Indicators for Ecological Health and Diversity on Rangelands

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Abstract

This paper is a progress report outlining efforts of the Sustainable Rangeland Roundtable to develop standardized Ecological Health and Diversity indicators for monitoring the sustainability of rangeland ecosystems. To date, 16 indicators have been developed to capture aspects of ecological health and diversity that range from a broad-based assessment of the location and amount of rangeland in the United States to detailed assessments of rangeland ecological processes. The current developmental status of these indicators will be reviewed.

Introduction

Ecological health and diversity are traits of ecological systems that science has identified, and the general public accepted, as important indicators of the sustainability of rangeland ecosystems (Anonymous 2001, Flather & Sieg 2000). As such, there is a need to develop a set of standardized assessment and monitoring protocols for U.S. rangelands (Anonymous 2001). This paper is a progress report outlining the efforts of members of the Sustainable Rangeland Roundtable (SRR) to develop standardized Ecological Health and Diversity indicators for monitoring the sustainability of rangeland ecosystems.

The development of these criteria is a reflection of the expert opinions of rangeland scientists and closely associated rangeland management agency personnel, non-governmental organization representatives, practitioners, and other interested stakeholders. Associated concepts and ideas have evolved from lively discussions at the SRR workshops as well as electronic correspondence between meetings.

Indicators

To date, we have identified, developed and tentatively adopted 16 indicators (Table 1). These indicators reflect many aspects of ecological health and diversity and range from broad-based assessment of the location and amount of rangeland in the United States to detailed assessments of rangeland ecological processes.

Extent of Land Area in Rangeland, Indicator 1, quantifies the total area of rangeland in the United States by location. Changes in area between times of assessment will reflect trends relative to increases and decreases in amount of U.S. lands classified as rangeland.

Biodiversity

Biodiversity is a term that has had wide acceptance and numerous definitions. Flather and Sieg (2000) reviewed 10 definitions and concluded that the following definition by the Keystone Center was cited most often: “the variety of life and its processes” which encompasses “the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.” The components of biodiversity have been described as landscape, community, population, and genetics (West 1993). We believe changes over time in the suite of biodiversity indicators we have selected will provide a scale-sensitive measure of elemental changes in biodiversity.

Landscape diversity includes variety, pattern, connectedness, resilience, and integrity. A major threat to sustaining biodiversity is reduced size of contiguous habitats (West 1993). We address landscape diversity through the many ways that rangelands can be fragmented, using three indicators. They are:

- **Indicator 3** - Fragmentation of Rangeland Area by Size, Pattern, and Dispersion of Rangeland Community Types,
- **Indicator 4** - Fragmentation of Rangeland Based on Size of Parcel (i.e., ranchettes, etc.),
- **Indicator** 5 - Extent of Rangeland Area Under Different Management Practices.

Size, pattern, and dispersion of rangeland community types are seen as important descriptions for rangeland, in terms of habitat, grazing use, and

Table 1. Indicators for maintenance of ecological health and diversity of rangelands

Indicator	What the Indicator Describes
1. Extent of Land Area in Rangeland	Area and trends in land that fits the definition of rangeland
2. Extent of Rangeland Area by Community Type	Area and trend of individual community types on rangeland
3. Fragmentation of Rangeland by Size, Pattern, and Dispersion of Rangeland Community Types	Spatial patterns on rangeland and of rangeland community types
4. Fragmentation of Rangeland based on Size of Parcel	Spatial patterns of ownership patterns on rangeland
5. Extent of Rangeland Area under Different Management Practices	Area of rangeland under different management practices
6. Percent Cover of Invasive and other Non-native Plant Species of Concern	Cover of Invasive and Non-native plants
7. Percent Cover by Vegetation Classes	Percent cover of grasses, forbs and shrubs
8. Presence and Status of Species of Concern or Threatened and Endangered Species	List and status of species that are threatened, endangered, or of concern for some other identified reason
9. Rangeland Plant and Animal Species that Occupy a Small Portion of Their Former Geographic Range	List of species whose geographic range is declining
10. Population Levels and Current Geographic Range of Representative Species Monitored across their Known Geographic Range	Finer scale information on select plant and animal species
11. Productivity	Vegetation productivity of rangelands
12. Carbon to Nitrogen Ratio in the Soil	Indication of site productivity and fertility
13. Depth to Shallow Groundwater	Indication of availability of water to vegetation
14. Natural Lake Levels	Indication of abiotic and biotic influences on aquatic systems
15. Riparian Condition	Indication of the condition of riparian vegetation and watershed health
16. Changes in Fire Regimes on Rangeland	Fire frequency, intensity, extent

ecosystem services. Fragmentation of community types is a particularly critical issue for wildlife because it relates to the ability of differing habitats to meet breeding, feeding, and shelter needs. While fragmentation of forested ecosystems have long been studied, fragmentation of rangelands and the agents that influence the rate of fragmentation are just now being studied (Flather and Sieg 2000).

Community diversity includes species richness, structure, composition, and function (West 1993). We are addressing community diversity through Indicators 2, 6, and 7 where each captures an element of community diversity (Table 1). Extent of rangeland area by community type (Indicator 2) addresses area of varying rangeland plant communities across the United States. Percent cover of invasive and other non-native plant species of concern (Indicator 6) captures the presence and cover of alien or non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health (definition in Executive Order on Invasive Species). Invasive plant species are of great concern to rangeland managers yet data quantifying the magnitude of this problem on U.S. rangelands is at best sparse and incomplete. Percent cover by vegetation classes (Indicator 7) also captures the structural diversity of rangelands through the percent cover of grasses, forbs, and shrubs. We are considering developing an indicator based on functional group composition. Generally, functional groups are plant and/or animal species that tend to affect ecological systems in a similar manner. Commonly defined functional groups are warm- and cool-season species plants, perennial and annual grasses, primary (i.e., herbivores) and secondary (i.e. carnivores) consumers, etc.

Population diversity reflects finer scale details on the absolute or relative abundance of species, their frequency, importance, cover, and density values (West 1993). This measure of rangeland biodiversity is challenging to encompass in a national inventory. Still, we are proposing three indicators (Indicators 8-10, Table 1). Presence and status of species of concern or threatened and endangered species (Indicator 8) captures the status of species that have been legally classified as threatened or endangered, or identified as a species of concern for another specified reason. Rangeland plant and animal species that occupy a small portion

of their former geographic range (Indicator 9) portrays a list of species whose ranges have decreased in area for some known or unknown reason. They are species that are sensitive and thus responsive to change. Similarly, population levels and current geographic range of representative species monitored across their known geographic range (Indicator 10) would allow for finer scale information on population dynamics of plant or animal species to be monitored closely.

Genetic diversity is the most challenging aspect of biodiversity to capture in a national inventory system. Little is known about the genetic diversity of most rangeland species; the notable exceptions being sagebrushes and wheat-and ryegrasses (West 1993). For those species in which there is concern about the genetic diversity, they could be identified as a representative species that bears closer monitoring (Indicator 10). Clearly, additional research and new techniques are needed to establish a baseline of genetic diversity within rangelands and to develop metrics for monitoring genetic diversity at large spatial scales.

Ecological Health

Ecological health is a phrase that also has wide acceptance but only limited formal definition. Rangeland health has been defined as "the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained" (Committee on Rangeland Classification 1994). Rangeland ecosystems are influenced by natural disturbances and manipulated through land use activities. The capacity of rangelands to produce commodities and to satisfy societal values and expectations on a sustained basis depends on internal, self-sustaining ecological processes such as soil genesis, nutrient cycling, energy flow, and the structure and functional dynamics of plant and animal communities (Committee on Rangeland Classification 1994). Humans depend on these natural processes to regenerate and restore these ecosystems after natural and human-induced disturbances. This dependency contrasts with agricultural systems where, for example, added fertilization has replaced nutrient cycling to make mineral nutrients available to plants. From our discussions, we identified hydrology, nutrient cycling, and energy flow to be ecosystem processes that this set of indicators should capture.

We selected two indicators (Indicators 13, 14) for assessing the functional "health" of hydrologic processes that are important to overall ecological health. A larger set of indicators for soil and water is being considered by the Soil and Water Resources Criterion Group (see Karl et al. 2002). But for our purposes, depth to shallow groundwater was selected as an important indicator because it is an indicator of the water available to vegetation. Likewise and for similar reasons, variations in level of water in natural lakes was selected as an indicator. Although small aquatic ecosystems are generally not considered to be significant components of larger rangeland ecosystems, natural lakes are important aquatic habitats in the Prairie Pothole region of the Great Plains, in Texas and Florida, and in the high-elevation alpine ecosystems.

For nutrient cycling and energy flow, we identified four indicators, Productivity (Indicator11), Carbon to Nitrogen Ratio in the Soil (Indicator 12), Riparian Condition (Indicator 15) and Changes in Fire Regimes on Rangelands (Indicator 16). Productivity of rangeland vegetation is fundamental to rangeland health. We recognize, however, that assessing primary productivity is an enormous challenge in a national inventory. Nonetheless, recent advances in the use of remotely sensed imagery may offer opportunities for capturing this information efficiently and inexpensively. Productivity indicators are also being proposed by the Productive Capacity Criterion Group (see Child 2002). We selected the soil carbon to nitrogen ratio as a potential measure of a system's status relative to nutrient cycling. Riparian condition is recognized as an important indicator of the "health" of rangeland watersheds but as of yet we have little agreement as to how this should be measured. An indicator is still important because riparian ecosystems are sensitive to impacts from varying types of land use.

Finally, rangelands are subject to many natural disturbances by insects, disease, fire, and extreme climate events such as droughts (Joyce et al. 2000). Over time, human intervention has probably changed fire regimes, relative to frequency, intensity and areal extent, more than any other factor. Thus, the last indicator (Indicator 16) was selected to ascertain these fire effects over time as it has been well documented that changing the fire regimes on rangelands significantly influences ecosystem dynamics.

Challenges and Opportunities

The greatest challenge, and thus opportunity in this work, is to develop a meaningful, measurable set of indicators that diverse stakeholders will deem appropriate and acceptable for assessing and monitoring the ecological health and diversity of rangeland ecosystems. The above set represents our initial attempt to meet this challenge. But, our work is obviously far from complete and, as such, we welcome the comments of all interested parties.

Other challenges stem from the fact that there are no nationally agreed-upon definitions or nationally recognized sampling protocols for several of our proposed indicators. For example, numerous approaches exist for classifying existing and

potential vegetation, but no single approach is universally accepted across all federal agencies. Another challenge is related to the interaction effects of various indicators and scale. Most likely, not all proposed indicators can be aggregated up to the national level to produce a meaningful indication of ecological health and diversity. Moreover, we do not currently have acceptable metrics for employing all indicators in a meaningful manner (e.g., riparian condition). But we are including such indicators because we believe they capture important aspects of ecological health and diversity.

Conclusions and Future Work with Criterion

Work to date has yielded 16 tentative indicators. There is near unanimous agreement among the members of our group on eight or nine of the indicators with the number varying depending upon who is at the table when members are polled as to their viewpoints. That means seven or eight indicators still require meaningful work before we can adopt our final list. In addition, we have not begun to assess the feasibility of actually measuring our proposed indicators. So, once we complete our "desired" list of indicators, much energy will yet have to be expended in a feasibility assessment. As such, we believe that the challenges associated with this work will continue to be both bewildering and inspiring. We are hopeful that our members' collective inspirations will carry us through to a "healthy" end point!

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