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METHODS FOR ASSESSING THE HEALTH OF AMERICA'S RANGELANDS

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ABSTRACT

Since the publication of the National Research Council's "RANGELAND HEALTH – New Methods to Classify, Inventory, and Monitor Rangelands", and the Society for Range Management, Unity in Concepts and Terminology Committee's report, there has been much activity toward the development of a common method to assess rangelands in the United States. Many individuals from several different federal and state agencies have worked together to develop a multi-indicator matrix to determine the "health" status of rangelands. Healthy rangelands have been defined as: The degree to which the integrity of the soil, the vegetation, the water, and the air as well as the ecological processes of the rangeland ecosystem are balanced and sustained. The site potential is the standard by which the "health" is judged. A rangeland ecological site must be judged against itself and not against an arbitrary standard or that of a different ecological site. It is apparent that a multi-indicator method of evaluation is necessary. Currently, the evaluation consists of a series of observational questions, some of which can be answered by observation or measurement. Characteristics such as canopy and ground cover, dominant plant species, invasive and noxious plants, and composition of functional/structural plant groups can be measured or observed. The observable data are arranged in a matrix with seventeen indicators. Each indicator is compared against the rangeland ecological site description and reference areas that represent the natural range of variability in the ecological site. Each indicator is rated on a sliding scale of five choices from most similar to most dissimilar to the ecological site. Similarity is referenced to the ecological site description and the reference areas. Interagency personnel, universities, scientists, and landowners have tested this methodology in the field in several locations. The indicators have been grouped into three attributes of *rangeland health. The three attributes give an indication of the soil or site stability, hydrologic function and biotic integrity of the site. The indicators currently include: Rills, Water Flow Patterns, Pedestals or Terracettes, Bare Ground, Gullies, Wind Scoured Areas, Litter Movement, Soil Surface Resistance to Erosion, Soil Surface Loss, Plant Community Composition and Distribution Relative to Infiltration and Runoff, Compaction Layer, Plant Functional/Structural Groups, Plant Mortality, Litter Amount, Annual Production, Invasive Plants, and Perennial Plant Reproductive Capability. The ratings for each indicator are recorded in a manner that allows for a visual interpretation based on the preponderance of evidence.*

KEYWORDS: Assessing Health; Multi-indicator Evaluation: Rangeland Health;

1 Introduction

The science of inventorying and assessing rangelands is changing as concepts and protocols continue to evolve. Recently the concept of "rangeland health" was advanced by a panel assembled by the National Research Council (NRC) as an alternative to range condition e.g. ecological status concept currently used by most range professionals as the basis for inventory, assessment and monitoring. Just prior to this publication the Society for Range Management's Unity in Concepts and Terminology Task Force published its report. An interagency ad hoc committee was established to integrate the NRC publication and the Society for Range Management's (SRM) Unity in Concepts and Terminology Task Group reports to develop a methodology for the various agencies to conduct inventory and assessment on rangelands. This committee defined rangeland health as:

"The degree to which the integrity of the soil, vegetation, water and air as well as the ecological processes of the rangeland ecosystem are balanced and sustained." They further defined integrity to mean: *"Maintenance of the functional attributes characteristic of a locale, including normal variability."*

The challenge to scientists and managers is to translate this concept that involves complex ecological processes and functions into terms that the public can comprehend and that resource specialists can use to assist in identifying rangeland ecological sites where ecological processes are or are not functioning properly. This paper describes a process to educate and train the land managers, the public and agency personnel on using indicators to interpret and evaluate rangeland health of selected ecological sites on North American rangelands. This process relies on the use of a qualitative procedure by resource professionals to evaluate the functional status of selected rangeland health indicators.

The use of qualitative information to determine range and soil conditions has a long history in land management and monitoring. Early procedures that used indicator ratings include 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 also used "soil surface factors" to determine erosional status of large acreages of public lands in the 1970's (USDI 1973). In 1993, and interagency Technical Reference (TR 1737-9) was published that utilized a qualitative checklist to assess the functioning condition of riparian areas (USDI 1993).

2 Components of Rangeland Health

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

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

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

Table 1. Attributes of rangeland health and the rating categories.

<table>
<tr><th colspan="2">Soil/Site Stability</th><th colspan="2">Hydrologic Function</th><th>Integrity of the Biotic Community</th></tr>
<tr><td colspan="5">Attribute ratings are based upon “departure from ecological site description /reference area(s)” in these categories.</td></tr>
<tr><td>Extreme</td><td>Moderate to Extreme</td><td>Moderate</td><td>Slight to Moderate</td><td>None to Slight</td></tr>
</table>

Definitions of these three closely interrelated attributes are:

Soil/Site Stability

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

Hydrologic Function

The capacity of the site to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity following degradation.

Integrity of the Biotic Community

The capacity of the site to support characteristic functional and structural communities in the context of normal variability, to resist loss of this function and structure due to a disturbance, and to recover following such a disturbance.

3 Indicators

Currently there are seventeen indicators used to assess the attributes of rangeland health. Each of these indicators is rated separately, and then the preponderance of evidence is evaluated. The indicators are rated on a sliding scale of five categories based on its departure from the expected for the ecological site. The indicators are not given a score, but are tallied. The preponderance of evidence is determined both by the number of indicators in each category and how the individual indicators are rated. Following is a brief description of each of the indicators.

3.1. Rills

Rills are small erosional rivulets that are generally linear and do not necessarily follow the microtopography as flow patterns do. They are formed through complex interactions between raindrops, overland flow, and the characteristics of the soil surface (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, Ellison and Ellison 1947 as cited in 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).

3.2 Water Flow Patterns

Flow patterns are the paths 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.

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.

3.3 Pedestals & Terracettes

Pedestals and terracettes are important indicators of the movement of soil by water and by wind (Anderson 1974, Morgan 1986, 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 process. However, these terracettes can increase erosion by concentrating water flow and/or reducing infiltration. These effects are recorded with the appropriate indicators (e.g., water flow patterns, compaction layer, and soil surface loss and degradation).

3.4 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 opposite of ground cover, which is the percentage of ground surface covered by vegetation, litter, standing dead vegetation, gravel/rock, and visible biological crust (e.g., lichen, mosses, algae), meaning everything except bare ground (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, Pierson et al. 1994,). 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,).

The determination of adequacy of ground cover at the area of interest is determined in a comparison with the ground cover information in the rangeland ecological site description and/or at the ecological reference area(s) (ERAs).

The amount of bare ground can vary seasonally depending on impacts on vegetation canopy cover (e.g., herbivore utilization), and litter amount (e.g., trampling loss), and 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.

3.4 Gullies

A gully is a channel that has been cut into the soil by moving water. Gullies generally follow the natural drainage ways and are caused by accelerated water flow and the resulting downcutting of soil. Gullies are a natural feature of some landscapes, while on others management actions (e.g., excessive grazing, recreation vehicles, or road drainage ways) may cause gullies to form or expand (Morgan 1986). Water flow is concentrated but intermittent, with gully depth 1/2 meter or more in depth.

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. 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).

3.6 Wind Scoured 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 on many rangelands with low canopy cover in protecting the soil surface from wind erosion. 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, Blifford and Fenster 1972, Gillette, Blifford and Fryrear 1974, Gillette and Walker 1977, Hagen 1984).

Areas of wind erosion within a vegetation community are represented 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 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). 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 deposition site.

3.7 Litter Movement

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

The inherent capacity for litter movement on a soil is a function of its slope and geomorphic stability. For example, alluvial fans and floodplains 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 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.

3.8 Soil Surface Resistance to Erosion

This indicator assesses the resistance of the surface of the soil to erosion. Resistance depends on soil stability, microtopography, 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).

Where soil surface resistance is high, soil erosion may be minimal even under rainfall intensities of over 5 inches/hour, generating high runoff rates on plots from which all cover has been removed. Conversely, the presence of highly erodible materials at the soil surface can dramatically increase soil erosion by water even when there is high vegetative cover (Morgan et al. 1997) and by wind when vegetative cover is removed.

In areas with low vegetative cover, the stability of soil in the 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 that is topographically above the flow path.

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

Biological crusts are primarily important as cover and in stabilizing soil surfaces (Bond and Harris 1964; Belnap and Gardner 1993). 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.

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 silty, clayey, and loamy soils and relatively thin, if at all present, in sandy soils. Physical and chemical crusts tend to have very low organic matter content, or contain only inert organic matter that is associated with little biological activity. As this physical crust becomes more extensive, infiltration rates are reduced and overland water flow increases. Also, water can pond in flat crusted areas and is more likely to evaporate than infiltrate into the soil.

Physical 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. Physical crusts also include vesicular crusts that contain numerous small air pockets or spaces similar to a sponge however; these soils are still resistant to infiltration.

3.9 Soil Surface Loss or Degradation

The loss or degradation of part or all of the soil surface layer or horizon is an indicator of a loss in site potential. In most sites, the soil at and near the surface has the highest organic matter and nutrient content. This generally controls the maximum rate of water infiltration into the soil and is essential for successful seedling establishment (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 a complete loss of this layer. In areas with limited slope, where wind erosion does not occur, the soil may remain in place, but all characteristics that distinguish the surface from the subsurface layers are lost. Except in soils with a clearly defined horizon immediately below the surface (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.

The two primary indicators used to make this evaluation are the organic matter content and structure of the surface layer or horizon. Soil organic matter content is frequently reflected in a darker color of the soil, although high amounts of oxidized iron (common in humid climates) can obscure the organic matter. In arid soils where organic matter 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 in the loss of clearly defined structural units or aggregates at one or more scales from <1/8 inch to 3-4 inches. In soils with good structure, pores of various sizes are visible within the aggregates. Structural degradation is reflected in a more massive, homogeneous surface horizon and is associated with a reduction in infiltration rates. Comparisons to intact soil profiles at reference sites can also be used, although in cases of severe degradation the removal of part or the entire A horizon, or of one or more textural components (e.g., Hennessey et al. 1986) may make identification of appropriate reference areas difficult.

3.10 Plant Community Composition & Distribution Relative to Infiltration and Runoff

Vegetation growth form is an important determinant of infiltration rate and interrill erosion (Thurow et al. 1988). Vegetation has been found to be the primary factor influencing the spatial and temporal variability of surface soil processes controlling infiltration and interrill erosion rates on semiarid rangelands (Blackburn et al. 1992).

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 et al.1990), and Texas (Wood and Blackburn 1984; Thurow at al. 1988). Changes in plant community composition 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. 1988). An example of a composition change that reduces infiltration and increases water runoff is the conversion of desert grasslands to shrub-dominated communities. However, infiltration and runoff are also affected when sagebrush steppe rangeland is converted to a monoculture of annual grasses. These annual grasses provide excellent watershed protection although they adversely affect the ecological processes in many other ways. Care must be exercised in interpreting this indicator in different ecosystems as the same species may have different effects.

3.11 Compaction Layer.

A compaction layer is a near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. Compaction becomes a problem when it begins to limit plant growth (Wallace 1987), water infiltration (Willat and Pullar 1983, Thurow et al. 1993) or nutrient cycling processes (Hassink et al. 1993). Farm machinery, herbivore trampling (Willat and Pullar 1983), recreational and military vehicles, foot traffic, or any other activity that repeatedly causes an impact on the soil surface can cause a compaction layer (Willat and Pullar 1983). Moist soil is more easily compacted than dry or saturated soil. Recovery processes (e.g., earthworm activity and frost heaving) are generally sufficient to limit compaction by livestock in many upland systems (Thurow et al. 1988).

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) with the determination of a compaction layer (i.e., a soil structure change) done by a person with soils experience. These layers may be detected in some soils with the use of a penetrometer or by simply probing the soil with a sharp rod or shovel and “feeling” for the compaction layer (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 and horizontal root growth, and increased density (measured by weighing a known volume of oven-dry soil). Increased resistance to a probe can be simply due to lower soil moisture or higher clay content.

3.12 Plant Functional/Structural Groups

This indicator addresses the various roles that different species fulfill in energy flow and nutrient cycles. Functional/structural groups are a suite of species that because of similar shoot or root structure, photosynthetic pathways, nitrogen fixing ability or life cycle are grouped together on an ecological site basis (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 (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) must specify these groupings after reviewing the ecological site description and/or ecological reference area(s) based upon the relative weight or relative cover that each structural/functional group collectively contributes to the total. The potential for functional/structural groups is derived by placing species into the appropriate groups from information found in the ecological site/description, and/or at the ERA. Functional groups that are now present, but were not original components of the site (e.g., weeds, introduced plants), need to be identified.

The number of species in each functional group is also considered when selecting the appropriate rating category. If the number 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)

3.13 Plant Mortality and/or 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 other undesirable plants (e.g., weeds or invasives) may increase (Pyke 1995). Healthy rangelands have a mixture of many age classes of plants relative to site potential and climatic conditions (Stoddard, Smith, and Box 1975).

Only plants native to the site (or seeded plants if in a seeding) are assessed for plant mortality. Plant mortality may vary considerably on the landscape depending on disturbance events (e.g., fire, drought, insect infestation, and disease). The cover of standing dead vegetation may be compared to values found in the ecological site description or on the ecological reference area to assist in assessing the expected to actual plant mortality.

3.14 Litter Amount

Litter is any dead plant material that is in contact with the soil surface. That portion of the litter component that is in contact with the soil surface (as opposed to standing dead vegetation, which is not) provides a major source of the soil organic material and the raw materials for onsite nutrient cycling (Whitford 1988, 1996). Litter also helps moderate the soil microclimate and provides food for microorganisms (Hester et al. 1997). The amount of litter present is also a factor 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. 1988).

The amount of litter present is compared to the amount that would be expected for the same type of growing conditions under the historic climax plant community or to that observed on the ecological reference area. Litter is directly related to weather and to the degree of utilization of biomass each year. Therefore, climatic influences (e.g., drought, wet years) must be carefully considered in determining the rating for the litter amount.

3.15 Annual Production

Aboveground biomass (i.e., annual production) 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 with latitude (Cooper 1975). Annual production of the area of interest is compared to the site potential from the rangeland ecological site description and/or the ecological reference area(s).

Comparisons to the ecological site description 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) should estimate the production of the annual biomass removed or expected and include this amount when making the total site biomass estimate. Do not include standing dead vegetation (i.e., produced in previous years) as annual production.

All species (e.g., native, seeded, and weeds) are included in the determination of total above- ground biomass if they were alive in the year that the evaluation takes place. This indicator is simply a measure of the total amount of vegetation available to harvest the sun's energy at a given point in time, therefore type of vegetation (e.g., native or introduced) is not the issue. For example, Rickard and Vaughan (1988) found that conversion of a sagebrush steppe plant community to an exotic annual grassland greatly affected vegetation structure and function but not above-ground biomass production.

3.16 Invasive Plants

This indicator deals with plants that are invasive to the area of interest. These plants may or may not be noxious and may or may not be exotic. Generally they are invaders or increasers to the site that can, and often do, continue to increase regardless of the management of the site and may eventually dominate the site.

Invasives can include noxious plants (i.e., plants that are listed by a local government because of their unfavorable economic or ecological impacts), non-native, and native plants. Native invasive plants (e.g., pinyon pine or juniper) must be assessed by comparing current status with their potential status described in the rangeland ecological site description and/or observed in the ecological reference area(s). Historical accounts and photographs also provide information on the historical distribution of invasive native plants.

Invasive plants may impact an ecosystem's type and abundance of species, their 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 further emphasizing their use as an indicator of new ecosystem stress. Even highly diverse, species-rich plant communities are susceptible to exotic species invasion.

3.17 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.

Comparing number of seedstalks and/or number of seeds per seedstalk of native or seeded plants (not weeds or invasives) in the evaluation area with that produced on the associated ecological reference area (ERA) can assess seed production. 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.

For plants that reproduce vegetatively, the number and distribution of tillers or rhizomes is assessed relative to the production of these reproductive structures on perennial plants in the ERA. Only native or seeded plants are evaluated with this indicator; invasive plants are not included in the evaluation.

Recruitment is not assessed as a part of this indicator since plant recruitment from seed is an episodic event in many rangeland ecological sites.

4 Methodology

The assessment area must be large enough to account for the natural variability within the ecological site. It must also be small enough to evaluate. An area of one to two acres is usually sufficient. Each indicator is evaluated based on its departure from what is expected for the ecological site. A Rangeland Health Ecological Indicator Evaluation Matrix has been developed for this use. (See Table 2) The assessment is made from a sliding scale of five choices. The critical link between observations of indicators and determining the degree of departure from the ecological site description and/or ecological reference area (ERA) for each health attribute of an area of interest is the interpretation process.

Table 2. Rangeland Health Ecological Indicator Evaluation Matrix

Rangeland Health Ecological Indicator Evaluation Matrix Departure from Ecological Site Description/Ecological Reference Area					
Indicator	**Extreme**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**Slight**
Rills	Rill formation is severe and well formed throughout most of the area.	Rill formation is moderately active and well defined throughout most of the area.	Active rill formation is slight at infrequent intervals, mostly in exposed areas.	No recent formation of rills; old rills have blunted or muted features.	Minimal evidence of current or past formation of rills.

A "preponderance of evidence" approach is used to determine which of the five departure categories are selected as best fits by the evaluator(s) for each attribute. This decision is based in part on where the majority of the indicators for each attribute fall under the five categories of departure. For example, if four of the soil/site stability indicators are in the "extreme" and six are in the "moderate to extreme" departure from the ecological site description/ERA categories, the soil/site stability attribute departure would be rated as "moderate to extreme assuming that the evaluator(s) interpretation of other information and local ecological knowledge supported this rating.

The preponderance of evidence is determined by the proportion of tallies in each category and by how each indicator is assessed. The indicators are grouped into the three rangeland health attributes and tallied for each attribute. The attribute of Soil/Site Stability includes indicators 3.1 – 3.6 and 3.8 - 3.11; Biotic Integrity includes indicators 3.9 and 3.11 – 3.17; and Watershed Function includes indicators 3.1 – 3.5, 3.7 – 3.11 and 3.14. The preponderance of evidence can then be viewed and evaluated. (Table 3)

Table 3. Indicator Summary

Indicator Summary	**Extreme**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**Slight**
Soil/Site Stability			III	IIIII	III
Biotic Integrity		III	IIIII		
Watershed Function			IIII	IIIII	II

The site evaluation will address each of the three attributes and will **not** give one "health" rating. In the above example, it can be said the Soil/Site Stability is stable, the Biotic Integrity is at risk and the Watershed Function is In Tact.

More information (inventory and/or monitoring) will generally be required if the preponderance of evidence indicates that an attribute falls in the "moderate departure" category. This information should be reviewed if available or if not available, it should be collected. The moderate rating is somewhat analogous to an "at risk" rating (NRC 1994). Therefore, these areas (i.e., moderate departure) are often good areas to implement monitoring studies on 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 or temporary type employees without training and assistance by more experienced and knowledgeable employees.

4 Conclusion

This methodology is still evolving, as are the applications of concepts of rangeland health. It has proven to be a valuable tool when used by experienced professionals. It is not meant to replace any other method of assessment, but rather to compliment other established methods. When used in the inventory phase of a planning process with land managers, it provides additional information other methods do not. The primary use of this tool is to begin the educational process of examining how the ecological processes on an ecological site are functioning. When this information is combined with composition, production and trend information a more complete picture of the rangeland resource is delivered to the land manager. This more complete picture enables the land manager to make resource decisions that are wiser and more sustainable.

Based upon a preponderance of evidence approach for the applicable indicators, each of these three attributes of rangeland health is summarized. This assessment is preliminary and may be modified with the interpretation of applicable quantitative monitoring and inventory data. Both the original rating and any modification of it require a written explanation.

To reiterate, the process described here will not produce just one rating of rangeland health, but three attributes departure from the ecological site description/ecological reference area(s).

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