interacting among themselves in a specific location; no particular successional status is implied. (Glossary Update Task Group 1998)

Community type
An aggregation of all plant communities with similar structure and floristic composition. A unit of vegetation within a classification with no particular successional status implied. (Glossary Update Task Group 1998)

Comparison area
An area with a documented history and/or condition that is used for purposes of comparison. (Glossary Update Task Group 1998)

Composition
The proportions of various plant species in relation to the total on a given area. It may be expressed in terms of relative cover, relative density, or relative weight. (Interagency Technical Team 1996b)

Confidence interval
A statistical range with a specified probability that a given parameter lies within the range. (The American Heritage Dictionary Online)

Coordinated Resource Management Planning
The process whereby various user groups are involved in discussion of alternate resource uses and collectively diagnose management problems, establish goals and objectives, and evaluate multiple use resource management. (Glossary Update Task Group 1998)

Cover

(1) The plant or plant parts, living or dead, on the surface of the ground. Vegetative cover or herbage cover is composed of living plants and litter cover of dead parts of plants. Syn. Foliar cover. *or*
(2) The area of ground covered by plants of one or more species, cf. basal area. (Glossary Update Task Group 1998)

Cover type
A classification of vegetation based on the kind and/or amount of plant cover.

Crown cover
Syn. canopy cover.

Critical area
An area which must be treated with special consideration because of inherent site factors, size, location condition, values, or significant potential conflicts among uses. (Glossary Update Task Group 1998) A critical area is not a key area because it is not representative of the grazing use on a pasture or allotment.

Cryptogamic crust
The portion of the soil surface covered with cryptogams. Syn. Microphytic crust, biological crust.

Current year's growth (production)
That portion of the plant biomass produced in the current forage year. For warm-season plants it is the growth produced during spring and summer. For cool-season plants it is growth produced during the spring and the preceding fall-winter.

Decreaser
For a given plant community, those species that decrease in amount as a result of a specific influence or management practice such as fire or grazing. (Glossary Update Task Group 1998)

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 the vegetation as a whole. Syn. use. (Glossary Update Task Group 1998)

Density
Numbers of individuals or stems per unit area. Density does not equate to any kind of cover measurement. (Glossary Update Task Group 1998)

Desirable plant species
Species which contribute positively to the management objectives. (Glossary Update Task Group 1998)

Desired condition
Desired conditions are fairly broad goals, which, should be determined and discussed in a specific, quantifiable and focused manner. Desired conditions should describe desired outcomes, not desired actions. Desired conditions should be achievable under specified levels of use and management actions (i.e. it is not reasonable to describe conditions that may have existed prior to settlement under a land use that impacts vegetation and precludes achieving that state). Desired condition may currently exist.

Desired future condition
A quantitative expression of the resource attributes such as vegetation, soil, or water identified in management goals or objectives. It usually focuses on important and attainable differences from current conditions in an area or on important resource attributes that could be lost or altered through management. Desired Future Condition is analogous to Desired Plant Community but has a broader perspective including other measurable resource attributes or features in addition to the vegetation resource (e.g. channel width, width-depth ration, etc.). (Swanson 2006). It is important to understand that DFC may be the same as existing condition.

Desired plant community

Of the several plant communities that may occupy a site, the one that has been identified through a management plan to best meet the plan's objectives for the site. It must protect the site as a minimum (Glossary Update Task Group 1998). It may be described as dynamic, changing through time, or within a range of variability. DPC may be the same as the present plant community.

Diversity
An expression of the number of species or variety of life forms in an area. It may refer to a stand of vegetation, an ecological site, or a landscape.

Dominance
A strict interpretation would refer to a state of being dominant (cf dominant) which implies ecological control within a plant community. However, dominance is often used to characterize a plant community by the plants or life forms that dominate the aspect or visual appearance of a plant community. In this case, prominence might be a better term since it refers to visual dominance. Cf Dominant.

Dominant
(1) Plant species or species groups, which by means of their number, coverage, or size, have considerable influence or control upon the conditions of existence of associated species. *or*
(2) Those individual animals which, by their aggressive behavior or otherwise, determine the behavior of one or more animals resulting in the establishment of a social hierarchy. (Glossary Update Task Group 1998)

Drouth (drought)
(1) A prolonged chronic shortage of water, as compared to the norm, often associated with high temperatures and winds during the spring, summer, and fall. *or*
(2) A period without precipitation during which the soil water content is reduced to such an extent that plants suffer from lack of water. (Glossary Update Task Group 1998). The Society for Range Management defines drought as an annual or seasonal precipitation that is 75% or less of the long term average.

Duration (of grazing)
Duration is the length of time grazing occurs within one pasture.

Ecological function
An ecological process. Commonly used to refer to energy flow, the hydrologic cycle, biogeochemical cycles, plant/animal production, and other processes occurring in ecosystems.

Ecological site
A kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce distinctive kids and amounts of vegetation and in its response to management. Apparently synonymous with ecological type used by USFS. (Glossary Update Task Group 1998)

Ecological Site Description (ESD)
A description of an ecological site. The ESD may contain information on soils, physical features, climatic features, associated hydrologic features, possible plant communities, plant community dynamics, annual production estimates, distribution of production throughout the year, associated animal communities, associated and similar sites, and interpretations for management. Many ESDs also have state and transition models developed for them.

Ecological Site Inventory (ESI)
A resource inventory that involves the use of soils information to map ecological sites and plant communities and the collection of natural resource and vegetation attributes. The sampling data from each of the soil-vegetation units, referred to as site write-up areas (SWAs), become the baseline data for natural resource management planning. (Habich 2001 & Swanson 2006)

Ecological status
The present state of vegetation and soil protection of an ecological site in relation to the potential natural community for the site. Vegetation status is the expression of the relative degree to which the kinds, proportions and amounts of

plants in a community resemble that of the potential natural community. If classes are used, they should be described in ecological rather than utilitarian terms. Soil status is a measure of present vegetation and litter cover relative to the amount of cover needed on the site to prevent accelerated erosion. (Range Inventory Standardization Committee 1983)

Ecological type
Syn. ecological site. (Glossary Update Task Group 1998)

Ecosystem
Organisms together with their abiotic environment, forming an interactive system, inhabiting an identifiable space. (Glossary Update Task Group 1998)

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. (Glossary Update Task Group 1998) This term is associated with the Clementsian view of plant communities as discrete entities. An alternative view (Gleasonian) is that "ecotones" are merely areas where plant composition changes relatively rapidly in space in response to changing site conditions.

Ecotype
A locally adapted population within a species which has certain genetically determined characteristics; interbreeding between ecotypes is not restricted. Cf. biotype. (Glossary Update Task Group 1998)

Endpoint indicators
Guides for land managers to assess resource use impacts at the end of the grazing and growing season, whichever comes last. The assessment is to determine if grazing use left the resource in an appropriate condition for moving toward objectives. Commonly, stubble height or utilization indicate the desired degree of use. Syn. end of season indicators. (Swanson 2006)

Erosion pavement
An accumulation of gravel or cobbles on the soil surface due to erosion of the finer materials by water or wind. Gravel pavements frequently form on older land surfaces in arid and semiarid climates because vegetation is not adequate to prevent soil erosion. Once formed the pavement protects the soil surface and slows the rate of natural erosion. Erosion pavement may or may not indicate erosion due to current or historical land use.

Evaluation
(1) An examination and judgment concerning the worth, quality, significance, amount, degree, or condition of something; *or*
(2) The systematic process for determining the effectiveness of on-the-ground management actions and assessing progress toward meeting objectives. Syn Assessment. (Interagency Technical Team 1996b)

Flow pattern
Indicators of the extent, size, and distribution of water flowing over the soil surface due to precipitation events or snow melt.

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%. Syn. cover. (Glossary Update Task Group 1998)

Forage
(n) Browse and herbage which is available and may provide food for grazing animals or be harvested for feeding.
(v) To search for or consume forage. Cf. (v.) browse, graze. (Glossary Update Task Group 1998)

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, etc.) cf. grazing inventory. (Glossary Update Task Group 1998)

Forage production
The weight of forage that is produced within a designated period of time on 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. (Glossary Update Task Group 1998)

Frequency
The proportion of quadrats that contain the species in question. To make frequency comparable the plot size must remain constant in each measurement time period. (Swanson 2006)

Frequency of defoliation (as used in GRI)
The number of times forage plants are defoliated during the actual or planned grazing period. It depends on plant growth rate and the length of time over which plants experience grazing within a growing season. (Swanson 2006)

Geologic erosion (natural erosion)
The rate of soil erosion assumed to occur on a specific site under current environmental conditions in the absence of "disturbance" by man's activities. "Natural" rates of erosion may be high or low and may fluctuate through time due to changes in climate, vegetation, animals, fire regime or other factors.

Goal
General statements of the desired direction of change or the status or state of resource conditions in the future. (Interagency Technical Team 1996b) A concise statement of the state or condition a land resource management plan is designed to achieve. (Arizona CRM)

Gravel, Cobble, Stones
As defined in Soil Taxonomy (Soil Conservation Service 1975); Gravel (2mm-7.5 cm or 0.1- 3 inches), cobble (7.5-25cm; 3-10 inches), stones (over 25 cm or 10 inches). (Note: For standard range inventory procedures it is recommended that gravel smaller than 5 mm in diameter be classed as bare ground in cover determinations.) (Glossary Update Task Group 1998)

Grazing capacity
Syn. carrying capacity. (Task Group on Unity in Concepts and Terminology 1996)

Grazing intensity (as used in GRI) – see also intensity (of grazing)
The amount of leaf material removed during the grazing period. The primary concern is the amount of photosynthetically active leaf material remaining for the plant to recover from grazing. This is <u>not</u> an estimate of percent utilization which also includes utilization after plants are dormant and/or may be modified by growth. Syn. intensity. (Swanson 2006)

Grazing management
The manipulation of animal grazing in pursuit of a defined objective. (Glossary Update Task Group 1998)

Grazing management plan
A program of action designed to secure the best practicable use of the forage resources with grazing or browsing animals. (Glossary Update Task Group 1998)

Grazing season
1) The time period during which grazing can normally be practiced each year or portion of each year. *or*
(2) On federal land, an established period for which grazing permits are issued. It may be the whole year or a very short time span, and is normally a function of forage mass and climate. In this context, the vegetative growing season may be only a part of the grazing season. (Glossary Update Task Group 1998)

Greenline
The first perennial vegetation that forms a lineal grouping of community types on or near the low water's edge. Most often occurs at or slightly below the bankfull stage (Winward 2000). It is found only along streams with defined channels. (Cowley and Burton 2005 & Swanson 2006)

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. (Glossary Update Task Group 1998)

Growing season
In temperate climates, that portion of the year when temperature and moisture permit plant growth. In tropical climates it is determined by availability of moisture. (Glossary Update Task Group 1998)

Growth form
The characteristic shape or appearance of an organism. cf. life-form. (Glossary Update Task Group 1998)

Habitat type
The collective area which one plant association occupies or will come to occupy as succession advances. The habitat type is defined and described on the basis of the vegetation and its associated environment. The concept was developed by Rexford Daubenmire. Habitat type is similar in concept to ecological site. The difference depends mainly on how specifically plant associations are defined. Habitat type is often misused to refer to classification of vegetation or wildlife habitat rather than a land classification. (Glossary Update Task Group 1998)

Hedging
The persistent browsing of terminal buds of browse species causing increased lateral branching and a reduction in main stem growth. (Glossary Update Task Group 1998)

Herbaceous
Vegetation growth with little or no woody component; nonwoody vegetation such as grasses and forbs. (Interagency Technical Team 1996b)

Herbage
The above ground material of any herbaceous plant. cf. forage. (Glossary Update Task Group 1998)

Historic Climax Plant Community
Is that assemblage of plants presumed to be in place on an ecological site at the time of European immigration and settlement in North America (ignoring climate change). (Swanson 2006)

Historical climax
The plant community considered to best typify the potential plant community of an ecological site prior to the advent of European man. May no longer be one of the potential plant communities for the site. Cf historic climax plant community, climax. (Glossary Update Task Group 1998)

Ice cream species
An exceptionally palatable species sought and grazed frequently by livestock or game animals. Such species are often overutilized under proper grazing. (Glossary Update Task Group 1998)

Increaser
For a given plant community, those species that increase in amount as a result of a specific abiotic/biotic influence or management practice. (Glossary Update Task Group 1998)

Indicator species
(1) species that indicate the presence of certain environmental conditions, seral stages, or previous treatment. *or*

(2) One or more plant species selected to indicate a certain level of grazing use. Cf. key species. (Glossary Update Task Group 1998)

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/hour. (Glossary Update Task Group 1998)

Interpretation
Explaining or telling the meaning of something and presenting it in understandable terms. (Interagency Technical Team 1996b)

Intensity (of grazing)
The herbage removed through grazing and trampling by livestock in relation to the amount remaining. Intensity may be described in terms herbage removed during the grazing and/or growing period or as a utilization level at the end of the growing period.

Invader
Plant species occurring on an ecological site that did not formerly occur there. Invaders are often introduced species but may include natives also. Cf. increaser.

Inventory
(1) An itemized list of current assets as in a survey of natural resources; survey, summary; quantity of goods or materials on hand (stock). (Merriam-Webster dictionary on line) (2) 1730. (3) NRH The systematic collection of quantitative data about a resource and its condition so that managers can learn about resource potentials, important problems, and the resource attributes in play for making changes to address issues. Often inventory data are used as a baseline for future comparisons.

Key area
A relatively small portion of a range 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 overall acceptability of current grazing management over the range. (Glossary Update Task Group 1998)

Key management species
Syn. Key species. (Glossary Update Task Group 1998)

Key species
Forage species whose use serves as an indicator to the degree of use of associated species. Syn. Key management species. (Glossary Update Task Group 1998)

Layer (of vegetation)
All plants with canopies occurring within a specified height above the ground; usually of similar life-form.

Leaf area index
The ratio of the total leaf surface of the plant community to the corresponding ground area expressed as a proportion. LAI may exceed 1. (Glossary Update Task Group 1998)

Life form
Grouping of species or individuals into classes on the basis of their similarities in structure and function. A plant life form is usually understood to be a growth form which displays an obvious relationship to important environmental factors. (Mueller-Dombois and Ellenberg 1974) Examples are: cool-warm season, C3, C4, CAM plants, evergreen-deciduous, and so on.

Line transect
A vegetation sampling unit consisting of a line stretched through vegetation or a line established by pacing through vegetation in a straight line. (Authors)

Litter
The uppermost layer of organic debris on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material. (Glossary Update Task Group 1998)

Litter dam
An accumulation against obstructions of litter material from the soil surface moved by overland water flow. (Authors)

Long-term monitoring
Measurement of changes in resource attributes such as soils or vegetation over time. It is used to periodically assess progress toward meeting long-term resource management objectives. (Swanson 2006)

Management adjustment
Change in animal numbers, seasons of use, kinds or classes or animals, or management practices designed to meet management objectives or special conditions such as drought or wildfire.

Management objective
The objectives for which rangeland and rangeland resources are managed which includes specified use accompanied by a description of the desired vegetation and the expected products and/or values. (Glossary Update Task Group 1998)

Management plan
A program of action designed to reach a given set of objectives. Cf. grazing management plan. (Glossary Update Task Group 1998)

Management unit
An area of land with common management objectives and management prescriptions.

Mapping unit

Minimal area/minimal area curve
The smallest area on which the species composition of the community in question is adequately represented. (Mueller-Dombois and Ellenberg 1974) A minimal area curve is a graph relating area sampled to the number of species encountered. Typically, the number of species increases rapidly with area sampled at first, then at a slower rate as sampling area increases.

Monitor- monitoring
The orderly collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives. This process must be conducted over time in order to determine whether or not management objectives are being met. (Glossary Update Task Group 1998)

Nested frequency
Collection of frequency data in several different-sized quadrats at the same time.

Objective
Planned results to be achieved within a stated time period. Objectives are subordinate to goals, are narrower in scope and shorter in range, and have increased possibility of attainment. The time periods for completion, and the outputs or achievements that are measurable and quantifiable are specified. (Interagency Technical Team 1996b) A specific statement of measurable results to be achieved within a stated time period. An objective should be quantifiable and measurable. (Arizona CRM)

Opportunity for growth or regrowth (as used in GRI)
The amount of time plants have to grow prior to grazing or regrow after grazing. This factor is related to season, time and duration of use. (Swanson 2006)

Oven-dry weight

The weight of a substance after it has been dried in an oven at a specific temperature to equilibrium. (Glossary Update Task Group 1998)

Overgrazed range
A range which has experienced loss of plant cover and accelerated erosion as a result of heavy grazing or browsing pressure. (Glossary Update Task Group 1998)
Overgrazing
(1) Continued or repeated heavy grazing over time (usually years or grazing seasons) which exceeds the recovery capacity of the community and creates a deteriorated range. Cf. overuse. (Glossary Update Task Group 1998) *or*
(2) Grazing of a plant that is too intense and/or too frequent to maintain ability of the plant to grow and survive.

Overland flow
Surface runoff of water following a precipitation event. Cf. runoff. (Glossary Update Task Group 1998)

Overstocking
Placing a number of animals on a given area that will result in overuse if continued to the end of the planned grazing period. (Glossary Update Task Group 1998)

Overstory
The upper canopy or canopies of plants. Usually refers to trees, tall shrubs and vines. (Glossary Update Task Group 1998)

Overuse
Utilizing an excessive amount of the current year's growth which, if continued over time (usually several years or grazing seasons), will result in range deterioration. Cf. overgrazing. (Glossary Update Task Group 1998)

Peak standing crop
The maximum standing crop of current year's production that can be measured in a given growing season. Cf Standing crop.

Pedestaled/Pedestalling
A condition where the soil has eroded from around individual plants or other objects such a small rocks, leaving them on small pedestals of soil. Sometimes the result of frost heaving. (Glossary Update Task Group 1998) Apparent pedestalling can result from deposition of soil or organic material under plants due to wind or leaf fall.

Percent use
Grazing use of current growth, usually expressed as a percent of the current growth (by weight) which has been removed. Cf. degree of use. (Glossary Update Task Group 1998)

Phenology
The study of periodic biological phenomena which are recurrent such as flowering, seeding, etc. especially as related to climate. (Glossary Update Task Group 1998)

Phytomass
Total amount of plants (including dead attached parts) above and below ground in an area at a given time. Cf biomass. (Glossary Update Task Group 1998)

Plant association
A kind of climax plant community consisting of stands with essentially the same dominant species in corresponding layers. (Glossary Update Task Group 1998) Syn. vegetation association.

Plant community
An assemblage of plants occurring together at any point in time, thus denoting no particular successional status. A unit of vegetation. (Glossary Update Task Group 1998)

Plant community type
See community type. (Glossary Update Task Group 1998)

Plant succession
Vegetation change. (Glossary Update Task Group 1998)

Plant vigor
Plant health. A subjective estimate of the overall health of a plant based on the appearance of leaf and shoot growth, dead or decadent leaves and shoots, and ability to produce reproductive structures relative to similar plants in the vicinity or the ability of the site to produce vigorous plant growth. Cf. plant vigor index. (Glossary Update Task Group 1998)

Potential natural community
See potential natural vegetation. (Glossary Update Task Group 1998)

Potential natural vegetation
An historical term originally defined by A. W. Kuchler as the stable vegetation community which could occupy a site under current climatic conditions without further influence by people. Often used interchangeably with potential natural community. (Glossary Update Task Group 1998) The potential natural vegetation or community may contain naturalized non-native species.

Potential plant community
One of usually several plant communities that may become established on an ecological site under the present environmental conditions, either with or without interference by man. (Glossary Update Task Group 1998)

Production
Plant or animal material present at a given time.

Productivity
The rate of production per unit area, usually expressed in terms of weight or energy. (Glossary Update Task Group 1998)

Proper grazing
The act of continuously obtaining proper use. (Glossary Update Task Group 1998)

Proper stocking
Placing a number of animals on a given area that will result in proper use at the end of the planned grazing period. Continued proper stocking will lead to proper grazing. (Glossary Update Task Group 1998)

Proper use
A degree of utilization of current year's growth which, 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. Syn. proper utilization, proper grazing use, cf. allowable use. (Glossary Update Task Group 1998)

Proper use factor
The percentage of a plant that is utilized when the rangeland as a whole is properly utilized.

Quadrats
Sampling frames within which vegetation information is gathered. (Swanson 2006) May be square, round, or rectangular in shape.

Range
Syn. rangeland.

Range condition

Historically, has usually been defined in one of two ways: (1) a generic term relating to present status of a unit of range in terms of specific values or potentials. Specific values or potentials must be stated. *or*
(2) The present state of vegetation on a range site in relation to the climax (natural potential) plant community for that site. It is an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site. (Task Group on Unity in Concepts and Terminology 1996)

Range condition class
One or a series of arbitrary categories used to classify range condition as that term has been variously defined. Cf range condition. (Glossary Update Task Group 1998)

Range degradation
The process that leads to an irreversible reduction in capability of an ecological site to produce vegetation. (Glossary Update Task Group 1998)

Rangeland health
The degree to which the integrity of the soil, the vegetation, the 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. (Glossary Update Task Group 1998)

Range readiness
The defined stage of plant growth or soil moisture content at which grazing may begin under a specific management plan without permanent damage to vegetation or soil. Usually applied to seasonal range at high altitudes where saturated soils during and after snowmelt are an issue.

Range site
Syn. of ecological site on rangelands. (Glossary Update Task Group 1998)

Range type
An historical term that refers to, and only to, the 18 standard range vegetation types recognized by the 1937 Task Force. (Interagency Range Survey Committee, 1937 & Glossary Update Task Group 1998)

Rangeland
A kind of land on which the native vegetation is predominantly grasses, grass-like plants, forbs, or shrubs. Includes lands revegetated naturally or artificially when routine management of that vegetation is through manipulation of grazing. Rangelands include natural grasslands, savannas, shrublands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows. (Interagency Technical Team 1996b)

Rangeland inventory
(1) The systematic acquisition and analysis of resource information needed for planning and for management of rangelands. *or*
(2) The information acquired through rangeland inventory. (Glossary Update Task Group 1998)

Relict area
An area of vegetation presumed to represent the original undisturbed or pristine plant community for a site as postulated by Clementsian ecological concepts.

Residual vegetation
The current year's above-ground plant material remaining after grazing. It may be recorded as weight per unit area, stubble height or as the opposite of utilization, the percent remaining. (Swanson 2006)

Resilience
The capability for recovery from disturbance without permanently altering ecological processes. (Swanson 2006)

Resistance

The capability to resist change in ecological processes due to climatic variability, land use or other factors Resistant plan communities accommodate more outside influences. Resilience and resistance determine the stability of a state or of the various phases within a state. (Swanson 2006)

Resource attributes
Resource characteristics or features that can be observed and described.

Resource value rating
The value of vegetation present on an ecological site for a particular use or benefit. RVR"s may be established for each plant community capable of being produced on an ecological site, including exotic or cultivated species. (Glossary Update Task Group 1998)

Retrogression
An historical term used by some ecologists to mean succession in reverse. According to Clements (1916), however retrogression is synonymous with destruction and denudation of a community. (Glossary Update Task Group 1998)

Rill/rill erosion
(1) Rill – A small, intermittent water course with steep sides, usually only a few centimeters deep. *or*
(2) Rill erosion – An erosion process in which numerous small channels only several centimeters in depth are formed. (Brady and Weil 1999)

Riparian
Refers to the existence of flowing water in a channel during all or a significant portion of the year, i.e. a perennial strea. cf. riparian zone

Riparian zone
The banks and adjacent areas of water bodies, water courses, seeps and springs whose waters provide soil moisture sufficiently in excess of that otherwise available locally so as to provide a more moist habitat than that of contiguous flood plains and uplands. (Adapted from Warner, 1979 & Glossary Update Task Group 1998)

Sacrifice area
A portion of the range, irrespective of site, that is unavoidably overgrazed to obtain efficient overall use of the management area. (Glossary Update Task Group 1998) Under modern management strategies these areas are largely confined to watering areas and bedding grounds.

Sample
A part of a population taken to estimate a parameter of the whole population. (Glossary Update Task Group 1998)

Sampling unit
Units on which observations are made. They could be a finite point, plots or quadrats, distance measures, a weight unit, or a transect. (Interagency Technical Team 1996b)

Seasonal use
(1) synonymous with seasonal grazing. *or*
(2) seasonal preference of certain plant species by animals. (Glossary Update Task Group 1998)

Seasonal utilization (relative utilization)
Proportion of current growing seasons' biomass growth used or destroyed relative to growth at that point in time prior to the end of the growing season.

Seral community
The relatively transitory communities that develop under plant succession.
Syn seral stage. (Odum 1971 & Glossary Update Task Group 1998)

Seral

Refers to species or communities that are eventually replaced by other species or communities within a sere. (Glossary Update Task Group 1998)

Seral stage
Syn seral communities. (Odum 1971 & Task Group on Unity in Concepts and Terminology 1996)

Sheet erosion
The removal of a fairly uniform layer of soil from the land surface by runoff water.

Short term monitoring
Addresses three topics, (1) conformance with the plan (2) current, annual, or short-term impacts of the implemented management on resources of interest, and (2) weather and other unplanned events. This information guides day to day and year to year management by monitoring within-season triggers and end-point indicators. It also helps interpret long-term monitoring data. (Swanson 2006)

Similarity index
A calculation of the percentage similarity in species composition presently occurring on an site compared to the historic climax community, potential natural community, desired plant community or other reference situation. Expressed as a percentage. Syn. range similarity index.

Site conservation threshold
The kind, amount and/or pattern of vegetation needed as a minimum on a given site to prevent accelerated erosion. (Glossary Update Task Group 1998)

Sod-grass
Stoloniferous or rhizomatous grasses which forma a sod or turf. Cf bunchgrass. (Glossary Update Task Group 1998)

Soil phase
A subdivision of a soil series or other unit classification having characteristics that affect the use and management of the soil but do not vary sufficiently to differentiate it as a separate series. Included are such characteristics as degree of slope, degree of erosion, and content of stones. (Brady and Weil 1999)

Soil series
The soil series is a subdivision of a family and consists of soils that are similar in all major profile characteristics. (Brady and Weil 1999)

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. (Glossary Update Task Group 1998)

Stand
An area of fairly uniform vegetation.

Standing crop
The total amount of plant material per unit of space at a given time. Often is divided into above-ground and below-ground portions and further may be modified by the descriptors "dead" or "live" to more accurately define the specific type of biomass. (Glossary Update Task Group 1998)

State
A combination of vegetation and soil processes that perpetuate through time or cycle in response to disturbance. (Swanson 2006)

State and transition model
Depicts the various states and transitions that an ecological site or a broader vegetation type may express. It describes vegetation dynamics and management interactions associated with an ecological site. (Swanson 2006)

Stocking rate
The relationship between the number of animals and the grazing management unit utilized over a specified time period. May be expressed as animal units per unit of land area (animal units over a described time period/area of land.). Cf. stocking density. (Glossary Update Task Group 1998)

Streambank
The edge of a stream that contains the flow of water except the water that floods out of the channel in flood conditions that may occur less often than once in two to three years. The streambank should not be confused with a gully bank or other high bank that is only wetted during rare flood events if ever. (Swanson 2006)

Streambank alteration
Change in the properties of a streambank due to impact of animals, people, vehicles, ice, or flooding.

Streambank stability
A measure of the proportion of a streambank that is free from signs of active erosion, vulnerability to erosion, or slumping/breakage.

Stream channel morphology
The shape of a stream, includes attributes such as average width and depth, slope, meandering, width/depth ratio, pool/riffle ratio, or other characteristics that may relate to energy dissipation, erosion, sediment transport, deposition, or fish habitats. (Swanson 2006)

Stratification
Subdividing an area into units which are, more or less, internally homogenous with respect to the (those) characteristic (s) of interest. (Interagency Technical Team 1996b)

Stubble
The basal portion of herbaceous plants remaining after the top portion has been harvested by mowing or by grazing animals. (Glossary Update Task Group 1998)

Stubble height
The height of forage plants remaining after grazing has occurred; average stubble height includes both grazed and ungrazed plants.

Succession
cf Plant succession.

Successional status
The present state of vegetation and soil protection of an ecological site in relation to the potential natural community for the site. Successional status is the expression of the relative degree to which kinds, proportions and amounts of plants in a community resemble that of the potential natural community. If classes or ratings are used, they should be described in successional rather than utilitarian terms. For example, some agencies are using four classes of successional status ratings (early seral, mid-seral, late seral, potential natural community) of vegetation corresponding to 0-25%, 26-50%, 51-75% and 76-100% of the potential natural community standard. Soil status is a measure of present vegetation and litter cover relative to the amount of cover needed on the site to prevent accelerated erosion. This term is not used by all agencies. Cf. range condition. (Glossary Update Task Group 1998)

Suitable range
Rangeland which has no physical or biological features that prohibit its use for grazing. Cf unsuitable range.

Sustainable (referring to range management)
Management that will not cause or accelerate decline in land productivity. Also used in reference to economic viability.

Taxonomic unit
The individual classes of things in a classification system, e.g soil series, ecological sites, plant species, etc.

Terracettes
Benches of soil deposition behind obstacles caused by water movement (not wind). Terracettes caused by livestock or wildlife movements on hillsides are not considered erosional terracettes. (Pellant, Pyke et al. 2005) Also defined as abrupt walls from 1-10 cm or so high, aligned with the local contour that progressively cut back up-slope, the eroded material being deposited in an alluvial fan downslope of the feature (Tongway and Hindley 2004).

Terrestrial ecosystem survey
The systematic analysis, classification and mapping of terrestrial ecosystems. A terrestrial ecosystem is an integrated representation of the ecological relationship between climate, soil and vegetation. Refer to Forest Service Manual 2551.6 R3 Supplement, page 1

For additional information refer to: Terrestrial Ecological Unit technical guide. 2005. General Technical Report, WO-68. Washington, DC; US Department of Agriculture, Forest Service, Washington Office, Ecosystem Management Coordination Staff, 245 p.

Threshold
A point of transition to a new state. After the transition, significant management effort (e.g. seeding, herbicide control, fire control, etc.) may be needed to restore the ecological processes of the prior state.

Timing (of grazing)
Season grazing occurs in relation to the morphological stage of plant development, such as early growth period, reproductive period, or dormant period.

Transect
Cf line transect.

Transition
A change from one state to another.

Trend
The direction of change in an attribute as observed over time. (Glossary Update Task Group 1998)

Trigger
Within-season guide for livestock managers to make changes or move livestock ensuring that end-point indicators are met. Generally don’t work well if codified into hard and fast requirements. (Swanson 2006)

Understory
Plants growing beneath the canopy of other plants; usually refers to grasses, forbs, and low shrubs under a tree or shrub canopy. (Interagency Technical Team 1996b)

Unsuitable range
Range which has no potential value for, or which should not be used for, a specific use because of permanent physical or biological restrictions. When unsuitable rage is identified, the identification must specify what use or uses are unsuitable (e.g. unsuitable cattle range). (Range Inventory Standardization Committee 1983)

Use pattern map
A map drawn or digitized onto a base map developed after a grazing period or season. It depicts zones of differing levels of utilization by livestock or some other herbivore within a pasture or other defined area. It is likely to show

patterns of heavier and lighter use that can be used to consider management alternatives. Syn. use zone map. (Swanson 2006)

Usable forage
That portion of the forage that can be grazed without damage to the basic resources; may vary with season of use, species and associated plant species. (Glossary Update Task Group 1998)

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, *or*
(2) Utilization of range for a purpose such as grazing, bedding, shelter, trailing, watering, watershed, recreation, forestry, etc. (Glossary Update Task Group 1998)

Utilization
Syn. use. (Glossary Update Task Group 1998)

Utilization cage
A small moveable or temporary exclosure to prevent grazing within its boundary. By moving the utilization cage to new representative areas each year before the grazing period it can be used to estimate the growth that would have occurred without grazing. (Swanson 2006)

Utilization gage
A device to calculate the percentage utilization by weight of different grass species based on measurements of grazed and ungrazed heights and pre-determined height/weight relationships for each species.

Vegetation association
Syn. plant association.

Vegetation pattern
Spatial distribution of vegetation in an area.

Vegetation structure
The organization in space of the individuals that form a stand, vegetation type, or plant association. The primary elements of structure are growth form, stratification, coverage. The term is complementary to function; function relating to physiological processes and structure to the anatomy and morphology of the objects under study. Vegetation structure, when not otherwise defined, should be used only in the sense of the spacing and height of plants forming a the matrix of vegetation cover (biomass structure). (Mueller-Dombois and Ellenberg 1974)

Vegetation type
A kind of existing plant community with distinguishable characteristics described in terms of the present vegetation that dominates the aspect or physiognomy of the area. (Glossary Update Task Group 1998)

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. (Glossary Update Task Group 1998) Not a quantifiable attribute.

Visual obstruction rating
A measure of foliage density in relation to height and plant spacing as determined by viewing target at a prescribed distance and height.

Water quality
The combination of biological, chemical, and physical characteristics of water and aquatic environments. Some agencies and laws have specific definitions for water quality. (Swanson 2006)

Yield
(1) the quantity of a product in a given space and/or time, *or*
(2) The harvested portion of a product. Syn. production, total annual yield, or runoff. (Glossary Update Task Group 1998)

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APPENDIX B
PLANT NAMES

Common Name	Scientific Name
Agave (several species)	Agave spp.
Alder	Alnus sp.
Alkali sacaton	Sporobolus airoides
Annual three awn (several species)	Aristida spp.
Arizona cottontop	Trichachne californica (Digitaria californica)
Aspen	Populus tremuloides
Beargrass	Nolina spp.
Big sacaton	Sporobolus wrightii
Black willow	Salix goodingii
Blue grama	Bouteloua gracilis
Burroweed	Happlopappus tenuisectus (Isocoma tenuisectus)
Bush muhly	Muhlenbergia porteri
Catclaw	Acacia greggii
Cheatgrass	Bromus tectorum
Cholla (several species)	Opuntia spp.(Cylindropuntia spp.)
Cliffrose	Cowania mexicana
Cottonwood	Populus fremontii
Coyote willow	Salix exigua
Cresosotebush	Larrea tridentata
Curley mesquitegrass	Hilaria belangeri
Douglas-fir	Pseudotsuga mentziezii
False mesquite	Calliandra eriophylla
Filaree	Erodium cicutarium
Fringed sage	Artemisia frigida
Greasewood	Sarcobatus vermiculatus
Hairy grama	Bouteloua hirsuta
Ironwood	Olneya tesota
Juniper (several species)	Juniperus spp.
Lehman's lovegrass	Eragrostis lehmaniana
Live oak (several species)	Quercus spp.
Lodgepole pine	Pinus contorta
Manazanita	Arctostaphylos pungens
Mediterranean grass	Schismus barbatus
Mesquite	Prosopis juliflora
Mormon tea	Ephedra spp.
Mountain mahogany	Cercocarpus montanus
Palo verde	Cercidium microphyllum
Pine (several species)	Pinus spp.
Prickly pear (several species)	Opuntia spp.
Rabbitbrush	Chrysothamnus spp.
Red brome	Bromus rubens
Sagebrush (several species)	Artemisa spp.
Saguaro	Carnegiea gigantea
Saltbush	Atriplex spp.
Sand dropseed	Sporobolus cryptandrus
Shinnery oak	Quercus turbinella
Shrubby buckwheat	Eriogonum wrightii
Six weeks grama	Bouteoua barbata
Snakeweed	Gutierrezia sarothrae
Sycamore	Platanus wrightii
Threeawns	Aristida spp.
Tobosa grass	Hilaria mutica (Pleuraphis mutica)
Tufted hairgrass	Deschampsia caespitosa
Whitethorn	Acacia constricta
Wolftail	Lycurus pheloides
Yucca (several species)	Yucca spp.
Zinnia	Zinnia pumila

APPENDIX C
ADDITIONAL SOURCES

There is a very large amount of information on monitoring and inventory for rangelands, ranging from theoretical to practical step by step procedures. The list below is not comprehensive but does list some of the more useful references that may be consulted on various methods or attributes.

Government Agency and Interagency Technical Manuals

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