Illinois Envirothon

2013 Current Issue Study Packet

Sustainable Rangeland Management:

Achieving a Balance between Traditional Agricultural Uses with Non-Traditional Uses on Montana Rangelands

Important Things to Remember

• The Illinois Envirothon will be held May 1st - 2nd , 2013, at Allerton Park in Monticello.
• This study packet for the 5th category should be used for your local Land Use Council (LUC) and Illinois Envirothon competition.
• If you are the winning team from your LUC and coming to the Illinois Envirothon, please bring this packet with you.
• Information on the Illinois Envirothon can be found on the Association of Illinois Soil & Water Conservation Districts website: www.aiswcd.org/programs/envirothon.htm
• Information on the North American Envirothon can be found on the following website: www.envirothon.org

Good Luck and Have Fun!

North American Envirothon
2013 Current Issue Key Topics & Learning Objectives

KEY TOPICS

1. Basic rangeland and pastureland knowledge, to include: identification of state grass, plant I.D. and definitions, importance of grazing lands in Montana.

2. Range Ecology Processes – definition of ecological sites (soil – plant relationships), ecological processes (energy flow, nutrient cycle, water cycle and plant succession).

3. Rangeland and pastureland management – stocking rates/carrying capacity, general types of grazing systems, improvement practices (fencing and water development), wetland, riparian and upland communities

4. Basic knowledge of livestock and wildlife interactions, forage preferences, forage overlap, and habitat requirements.

LEARNING OBJECTIVES

1. Define rangeland and pastureland, percentage of state encompassed by rangeland and pastureland, importance of grazing lands.

2. Identify state grasses of Montana, differentiate between plant types (grass, forb, shrub, and trees), identify parts of a grass and/or grass like species.

3. Define rangeland ecological sites, understand ecological process, understanding of all definitions inclusion to all key topic areas.

4. Understanding of basic rangeland and pastureland management concepts, i. e. grazing systems, stocking rates, and rangeland improvements.

5. Understanding of Best Management Practices (BMPs) on rangeland and pastureland and how different communities (wetland, riparian, and upland areas) interact.

6. Recognize different classes of livestock and understand their interaction with wildlife species.

7. Understanding of the historical use of the land by humans, domestic livestock and wildlife and its effect on the plant community.

8. Understanding the rights of the private landowner and citizens' rights to public land.

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All materials are located on the North American Envirothon website, Recommended Resources page. http://www.envirothon.org/2013-recommended-resources

The ABC of Pasture Grazing

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Sustainable Grazing Lands Providing a Healthy Environment

Ecosystems, Sustainability and Grassland Management

Montana Access Guide to Federal and State Lands

Rangelands - An Intro to Wild Open Spaces

Livestock and Poultry
Environmental Stewardship
<LPES> Curriculum

LPES Small Farms Fact Sheets*

Photos courtesy of USDA NRCS.

The ABCs of Pasture Grazing

By Ben Bartlett, Michigan State University

Summary

Well-managed pastures are Always the Best Crop for the environment, for the grazing animal, and for you. A well-managed pasture is a dense, healthy crop of grass and legumes that can provide a security blanket for the land, good nutrition for the animal, and more money in your pocket. Achieving a well-managed pasture does not take a big investment. It does require animal and plant knowledge, identification of your goals, some equipment, and practice.

MWPS USDA EPA

**Now available online at* <www.lpes.org>.

Why is a Well-Managed Pasture Always the Best Crop?

The best crop for the *environment* would protect the soil from wind and water erosion; catch the most rainfall possible to recharge the underground water system; hold, capture, and use nutrients applied in the form of manure and fertilizer; and provide a valuable product for human society. A well-managed pasture can do all this.

Managed grazing of pastures can provide nutritious grasses and legumes, or forage, rations for cattle, sheep, horses, goats, and other grazing animals. Pasture also gives the animals the freedom to exercise, choose their diet, and recycle their own manure (Figure 1). Pasture managed with controlled grazing can lower your costs by reducing equipment used, facility investments, and labor required. This results in the potential for *decreased costs and increased net profit.*

Pasture managed with controlled grazing can lower your costs.

Grazing for Productive and Environmentally Friendly Pastures

The four steps to a grazing plan are as follows:

1. Learn how plants grow and animals graze.
2. Identify your goals for your pasture.
3. Determine your fencing, water, and animal facility needs.
4. Practice, practice, practice the art of grazing.

Figure 1. Horses getting exercise and feed.

Photo courtesy of USDA-NRCS.

Step #1. Learn how plants grow and animals graze.

It rains, grasses and legumes grow, and the cow eats this forage. What else do you need to know? Animals can graze and forages will grow. But to achieve *your* goals, you need to know how plants grow and how animals graze.

> To achieve your goals, you need to know how plants grow and how animals graze.

The three principles of plant growth are the growth cycle (Figure 2), what controls growth per year, and the importance of grazing management.

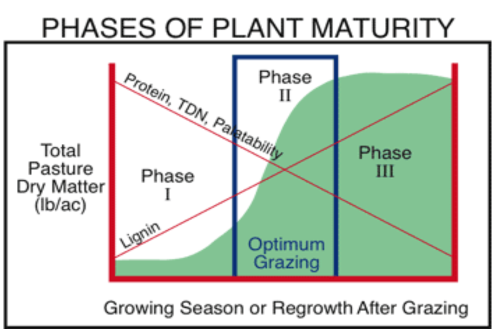

Figure 2. The three phrases of growth.

The growth cycle. Phase I is the first growth after dormancy or winter. It is supplied from the root reserves and is slow. There is limited plant growth but it is very high quality.

In Phase II, the green leaves are big enough to use energy from the sun. This process causes a fast growth rate and a rebuilding of reserves. A high quantity and high quality of forage results.

In Phase III, the growth rate slows as the plant produces seeds and plant decay begins. This yields a large quantity of feed but with decreasing quality.

The ideal grazing system would start grazing near the end of Phase II growth and stop grazing with enough green leaf for rapid regrowth.

These plant growth principles are usable for almost all environments and all kinds of plants.

Growth per year. Each plant can have one or more growth cycles per year but other factors influence the total amount of growth per year. Rainfall, temperature, soil fertility, and length of day are the main factors that determine season long growth rate. These factors will also have different impact depending on the species or mix of forage species you are growing. To increase the total amount of forage produced, you need to identify the limiting growth factor such as length of day or rainfall. You can add fertility in the form of commercial fertilizer or manure and you can install irrigation, but you cannot control temperature and length of day. (For more information on manure management, see the Small Farms fact sheet titled "Manure on Your Farm: Asset or Liability?") While you cannot make more sunshine, it is important to realize that with cool season grasses the fastest growth will occur during the longest daylight if other factors are adequate. In areas with warm season forages and less rain-fall, growth will depend more on rainfall.

To increase the total amount of forage produced, you need to identify the limiting growth factor, such as rainfall or length of day.

Grazing management. How you control the animal's grazing can have a big impact on regrowth rates, pasture species, plant density, and nutrient recycling. If you allow animals to graze a long time in the same pasture, they will over-harvest the tasty plants and not put any grazing pressure on the undesirable species. If you graze pastures very frequently and short, like a mowed lawn, it will favor species like clover and the pastures will become more dense. Pastures grazed very short in the fall will be slower to grow in the spring due to decreased reserves (Figure 3).

Figure 3. Beef cattle waiting to graze the next pasture.

Photo courtesy of USDA-NRCS.

Pastures grazed very short in the fall will be slower to grow in the spring.

Your pastures are the product of how they have been grazed in the past. Your current grazing management will determine what your pasture looks like in the future.

Spend time in your pastures learning what forages you have, how they grow, and how you and the environment affect their growth.

These grazing principals work on irrigated or non-irrigated land and for sheep (Figure 4) or cattle grazing.

Figure 4. Sheep grazing irrigated land.

Photo courtesy of USDA-NRCS.

How animals graze.

Grazing animals go for the best plants first and get the most nutrition when first turned into a pasture. Therefore, we can control the level of animal performance by how much of the plant we make the animals eat. For high-input animals like dairy cows, pastures also need to be dense so the cow gets lots of forage with every bite.

How often do animals need a new pasture? The golden rule is that you move animals to a fresh area before they graze any plant regrowth. This could be as short as three days or maybe as long as six months. If animals are allowed to graze regrowth that is not given enough rest to restore root reserves, the plant is weakened. This lack of rest is overgrazing.

> The golden rule is that you move animals to a fresh area before they graze any plant regrowth.

Step #2. Identify your goals for your pasture.

There is not a "right" way to graze or manage your pasture because it depends on your goals. You might want to graze one way for maximum gain per acre or another way for maximum average daily gain per animal. You are in control, and your grazing system can change pasture plant species, plant density, regrowth rates, level of animal performance, and the diversity of the plant community.

> Managed grazing puts you in control.

To create a successful grazing program, you need to write down short-term goals for your pastures and long-term goals for your grazing program. Test your grazing system practices against your long-term goals. The most important thing is that you set goals before you make plans and major investments. Where do you want to go? What profit or environmental or personal changes do you expect?

> To create a successful grazing program, write down your short- and long-term goals.

Step #3. Determine your fencing, water, and animal facility needs.

Fencing. New fencing materials and fencing techniques have greatly increased the fencing options.

The first fencing decision is to decide where to use an electric (psychological) or a non-electric (physical) barrier fence. Electric fence is generally lower cost and is the most common choice (Figure 5). Non-electric fences should be used where escape would be very undesirable, animals could be crowded against the fence, or there is danger to humans, especially children (Figure 6).


Figure 5. Electric psychological barrier fence.


Figure 6. Board physical barrier fence.

The fence must be effective. If the animals escape, you do not have controlled grazing. Design your fence for 99% of your animals and sell the 1% who are chronic escapers. Two more important items: the fence must be fixable and low cost over its usable life. Cheap materials may result in a high-cost fence in the long run since the cost of a fence is ½ materials and ½ labor.

Design your fence for 99% of your animals and sell the 1% who are chronic escapers.

To create a fencing plan,

- Determine fence location and legal boundaries.
- Determine what kind of animals you may be grazing.
- Draw your farm/ranch fencing plan on an aerial map.
- Design your fence, that is, the number of posts, wires, gates, etc.

- Make a fence-building priority plan; people rarely build all of their fence in one year.

A good fence includes well-built corner and end posts. See Figure 7 for an example of good end post construction.

Figure 7. Well-built post assembly.

Water. Many pasture systems use streams or ponds/-reservoirs for animal watering. Animal access to the water needs to be managed to prevent environmental damage from hooves and too much manure. It may be necessary to fence the entire stream or pond and use a controlled and designed water access site (Figure 8). In many situations, water can be easily and cheaply moved to portable water tanks via the new plastic pipe (Figure 9). The key is to monitor the streamside areas in your pasture to maintain a healthy ecosystem. (For more information about safeguarding the water on your farm, see the Small Farms fact sheet titled "Protecting the Water on Your Small Farm.")

Figure 8. Stream access site for cattle.

Photo courtesy of USDA NRCS.

Figure 9. Dairy cows drinking from portable water tank in pasture.

Photo courtesy of USDA NRCS.

Animal facilities. Managed grazing is a low-cost system, but investing in adequate facilities like good fencing is critical. Other animal facilities include handling equipment for gathering and working animals; lanes for mud-free, wet weather travel; and shade for extremely hot weather. Every pasture, every kind of animal, and every part of the country will have different challenges to a productive grazing system. Your responsibility as the manager is to identify the problems and apply solutions.

> Managed grazing is a low-cost system, but investing in adequate facilities like good fencing is critical.

How do you design a fence, build a stream access site, or determine the correct fence charger? Local experts are often the best source of this information. Get to know your fence builders, extension agent, NRCS staff, and other land and animal experts in your area. Some of these organizations also have cost share programs for grazing and environmental conservation practices. The Internet and various websites are other important sources of information.

> If you do the right thing at the right time, grazing animals are good for grazing land.

Step #4. Practice, practice, practice the art of grazing.

A well-managed grazing system will improve the health and the productivity of a pasture. If you do the right thing at the right time, grazing animals are good for grazing land. Knowledge of plant growth and how animals graze will help you do the right thing. Do not worry about having the correct size or number of pastures or be overwhelmed by the details of a grazing system. The most important thing is to get started on an improved grazing system. Your experience on your farm, combined with new grazing knowledge, is the best teacher. A well-managed pasture can improve the environment and your bottom line.

Points to Remember

- Have a goal. Why are you grazing? What will success look like?
- Understand both the why and the how to. If you do not know why you are doing something, do not do it. More fences are just more fences, not a grazing system.
- Practice, monitor, re-plan, practice, monitor, re-plan. You may never get it all right, but with increasing knowledge and practice, you can get a little closer.

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For More Information

Small Farm Resources

Contact The Stockman Grass Farmer, 800-748-9808, to purchase *Intensive Grazing Management: Forage, Animals, Men, Profits*.

Contact the Iowa State University Extension Distribution Center, 515-294-5247 or www.extension.iastate.edu, to purchase *Pasture Management Guide for Livestock Producers*, 1998.

Contact the University of Wisconsin Extension, 877-947-7827 or cecommerce.uwex.edu, to purchase *Wisconsin Pastures for Profit*, 2002.

Contact University of Missouri Extension Publications, 800-292-0969 or muextension.missouri.edu, to purchase the 1996 *Missouri Grazing Manual*.

Contact Ben Bartlett, MSU Extension, 906-439-5880, to purchase *Watering Systems for Grazing Livestock*, 1998.

Contact University of Wisconsin Extension, 877-947-7827 or cecommerce.uwex.edu, to purchase the CD Pastures for Horses, *A Guide to Rotational Grazing*, 2003.

http://forages.oregonstate.edu–Oregon State University Forage Information website

http://www.sare.org–Sustainable Agriculture Research and Education

http://www.attra.org–National Sustainable Agricultural Information Service

http://www.uwex.edu/ces/forage/links.htm–University of Wisconsin Forage and Extension Links

USDA-CSREES Small Farm hotline–800-583-3071

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Interpreting Indicators of Rangeland Health

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Interpreting Indicators of Rangeland Health

Version 4

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Interagency coordination between the Bureau of Land Management (BLM), the Natural Resources Conservation Service (NRCS), the Agricultural Research Service (ARS), and the USGS Forest and Rangeland Ecosystem Science Center was essential to successfully completing this document. The order of authors cited for this publication is a reflection of the amount of time spent on document organization and preparation for Version 4.0, not the important and equal contribution that each author made to the scientific and procedural content of this technical reference.

The authors want to again acknowledge and thank all of the previous contributors to Version 3 and earlier versions of *Interpreting Indicators of Rangeland Health* for their valuable input, which has cumulatively added to the quality and usefulness of this technical reference. As the concept of rangeland health continues to evolve and mature, the application of this concept and protocol will also evolve and be reflected in future versions of the document.

The changes in Version 4 reflect input from several hundred workshop participants in the United States, Canada, and Mexico, as well as numerous individual discussions and evaluations and scientific review through the USGS peer-review process. The document also benefited from significant input from the National Science Foundation-funded Jornada Basin Long-Term Ecological Research Project. The BLM's National Training Center, under the leadership of Julie Decker, provided support for numerous interagency training sessions that provided the authors with the feedback used to move from Version 3 to Version 4. Individuals who reviewed or contributed to significant modifications of Version 4 include Jack Alexander, Brandon Bestelmeyer, Peter Dunwiddie, Kirk Gadzia, Sherm Karl, Patrick McCarthy, Mark Miller, Laura Burkett, Peter Russell, George Ruyle, Pete Sundt, Arlene Tugel, and Bob Unnasch. Cynthia Dalzell reviewed and edited several drafts of this document and is recognized for her contribution.

Thanks to Kathy Rohling and Janine Koselak of BLM's National Science and Technology Center for the editing, design, and layout of this technical reference and to BLM's National Business Center for managing the production aspects of the final document.

Preface

Version 4 of Interpreting Indicators of Rangeland Health, Technical Reference 1734-6, is the second published edition of this technique. It follows the recommendations published in Pyke et al. (2002). The indicators are unchanged from Version 3, allowing this document to replace Version 3 even in areas where the evaluation process has already begun.

The changes in Version 4 are designed to improve the consistency in the application of the process. The most significant modification is the replacement of the Ecological Reference Area Worksheet with the Reference Sheet (Appendix 2). The Reference Sheet facilitates consistent application of the process on each ecological site by integrating all available sources of data and knowledge to generate a single range of reference conditions for each indicator.

We have removed the Species Dominance Worksheet (Version 3, Appendix 4), since the information gained from this worksheet is similar to the information in the Functional/Structural Groups Sheet. We have included cells for noxious weeds and invasive plants in the Functional/Structural Groups Sheet (Version 4, Appendix 3). This allows users to continue to document the presence and abundance of invasive species for their records.

The Cover Sheet (Version 3, Appendix 3) has been deleted and information on collecting quantitative data is deferred to other publications.

Based on a more thorough review of the literature, we have switched the attribute assignment for the litter movement indicator from Hydrologic Function to Soil/Site Stability in Version 4, Appendix 1.

In Version 3, Appendix 1, all of the indicator rating categories except "Extreme departure from the Ecological Site Description/Reference Area" implied that the category included a range of values. This implication came either from the title (for example None to Slight departure) or from the position within the range of the other categories (for example Moderate was between Slight to Moderate and Moderate to Extreme), but the fifth category, Extreme, caused some users to believe that this category did not include a range, but was the absolute worst departure possible. This was not our intention and we have changed the Extreme category to Extreme to Total in Version 4, Appendix 1.

We strongly recommend that the indicator descriptors in the Evaluation Matrix in Version 4, Appendix 4, for each ecological site be revised and made more specific. This change has been designed to improve consistency among observers. The wording of the "default descriptors" has been retained as "generic descriptors" in nearly all cases. Only minor changes were made to the generic descriptors. These changes clarify the indicators and do not change their interpretation.

In other words, interpretations made with Version 3 will be consistent with those made with Version 4 *provided that the same reference information is used.*

A flow chart under the "Instructions for Using the Rangeland Health Assessment Protocol" section and the Checklist for Rangeland Health Assessment Protocol, Appendix 8, were added to help ensure that all the necessary steps are completed.

Finally, we have added new information, "Quantitative Measures for the 17 Indicators" (Appendix 6), that describes quantitative methods that can be used to generate data to complement this qualitative assessment process.

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Intended Applications

Qualitative assessments of rangeland health provide land managers and technical assistance specialists with a good communication tool for use with the public. Many of these tools have been used successfully for this purpose over the past 100 years. This technique, in association with quantitative monitoring and inventory information, can be used to provide early warnings of resource problems on upland rangelands. Rangelands are defined as "land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangelands include natural grasslands, savannas, shrublands, many deserts, tundra, alpine communities, marshes, and wet meadows" (Society for Range Management 1999). Also included in this definition are oak and pinyon-juniper woodlands.

The protocol described in this technical reference IS designed to:

- Be used only by knowledgeable, experienced people.
- Provide a preliminary evaluation of soil/site stability, hydrologic function, and biotic integrity (at the ecological site level).
- Be used to communicate fundamental ecological concepts to a wide variety of audiences.
- Improve communication among interest groups by focusing discussion on critical ecosystem properties and processes.
- Select monitoring sites in the development of monitoring programs.
- Provide early warnings of potential problems and opportunities by helping land managers identify areas that are potentially at risk of degradation or where resource problems currently exist.

The protocol is NOT to be used to:

- Identify the cause(s) of resource problems.
- Independently make grazing and other management changes.
- Monitor land or determine trend.
- Independently generate national or regional assessments of rangeland health.

Interpreting Indicators for Rangeland Health has been developed for use by experienced, knowledgeable land managers or technical assistance specialists. This assessment protocol is not intended for use by individuals who do not have experience or knowledge of the rangeland ecological sites they are evaluating. This protocol requires a good understanding of ecological processes, vegetation, and soils for each site to which it is applied. Our research has shown that the quality and consistency of evaluations is improved when two or more individuals (e.g., ecologist and soil scientist) work together. The input of multiple individuals is particularly critical in the development of reference sheets for each ecological site. Development of the reference sheets requires a knowledge of the range of spatial and temporal variability apparent at a particular ecological site.

Introduction

The science of assessing rangelands is changing as concepts and protocols continue to evolve. The concept of rangeland health was advanced as an alternative to range condition (National Research Council 1994). The ecological status concept is currently used by most range professionals as the basis for inventory and assessment. Although the term "health" has been controversial when used in association with natural systems (Wicklum and Davies 1995, Lackey 1998, Rapport et al. 1998, and Smith 1999), this document follows the lead provided by the National Academy of Science (National Research Council 1994).

The National Research Council (NRC 1994) publication, *Rangeland Health: New Methods to Classify, Inventory, and Monitor Rangelands* defined rangeland health as:

> *"The degree to which the integrity of the soil and ecological processes of rangeland ecosystems are maintained."*

In a parallel effort, the Society for Range Management's committee on *Unity in Concepts and Terminology* recommended that rangeland assessments should focus on the maintenance of soil at the site (Task Group on Unity in Concepts and Terminology 1995). A Federal interagency ad hoc committee was established to integrate the concepts of these two groups into the various agencies' rangeland inventories and assessments. This committee refined the above definition to read:

> *"The degree to which the integrity of the soil, vegetation, water, and air, as well as the ecological processes of the rangeland ecosystem are balanced and sustained."*

They defined integrity to mean *"maintenance of the functional attributes characteristic of a locale, including normal variability" (USDA 1997).*

The challenge to scientists and managers is to translate this concept into terms that the public can comprehend, and that resource specialists can use to assist in identifying areas where ecological processes are or are not functioning properly. This document describes a protocol to educate the public and agency personnel on using observable indicators to interpret and assess rangeland health. This protocol relies on the use of a qualitative (non-measurement) procedure to assess the functional status of each indicator.

The use of qualitative assessments is suggested as a fast survey technique to rate site protection indicators, including both plant and soil components (Morgan 1986). The use of qualitative information (e.g., observations) to determine range and soil conditions has a long history of use in land management inventory and monitoring. In some cases, qualitative assessments were used independently, while in other cases they were blended with quantitative measurements. Early procedures that included indicator ratings (e.g., a scorecard approach) included the Interagency Range Survey of 1937, Deming Two-Phase and Parker Three-Step Methods that determined, among other things, site-soil stability and usefulness of forage for livestock grazing (Wagner 1989). The Bureau of Land Management (BLM) also used soil surface factors to determine the erosional status of public lands in the 1970s (USDI 1973). Interagency Technical Reference 1737-9, *Riparian Area Management: Process for Assessing Proper Functioning Condition* (USDI 1993) included a qualitative checklist to assess the proper functioning condition of riparian areas.

This version of *Interpreting Indicators of Rangeland Health* incorporates concepts and materials from previous inventory and monitoring procedures, as well as from the National Research Council's book on Rangeland Health (NRC 1994), and the Society for Range Management's Task Group on Unity in Concepts and Terminology (1995). Development of a landscape ecology approach to assessing rangeland function in Australia also contributed to the understanding of soil processes on North American rangelands and to the interpretations derived from this protocol (Tongway 1994).

The earliest versions of the current procedure were developed concurrently. An interagency technical team led by the BLM developed Version 1a (Pellant 1996). The Natural Resources Conservation Service (NRCS) developed Version 1b, as published in the National Range and Pasture Handbook (USDA 1997). Another interagency team melded these concepts and protocols with the results from numerous field tests of Version 1a (Rasmussen, Pellant, and Pyke 1999) and Version 1b into Version 2. Modifications of Version 2 received peer review and numerous other comments to arrive at the process described in Version 3.

The changes in Version 4 were based on input from a large number of users of Version 3 and are designed to improve the consistency of the application of the process. The most significant modification was the replacement of the Ecological Reference Area Sheet with the Reference Sheet (Appendix 2) (Pyke et al. 2002). The Reference Sheet facilitates consistent application of the process throughout the ecological site by integrating all available sources of data and knowledge to generate a description of the range of expected conditions for each indicator if a site is in the reference state. This includes the associated spatial and temporal variability. It is normally developed for existing ecological sites, but can also be applied to any soil/climate-based land classification system that reflects site potential (see ecological site definition in the Glossary).

Along the way, this procedure has been termed "rapid assessment," "qualitative assessment of rangeland health," and "visualization of rangeland health." This document refers to this procedure as **Interpreting Indicators of Rangeland Health – Version 4**. This version will be revised in the future as science and experience provide additional information on indicators of rangeland health and their assessment.

Relationship to Similarity Index and Trend

The similarity index (range condition) and trend studies have long been used for rangeland assessments. The similarity index can be used as an index of the current plant community in relation to the historic climax plant community, or to a desired plant community that is one of the communities in the reference state for that ecological site (see the section on Concepts: States, Transitions, and Disturbances). Trend is a determination of the direction of change in the current plant community and soils in relation to the community that existed in the past and to the current community along a continuum moving toward a historic climax plant community or some other desired plant community.

This rangeland health assessment is an attempt to look at how well ecological processes on a site are functioning. These three assessment tools (similarity index, trend, and rangeland health assessment) evaluate the rangeland site from different perspectives and are not necessarily correlated (Pierson et al. 2002).

Attributes of Rangeland Health

Ecological processes include the **water cycle** (the capture, storage, and safe release of precipitation), **energy flow** (conversion of sunlight to plant and then animal matter), and **nutrient cycle** (the cycle of nutrients through the physical and biotic components of the environment).

Ecological processes functioning within a normal range of variation support specific plant and animal communities. Direct measures of site integrity and status of ecological processes are difficult or expensive to measure due to the complexity of the processes and their interrelationships. Therefore, biological and physical components are often used as indicators of the functional status of ecological processes and site integrity.

The product of this qualitative assessment is **not** a single rating of rangeland health, but an assessment of three components called attributes (Table 1).

Definitions of these three interrelated attributes are:

Soil/Site Stability

The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function

The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic Integrity

The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

Each of these three attributes is summarized at the end of the Evaluation Sheet based upon a preponderance of evidence approach using the applicable indicators (Appendix 1). This assessment is preliminary and may be modified with the interpretation of applicable quantitative monitoring and inventory data. Support or rationale for the original rating and any modification of them should be documented on the Evaluation Sheet (Appendix 1).

To reiterate, the protocol described here will produce three ratings, one for each attribute.

Table 1. The three attributes of rangeland health and the rating categories for each attribute.

Soil/Site Stability	Hydrologic Function	Biotic Integrity		
Attribute ratings reflect the degree of departure from expected levels for each indicator per the Reference Sheet				
Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight

Concepts

An understanding of the following five concepts is necessary to apply this method.

Landscape Context: Ecological Sites and Watersheds

A landscape is comprised of part or all of one or more watersheds. Several systems have been devised to classify landscapes into similar units for comparisons. *Interpreting Indicators of Rangeland Health* requires the use of a classification system that divides landscapes based on the potential of the land to produce distinctive kinds, amounts, and proportions of vegetation. Soils, climate, and topography together determine this potential. The ecological site concept was developed by the USDA NRCS as one such land classification system. Other site potential-based classification systems can also be used. Where no such system exists (e.g., in Mexico), the method can be locally applied using the best available information. This information is documented in the Reference Sheet (Appendix 2).

Interpreting Indicators of Rangeland Health was designed to be applied at specific locations, known as evaluation areas, in the larger landscape. Evaluators must be able to recognize and correctly identify ecological sites because evaluations are made relative to an ecological site or equivalent. Ecological sites or their equivalents are identified in the field using the factors that determine the site's potential: soils, climate, and topography (USDA 1997).

In addition to ecological site identification, some knowledge of the potential range of spatial variability and of landscape relationships (including characteristics of surrounding areas) is required to interpret evaluations. Since the status of surrounding areas on other ecological sites may influence the evaluation area, we have provided a means of documenting pertinent information about these surrounding areas in the Evaluation Sheet (Appendix 1) and in the Reference Sheet (Appendix 2).

Spatial Variability

An understanding of the potential range of spatial variability both within and among ecological sites is necessary to apply this technique. For example, south-facing slopes are subject to higher evaporation rates and generally have shallower soils than north-facing slopes. Both higher evaporation rates and shallower soil depth result in lower soil moisture availability, increasing bare ground and the potential for rill formation, even on sites that are at or near their potential. Sites that are located lower on the landscape (downslope) may receive runoff water during intense storms or snowmelt. The effect of increased runoff can be positive when the additional water is retained onsite and becomes available for plant growth. Increased runoff can be negative if it results in greater erosion. Microsites that capture wind-driven snow generally have a higher production potential than sites that are typically free of snow, except where snow persists long enough that it significantly limits the length of the growing season. Sometimes these microsite differences are reflected in different ecological sites, but most ecological sites include a broad range of microsites with variable potential.

Landscape Relationships

Some knowledge of landscape relationships is often required to interpret an indicator's departure from that expected for a specific ecological site. Both direct and indirect effects of other landscape units can be important. Direct effects include runoff, erosion, and seed dispersal from surrounding areas. Indirect effects include differences in herbivory, predator-prey, or pathogen-host relationships associated with proximity to water or alternative habitats. For example, recovery or degradation at one location can affect indicators evaluated downslope. While effects of degradation are reflected in the downslope location (e.g., an active gully might be rated as an "extreme to total" departure from the Reference Sheet (Appendix 2), the cause might be increased runoff from another location. Conversely, recovery of plant cover and soil water infiltration capacity in upslope locations can result in reduced water availability for plant growth downslope. These are excellent examples of why it is not recommended that this approach be used alone to assign cause of resource problems. Defining the cause of the gully and the increased production requires a landscape-level analysis and it is possible that the source of the problem is on land controlled by a different manager. Document any off-site influences that affect the evaluation area on the first page of the Evaluation Sheet (Appendix 1).

Spatial Extrapolation

Qualitative watershed, sub-watershed, or sub-basin-scale analyses could be used to generate a map for each of the three attributes based on ecological, site-level evaluations. Appropriate sampling designs are required to aggregate qualitative assessments to larger landscape units. These maps can be overlaid on a soil or ecological site map and used to help identify areas where management interventions are likely to have the greatest effect on runoff, water quality, and other resource concerns. Due to the inherent complexity of many landscapes, many parts of the watershed may need to be mapped as "complexes" in which a single map unit represents several ecological sites and/or a single ecological site that is rated differently in different areas within the map unit (e.g., areas near herbivore watering points may be more degraded than those far from water).

Natural Range of Variability

The biological and physical potential of every location is unique in space and time (Bestelmeyer et al. 2004). To the extent possible, the types and sources of spatial and temporal variability should be described for each indicator on the Reference Sheet (Appendix 2). Sources of spatial variability include soils, climate, natural disturbance events, vegetation communities within the reference state (see States, Transitions, and Disturbances), and topographic position. While all of these are expected to be similar within an ecological site, the quality of evaluations can be improved by recognizing and documenting the expected variation in these sources and documenting how these sources of variation may influence individual indicators on the Reference Sheet.

Plant communities and soils also vary naturally through time. It is expected that bare ground will increase during extended periods of drought, and that woody species and litter cover will be lower following fire. More litter movement and water flow patterns are expected following intense storms in many ecosystems. The temporal range of variability expected within an ecological site should also be reflected in the Reference Sheet (Appendix 2). For example, plant community shifts along pathways within the reference state (Figure 2) should be reflected in the description of the "Plant Functional/Structural Groups" indicator on the Reference Sheet.

Resistance and Resilience

Staying within the natural range of variability depends on the resistance and resilience of the ecosystem. Resistance is the capacity of ecological processes to continue to function with minimal change following a disturbance. Resilience is the capacity of these processes to recover following a disturbance (Figure 1). Resilience can be defined in terms of the rate of recovery, the extent of recovery during a particular period of time, or both (Figure 1).

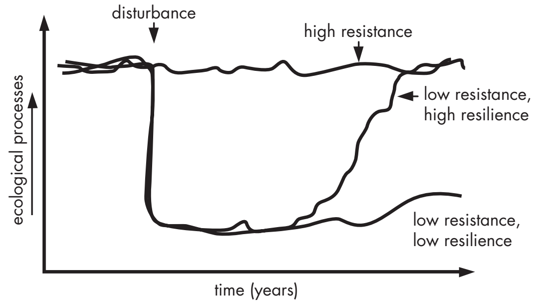


Figure 1. Changes in ecological processes over time following disturbance for systems that vary in resistance and resilience (adapted from Seybold et al. 1999)

The resistance and resilience of individual communities vary within a state. Consequently, the specific community that is the least resistant to and/or resilient following a particular disturbance is the one that is most likely to proceed through a transition to another state.

Indicators

Ecological processes are difficult to observe or measure in the field due to the complexity of most rangeland ecosystems. Indicators are components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., hydrologic function) that is too difficult, inconvenient, or expensive to measure. Just as the Dow Jones Index is used to gauge the strength of a portion of the stock market, different combinations of the 17 indicators are used to gauge soil/site stability, hydrologic function, and biotic integrity.

Indicators have historically been used in rangeland monitoring and resource inventories by land management and technical assistance agencies. These indicators focused on vegetation (e.g., production, composition, density) or soil stability as surrogates for rangeland condition or livestock carrying capacity. Such single attribute assessments are inadequate to determine rangeland health because they do not reflect the complexity of the ecological processes. There is no one indicator of ecosystem health; instead, a suite of key indicators should be used for an assessment (Karr 1992).

Qualitative vs. Quantitative Indicators

Interpreting Indicators of Rangeland Health is based on qualitative indicators. These indicators are appropriate for the objectives described in the "Intended Applications" chapter. Quantitative measurements should be made where it is necessary to document assessments for direct comparisons with other locations, or where monitoring data are required to determine trend.

Quantitative indicators that are correlated with many of the qualitative indicators used in this protocol can be calculated from quantitative measurements (Table 2). More detailed information is included in Appendix 6, Quantitative Measures for the 17 Indicators. In some cases, no equivalent quantitative indicator exists. This reflects the fact that some ecosystem properties are more accurately reflected by qualitative indicators, while others are more effectively measured quantitatively (Rapport 1995). In most cases, the general relationship is similar, but the specific values associated with each departure class vary significantly among ecological sites. For example, rill density for a "none–slight" rating is much higher in badlands ecological sites than in ecological sites located on flat terrain in the central Great Plains of the United States.

The best approach to designing a quantitative monitoring program that is compatible with this qualitative assessment protocol is to select the best quantitative indicators for each of the three *attributes*, rather than selecting an equivalent quantitative indicator for each qualitative indicator. The best quantitative indicators are those that, as a group, are most consistently correlated with the ecosystem functions associated with each of the three attributes. For example, bare ground and soil aggregate stability are both highly correlated with resistance to erosion in most ecological sites, and are therefore good indicators of the "soil/site stability" attribute (Herrick et al. 2005).

Table 2. Key quantitative indicators and measurements relevant to each of the three attributes. Because an appropriate quantitative indicator does not exist for each qualitative indicator, we recommend focusing on selecting the best possible indicators (qualitative and quantitative) for each attribute (for indicator-specific comparisons, please see Appendix 6. References: (1) USDA 1997; (2) Elzinga et al. 1998; and (3) Herrick et al. 2005.

Attribute	Qualitative Assessment Indicators	Key Quantitative Assessment Indicators	Selected Measurements and References
Soil/Site Stability	• Rills • Water flow patterns • Pedestals and/or terracettes • Bare ground • Gullies • Wind-scoured, blowout, and/or depositional areas • Litter movement • Soil surface resistance to erosion • Soil surface loss or degradation • Compaction layer	Bare ground	Line point intercept (2, 3) Point frame (2)
		Proportion of soil surface covered by canopy gaps longer than a defined minimum	Canopy gap intercept (3) Continuous line intercept (2)
		Proportion of soil surface covered by basal gaps longer than a defined minimum	Basal gap intercept (3) Continuous line intercept (2)
		Soil macro-aggregate stability in water	Soil stability kit (3)
Hydrologic Function	• Rills • Water flow patterns • Pedestals and/or terracettes • Bare ground • Gullies • Soil surface resistance to erosion • Soil surface loss or degradation • Plant community composition and distribution relative to infiltration and runoff • Compaction layer • Litter amount	Bare ground	Line point intercept (2, 3) Point frame (2)
		Proportion of soil surface covered by canopy gaps longer than a defined minimum	Canopy gap intercept (3) Continuous line intercept (2)
		Proportion of soil surface covered by basal gaps longer than a defined minimum	Basal gap intercept (3) Continuous line intercept (2)
		Soil macro-aggregate stability in water	Soil stability kit (3)
Biotic Integrity	• Soil surface resistance to erosion • Soil surface loss or degradation • Compaction layer • Functional/structural groups • Plant mortality/decadence • Litter amount • Annual production • Invasive plants • Reproductive capability of perennial plants	Soil macro-aggregate stability in water	Soil stability kit (3)
		Plant canopy (foliar) cover by functional group	Line point intercept (2, 3) Point frame (2)
		Plant basal cover by functional group	Line point intercept (2, 3) Point frame (2)
		Litter cover	Line point intercept (1, 3) Point frame (2)
		Plant production by functional group	Harvest (1) Double sampling (1)
		Invasive plant cover	Line point intercept (1, 3)
		Invasive plant density	Belt transect (2, 3) Quadrats (2)

Vegetation Indicator Consistency: Production, Foliar Cover, and Standing Biomass

The application of this method depends on comparisons to a consistent benchmark. This benchmark varies depending on which indicator is being evaluated, the relationship of certain indicators to production, foliar cover, or biomass, and data collection methods. For *Interpreting Indicators of Rangeland Health*, the Reference Sheet serves as the standard for the 17 indicators. The reference sheet includes information on vegetation composition for several indicators, including but not limited to, functional and structural groups. The evaluation of these indicators is often based on annual production because of the widespread availability of ecological site descriptions, which include production data.

Both standing biomass and foliar cover are correlated with production. However, these relationships vary by species. The relationships between foliar cover, biomass, and production vary among locations and both within and among years in a single location. Dominance rankings of species or functional/structural groups may change depending on which vegetation measure is used. Consequently, uniform substitution of foliar cover or biomass for production is not appropriate. However, foliar cover and biomass can be used as surrogates for production where the relationships are well understood.

Inconsistent comparisons can also arise when different methods are used to quantify or estimate production, foliar cover, or biomass. Annual production estimates include three components: current year's growth present at the time of the evaluation, current year's growth that has been removed by livestock and/or wildlife, and the expected growth (production) during the rest of the year. Expected growth is estimated from standard growth curves. Annual production includes all aboveground production of all species, including stem elongation. Biomass includes all above ground production regardless of the year it was produced.

Foliar cover is simply the proportion of soil surface covered by a vertical projection of a plant canopy. This is effectively the area that is protected from raindrops and the area in shade when the sun is directly overhead. This is the definition used in erosion models. Foliar cover reflects changes in the density of the plant canopy associated with leaf and twig mortality, as well as changes in the size and number of individual plants in a defined area.

Foliar cover measurement or estimates may be based on several approaches including line-point and visual estimates. The line-point method (Elzinga et al. 1998; Herrick et al. 2005) is recommended because it measures the area actually covered by leaves, twigs, and stems, and can be used to assess indicators that are generally more directly related to production, runoff, erosion, and to remote sensing. This method is among the easiest to standardize of all vegetation cover methods and is the preferred method to collect foliar cover for new ecological site descriptions.

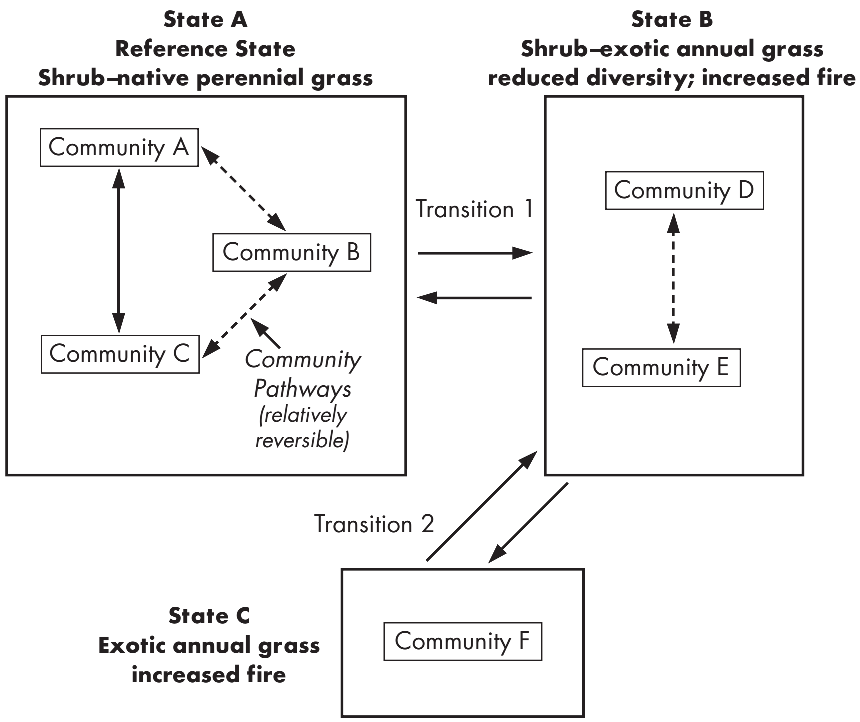
Care must be taken in interpreting ecological site descriptions developed prior to 1997 when the NRCS began using foliar cover (USDA 1997) instead of canopy cover in these site descriptions. Canopy cover includes all spaces located within the canopy of an individual plant as "cover," whether or not they were actually protected by a leaf or twig. This resulted in a higher estimate of "cover" particularly for stoloniferous grasses and for shrubs and trees with diffuse canopies and did not reflect foliar cover. Cover data collected for new ecological site descriptions are based on foliar cover.

States, Transitions, and Disturbances

A state includes one or more biological (including soil) communities that occur on a particular ecological site and that are functionally similar with respect to the three attributes (soil/site stability, hydrologic function, and biotic integrity). States are generally distinguished by relatively large differences in plant functional groups, dynamic soil properties, and ecosystem processes, and consequently in vegetation structure, biodiversity, and management requirements. They are also distinguished by their responses to disturbance. A number of different plant communities may be included in a state, and the communities are often connected by community pathways (See Figure 2, Generic state and transition diagram; Bestelmeyer et al. 2002, Stringham et al. 2001).

Shifts between states (solid arrows in Figure 2) are referred to as "transitions." Unlike community pathways (dashed arrows in Figure 2), these "threshold" transitions are not reversible by simply altering the intensity or direction of factors that produced the change. Instead, they may create a physically-altered state, such as an eroded state that has lost part of its A soil horizon. Alternatively, they may require new inputs such as revegetation or shrub removal. Practices such as these, enabling a return to a pre-existing state (USDA 1997), are often expensive to apply. Transitions among states in an ecological site are often caused by a combination of feedback mechanisms that alter soil and plant community dynamics (e.g., Schlesinger et al. 1990). For example, as shrubs replace grasses, runoff and erosion increase from shrub interspaces further reducing soil resource availability for grasses.

The reference state is the state where the functional capacities represented by soil/site stability, hydrologic function, and biotic integrity are performing at a near optimum level under the natural disturbance regime. This state usually includes more than one community, one of which is known as the "historic climax plant community" (see Glossary) and is depicted as one of the communities in the Reference State in Figure 2. Alternatively, some rangeland management or ecology literature (Heady and Child 1994, SRM 1999, Vallentine 1990), recognize one of the communities as the "potential natural plant community." While this technical reference uses the reference state (but not any particular community within the state) as the reference for the rangeland health evaluation, we recognize that managers may choose to manage for communities in another state. In other words, the reference state usually, but not



Community Pathways	Example
A	Shrubs and native perennial grasses co-dominate (historic climax plant community)
B	Native perennial grasses are dominant; shrubs subdominant
C	Shrubs dominate; perennial grasses subdominant
D	Shrubs dominate; exotic grasses subdominant
E	Exotic grasses dominate; shrubs subdominant
F	Exotic annual grasses dominate
Transitions (relatively non-reversible)	
1	Wildfire and introduction of exotic, invasive, annual grasses
2	Repeated wildfires that exceed natural fire-return interval

Figure 2. Generic state and transition diagram. Dashed lines between communities within a state are community pathways; solid lines between states are transitions; and dotted lines between states indicate unlikely reverse transitions (see table with figure for further explanation).

always, includes the manager's desired plant community. However, if sustainability is an objective, the desired plant community will nearly always be found in the reference state (Borman and Pyke 1994).

Some type of disturbance is a natural and necessary part of all ecosystems. Healthy ecosystems are generally both resistant to external disturbances and resilient (able to recover) if external disturbances occur (Pimm 1984). Healthy ecosystems generally allow various communities to fluctuate over time within a state. Transitions rarely occur in response to the natural disturbance regime. However, resistance and resilience alone are insufficient criteria for healthy ecosystems; degraded systems are often highly resistant to change.

Instructions for Using the Rangeland Health Assessment Protocol

A rangeland health assessment provides information on the functioning of ecological processes relative to the reference state for the ecological site or other functionally similar unit for that land area. This assessment provides information that is not available with other methods of evaluation. It gives an indication of the status of the three attributes chosen to represent the health of the "evaluation area" (i.e., the area where the evaluation of the rangeland health attributes occurs). Interest in an evaluation area may be based on concern about current conditions, lack of information on conditions, or public perceptions of conditions.

The following instructions are intended to provide a step-by-step guide for users. Steps are identified along with the document(s) required to complete each step. The action or concept for that step is then explained.

The flow chart in Figure 3 illustrates the entire process and can be used to help decide which steps to complete and the sequence of those steps. Use the Checklist for Rangeland Health Assessment Protocol (Appendix 8) to ensure that you have completed all the required steps.

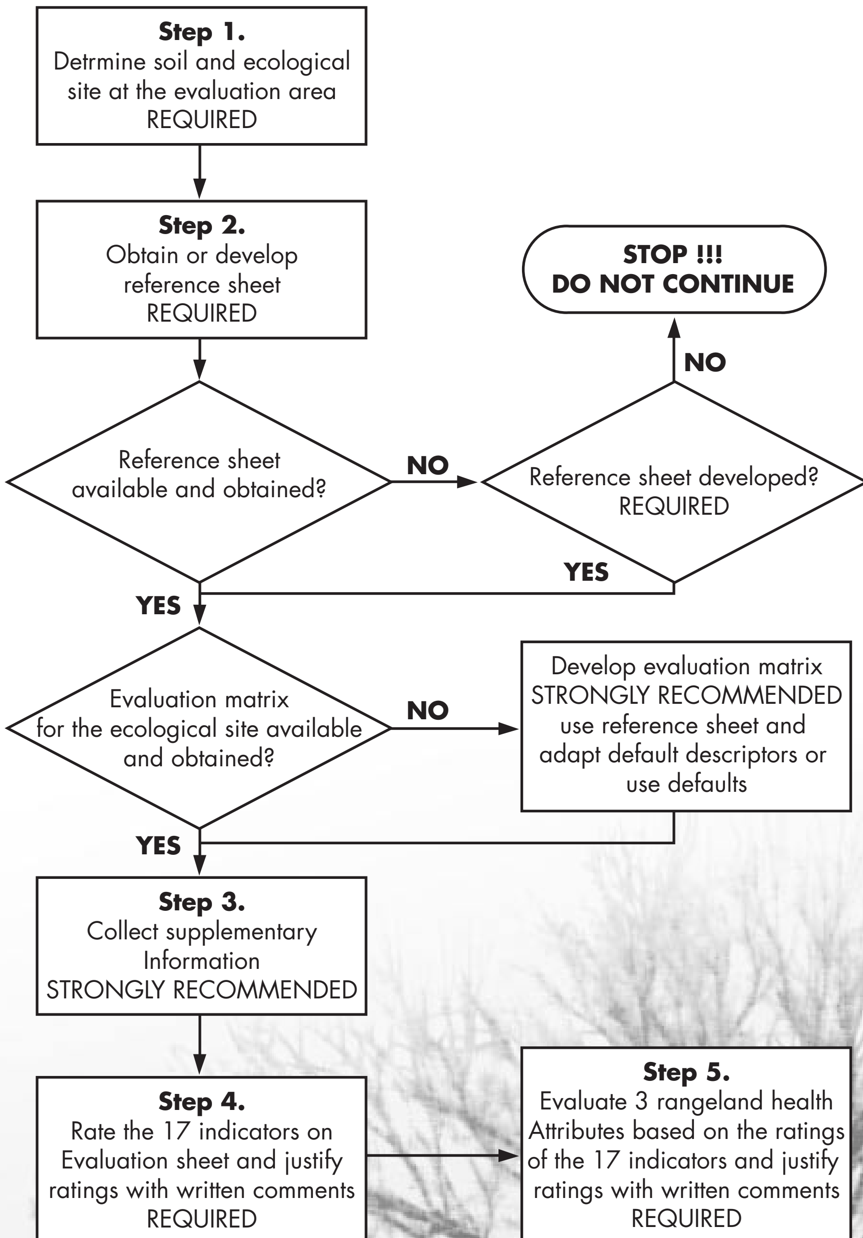


Figure 3. Flowchart for the rangeland health assessment protocol.

Step 1. Identify the Evaluation Area, Determine the Soil and Ecological Site (REQUIRED)

Complete page one of the Evaluation Sheet (Appendix 1).

Describe the Evaluation Area

The front of the Evaluation Sheet is used to record information on site location for the assessment and basic site characteristic information for an evaluation area (Appendix 1). The back of this sheet is completed during Step 5.

The evaluation area should be large enough to accurately evaluate all indicators and should be at least 1/2 to 1 acre in size. An acre is approximately the size of a football field without the end zones. Upon arrival at the location, the evaluator(s) should identify the boundaries of the evaluation area and walk and observe biological and physical characteristics on up to 2 acres of each ecological site in the evaluation area. This enables the evaluator(s) to become familiar with the plant species, soil surface features, and the variability of each ecological site on an evaluation area. A separate evaluation is completed for each ecological site if there is more than one ecological site in the evaluation area unless only one ecological site is of concern in the evaluation area. In this case, ensure that the ecological site boundaries are clearly understood or delineated before conducting the evaluation.

Surrounding features that may affect ecological processes within the evaluation area should also be noted. The topographic position of the evaluation area, adjacent roads, trails, watering points, gullies, timber harvests, and other disturbances can all affect on-site processes. The topographic position should be carefully described with documentation of off-site influences on the evaluation area. There is significant variability in the ecological potential of different ecological sites. This variability is associated with relatively minor differences in landscape position and soils (e.g., differences in aspect, or location at the top versus the bottom of a slope). Landscape position and surrounding features are documented on Page 1 of the Evaluation Sheet (Appendix 1).

Photographs should be taken and included as an attachment to this sheet. Two general view photographs taken in different directions (include some skyline for future point of reference) should be taken along with photographs that illustrate important indicator values or anomalies. Time, date, orientation, and location of the photo should be recorded.

Determine the Soil and Ecological Site

Each ecological site within the evaluation area should be verified by matching the evaluation area to the appropriate ecological site description and soils. The best way to confirm the soil classification, and thus the ecological site, is to dig several shallow pits to verify that the soil profile characteristics are consistent with those of the soils listed in the ecological site description. Soil surveys (which include soil maps and other useful information) should also be consulted if the soil information in the ecological site description is inadequate to correlate soils to the appropriate ecological site description. The evaluator(s) should review the ecological site description for consistency with the soils and vegetation found on the evaluation area.

Always use the Reference Sheet corresponding to the appropriate ecological site. On-site soil description and comparison with soils listed or described in the ecological site description should be completed even when a soil map is available. Soil maps should only be used to help predict soils (and therefore ecological sites) that might be found in the evaluation area. This is because many soil map units are comprised of more than one soil. In addition, soil "inclusions" or soils representing a relatively small proportion of each map unit are found in the vast majority of soil map units in the United States. Inclusions may or may not be listed in the soil survey. Each soil in a map unit may belong to a different ecological site. Finally, even single soil series can belong to more than one ecological site if the functionally significant properties vary significantly within the same soil series. Surface texture and slope are examples of functionally significant properties.

Document the soil profile information in the soil/site identification section of the front page of the Evaluation Sheet (Appendix 1). Soil features that are important to soil/plant/air/water relationships are also included whether or not they are required for soil identification. Soil texture for each horizon, and soil depth, or depth to horizons which may restrict water movement or root growth (e.g., calcic or sodic) or hold more water (e.g., argillic), and other soil features which are important to soil/plant/air/water relationships need to be identified in order to interpret the indicators. Including a soil scientist or resource specialist familiar with soil classifications in this phase of the evaluation is recommended.

Actions to Take if Soil and/or Ecological Site Information Are Not Available

In areas where soil surveys are unavailable or inadequate, aerial photographs, topographic maps, geologic maps, and local weather records can often be used to help decide which ecological site description from adjacent surveyed areas is most appropriate (see Table 3). Where ecological site descriptions are unavailable, these resources can sometimes be used to identify relevant ecological site descriptions that have been developed for similar areas in the region. Vegetation information may be available from other sources, such as habitat-type descriptions, long-term monitoring studies, and other inventory data. If possible, enlist the service of a soil scientist to assist the evaluator(s) in making the initial soil/site correlations.

The process used to conduct the evaluation without the required soils and ecological site information should be clearly documented by the team on the Evaluation Sheet (Appendix 1).

Table 3. Information sources useful in completing Part I of the Evaluation Sheet (Appendix 1) and development of Reference Sheets (Appendix 2). For an updated version of this form, see http://usda-ars.nmsu.edu/JER/Monit_Assess/monitoring.htm.

Resources	Sources
Aerial photos	• USGS at http://edcsns17.cr.usgs.gov/EarthExplorer • Companies selling USGS photos at http://geography.usgs.gov/partners/viewonline.html • http://mapping.usgs.gov/esic/esic_index.html, http://ask.usgs.gov/sources.html, or call 1-888-ASK-USGS (1-888-275-8747). Images newer than 1996 can be obtained from the National Aerial Photography Program (NAPP) and National High Altitude Photography (NHAP), and are searchable on Earth Explorer at http://edcsns17.cr.usgs.gov/EarthExplorer • USDA Sales Branch, USDA FSA APFO, 2222 West 2300 South, Salt Lake City, Utah, 84119-2020, or 801-975-3503, or http://www.apfo.usda.gov/Ordering%20Imagery.htm
Aerial photos: Digital Orthophoto Quarter Quadrangle (DOQQ)	• An aerial photograph that has been digitized (scanned into a computer) and georectified, giving it all the properties of a map. DOQQs are helpful when using GIS technology to stratify landscapes • USGS or its business partners at http://rockyweb.cr.usgs.gov/acis-bin/querypartner.cgi • USDA NRCS at http://www.ncgc.nrcs.usda.gov/products/datasets/index.html
Topographic maps	• 7.5 minute USGS topographic maps at http://topomaps.usgs.gov • Other topographic maps can be purchased in hard copy or CD from USGS or its business partners at http://geography.usgs.gov/www/partners/bpprod.html
Digital Raster Graphic (DRG)	• A scanned USGS topographic map that has been digitized (scanned into a computer) and georectified, ready for GIS applications • USGS or its business partners at http://topomaps.usgs.gov/drg
Soil surveys and maps	• Visit the local NRCS office (look under United States Government, Department of Agriculture, USDA Natural Resources Conservation Service in the blue pages of the phone book), or check the NRCS website (http://soils.usda.gov/survey) to obtain a copy of a soil survey for the county of interest. • STATSGO (State Soil Geographic Database) map coverage (1:250,000) is available for most areas. SSURGO (1:24,000) maps are in the process of being digitized. Hard copies are available through local NRCS offices. • Visit the local USFS office to obtain a Terrestrial Ecosystem Survey for the area of interest. Some offices may have this data available in digital form.
Vegetation inventory data	• BLM land: Soil Vegetation Inventory Method (SVIM) maps. These are maps of field-collected vegetation inventory data. Some offices may have this data available in GIS form. • Private land: NRCS status maps and Natural Resources Inventory data are found at http://www.nrcs.usda.gov/technical/dataresources or http://www.nrcs.usda.gov/technical/land
General maps	• BLM land status maps (look under United States Government, Department of the Interior, Bureau of Land Management, in the blue pages of the phone book)
Species lists	• USFS, BLM, and NRCS offices (especially old monitoring records) • NRCS lists of plants: http://www.nrcs.usda.gov/technical/dataresources • See ecological site descriptions (NRCS) below. • Look up your local chapter of the Native Plant Society at http://www.nanps.org/about/frame.shtml • Plants national database at http://plants.usda.gov
Ecological (range) site descriptions	• Local NRCS office (ask for the "range site handbook" or go to http://esis.sc.egov.usda.gov). • Some revised descriptions may not yet be on the Web.
Geologic maps	• USGS Geologic Maps at http://ngmdb.usgs.gov
Invasive species	• NRCS at http://plants.usda.gov/cgi_bin/topics.cgi?earl=noxious.cgi

Step 2. Obtain or Develop the Reference Sheet (REQUIRED) and the Corresponding Evaluation Matrix (STRONGLY RECOMMENDED)

Obtain a Reference Sheet (Appendix 2) (REQUIRED)

The Reference Sheet describes the status of each indicator for the reference state (see "States, Transitions, and Disturbances" in the Concepts section). It serves as the primary reference for the evaluation. The reference sheet describes a range for each indicator based on expected spatial and temporal variability within each ecological site (or equivalent).

Reference Sheets are currently being incorporated into ecological site descriptions. If the ecological site description does not include this information, ask the person responsible for maintaining ecological site descriptions in the state (usually the NRCS State Rangeland Management Specialist) if a draft is available.

If an ecological site description does not exist, additional expertise will be required to develop the Reference Sheet (see the Instructions for Reference Sheet Development). If expertise or time is limited, the rangeland health evaluation should not proceed. It is not possible to properly conduct an evaluation without a Reference Sheet. Development of the Reference Sheet will require as much or more expertise than is required to conduct the evaluation. Memory of a similar site, professional opinion of what the site could be, visits to reference areas, or reviews of old range or ecological site descriptions that do not contain reference sheets are not adequate substitutes for a properly developed Reference Sheet. However, all of these information sources can be used in the development of the Reference Sheet.

Instructions for Reference Sheet Development

Before beginning development, be sure to check with the NRCS State Rangeland Management Specialist to find out if a final or draft Reference Sheet is available. If a draft is available, but has not been finalized, you may use it and provide comments or suggest modifications to the NRCS State Rangeland Management Specialist. If no Reference Sheet exists, develop one using the following protocol and send it to the NRCS State Rangeland Management Specialist.

1. Assemble a diverse group of experts with extensive knowledge of the ecological site.
Individuals should be included who have long-term knowledge of the variability and dynamics of the ecological site, in addition to rangeland professionals who understand general soil-climate-vegetation relationships.

2. Provide this group of experts with all available sources of information.
Information should include relevant scientific literature and data from potential reference areas, including data used to support the ecological site descriptions.

3. Define the functional/structural groups for the ecological site (or equivalent).
Use the Functional/Structural Groups Sheet (Appendix 3) to define the functional/structural groups and the species associated with each group. This sheet is used to group species into life form/functional/structural categories, to determine the potential dominance rating (complete the "potential" column on this sheet) expected among these groups within the reference state, and to aid in the rating of Indicator 12, Functional/Structural Groups. It is important to have a good understanding of the characteristics that may define functional groups. These characteristics include, but are not limited to, lifeform (e.g., tree, shrub, sub-shrub, grass, forb, moss, lichen, cyanobacteria), nitrogen fixation potential, rooting depth, morphology, photosynthetic pathways (warm vs. cool season plants), and whether or not the plants are native to the ecological site. Examples of functional/structural groups, and more information on the determination of these groups, may be found in the narrative for Indicator 12 (Functional/Structural Groups) in Step 4.

The dominance rating for each functional/structural group included in the Functional/Structural Groups Sheet and the Reference Sheet are based on a description of dominant or subdominant based on percent composition (relative production, biomass, or cover per unit area). Each Functional/Structural Group should be identified on the Reference Sheet as either dominant, subdominant, or other for Indicator 12. Then on the optional Functional/Structural Groups Sheet, each Functional/Structural Group is placed into one of four categories (dominant, subdominant, minor, or trace) in the Potential column (indicating the expected dominance rating for the reference state). This column should correspond with the ratings given on Indicator 12 on the Reference Sheet. Later at an evaluation area, the observers can complete the actual dominance rating (complete the "Actual" column on the worksheet) to aid in rating indicators on the evaluation sheet.

When evaluating a site, several of the 17 indicators require an interpretation regarding changes in this dominance rating for the Functional/Structural Groups, or in the numbers of species within these Functional/Structural Groups. It is important to use the same measure of dominance in the evaluation as was used in the Reference Sheet. For example, if percent of composition based on production was used because the ecological site description used it, then percent of composition by production should be the variable used by the observer when making the evaluation of these indicators.

4. Visit one or more ecological reference areas (optional).
A visit to one or more potential ecological reference areas (ERAs) can be a useful source of additional information for the Reference Sheet. It can also be used by evaluators to improve their ability to recognize the indicators in the field and to "field check" the descriptors developed in the office.

An ERA is a landscape unit in which ecological processes are functioning within a normal range of variability and the plant communities have adequate resistance to and resiliency from most disturbances. An

ERA is the visual representation of the characteristics and variability of the components found in the ecological site description. These areas do not need to be pristine, historically unused lands (e.g., climax plant communities or relict areas).

A number of different plant communities have the potential to meet these criteria. Species composition does not have to match the ecological site description. However, the functional and structural groups must closely match the potential depicted in the ecological site description. Care must be taken in using the ecological site description or ERA as a reference when disturbances have occurred. For example, if a fire occurred 5 years ago in the evaluation area, the ERA should reflect the effects of a recent burn. To obtain this understanding, the evaluator(s) should review appropriate rangeland ecological site (range site) descriptions and select and use appropriate ERAs for training and evaluation purposes.

Sources to assist in the selection of potential ERAs include:

- Ecological site descriptions
- Soil surveys
- Topographic maps
- Vegetation inventories
- Maps showing locations of Research Natural Areas, Wilderness Study Areas, or other protected (large exclosures)/special management areas
- Historical records and photographs
- Records of well-managed rangelands where grazing use has maintained ecological processes and the plant community in a proper functioning state; grazing use pattern maps are helpful in identifying these areas.

This concept is similar to that proposed by the Western Regional Coordinating Committee-40 on Rangeland Research for using well-managed rangelands and appropriate relict areas as benchmarks for assessments (West et al. 1994). The concept of ERAs is also an integral component in the development of ecological site descriptions.

At each ERA, the evaluator(s) should take photographs, collect relevant quantitative data (see Appendix 6), describe the status of each indicator, and record whether or not you believe that it reflects reference conditions (based on all other available information). The area should be used as a reference only for indicators that would be rated as None to Slight based on the final version of the Reference Sheet. The Reference Sheet is the ultimate standard against which all areas, including "reference" areas, are evaluated.

Where possible, a number of ERAs that represent the range of variability in the reference state should be visited (see Figure 2 in States, Transitions, and Disturbances in the Concepts section).

5. Describe the status of each indicator in the reference state (Corresponds to the None-to-Slight departure from the expected for the site in the Evaluation Matrix). These descriptors should be quantitative whenever possible and must include expected ranges based on natural disturbance regimes (e.g., insect outbreaks, wildfires, native herbivore influence), weather, and spatial variability for all plant communities included in the reference state for the ecological site (see Appendix 2, Reference Sheet, Standard Example). Ecological sites include a range of soils with similar, but not identical, characteristics. In many cases, the effects of within-site variability in factors such as soil texture, depth, aspect, slope, and shape of slope on the indicator must be described. For example, concave areas within an ecological site are more likely to receive run-on water and therefore production potential is higher. For additional guidance, please see Landscape Context and Natural Range of Variability in the Concepts section.

Where available, data or other information used to support the descriptor should be cited (e.g., from the ecological site description). Be sure to specify whether composition estimates are based on current year's production, cover produced during the current year, or biomass (check appropriate box at top of sheet).

Obtain the Evaluation Matrix (Appendix 4) for the Ecological Site (or Equivalent Unit) (STRONGLY RECOMMENDED)

The Evaluation Matrix includes detailed descriptions for each of the five departure categories for each indicator.

The Evaluation Matrix includes five descriptors for each indicator which reflect the range of departure from what is expected for the site: None to Slight, Slight to Moderate, Moderate, Moderate to Extreme, and Extreme to Total. The descriptor for "None to Slight" comes directly from the Reference Sheet (Appendix 2) and reflects the range of variation of the indicator in the reference state. The descriptors for the other four classes are derived from the Reference Sheet and the generic descriptors included in Appendix 4 by the team developing the Evaluation Matrix.

A unique Evaluation Matrix will eventually be included in each ecological site description. Until this information is available, generic descriptors may be used or adapted to better reflect current knowledge. To maintain consistency of assessments on specific ecological sites, one of the following options MUST be applied:

- Add notes to the generic descriptors (Appendix 4) to clarify how each descriptor is interpreted for the site.

OR

- Create an ecological site-specific Evaluation Matrix (see the following instructions for Evaluation Matrix Development).

This Evaluation Matrix (Appendix 4) should be used for subsequent evaluations on the **same ecological site** and any changes should be forwarded to the person responsible for maintaining ecological site descriptions in the State (usually the NRCS State Rangeland Management Specialist). This will ensure that these modifications will be considered in ongoing revisions of ecological site descriptions.

Instructions for Evaluation Matrix Development

1. For each indicator, copy a summary of the reference sheet description into the None-to-Slight box. This summary will include a range of values that accounts for the spatial and temporal variability expected within an ecological site.

2. Write a descriptor for "Extreme" or modify the generic descriptor. Extreme is defined as Extreme to Total (e.g., 100 percent or complete) departure from the narrative found in the None-to-Slight box. The range included in this departure category varies among ecological sites and is relative to disturbance events. For example, in a tallgrass prairie site (40″ precipitation), Extreme departure for bare ground might include 30–100 percent bare ground except immediately following fire or an extended drought. In a non-gravelly Mojave Desert site (less than 6″ precipitation), Extreme to Total departure might range from 95–100 percent bare ground. As for the None-to-Slight descriptor, this will include a range of values that accounts for the spatial and temporal variability expected within an ecological site.

3. Write or modify descriptors for Slight to Moderate, Moderate, and Moderate to Extreme.

Indicators of soil/site stability are particularly likely to require these changes due to the inherently higher erosion potential on certain ecological sites. An Evaluation Matrix (Appendix 4) example follows (Table 4) of a modified and expanded bare ground descriptor narrative for the Limy ecological site in MLRA 42 (south-central New Mexico). Similar changes should be made for other indicators.

Table 4. Example of a revised descriptor for the bare ground indicator.

	Departure from Reference Sheet				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
4. Bare ground	Greater than 75% bare ground with entire area connected. Only occasional areas where ground cover is contiguous, mostly patchy and sparse.	60-75% bare ground. Bare patches are large (>24″ diameter) and connected. Surface disturbance areas becoming connected to one another. Connectivity of bare ground broken occasionally by contiguous ground cover.	45-60% bare ground with much connectivity especially associated with surface disturbance.Individual bare spaces are large and dominate the area.	30-45% bare ground. Bare spaces greater than 12″ diameter and rarely connected. Bare areas associated with surface disturbance are larger (> 15″) and may be connected to other bare patches.	**Reference Sheet:** 20-30% bare ground; bare patches should be less than 8-10″ diameter and not connected; occasional 12″ patches associated w/shrubs. Larger bare patches also associated with ant mounds and small mammal disturbances.
Generic Descriptor	Much higher than expected for the site. Bare areas are large and generally connected.	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.	Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected.	Amount and size of bare areas match that expected for the site.

Step 3. Collect Supplementary Information (STRONGLY RECOMMENDED)

Supplementary information is collected to improve the evaluators' ability to make an accurate evaluation. There are four general types of supplementary information: (1) spatial and temporal variability, including factors affecting the variability; (2) information from relevant ecological reference areas; (3) functional/ structural groups; and (4) quantitative cover and composition data for the evaluation site.

Spatial and Temporal Variability

The Reference Sheet and Evaluation Matrix describe the range of variability expected to occur in an ecological site (or equivalent geographic unit). There is significant spatial variability in site potential within ecological sites depending on soils, slope, aspect, and landscape position. For example, for an ecological site that includes slopes ranging from 5-15 percent, water flow patterns are expected to be more pronounced on steeper slopes. Documenting these relatively static properties on the first page of the Evaluation Sheet (Appendix 1) can help increase the accuracy of the evaluation.

Temporal variability is even greater than spatial variability in most ecological sites. The season, time since the last storm or fire, and recent precipitation are just a few of the factors that can affect current site potential. These factors can also be documented on the Evaluation Sheet and used to increase evaluation accuracy.

Ecological Reference Areas

Ecological reference areas (see Step 2), where available, can help by providing a visual representation of the expected status of each indicator at the time of the evaluation. Quantitative data (see Table 5) can also be used to supplement the information in the Reference Sheet. Ecological reference areas should be functioning at least as well as described in the Reference Sheet with respect to soil/site stability, hydrologic function, and biotic integrity.

Evaluators need to examine ecological reference areas in the same year and season as the evaluation area, since weather during that year may affect the rating of indicators. However, ecological reference areas may be located in different watersheds within the geographic region as long as the current year's weather has been similar between locations. See the "Reference Sheet Development" section in Step 2 for more information on ecological reference areas.

Functional/Structural Groups Sheet

The Functional/Structural Groups Sheet (part of which was developed as part of Step 2) can be used to directly compare potential (Step 2) and actual (fill in the "Actual" column of the Functional/Structural Groups Sheet) relative dominance (composition) of the functional/ structural groups.

Quantitative Data

Table 5 shows how quantitative vegetation and soil data can be used to support the indicator evaluation. For additional quantitative indicators, see Table 2 and Appendix 6.

Table 5. Quantitative indicators for selected indicators

Indicator	4. Bare ground	8. Soil surface resistance to erosion	10. Plant community composition and distribution relative to infiltration and runoff	12. Functional/ structural groups	13.Plant mortality and decadence	14. Litter amount	15. Annual production	16. Invasive plants
Information	Bare ground % Size of inter-canopy gaps	Stability of soil surface in water	Functional group composition (relative dominance)	Functional group composition (relative dominance)	Percentage of point species intercepts that are dead	Litter cover (litter depth and density also required to calculate amount but are rarely collected)	Total annual production	Relative dominance
Recommended methods*	Line point Gap intercept	Stability kit	Production OR Line point	Production OR Line point	Line point	Line point (for litter cover)	Production	Production OR Line point Belt transect (for low cover)

* Described in the "Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems" (printed copies available from University of Arizona Press in pdf format at http://usda-ars.nmsu.edu/JER/Monit_Assess/monitoring.htm.

Step 4. Rate the 17 Indicators on the Evaluation Sheet (REQUIRED)

Complete the Evaluation Sheet (Appendix 1, back page) using the Evaluation Matrix (Appendix 4).

Evaluators select the category descriptor (i.e., narrative) on the Evaluation Matrix (Appendix 4) that most closely describes each indicator and records it on the Evaluation Sheet, Page 2. The rating for each indicator in the evaluation area is based on that indicator's degree of departure from the Reference Sheet (Appendix 2). This is based on the ecological site description and other information, including expert knowledge of structure, function, and dynamics of ecological reference areas and other areas within the ecological site (see Step 2). The Reference Sheet reflects the range of variability expected for soils and plant communities in the reference state. The Functional/Structural Groups worksheet (Appendix 3) is also useful in evaluating several indicators. For other relevant quantitative indicators, see Table 2 in the Concepts section.

Narrative descriptions in the Evaluation Matrix are intended to aid in the determination of the degree of departure. The narrative descriptors for each indicator form a relative scale from "Extreme to Total" to "None to Slight." Not all indicator descriptors will match what is observed, requiring a "best fit" approach when making ratings. The rating for each indicator should be supported by comments in the space provided by each indicator rating. In some instances, there may be no evidence of the indicator on the evaluation area. Those indicators are rated "None to Slight."

When making an assessment, the effects of natural disturbances (e.g., drought, fire) should be considered. For example, if a fire occurred 5 years ago in the area being assessed, reduced shrub (e.g., sagebrush) cover is not necessarily an indication of lack of biotic integrity if natural processes alone are sufficient to allow recovery of the original plant community. Both the pre- and post-fire plant community are in the same reference state (see Figure 2, generic state and transition diagram, in the Concepts section). Comments on wildfire return intervals (expected and current) must be documented in the comments section on this sheet.

Important: Be sure to specify whether composition estimates are based on current year's production, cover produced during the current year, or biomass, and check the appropriate box at top of the sheet).

Indicators

Descriptions of each indicator are provided in the following sections. Color photographs of the indicators are located in Appendix 5. Additional information on many of the soil-related indicators can be found in the Rangeland Soil Quality Information Sheets (NRCS Soil Quality Institute et al.2002; http://soils.usda.gov/sqi/soil_quality/land_management/range.html).

1. Rills

Rills (small erosional rivulets) are generally linear and do not necessarily follow the microtopography that flow patterns do. They are formed through complex interactions between raindrops, overland flow, and the characteristics of the soil surface (Bryan 1987). The potential for rills increases as the degree of disturbance (loss of cover) and slope increases. Some soils have a greater potential for rill formation than others (Bryan 1987, Quansah 1985). Therefore, it is important to establish the degree of natural versus accelerated rill formation by interpretations made from the soil survey, rangeland ecological site description, and the ecological reference area. Generally, concentrated flow erosional processes are accelerated when the distance between rills decreases and the depth and width of rills increase (Morgan 1986, Bryan 1987).

2. Water Flow Patterns

Flow patterns are the path that water takes (i.e., accumulates) as it moves across the soil surface during overland flow. Overland flow will occur during rainstorms or snowmelt when a surface crust impedes water infiltration, or the infiltration capacity is exceeded. These patterns are generally evidenced by litter, soil or gravel redistribution, or pedestalling of vegetation or stones that break the flow of water (Morgan 1986). Interrill erosion caused by overland flow has been identified as the dominant sediment transport mechanism on rangelands (Tiscareno-Lopez et al. 1993). Water flow patterns are controlled in length and coverage by the number and kinds of obstructions to water flow provided by basal intercepts of living or dead plants, biological crust, persistent litter, or rocks. They are rarely continuous, and appear and disappear as the slope and microtopography of the slope changes. Shorter flow patterns facilitate infiltration by helping to pond water in depositional areas, thereby increasing the time for water to soak into the soil.

Generally, as slope increases and ground cover decreases, flow patterns increase (Morgan 1986). Soils with inherently low infiltration capacity may have a large number of natural flow patterns.

3. Pedestals and/or Terracettes

Pedestals and terracettes are important indicators of the movement of soil by water and/or by wind (Anderson 1974, Morgan 1986, Satterlund and Adams 1992, Hudson 1993). Pedestals are rocks or plants that appear elevated as a result of soil loss by wind or water erosion. Pedestals can also be caused by non-erosional processes, such as frost heaving or through soil or litter deposition on and around plants (Hudson 1993). Thus, it is important to distinguish and not include this type of pedestalling as an indication of erosional processes.

Terracettes are benches of soil deposition behind obstacles caused by water movement (not wind). As the degree of soil movement by water increases, terracettes become higher and more numerous and the area of soil deposition becomes larger. Terracettes caused by livestock or wildlife movements on hillsides are not considered erosional terracettes, thus they are not assessed in this protocol. However, these terracettes can affect erosion by concentrating water flow and/or changing infiltration. These effects are recorded with the appropriate indicators (e.g., water flow patterns, compaction layer, and soil surface loss and degradation).

4. Bare Ground

Bare ground is exposed mineral or organic soil that is susceptible to raindrop splash erosion, the initial form of most water-related erosion (Morgan 1986). It is the remaining ground cover after accounting for ground surface covered by vegetation (basal and canopy (foliar) cover), litter, standing dead vegetation, gravel/rock, and visible biological crust (e.g., lichen, mosses, algae) (Weltz, et al. 1998).

The amount and distribution of bare ground is one of the most important contributors to site stability relative to the site potential; therefore, it is a direct indication of site susceptibility to accelerated wind or water erosion (Smith and Wischmeier 1962, Morgan 1986, Benkobi, et al. 1993, Blackburn and Pierson 1994, Pierson et al. 1994, Gutierrez and Hernandez 1996, Cerda 1999). In general, a site with bare soil present in a few large patches will be less stable than a site with the same ground cover percentage in which the bare soil is distributed in many small patches, especially if these patches are unconnected (Gould 1982, Spaeth et al. 1994, Puigdefabregas and Sanchez 1996).

The amount of bare ground can vary seasonally, depending on impacts on vegetation canopy (foliar) cover (e.g., herbivore utilization), and litter amount (e.g., trampling loss), and can vary annually relative to weather (e.g., drought, above average precipitation) (Gutierrez and Hernandez 1996, Anderson 1974). Current and past climate must be considered in determining the adequacy of current cover in protecting the site against the potential for accelerated erosion.

5. Gullies

A gully is a channel that has been cut into the soil by moving water. Gullies generally follow natural drainages and are caused by accelerated water flow and the resulting downcutting of soil. Gullies are a natural feature of some landscapes and ecological sites, while on others management actions (e.g., excessive grazing, recreation vehicles, or road drainages) may cause gullies to form or expand (Morgan 1986). In gullies, water flow is concentrated but intermittent. Gullies can be caused by resource problems offsite (document this on the Evaluation Sheet, Appendix 2), but still affect the site function on the evaluation area.

Gullies may be assessed by observing the numbers of gullies in an area and/or assessing the severity of erosion on individual gullies. General signs of active erosion, (e.g., incised sides along a gully) are indicative of a current erosional problem, while a healing gully is characterized by rounded banks, vegetation growing in the bottom and on the sides (Anderson 1974), and a reduction in gully depth (Martin and Morton 1993). Active headcuts may be a sign of accelerated erosion in a gully even if the rest of the gully is showing signs of healing (Morgan 1986).

6. Wind-Scoured, Blowout, and/or Depositional Areas

Accelerated wind erosion, on an otherwise stable soil, increases as the surface crust (i.e., either physical, chemical, or biological crust) is worn by disturbance or abrasion. Physical crusts are extremely important in protecting the soil surface from wind erosion on many rangelands with low canopy (foliar) cover. The exposed soil beneath these surface crusts is often weakly consolidated and vulnerable to movement via wind (Chepil and Woodruff 1963). As wind velocity increases, soil particles begin bouncing against each other in the saltation process. This abrasion leads to suspension of fine particles into the wind stream where they may be transported off the site (Chepil 1945, Gillette, et al. 1972, Gillette, et al. 1974, Gillette and Walker 1977, Hagen 1984).

Wind erosion is reflected by wind-scoured or blowout areas where the finer particles of the topsoil have blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface (Anderson 1974). They are generally found in interspace areas with a close correlation between soil cover/bare patch size, soil texture, and degree of accelerated erosion (Morgan 1986).

Deposition of suspended soil particles is often associated with vegetation that provides roughness to slow the wind velocity and allow soil particles to settle from the wind stream. The taller the vegetation, the greater the deposition rate (Pye 1987); thus shrubs and trees in rangeland ecosystems are likely sinks for deposition (e.g., mesquite dunes, Gibbens et al. 1983, Hennessey et al. 1983). The soil removed from wind-scoured depressions is redistributed to accumulation areas (e.g., eolian deposits), which increase in size and area of coverage as the degree of wind erosion increases (Anderson 1974).

Like water erosion, wind deposited soil particles can originate from offsite but affect the function of the site by modifying soil surface texture (Hennessey et al. 1986, Morin and Van Winkel 1996). The changes in texture will influence the site's hydrologic function. Even when soil particles originate from offsite, they can have detrimental effects on plants at the depositional site.

7. Litter Movement

The degree and amount of litter (i.e., dead plant material that is in contact with the soil surface) movement is an indicator of the degree of wind and/or water erosion. The redistribution of litter within a small area on a site is indicative of less erosion, whereas the movement of litter offsite is an indication of more severe erosion. In a study in the Edwards Plateau in Texas, litter accumulation was shown to be the variable most closely correlated with interrill erosion. The same study showed that litter of bunchgrasses represented significant obstructions to runoff, thereby causing sediment transport capacity to be reduced and a portion of the sediment to be deposited (Thurow, et al. 1988a).

The inherent capacity for litter movement on a soil is a function of its slope and geomorphic stability. For example, alluvial fans and flood plains are active surfaces over which water and sediments are moved in response to major storm events. The amount of litter movement varies from large to small depending on the amount of bare space typical of the plant community and the intensity of the storm.

The size of litter moved by wind or water is also an indicator of the degree of litter redistribution. In general, the greater distance that litter is moved from its point of origin and the larger the size and/or amount of litter moved, the more the site is being influenced by erosional processes.

8. Soil Surface Resistance to Erosion

This indicator assesses the resistance of the surface of the soil to erosion. Resistance depends on soil stability and on the spatial variability in soil stability relative to vegetation and microtopographic features. The stability of the soil surface is key to this indicator (Morgan 1986). Soil surfaces may be stabilized by soil organic matter which has been fully incorporated into aggregates at the soil surface, adhesion of decomposing organic matter to the soil surface, and biological crusts. The presence of one or more of these factors is a good indicator of soil surface resistance to erosion (Blackburn et al. 1992, Pierson et al. 1994).

Soil surface resistance to erosion in arid and semi-arid ecosystems is often higher under plant canopies than in interspaces. Where the site potential is different under plant canopies, both canopy and interspace values should be reported on the Reference Sheet (Appendix 2).

When soil surface resistance is high, soil erosion may be minimal even under rainfall intensities of over 5 inches/hour (Goff, et al. 1993). Conversely, the presence of highly erodible materials at the soil surface can dramatically increase soil erosion by water, even when there is high vegetative cover (Morgan et al. 1997), and by wind when vegetative cover is removed (Fryrear et al.1994, Belnap and Gillette 1998).

In areas with low vegetative cover, soil stability in plant interspaces is more important than stability under plants. Similarly, where pedestals have formed along flow paths, the soil at the edge of the pedestal will be subjected to more intense forces during overland flow than soil which is topographically above the flow path.

Another good indicator is the resistance of soil surface fragments to breakdown when placed in water. For a simple test, use the tip of a knife to remove several small (maximum 1/4 inch diameter, 1/8 inch deep) soil surface fragments from beneath plants, interspaces, and any other areas which might differ in soil stability. Place each in a separate bottlecap filled with water. Fragments with low stability will appear to lose their structure or "melt" within 30 seconds. Fragments with extremely low stability will "melt" immediately upon contact with the water and the water will become cloudy as the soil particles disperse. Fragments with moderate stability will appear to retain their integrity until the water in the bottlecap is agitated or gently swirled. Highly stable aggregates will retain their shape, even when agitated indefinitely. For multiple samples, or where more precision is desired, a simple soil stability kit can be used to generate a rating from one (unstable) to six (stable) (Herrick et al. 2001) (Appendix 7). This indicator is more highly correlated with water erosion (Blackburn and Pierson 1994; Pierson et al. 1994) than with wind erosion. However, susceptibility to wind erosion also declines with an increase in soil organic matter (Fryrear et al. 1994) and biological crust cover (Belnap and Gillette, 1998). Both are correlated with soil stability in water.

Biological crusts consist of microorganisms (e.g. algae, cyanobacteria) and nonvascular plants (e.g. mosses and lichens) that grow on or just below the soil surface. Soil physical and chemical characteristics, along with seasonal precipitation patterns, largely determine the dominant organisms comprising the crust.

Biological crusts are important as cover and in stabilizing soil surfaces (Bond and Harris 1964, Belnap and Gardner 1993, Eldridge and Greene 1994). In some areas, depending on soil characteristics, they may increase or reduce the infiltration of water through the soil surface or enhance the retention of soil water (i.e., acting as living mulch). In general, the relative importance of biological crusts increases as annual precipitation and potential vascular plant cover decreases. If information on biological crusts is lacking in the ecological site descriptions, refer to ERAs, if available, for baseline information prior to conducting the evaluation.

Physical crusts are thin surface layers induced by the impact of raindrops on bare soil causing the soil surface to seal and absorb less water. Physical crusts are more common on silt, clay, and loam soils. When present, they are relatively thin in sandy soils. Physical and chemical crusts tend to have very low organic matter content, or contain only relatively inert organic matter that is associated with low biological activity. As this physical crust becomes more extensive, infiltration rates are reduced and overland water flow increases. Also, water can pond in flat crusted areas and will be more likely to evaporate than infiltrate into the soil.

Physical soil crusts are identified by lifting the soil surface with a pen or other sharp object and looking for cohesive layers at the soil surface which are not perforated by pores or fissures and in which there is no apparent binding by visible strands of organic material, such as cyanobacteria.

Physical crusts may exert a positive influence on reducing wind erosion (see discussion in Indicator 6, Wind Scoured, Blowouts, and/or Deposition Areas). However, their function in stabilizing the soil surface against water erosion is generally negative. Although physical crusts also include vesicular crusts, which contain numerous small air pockets or spaces similar to a sponge, these soils are still resistant to infiltration.

Chemical crusts rarely form in rangelands except on soils formed from particular parent materials (e.g., salt desert shrub communities; see the soil survey that covers the evaluation area and/or the ecological reference area) and in abandoned, irrigated agricultural fields. Where they do occur, they can reduce infiltration and increase overland water flow similar to physical crusts. They are usually identified by a white color on the soil surface.

Areas in which there is little to no soil present due to the presence of natural rock cover (nearly 100 percent surface cover by stones) or there is continuous open water (e.g., marshes in the Southeast) should be rated as “None to Slight.”

9. Soil Surface Loss or Degradation

The loss or degradation of part or all of the soil surface layer or horizon is an indication of a loss in site potential (Dormaar and Willms 1998, Davenport et al. 1998). In most sites, the soil at and near the surface has the highest organic matter and nutrient content. This generally controls the maximum rate of water infiltration into the soil and is essential for successful seedling establishment (Wood et al. 1997). As erosion increases, the potential for loss of soil surface organic matter increases, resulting in further degradation of soil structure. Historic soil erosion may result in complete loss of this layer (Satterlund and Adams 1992, O’Hara et al. 1993). In areas with limited slope, where wind erosion does not occur, the soil may remain in place, but all characteristics that distinguish the surface from the subsurface layers are lost. Except in soils with a clearly defined horizon immediately below the surface (e.g., argillic), it is often difficult to distinguish between the loss and degradation of the soil surface. For the purposes of this indicator, this distinction is unnecessary—the objective is to determine to what extent the functional characteristics of the surface layer have been degraded. Note also that visible soil erosion is covered in discussions of Indicator 3, Pedestals and/or Terracettes, and subsurface degradation in Indicator 11, Compaction Layer.

The two primary indicators used to make this evaluation are the organic matter content (Dormaar and Willms 1998) and the structure (Karlen and Stott 1994) of the surface layer or horizon. Soil organic matter content is frequently reflected in a darker color of the soil, although high amounts of oxidized iron (common in humid climates) can obscure the organic matter. In arid soils, where organic matter contents are low, this accumulation can be quite faint. The use of a mister to wet the soil profile can help make these layers more visible.

Soil structural degradation is reflected by the loss of clearly defined structural units or aggregates at one or more scales from <1/8 inch to 3 to 4 inches. In soils with good structure, pores of various sizes are visible within the aggregates. Structural degradation is reflected in a more massive, homogeneous surface horizon and is associated with a reduction in infiltration rates (Warren et al. 1986). In heavier soils, degradation may also be reflected by more angular structural units. Comparisons to intact soil profiles at reference sites can also be used, although in cases of severe degradation, the removal of part or all of the A horizon, or of one or more textural components (e.g., Hennessey et al. 1986) may make identification of appropriate reference areas difficult.

10. Plant Community Composition and Distribution Relative to Infiltration and Runoff

Vegetation growth form is an important determinant of infiltration rate and interrill erosion (Thurow et al 1988a, b). The distribution of the amount and type of vegetation has been found to be an important factor controlling spatial and temporal variations in infiltration and interrill erosion rates on rangelands in Nevada (Blackburn 1975; Blackburn and Wood 1990), Idaho (Johnson and Gordon 1988, Blackburn and Wood 1990) and Texas (Wood and Blackburn 1984, Thurow et al. 1988a, b).

Changes in plant community composition (see Appendix 3, Functional/Structural Groups Sheet) and the distribution of species can influence (positively or negatively) the ability of a site to capture and store precipitation. Plant rooting patterns, litter production and associated decomposition processes, basal area and spatial distribution can all affect infiltration and/or runoff. In the Edwards Plateau in Texas, shifts in plant composition between bunchgrass and short grasses over time have the greatest potential to influence infiltration and soil erosion (Thurow et al. 1986, 1988a, b). An example of a composition change that reduces infiltration and increases water runoff is the conversion of desert grasslands to shrub-dominated communities (Schlesinger et al. 1990). However, infiltration and runoff are also affected when sagebrush steppe rangeland is converted to a monoculture of annual grasses. These annual grasses provide excellent watershed protection, although snow entrapment and soil water storage may be reduced by this vegetation type conversion. Care must be exercised in interpreting this indicator in different ecosystems as the same species may have different effects.

11. Compaction Layer

A compaction layer is a near-surface layer of dense soil caused by repeated impacts on or disturbances of the soil surface. Compaction can also occur below the surface at the bottom of a tillage layer. These plow pans are often found in abandoned agricultural fields. Compaction becomes a problem when it begins to limit plant growth (Wallace 1987), water infiltration (Willat and Pullar 1983, Thurow et al 1988a), or nutrient cycling processes (Hassink et al. 1993). Farm machinery, herbivore trampling (Willat and Pullar 1983, Warren et al. 1986, Chanysk and Naeth 1995), recreational and military vehicles (Webb and Wilshire 1983, Thurow et al. 1988a), foot traffic (Cole 1985), brush removal, and seeding equipment, or any other activity that repeatedly causes an impact to the soil surface can cause a compaction layer. Moist soil is more easily compacted than dry or saturated soil (Hillel 1998). Recovery processes (e.g., earthworm activity and frost heaving) are generally sufficient to limit compaction by livestock in many upland systems (e.g., Thurow et al 1988a).

A compaction layer is a structural change, not a textural change, as described in a soil survey or observed at an ecological reference area. Compacted layers in rangelands are usually less than 6 inches below the soil surface. They are detected by digging a small hole (generally less than 1-foot deep) and describing the soil structure and root morphology; this is done by a person with soils experience. These layers may be detected in some soils with the use of a penetrometer (Larson and Pierce 1993) or by simply probing the soil with a sharp rod or shovel and “feeling” for the compaction layer (Barnes et al. 1971). However, any potential compaction layer should be confirmed using multiple indicators, including direct observation of physical features. Those physical features include such things as platy or blocky, dense soil structure over less dense soil layers, horizontal root growth, and increased density (measured by weighing a known volume of oven-dry soil) (Blake and Hartge 1986). Increased resistance to a probe can be simply due to lower soil moisture or higher clay content.

12. Functional/Structural Groups

Functional/structural groups are a suite of species that are grouped together, on an ecological site basis, because of similar shoot (height and volume) or root (fibrous vs. tap) structure, photosynthetic pathways, nitrogen fixing ability, or life cycle (Chapin 1993, Dawson and Chapin 1993, Solbrig et al. 1996). Functional composition and functional diversity are the principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration

Table 6. Six functional/structural groups and examples of representative species that a prairie ecological site might include.

Warm Season Tall Grasses	Big bluestem	Indiangrass
Warm Season Midgrasses	Sideoats grama	Little bluestem
Cool Season Midgrasses	Western wheatgrass	Green needlegrass
Warm Season Shortgrass	Buffalograss	Blue grama
Perennial Forbs	Dotted gayfeather	Prairie coneflower
Leguminous Shrubs	Leadplant	

(Tilman et al. 1997). The study by Tilman et al. (1997) showed that functional composition has a large impact on ecosystem processes. This and related studies have demonstrated that factors that change ecosystem composition, such as invasion by novel organisms, nitrogen deposition, disturbance frequency, fragmentation, predator decimation, species removal, and alternative management practices can have a strong effect on ecosystem processes.

The evaluator(s) should use the Functional/Structural Groups Worksheet (Appendix 3) in the development of the Reference Sheet (Appendix 2) and in the assessment of the evaluation area.

Relative dominance is based upon the relative annual production, biomass, or relative cover that each functional/structural group collectively contributes to the total. The recommended protocol to use for grouping species is composition by annual production. If the evaluator(s) doesn't have experience in estimating composition by annual production, then composition by cover may be used if appropriate reference data are available. The potential for functional/structural groups is derived by placing species into the appropriate groups from information found in the Reference Sheet that has been developed from the Functional/Structural Groups Worksheet. The list and ranking of functional/structural groups should reflect *all* of the plant (including biological crust) communities in the reference state, under the natural disturbance regime, and in the context of normal climatic variability. It should not be limited to a comparison with the historic climax community, which is the reference included in the old NRCS Range Site Descriptions. Instead, the comparison should be to communities in the reference state (in the state and transition model for the ecological site). For more information, please see the Concepts section.

The Functional/Structural Groups Worksheet can accommodate changing or adding functional group categories for different ecological sites (see Tables 6 and 7). Functional groups that are now present, but were not original components of the site (e.g., weeds, introduced plants), need to be identified on this sheet.

The number of species in each functional group is also considered when selecting the appropriate rating category on the Evaluation Sheet. If the numbers of species in many of the functional/structural plant groups have been greatly reduced, this may be an indication of loss of biotic integrity. Both the presence of functional groups and the number of species within the groups have a significant effect on ecosystem processes (Tilman et al. 1997).

Non-vascular plants (e.g., biological crusts) are included in this example since they are an important component of this Great Basin ecological site. Biological crusts are components of many ecosystems and should be included in this evaluation when appropriate.

13. Plant Mortality/Decadence

The proportion of dead or decadent (e.g., moribund, dying) to young or mature plants in the community, relative to that expected for the site under normal disturbance regimes, is an indicator of the population dynamics of the stand. If recruitment is not occurring and existing plants are either dying or dead, the integrity of the stand would be expected to decline and undesirable plants (e.g., weeds or invasives) may increase (Pyke 1995). A healthy range has a mixture of many age classes of plants relative to site potential and climatic conditions (Stoddard et al. 1975).

Only plants native to the site (or seeded plants if in a seeding) are assessed for plant mortality. Plant mortality may vary considerably depending on natural disturbance events (e.g., fire, drought, insect infestation, disease).

14. Litter Amount

Litter is any dead plant material (from both native and exotic plants) that is detached from the base of the plant. The portion of litter that is in contact with the soil surface (as opposed to standing dead vegetation) provides a source of soil organic material and raw materials for on-site nutrient cycling (Whitford 1988, 1996). All litter helps to moderate the soil microclimate and provides food for microorganisms (Hester et al. 1997). Also, the amount of litter present can play a role in enhancing the ability of the site to resist erosion. Litter helps to dissipate the energy of raindrops and overland flow, thereby reducing the potential detachment and transport of soil (Hester et al. 1997). Litter biomass represents a significant obstruction to runoff (Thurow et al. 1988a or b).

The amount of litter (herbaceous and woody) present is compared to the amount that would be expected for the same type of growing conditions in the reference state per the Reference Sheet. Litter is directly related to weather and the degree of biomass utilization each year. Therefore, climatic influences (e.g., drought, wet years) must be carefully considered in determining the rating for the amount of litter. Be careful not to confuse standing-dead plants (plant material that is not detached from the plant and is still standing) with litter during this evaluation.

Some plant communities have increased litter quantities relative to the site potential and current weather conditions. An example is the increased accumulation of litter in exotic grass communities (e.g., cheatgrass) compared to native shrub steppe plant communities. In this case, the litter in excess of the expected amount results in a downgraded rating for the site. Note in the Comments section on the Evaluation Sheet for this indicator if the litter is undergoing decomposition (darker color) or oxidation (whitish color which may also be an indication of fungal growth). In addition to amount, litter size may be important because larger litter tends to decompose more slowly and is more resistant to runoff. If litter size is considered as part of this indicator, it should be addressed in the Reference Sheet (Appendix 2).

Table 7. Selected species for nine functional/structural groups that a Great Basin Desert shrub steppe site might include.

Tall Shrubs (Deep Rooted)	Wyo. Big sagebrush		
Half Shrub	Broom Snake-weed		
Warm Season Bunchgrass	Sand Dropseed	Red Threeawn	
Cool Season Short Bunchgrass	Sandberg bluegrass		
Cool Season Mid Bunchgrass	Squirreltail	Thurbers needlegrass	Indian Ricegrass
Perennial Forbs–N Fixers	Astragalus	Lupine	
Perennial Forbs–Not N fixers	Phlox	Arrowleaf Balsamroot	Biscuitroot
Annual Grass	Cheatgrass		
Biological Crust	Moss	Lichens	

15. Annual Production

Primary production is the conversion of solar energy to chemical energy through the process of photosynthesis. Annual production, as used in this document, is the net quantity of above-ground vascular plant material produced within a year. It is an indicator of the energy captured by plants and its availability for secondary consumers in an ecosystem given current weather conditions. Production potential will change with communities or ecological sites (Whittaker 1975), biological diversity (Tilman and Downing 1994), and latitude (Cooper 1975). Annual production of the evaluation area is compared to the site potential (total annual production) as described in the Reference Sheet.

Comparisons to the Reference Sheet are based on peak above ground standing crop, no matter when the site is assessed. If utilization of vegetation has occurred or plants are in early stages of growth, the evaluator(s) is required to estimate the annual production removed or expected and include this amount when making the total site production estimate. Do not include standing dead vegetation (produced in previous years) or live tissue (woody stems) not produced in the current year as annual production.

All species (e.g., native, seeded, and weeds) alive (annual production only) in the year of the evaluation, are included in the determination of total aboveground production. Therefore, type of vegetation (e.g., native or introduced) is not an issue. For example, Rickard and Rogers (1988) found that conversion of a sagebrush steppe plant community to an exotic annual grassland greatly affected vegetation structure and function, but not above-ground biomass production.

As with the other indicators, it is important to consider all possible local and landscape level explanations for differences in production (e.g., runoff/run-on due to landscape position, weather, regional location, or different soils within an ecological site) before attributing production differences to differences in other site characteristics.

16. Invasive Plants

Invasive plants are plants that are not part of (if exotic), or are a minor component of (if native), the original plant community or communities that have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g. short-term response to drought or wildfire) are not invasive plants. This indicator deals with plants that are invasive to the evaluation area. These plants may or may not be noxious and may or may not be exotic.

Invasives can include noxious plants (i.e., plants that are listed by a State because of their unfavorable economic or ecological impacts), non-native, and native plants. Native invasive plants (e.g., pinyon pine or juniper into sagebrush steppe) must be assessed by comparing current status with potential status described in the Reference Sheet. Historical accounts, ecological reference areas, and photographs also provide information on the historical distribution of invasive native plants.

Invasive plants may impact an ecosystem's type and abundance of species, their interrelationships, and the processes by which energy and nutrients move through the ecosystem. These impacts can influence both biological organisms and physical properties of the site (Olson 1999). These impacts may range from slight to catastrophic depending on the species involved and their degree of dominance. Invasive species may adversely affect a site by increased water usage (e.g., salt cedar (tamarisk) in riparian areas) or rapid nutrient depletion (e.g., high nitrogen use by cheatgrass).

Some invasive plants (e.g., knapweeds) are capable of invading undisturbed, climax bunchgrass communities (Lacey et al. 1990), further emphasizing their use as an indicator of new ecosystem stress. Even highly diverse, species rich plant communities are susceptible to exotic species invasion (Stohlgren et al. 1999).

17. Reproductive Capability of Perennial Plants

Adequate seed production is essential to maintain populations of plants when sexual reproduction is the primary mechanism of individual plant replacement at a site. However, annual seed production of perennial plants is highly variable (Harper 1977). Since reproductive growth occurs in a modular fashion similar to the remainder of the plant (White 1979), inflorescence production (e.g., seedstalks) becomes a basic measure of reproductive potential for sexually reproducing plants, and clonal production (e.g., tillers) for vegetatively reproducing plants. Since reproductive capability of perennial plants is greatly influenced by weather, it is important to determine departure from the expected value in the Reference Sheet by evaluating management effects on this indicator. Ecological reference areas provide a good benchmark to separate weather versus management influences on this indicator.

Seed production can be assessed by comparing the number of seedstalks and/or number of seeds per seedstalk of native or seeded plants (not including invasives) in the evaluation area with what is expected as documented on the Reference Sheet. Mueggler (1975) recommended comparison of seedstalk numbers or culm length on grazed and ungrazed bluebunch wheatgrass plants as a measure of plant recruitment potential. Seed production is related to plant vigor since healthy plants are better able to produce adequate quantities of viable seed than are plants that are stressed or decadent (Hanson and Stoddart 1940).

For plants that reproduce vegetatively, the number and distribution of tillers or rhizomes is assessed relative to the expected production of these reproductive structures as documented in the Reference Sheet.

Recruitment is not assessed as a part of this indicator since plant recruitment from seed is an episodic event in many rangeland ecological sites. Therefore, evidence of recruitment (seedlings or vegetative spread) of perennial, native, or seeded plants is recorded in the comment section on the Evaluation Sheet, but is not considered in rating the reproductive capabilities of perennial plants.

This indicator considers only perennial plants. With the exception of hyperarid ecosystems (e.g., Arabian peninsula and northern Atacama desert), nearly all rangelands have the potential to support perennial plants (Whitford 2002). A plant community that lacks perennial plants is rarely, if ever, included in the reference state. Evaluation areas that have no perennial plants would be rated "Extreme to Total" for this indicator because they no longer have the capacity to (re)produce perennial plants.

18. Optional Indicators

The 17 indicators described previously represent the baseline indicators that must be assessed on all sites. Other indicators and descriptors may be developed to meet local needs. The only restriction on the development of optional indicators and their use is that they must be ecologically, not management, related. They should also significantly increase the quality of evaluation. For example, an indicator of suitability for livestock, wildlife, or special status species are not appropriate indicators to determine the health of a land unit. They may be important in the allotment or ranch evaluation, but are not included in the determination of the status of soil/site stability, hydrologic function, or biotic integrity.

Examples of two optional indicators, Biological Crusts and Vertical Vegetation Structure, are included in Table 8. Both are partially addressed by Indicator 12 (Functional/Structural Groups); however, many users find that this indicator often becomes heavily focused on plant community composition. Both optional indicators are also partially reflected by Indicator 4 (Bare Ground). Soil stabilized by visible biological crust (e.g., lichens, mosses, and algae) is not considered bare ground.

Table 8. Optional indicator and generic descriptors for biological crusts and vegetation structure.

	Departure from Reference Sheet				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
Biological Crusts	Found only in protected areas, very limited suite of functional groups.	Largely absent, occurring mostly in protected areas.	In protected areas and with a minor component in interspaces.	Evident throughout the site but continuity is broken.	Largely intact and nearly matches site capability.
Vertical Vegetation Structure	Number of height classes greatly reduced and/or most height classes lost and/or dramatic increase in number of height classes expected for site and/or dramatic reduction in the number or density of individuals across several height classes.	Number of height classes significantly reduced and/or more than one height class lost and/or addition of more than one height class not expected for site and/or significant reduction in the number or density of individuals across several height classes.	Number of height classes moderately reduced and/ or one height class lost and/or addition of height class not expected for site and/or moderate reduction in the number or density of individuals across several height classes.	Number of height classes slightly reduced and/or slight reduction in the number or density of individuals across several height classes.	Number and type of height classes and the number and density of individuals in each height class closely match that expected for the site.

Because the Bare Ground indicator includes the spatial distribution of bare areas, it also provides some indication of the horizontal vegetation distribution.

The biological crusts indicator might be applied where these crusts play a particularly important biological or physical role (e.g., for nitrogen fixation or soil stabilization). The vegetation structure indicator is useful where variability in vertical vegetation structure within functional/structural groups affects wind erosion or the integrity of animal populations. This variability may be due to species differences within functional/structural groups, in age class distributions, or to disturbances such as fire and grazing that affect growth form.

The indicators included in these sheets are not intended to be all inclusive for all rangelands. Additional indicators may be added to the sheets to improve sensitivity in detecting changes in soil/site stability, hydrologic function, and biotic integrity.

The extensive comments received both prior to and following the publication of previous editions of this protocol included relatively few suggestions for new indicators, except where individuals wanted to include management-based indicators that are not appropriate for this protocol. There were also relatively few requests that particular indicators be dropped from the protocol, in part because users wanted to maintain consistency across evaluations. **The value of maintaining a consistent protocol often exceeds the benefit of including optional indicators**.

Step 5. Determine the Functional Status of the Three Rangeland Health Attributes (REQUIRED)

Complete the Evaluation Sheet (Appendix 1, back page).

The interpretation process is the critical link between observations of indicators and determining the degree of departure from the Reference Sheet for each health attribute in an evaluation area. The interpretation of the indicators and the selection of the degree of departure of the rangeland health attributes (soil/site stability, hydrologic function, and biotic integrity) are made at the bottom of Page 2 of the Evaluation Sheet. This summary rating is made by reviewing the indicator ratings and comments from all of the sheets, to arrive at a single degree of departure from the Reference Sheet for each attribute.

A "preponderance of evidence" approach is used to select the appropriate departure category for each attribute. This decision is based, in part, on where the majority of the indicators for each attribute fall under the five categories. For example, if four of the soil/site stability indicators are in the "moderate" and six are in the "slight to moderate" departure from the ecological site description/ERA categories, the soil/site stability attribute departure would be rated as "slight to moderate" assuming that the evaluator(s) interpretation of other information and local ecological knowledge supported this rating. However, if one of the four indicators in the "moderate" category is particularly important for the site (e.g., bare ground), a rating of "moderate" can be supported.

Once an evaluation is made for each attribute, managers may use the attribute evaluation to identify where more information (monitoring and/or inventory data) is required. This information should be reviewed if available, or if not available, the information should be collected. Therefore, these areas (i.e., moderate departure) are often ideal for the implementation of monitoring studies since they should be the most responsive to management activities. However, additional monitoring may be useful regardless of the departure rating, dependent upon future changes in uses or management of an area.

This procedure relies upon the collective experience and knowledge of the evaluator(s) to classify each indicator and then to interpret the collective rating for the indicators into one summary rating of departure for each attribute. The rating of each indicator and the interpretation into a collective rating for each attribute is not apprentice-level work. This procedure has been developed for use by experienced, knowledgeable evaluator(s). It is not intended that this assessment procedure be used by new and/or inexperienced employees, without training and assistance by more experienced and knowledgeable employees.

Applications to Larger Areas

Although the procedure described in this document is based upon a site-specific evaluation area, it can be applied at a watershed, pasture, allotment, or ranch level with the proper study design. Tools to help apply this to larger areas include topographic maps, water locations, grazing-use pattern maps, inventory or monitoring information, soil surveys, geographical information system (GIS) technology, and local knowledge. Individual site evaluations are made on selected rangeland ecological sites. Areas in the same rangeland ecological site, with the same ratings for the three rangeland health attributes, may be mapped and consolidated within a pasture or management unit (e.g., ranch or allotment). Where ecological site units are too small to be mapped, a "complex" map unit can be applied. Each complex includes two or more ecological sites. The attribute ratings for each ecological site in a complex are included in the map legend "ecological sites."

Additional studies or information may be required to confirm these ratings. The protocol described in this document is not intended to be used as a "stand-alone" tool to determine the final "health" or functional status of the three attributes of rangeland health.

Attribute ratings may stimulate further actions (e.g., review or initiation of inventory, monitoring, or different assessments; communication with various groups interested in the management of the area) to determine the reason for these ratings or determine if the trend is satisfactory under existing management. Areas in which one or more attributes is rated "Extreme to Total" or "Moderate to Extreme" usually have easily identified severe resource problems and have often crossed an ecological threshold. The cost effectiveness of management actions in these areas is often lower than in areas that have not yet crossed a threshold. Changes in management are not appropriate based solely on the evaluation of range health per the procedures in this document.

Summary

Qualitative assessments of rangeland health provide land managers and technical assistance specialists with a good communication tool for use with the public. This technique, in association with quantitative monitoring and inventory information (e.g., Table 2 in Concepts section), can be used to provide early warnings of resource problems. This procedure does not establish the cause of rangeland health problems; it simply identifies where a problem exists. This procedure is not intended nor designed to replace quantitative monitoring, serve as a trend study, or provide data that can be aggregated for a national report on rangeland health.

However, more research is needed to quantify indicator attributes and identify thresholds for rangeland health. Once this information is available, the assessment of rangeland health will become more quantitative and less reliant on qualitative assessment of the indicators. This document will continue to be revised as a result of continued research and application of this procedure. Where possible, ecological site-specific indicators and descriptors will be developed. The interpretation of the indicators will continue to evolve as our understanding of ecological dynamics (e.g., as described in state and transition diagrams) continues to grow. As the concept of rangeland health continues to evolve and mature, the application of this concept and protocol will also evolve.

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