PROGRESS REPORT
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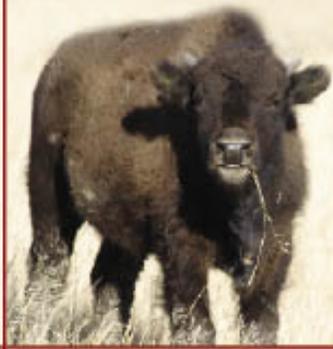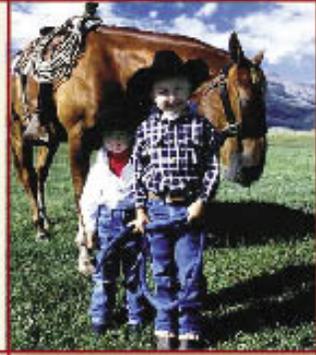
SUSTAINABLE RANGELANDS ROUNDTABLE

Written by: *Members of the Sustainable Rangelands Roundtable*
March 2006

Sustainable Rangelands Roundtable

Executive Summary

Rangeland sustainability is the capacity of rangelands to maintain their health, productivity, diversity and overall integrity, from generation to generation, in the context of human activity and use. Because the ecological-social-economic systems comprising rangelands are complex, many indicators are needed to assess their sustainability. Indeed, the Sustainable Rangelands Roundtable (SRR) has identified 64 indicators that we believe are relevant to assessing rangeland sustainability <http://sustainablerangelands.cnr.colostate.edu>.

Several legal mandates, such as the Public Rangelands Improvement Act of 1978 for the BLM, Forest and Rangeland Renewable Resources Planning Act of 1974 for the Forest Service, and the Soil and Water Resources Conservation Act of 1977 for the NRCS, require federal land management agencies to report periodically on the status of the rangelands they administer. Although this is happening, most agency reports have focused primarily on the ecological aspects of rangelands and less so on the socio-economic factors affecting them.

A report encompassing all three characteristics of rangeland sustainability – ecological, social, and economic – conducted across the breadth of agencies who administer our Nation's rangelands, can help decision-makers allocate scarce financial and workforce resources to monitor the indicators known to be related to key processes affecting rangeland sustainability. This Progress Report gives perspectives on the overall importance of the 64 SRR indicators, but it also shows how a refined set of 27 indicators can provide the initial focus of a first national report on rangeland sustainability, and it makes a case to rangeland stewardship agencies that a first report is actually feasible in the near future.

With creation of a system for standardized, periodic monitoring and reporting of rangeland sustainability in mind, a group of rangeland stakeholders met in Denver in 1999 and envisioned establishment of a group now known as the SRR. After extensive discussions, participants decided to move forward, and the first meeting of the SRR was held in April 2001.

The SRR is a collaborative process comprised of participants representing about 50 organizations since its establishment, including federal land management and research agencies, tribal, state, and local governments, NGOs, scientific societies, academics, and other researchers. The SRR operates as an inclusive, open partnership with all interested representatives having an equal voice.

The original purpose of SRR was to develop and report upon a set of criteria and indicators (C&I) for sustainable rangeland management at a national scale. Criteria are explicit conditions by which sustainable rangeland management may be assessed, but they are too general in scope to monitor directly. Thus, each criterion is characterized by indicators that can be periodically measured or described to demonstrate trends.

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Chapter 1: Introduction

Rangeland sustainability is the capacity of rangelands to maintain their health, productivity, diversity and overall integrity, from generation to generation, in the context of human activity and use. Because the ecological-social-economic systems comprising rangelands are complex, many indicators are needed to assess their sustainability. Indeed, the Sustainable Rangelands Roundtable (SRR) has identified 64 indicators that we believe are relevant to assessing rangeland sustainability <http://sustainablerangelands.cnr.colostate.edu>.

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Selection of indicators was a slow, steady process, a consequence of the broad range of stakeholders' training, experience, and values, and the need to build a bond of trust among such a diverse group of participants. After two years and 11 meetings, SRR participants converged upon the above-mentioned 64 indicators, categorized under five criteria, to describe social, economic, and ecological factors that might form a framework for monitoring sustainable rangeland management (see Appendix).

While all 64 indicators are believed to be relevant to rangeland sustainability, participants subsequently recognized that it will not be practical for agencies to begin

monitoring such a large number of indicators in light of limited budgets and staffing. Therefore, during the past 2 years SRR participants identified a refined set of 27 core indicators from among the larger set that could be used to assess the status and trends of economic, social, and ecological factors affecting rangeland sustainability within the decade. Core indicators constitute the "low hanging" elements that are broadly agreed to be important and for which a reasonable potential exists to obtain adequate data.

Much of this report is devoted to the applicability of these core indicators to assess the sustainable management of our Nation's rangelands. As is shown in the next chapter, core indicators can be linked to basic ecosystem and socio-economic processes through the development of a conceptual systems model. A following chapter reviews the status of rangeland indicators in relation to data quantity and quality. Finally, the report shows how monitoring and reporting upon a suite of core indicators can support and benefit the strategic goals of both governmental agencies and non-governmental organizations having interests in sustainable rangeland management.

Indicator Benefits and Potential Applications

Acceptance of SRR C&I could form the foundation for better coordination among regional and national rangeland monitoring programs, which, in turn, will help illustrate trends in resource condition, management, economic benefits, and social values derived from rangelands. For public and private rangeland managers and stakeholders, potential benefits include:

- Implementation of standardized periodic inventory, monitoring, and reporting on private and public rangelands;
- Improved coordination among local, regional, and national assessments;
- Enhanced interagency cooperation and collaboration;

- Identification of research needed to address indicator data gaps;
- Provision of a basis for stakeholder dialogue and better informed national policy deliberations;
- Justification of resource allocations for rangeland management and science; and,
- Expansion of public awareness and understanding of rangeland sustainability.

Within government, rangeland monitoring is a key source of information used in measuring the performance of land management organizations. Indicators for sustainable rangelands provide accountability and promote effective public land management practices to achieve organizational goals and objectives. Collaborative efforts involving affected stakeholders typically foster sound decision-making in the areas of community capacity building and improved resource management. Criteria and indicators emanating from monitoring frameworks developed collaboratively from multiple stakeholders can often help illuminate and better define important issues associated with rangelands.

Rangeland-related phenomena, like drought and fire, are complex and often poorly understood. One or two indicators are inadequate to characterize the multiple interactions taking place between ecosystems and societies during droughts and extreme fire years. A suite of indicators has much greater potential to monitor trends in complex rangeland issues. For example, fire is both a natural disturbance factor and a valuable management tool on rangelands. It is a key ecological driver in many ecosystems that helps maintain a number of major grassland, shrub, and savanna ecosystems. In recent years, the interaction of fire with invasive species outbreaks has modified how fire affects ecosystem structure and function.

Indicator-based monitoring also reflects the shift in human values concerning rangelands and the environment that has occurred

during the past 50 years. Until the mid-20th Century, people thought of rangelands mainly in terms of domestic livestock production, and policy decisions were made wholly by land management agencies. The concept of sustainability arose with the environmental movement in the 1970s. In a 1987 report, the World Commission on Environment and Development suggested that economic growth, social equity, and environmental quality are closely related under the concept of sustainable development. The 1972 UN Conference on Environment and Development provided a blueprint for nations to achieve sustainable development in the 21st Century. In 1994, an international initiative called the Montreal Process was started to develop C&I of sustainable management of temperate and boreal forests at a national scale. USDA Forest Service recently released the first national report on sustainable forests based upon the Montreal Process C&I <http://www.fs.fed.us/research/sustain/>

The concept of sustainability is broadly understood. Sustainable development refers to the ability of a nation or state to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable management involves the kinds of management that considers all aspects of rangelands, including their environmental, economic, and social values, and attempts to integrate them to achieve a sustainable future.

Challenges to Successful Indicator Application

A number of challenges to C&I application exist. Priority issues include scale limitations, database management and integration, definitions of forest and rangeland, and a better understanding of community and economic conditions.

Scale is emerging as an important aspect of indicator system design. It is relevant to the effective use of indicators, to the design of data acquisition systems, and to the interpretation of indicators. The choice of scale interacts with the grain and extent of data and must be commensurate. The scale of data is critical to decisions regarding monitoring system behavior. Patterns that are evident at one level of resolution can be lost at lower or higher levels. Explanatory landscape variables can change substantially across scale; i.e., patterns found at different scales are rarely explained by a single mechanism.

Not only are grain and extent of data correlated to scale, but analytical tools also are scale-sensitive in both time and space. For example, ecological sampling designs and statistical techniques at a national scale commonly monitor trends on a decadal interval while those at the local level are designed to monitor trends annually. Moreover, the analytical techniques, themselves, change more rapidly at smaller scales and there are more techniques available. As agencies and NGO's move forward with indicator development, they will need ways to address the treatment of scale.

Resolving data management issues will be critical to the reporting of some sustainability indicators. No standards for data collection exist for most ecological and social indicators, particularly across administrative boundaries. The purpose of data management is to provide a means for dealing with disparate data sets by developing common formats to handle the data. A viable data management system allows individual data providers to remain independent while still being able to meet broader scale needs. Technologies for doing this involve putting structures in place that develop indices of metadata and provide standardized approaches for accessing data. Operational definitions of forest and rangelands are numerous and inconsistent. The general definition of rangeland – a kind of land on which the indigenous vegetation is predominantly graminoids, forbs, and shrubs – is inadequate for technically dividing rangeland from forests, pastures, and deserts on the ground. Perhaps the greatest definitional inconsistency is manifested in how different federal agencies define pinion-juniper and other woodlands. The Forest

Service currently defines woodland as forest land while the BLM and NRCS define woodland as rangeland. Woodlands amount to nearly 60 million acres in the United States and a number of SRR indicators are tied to the rangeland base, so this issue is significant. Earlier, the SRR relied on the Federal Geographic Data Committee (FGDC) to resolve the dilemma of technically defining forests and rangeland. Unfortunately, the FGDC was unable to resolve this dilemma, but the Committee is still optimally positioned to achieve this goal, and their efforts need to be reenergized. The FGDC is a 19-member interagency federal committee whose mission is to develop policies, standards, and procedures for organizations to cooperatively produce and share geographic data.

Another substantial issue facing the implementation of SRR C&I is our understanding of human community and economic conditions. We recognize that some socio-economic indicators might seem to be important variables that should be monitored and reported; however, little scientific evidence is available to correlate such indicators with sustainability.

Perhaps the greatest opportunity now facing SRR is our strategic goal of facilitating an initial report on the sustainability of our Nations' rangelands by 2010. Such a national report will require substantive commitments of funds and personnel from federal agencies; however, SRR provides here a refined set of 27 indicators that could form the basis for feasibly achieving a multi-agency report within this time frame. Producing a national report on the sustainability of rangelands in the U.S. will require a comprehensive joint effort by Forest Service, Bureau of Land Management, Natural Resources Conservation Service, and other federal agencies charged with the stewardship of rangelands, as well as strong Congressional support.

Since the public is also involved in the management and use of rangelands, interested NGOs will also have a place in the process of preparing a national report. Ultimately, a report on the status and trends of U.S. rangelands will be a win-win situation for all participants – helping forge a coordinated and comprehensive set of strategies by public land agencies and providing agencies and organizations responsible for privately owned rangelands with a clearer vision of their future alternatives.

Overview of SRR C&I and Selection Process

The SRR utilized an issue-based framework for identifying criteria, and then organized indicators within them. Such a framework is commonly adopted because it deals with highly visible conditions and situations pertaining to the system being appraised. Participants began by identifying specific issues to frame indicators for sustainable rangeland management. These issues transcended agencies, land ownership, and other artificial boundaries. SRR members subjectively grouped these distinct issues into topical clusters to represent broader rangeland management issues.

After intensive discussions, SRR settled upon five criteria: (1) Conservation and maintenance of soil and water resources on rangelands; (2) conservation and maintenance of plant and animal resources on rangelands; (3) maintenance of productive capacity on rangeland ecosystems; (4) maintenance and enhancement of multiple economic and social benefits to current and future generations; and (5) legal, institutional and economic framework for rangeland conservation and sustainable.

To guide indicator development and standardize the manner in which indicators were described, the SRR devised a six-point indicator evaluation framework:

- What the indicator is; what it measures.
  - Importance of the indicator as a measure of the criterion. This included the indicators' scientific importance,

based upon literature and its robustness to changes in technology.
- o Geographic applicability of the indicator throughout the United States.
- o Spatial/temporal scales of the indicator. Indicators valid at multiple scales can be more useful.
- Data availability:
  - o Methods and data exist to monitor the indicator on all rangelands.
  - o Methods exist to monitor the indicator, but usable data are not available.
  - o Data sets only partially exist and/or methods are not standardized for the indicator.
  - o Although the indicator is conceptually feasible, no methods or data exist to monitor it.
  - o The degree of understanding that stakeholders and the general public have for the indicator.

In general, the process of indicator selection for all five criteria groups was one of reducing a large indicator set proposed by individual participants during the first few meetings. Occasionally, an indicator would be added in response to information appearing in the literature and findings coming from other C&I programs.

Conceptual Model and Determination of Core Indicators

An issues-based monitoring framework, like that used by the SRR to develop its 64 indicators, is popular because it deals with conditions familiar to both stakeholders and the public. However, this approach to developing indicators lacks the structure to assure a comprehensive identification of all important processes associated with rangeland ecosystems and social systems.

In order to validate the 64 indicators, SRR members built a rangelands conceptual model that identifies states and processes associated with biophysical conditions, natural resource capital, social capacity, economic capital, and human conditions. While doing so, we also found the model to be an optimal vehicle for setting priorities for

identifying a set of core indicators. The description of the conceptual model and identification of core indicators are described in the following chapter.

Chapter 2: Conceptual Framework – A Tool for Selecting & Understanding Indicators

Evaluating the validity and application of indicators for assessing sustainability on rangelands is critical to the successful implementation of a comprehensive National program for rangeland Criteria & Indicators. The challenge faced is one not readily addressed: the integration of bio-physical indicators with socio-economic indicators. How do they affect one another? Are assumptions of interrelatedness valid and are the indicator sets developed by the Sustainable Rangelands Roundtable (SRR) consistent with those assumptions? These and other similar questions are the driving force behind the SRR's development of a conceptual framework to evaluate indicators selected for assessing sustainability on the Nation's rangelands.

Development of Criteria & Indicators

Development of criteria and indicators for assessing natural resource systems can follow multiple pathways. Some efforts have centered on the development of a conceptual model or framework that identifies the categories that might be usefully addressed by indicators and shows the relationships among them. Indicators are then selected for the most important categories. Other indicator projects begin by identifying issues or criteria for assessing success. Indicators are then selected for the issues or criteria that are most relevant and important to people.

In the case of the SRR, criteria and indicators were selected first using an issues based approach. Then the Roundtable developed a conceptual framework with which to review the indicators it had selected. This approach was chosen to assure that the suite of indicators developed would adequately address the complexity of a rangeland resource system. The conceptual framework was also intended to provide a basis for understanding how the various conditions and processes affect each other.

Reasons for a Conceptual Framework

An important feature of the conceptual framework is to provide a basis from which an integrated "story" about the sustainability of our rangeland systems can be told using the factual information provided by the data for the selected indicators. It is essential to realize that the SRR Conceptual Framework is not a predictive or mathematical model; instead, it is a framework for evaluating the validity of the SRR indicator set and for explaining what the indicators mean.

In developing its conceptual framework the SRR faced the challenge of depicting how indicators for five quite different criteria can be combined to give an integrated understanding of the rangeland system. To meet this challenge, the SRR drew upon the knowledge of range ecologists, economists and sociologists. Each discipline contributed knowledge of its own system. The resulting conceptual framework shows the relationships among bio-physical and socio-economic indicators at increasing levels of detail.

State/Status Boxes

Figure 1 depicts that basic layout of the SRR conceptual framework. Time (depicted on the left of the framework) is illustrated across "states," T0 representing the starting point of an assessment program, T1 representing the next point in time that the assessment takes place, continuing to Tx. The right side of the framework indicates the purpose of assessment and represents the desire to evaluate progress towards or away from a "sustainable" rangeland system.
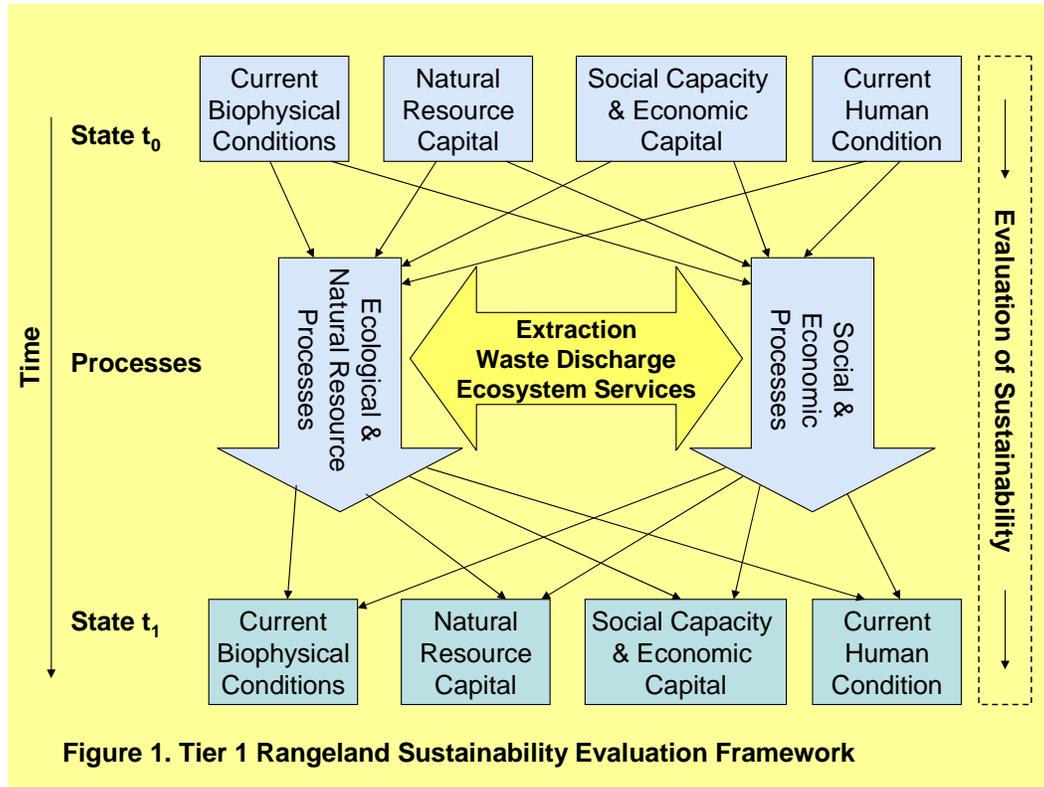
Figure 1. Tier 1 Rangeland Sustainability Evaluation Framework

It is important to keep in mind that "sustainability" is an abstract goal in that it is a moving target influenced by the values of the person or persons view of the system. The ability to classify a system as "sustainable" should not be the goal in using the criteria and indicators; instead, we should use them in a way that will build our understanding of the changes occurring in rangeland conditions and their causes so that we can change management practices as needed to sustain the values and outputs people desire.

Within the body of the framework, there are four "state" or "status" boxes at the top separated between the human and biophysical subsystems of a rangeland. The biophysical subsystem is divided into two states; Current Biophysical Conditions &

Natural Resources Capital. Similarly, the human subsystem is divided into two states; Social Capacity & Economic Capital and Current Human Condition. These will be described below:

Environmental Subsystem

The environmental subsystem, as stated above, is divided into two categories; 1) current biophysical condition and 2) natural resource capital. The current biophysical condition state illustrates the full spectrum of biological and physical characteristics of a particular rangeland system including plants, animals, soil, water, air and rocks. Natural resource capital incorporates the "stock" of resources and the productive capacities within the biophysical environment that

provide the goods and services used within the human subsystem.

Human Subsystem

The social capacity and economic capital state is comprised of the "traditional" economic notion of capital – all assets and liabilities present in the economy. Also included are the concepts of social capital or capacity representing the potential opportunities afforded by the way society exists. Current human condition encompasses the current status of people and society, human well-being including values and norms of current generations.

Biophysical/Socio-Economic Processes Boxes

Between each time period of the framework, SRR recognized that many processes would be taking place in both the environmental and human subsystems. These processes are illustrated with the large arrows flowing through the time step to the following assessment time. Members of the Conceptual Modeling Group (CMG) of the SRR further recognized that these processes do not take place independently and that there are important interactions between environmental and human subsystems, illustrated by the double arrow across the two subsystems. The actions and interactions of the processes between time steps lead to the following states/status of the major categories.

Refining the Conceptual Framework

For the evaluation and testing of validity of indicators, the SRR recognized the need to provide a refinement of the framework incorporating more detail into the processes

component of the framework. Figure 2 illustrates the current status of Tier 2 of the SRR Conceptual Framework.

Within Tier 2, the CMG developed a more detailed view of both the environmental and human subsystem processes. In doing so, we have presented a format for validating the efficacy of and potential integration of multiple processes that would be occurring between time steps. This representation is not intended to be an exhaustive list of all processes occurring; but, instead is to illustrate major processes identified by experts within each of the subsystems.

Also represented in Tier 2 of the framework is an attempt to depict the points where an interaction between environmental and human subsystems occurs. The green process boxes including ecosystem services, extraction, waste discharge and use of ecosystem services provide a mechanism for understanding how the two subsystems interact and a means to illustrate the abilities of one subsystem to influence the processes of the other subsystem.

Illustrating the Concept of Changes from One Time Period to the Next

Reality dictates that constant, real-time assessment of rangeland systems is not practical. It is understood that the assessment of indicators and subsequent development of a National Report on Rangelands would take place within a set time frame (ex. every 10 years). This has been represented by the treatment of changes over time within the conceptual framework. Figure 3 illustrates this and defines what types of assessments might be made over a series of time steps using the indicators provided by the SRR.
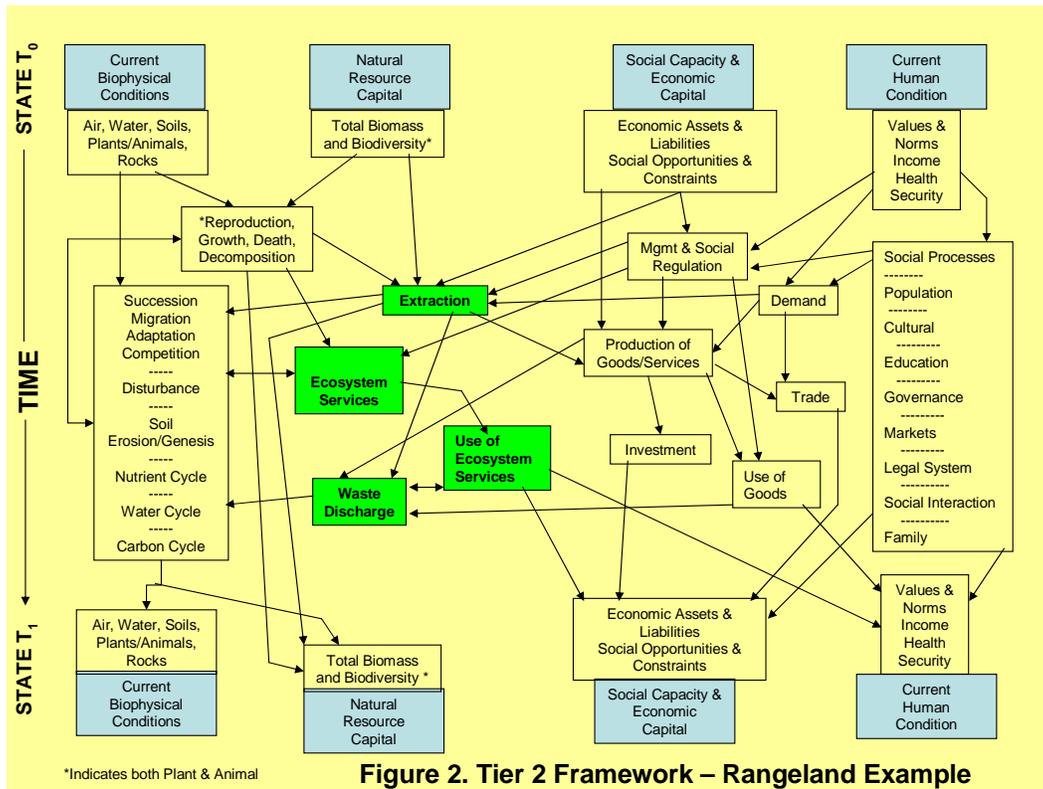
Figure 2. Tier 2 Framework – Rangeland Example

*Indicates both Plant & Animal

Over time, the use of the proposed approach within the conceptual framework provided would result in a development of trends associated with individual indicators. Ultimately, by evaluation of suites of indicators depending on issues of interest, land managers and interested parties would be able to make determinations of the direction of the rangeland systems towards or away from "sustainable" systems.

Conclusions

The SRR is "testing" its set of indicators by identifying elements of the framework to which each indicator applies. SRR is also using the framework to develop stories regarding specific issues associated with

rangelands such as the spread of an invasive species and impacts of fire and drought. To this point, the members of the CMG feel that we have a relevant set of indicators that are meeting the assumptions first identified in the development of criteria for assessing sustainability on rangelands. In essence, at this time, we feel that we have a "good" set of indicators.

CMG members are continuing to refine Tier 2 of the model and test various rangeland "issues" within the model. Next steps include the development of a Tier 3 model that will further the ability to examine how indicators are functioning and how they integrate across the environmental and human subsystems.
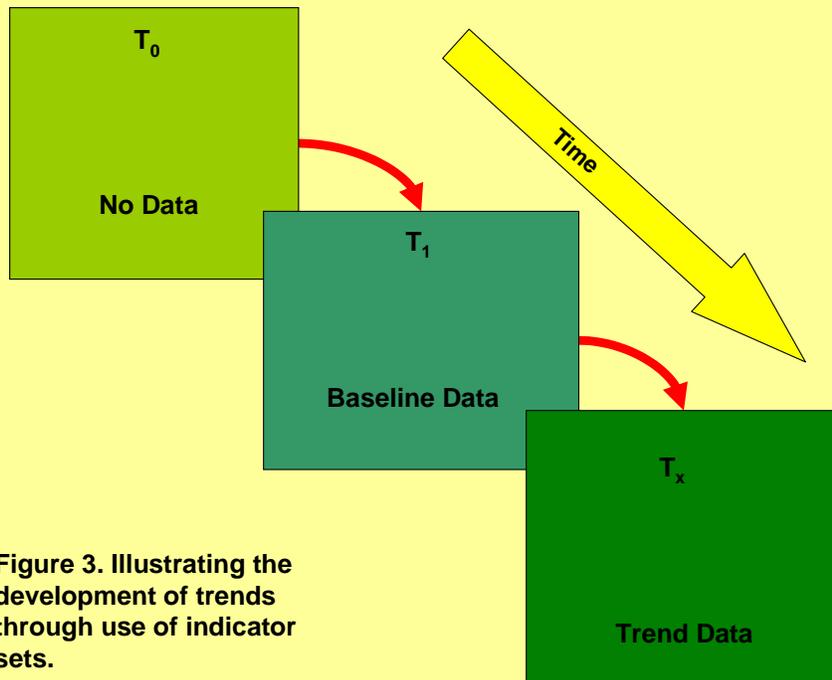
Figure 3. Illustrating the development of trends through use of indicator sets.

Chapter 3: Data and Example Trend Analyses

Indicators provide measures of processes and change in state of systems. Sustainable management is a broad goal of a country's integrated ecological, economic, and social systems, but the mechanisms that drive these systems are often manifested at a finer scale. In this chapter we will summarize data availability for all 64 SRR indicators, and then evaluate the sources, availability, and utility of data sets identified by the Sustainable Rangelands Roundtable (SRR) for their 27 core indicators of rangeland sustainable management.

In order to describe the status of data for various indicators, the SRR adopted a six-point evaluation framework that included an index of data availability (table 1). Many of the indicators, particularly those of a biophysical nature, can be measured in a number of ways. Indicators are comprised of variables that can be measured at various scales (nominal, ordinal, interval, ratio), but the expression of indicators does not necessarily imply a measurement method, a specific scale, or a reference value. Some workers classify specific measures as the next lower level below criteria and indicators. In this report, indicators can have more than one measure if data sets or monitoring protocols are available.

After devising the six-point evaluation framework, the Roundtable developed a data matrix to organize added detail about known data sets that applied to the indicators (table 2). Each indicator had its own matrix, and information on each data set was contained in a column.

Review of the 64 Indicators

A summary of data availability, as indexed using the four categories shown in table 1, is presented in table 3. Four of the 10 indicators associated with the conservation of soil and water resources were deemed to have data sets of usable quality at the regional or national levels, all of them associated with water measures. Clearly, our country needs better soils data to appraise how this criterion is trending over the long term, including measures of bare ground and accelerated erosion. Three out of the 10 indicators associated with the conservation and maintenance of plant and animal resources fell into data category A. Two of them are populated with remotely sensed data. Two productive capacity indicators can be measured today using remote sensing technology – aboveground phytomass (standing crop of plant biomass plus standing dead plant material) and net annual primary productivity.

Criterion 4, maintenance and enhancement of multiple economic and social benefits to current and future generations, contains 28 indicators. The good news is that about one-half of them can be populated with data at a national scale, primarily because of data being collected by agencies such as the Census Bureau, National Agricultural Statistics Service, Bureau of Economic Analysis, Bureau of Labor Statistics, and the Federal Reserve Board. The bad news is some of indicators recognized to be most relevant to sustainable management, like value of investments in rangeland infrastructures and return on investment for rangeland livestock enterprises, do not have data sets supporting them.

The criterion on the legal, institutional, and economic framework for rangeland conservation and sustainable management has only 10 indicators; however, the indicators are broadly defined and each can be measured in a number of different ways. None of these indicators can presently be reported upon using existing data sources. Most will require developing indices that integrate measures from multiple data and information sources. Such indices are difficult to interpret; moreover, it can be difficult to achieve agreement across different stakeholder groups over how

different measures can be amalgamated. Monitoring trends in laws, regulations, public participation in agency planning, and the activities of educational, research, and extension institutions was judged to be plausible by those developing these indicators.

Review of Core Indicators

The 27 core indicators have the capacity for providing a reasonably good description of the condition and use of rangelands in the United States if they can all be monitored and assessed. As can be seen in table 3, only four out of 13 ecological indicators and six out of 14 socio-economic indicators have regional or national-level data sets based upon broadly accepted methodologies. On the other hand, only one and four indicators, respectively, have no accepted methodologies and no data at regional or national levels.

On the following pages, each of the core indicators are individually described and evaluated in a two-part format parallel to that employed in the National Report on Sustainable Forests <http://www.fs.fed.us/research/sustain/> and the Heinz Center report on The State of the Nation's Ecosystems <http://www.heinzctr.org/ecosystems/>: (1) What is the indicator and why is it important? (2) What are the data and what do they show? We will also highlight the availability of data for each core indicator using a color-coded symbol, as shown below.

🟩	Regional or national-level data sets exist using standardized methods of data collection.
🟦	Standardized methods exist, but usable data sets are not available at the regional or national level.
🟧	Some regional or national data exist, but methods or procedures are not standardized.
🟥	Regional or national data do not exist, and methods and procedures are not standardized or available.

Criterion 1: Conservation and maintenance of soil and water resources on rangelands

🟥	Area and percent of rangeland with significantly diminished soil organic matter and/or high Carbon:Nitrogen (C:N) ratio

What is the indicator and why is it important?

This indicator measures the soil organic carbon (SOC) content of the soil and the carbon :nitrogen (C:N) ratio of the soil organic matter (SOM). The C:N ratio is a relative measure of SOM's potential for biological decomposition. Soil organic matter provides many benefits to the soil and is associated with the productive potential of soils and soil sustainability.

What are the data and what do they show?

Methods of assessing SOM and C:N ratios are available and are adaptable to the regional and national level. Soil organic matter is generally reported as SOC, rather than vice-versa. The laboratory methodologies available for measuring SOC are economical, repeatable, and accurate, but no in situ field methodology presently exists for estimating it. USDA-NRCS collected SOM data nationally, but only on non-federal lands, between 1982 and 1992. USDA-ARS has recently initiated a national research program called GRACEnet (Greenhouse Gas Reduction through Agricultural Carbon Enhancement Network) to assess the effects of management on SOC stocks on croplands, rangelands, and forestlands. Sampling protocols are being developed for soil carbon assessment and data presentation through GRACEnet.

C:N ratio data are not as prevalent as organic carbon data because simultaneous nitrogen data were not always collected in earlier studies. In general, rangeland SOC and nitrogen data are limited in comparison data for croplands.

	Area and percent of rangeland with a significant change in the extent of bare ground.

What is the indicator and why is it important?

Bare ground is exposed mineral soil that is susceptible to water and wind erosion. The extent and homogeneity of bare ground directly relate to susceptibility to accelerated erosion. The distribution of bare ground is important; bare ground occurring in numerous small patches is less susceptible to soil movement than in a few large patches. The importance of bare ground as an indicator is also a function of its known value as an indicator of changes in land management and watershed function. Bare ground is a meaningful indicator in all different regions when compared by site over time so that the natural range of variation is established

What are the data and what do they show?

Some data sets exist at the regional to national level, but methods and procedures are not standardized. Data sets exist as ground data collected with various field methods and remotely sensed data. Bare ground is included in vegetation analyses for many agencies and NGO's, but these data lack adequate sampling designs for regional to national aggregation. Remote sensing data sets having an image resolution that potentially allows an accurate measure of bare ground are largely limited to research efforts. Theoretically, bare ground can be measured using existing remote sensing data bases but measurement inaccuracies are likely. Research is addressing these limitations. Recently, researchers have been experimenting with hyperspectral data, which can show discrete absorption features that can represent bare ground. The dilemma has been in choosing where to error. If larger sized pixels are used in remote sensing, greater extensive information about broad geographic areas is obtained, but information about specific details needed to assess erosion is inaccurate and can be misleading.

	Area and percent of rangeland with accelerated soil erosion by water and wind.			Percent of water bodies in rangeland areas with significant changes in natural biotic assemblage composition.

What is the indicator and why is it important?

Soil erosion by wind or water begins with the loss of all or part of the surface horizon, the soil layer containing the highest organic matter and nutrient content, thus controlling infiltration, plant establishment, and growth. Excessive erosion contributes sediments to waterways, thereby reducing water quality. Accelerated erosion has arguably been the primary cause of declines in human civilizations over the millennia. This indicator identifies areas where wind or water erosion is greater than expected, not areas with high natural erosion rates. Soil erosion varies from soil to soil and from plant community to plant community, but is important in any region.

What are the data and what do they show?

Standardized methods and procedures for data collection and reporting of soil erosion have been advanced for use at the regional/national levels; however, useable data sets do not exist at these scales. The Universal Soil Loss Equation (USLE), Revised USLE (RUSLE), RUSLE2 and Water Erosion Prediction Project (WEPP) have been or are being evaluated for rangeland use, but these models estimate erodibility, not actual erosion. NRCS soil survey data potentially can provide a national level soil erosion data set on rangelands. Erosion estimates were collected on non-federal rangeland as part of the USDA-NRCS NRI between 19982 and 1992.

What is the indicator and why is it important?

The health and status of aquatic biota can be used as a broad-scale indicator of watershed health and rangeland sustainability. Downward trends in rangeland health, if other attributes besides vegetation are considered, can be associated with declines in water quality, aquatic and riparian habitats, and the ability of aquatic habitats to support native biota. These changes in species composition can affect several measures of aquatic system balance, such as predator-prey dynamics, nutrient cycling, and exotic species invasions. Species that are sensitive to a particular pollutant or habitat change will decline disappear completely, whereas other species might benefit from these habitat changes and their populations will increase. This indicator measures how well aquatic invertebrate assemblages collected within managed watersheds compare to assemblages that would be expected to occur under natural conditions. The importance of this indicator lies in its relation to overall watershed conditions and natural biological diversity.

What are the data and what do they show?

Standardized methods and procedures for data collecting and reporting for aquatic macroinvertebrate assemblages exist at the regional to national level, and useable data set(s) exist at the local and regional levels.

Example: The data presented below are from the PACFISH-INFISH Effectiveness Monitoring Program that is conducted on federally managed lands within the interior Columbia River Basin. All data were collected between 2000 and 2003. A multi-metric model of biotic integrity was developed based on data collected at 96 reference sites. The model was then applied to data collected at 709 sites. This model

indicated that 84% of the streams sampled had aquatic invertebrate assemblages that were similar to that expected to occur in reference quality streams (green dots) and would be considered to be meeting expectations for biological integrity (Figure 1). Sixteen percent of the streams sampled had aquatic invertebrate assemblages that showed significant departure from that which would be expected to occur in the absence of management actions (red dots). These streams could be considered to be impaired and not meeting objectives for maintaining biological integrity.

Why the Entire Indicator Can't Be Reported at This Time? The available data and current model development do not permit a national analysis or west-wide analysis of changes in natural aquatic invertebrate assemblages. There is currently a lack of data from both reference quality and managed waters for much of the country. Additional data modeling is also required to develop the biological conditions that would be expected to occur under natural conditions for much of the area where samples are currently available. Figure 2 shows the location of aquatic invertebrate samples that have been collected in the western United States and that could potentially be used in an expanded analysis with further model development.

As seen on the left, USDI-BLM, in cooperation with Utah State University, maintains an aquatic invertebrate database of 20,000 samples collected at more than 7,000 sites. EPA also has a national water quality database, STORET, that may be publicly accessed. Data are available for the most part since 1992.


Figure 1. Results of a multi-metric model to assess the biological integrity of aquatic invertebrate assemblages. Green dots indicate sites that were considered unimpaired and red dots indicate sites that showed signs of biological impairment.

Reference:

Kershner, J.L., M. Coles-Ricthie, E.Cowley, R.C. Henderson, K. Kratz, C. Quimby, D.M. Turner, L.C. Ulmer, and M.R. Vinson. 2004. Guide to effective monitoring of aquatic and riparian resources. General Technical Report, RMRS-GTR-121, USDA, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Available at: <http://www.fs.fed.us/biology/resources/pubs/feu/rmrs_gtr_121.pdf>

The data reported on were collected by the Pacfish Infish Biological Opinion (PIBO) Effectiveness monitoring effort
http://www.fs.fed.us/biology/fishecology/emp/

	Percent of surface water on rangeland areas with significant deterioration of their chemical, physical, and biological properties from acceptable levels.

What is the indicator and why is it important?

This indicator measures the percent of surface water with impaired water quality. Under the Clean Water Act, states and authorized tribes develop water quality standards, based on different criteria, for their individual stream and river segments, as well as lakes and reservoirs. A water quality criterion is an ambient concentration of an important parameter (e.g., dissolved oxygen, pH, or temperature) that ensures that the designated use or uses for a given water segment are not impaired. Leading causes of water quality impairment of our nation's waters are excess nutrients (nitrogen and phosphorus), sediment/siltation, pathogens, and metals.

What are the data and what do they show?

Under Section 305(b) of the Clean Water Act, federal agencies, states, and tribes are to monitor their waters for water quality and report that information into EPA's national water quality database—STORET. Also required is a biennial Section 303(d) list of impaired waters (US EPA 2003). These impaired waters are required to develop a TMDL (total maximum daily load), the amount of a pollutant that a water body can receive and still meet water quality standards. This is probably the best information we have on impaired water quality, and initially should be the data sources for this water quality indicator.

Another potentially useful data source is the USGS National Water Quality Assessment (NAWQA) program. It covers 42 large hydrologic systems representing about 60% of the nation's waters used for drinking and irrigation, and includes a broad list of physical, chemical, and biological measures.

However, NAWQA data coverage on rangelands is limited, because at least half of the 40% non-coverage area is rangeland.

Changes in the frequency and duration of surface no-flow periods in rangeland streams.

What is the indicator and why is it important?

This indicator annually measures: 1) the percentage of rangeland streams with at least one day of zero flow in a year; and 2) for stream gauging stations showing at least one day of zero flow, the duration of zero flow events compared with a long-term average. Together, these two variables describe the frequency and duration of surface no-flow periods. There are several reasons for why streamflow is critical, including groundwater recharge, retention of streambank-stabilizing vegetation, maintaining fish habitats, and providing water for human uses.

What are the data and what do they show?

Methods and procedures for data collecting and reporting and data sets of useable quality exist at the regional to national level. They are maintained by USGS and are available at <http://nwis.waterdata.usgs.gov/usa/nwis/discharge>.

Streams That Have Zero-Flow Periods

Legend: All Areas; California/Mediterranean; Desert/Shrub; Grassland/Steppe

Data Source: U.S. Geological Survey; analysis by Colorado State University. Coverage: grassland/shrubland regions (see map on p. 160) in lower 48 states.

Duration of Zero-Flow Periods (Compared to 50-Year Average)

Legend: Substantially Shorter; Substantially Longer

Data Source: U.S. Geological Survey; analysis by Colorado State University. Coverage: grassland/shrubland regions (see map on p. 160) in lower 48 states.

Note: zero-flow periods are "substantially longer" than the long-term average if they are at least twice as long as the average and "substantially shorter" if they are 50% or less of the average.

Figures on left are from The State of the Nation's Ecosystems, published in 2002 by The H. John Heinz Center for Science, Economics and the Environment and Cambridge University Press, using the USGS stream gauge network referred to above.
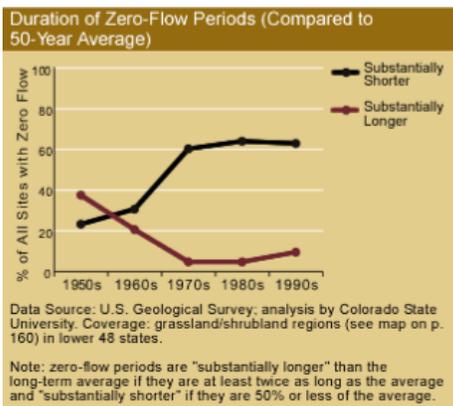
Criterion 2: Conservation and maintenance of plant and animal resources on rangelands

▢	Rangeland area by vegetation community.

What is the indicator and why is it important?

This indicator describes rangeland plant communities and their abundance at any given time. It has a classification component—how we name and describe the plant community—and an inventory component— what area they cover. Numerous strategies for classifying vegetation have been developed over the last century. The National Vegetation Classification System <http://biology.usgs.gov/npsveg/nvcs.html>, a hierarchal classification system for existing vegetation serves as a first approximation of a federal government standard for classifying terrestrial vegetation for the nation. A goal of SRR is to facilitate the adoption of standardized assessment and monitoring technologies by all rangeland resource agencies/users so as to enhance interpretation of said data regardless of land ownership. To accomplish this goal and to enhance the utility of this indicator, a nationally consistent definition of rangelands is needed as well as accepted definitions and descriptions of associated rangeland communities.

What are the data and what do they show?

Standardized methods and procedures for data collecting and reporting exist at the regional-national level, but useable data sets do not exist at this level. Some data sets exist at the regional-national level, but methods and procedures are not standardized. This is because: 1) information on the area of rangeland vegetation at the national scale is limited; 2) definitions and classification and mapping approaches vary among federal agencies, non-governmental organizations, and vegetation scientists; and 3) no national soils inventory exists.

▢	Fragmentation of rangeland and rangeland vegetation communities.

What is the indicator and why is it important?

This indicator is defined as the breaking up of a rangeland cover type across a landscape into patches. Landscapes are characteristically a mosaic of heterogeneous. A patch or cover type has both regional and national spatial extents, delineated both by total rangeland area and by rangeland plant communities (Area of Rangeland by Plant Community). Fragmentation measures the size of contiguous areas, spatial organization, and community type dispersion within the ecosystem, which are important rangeland descriptors, in terms of grazing use, habitat and niche, and ecosystem services.

Recent research has described fragmentation as an interruptive process affecting the sustainability of rangeland ecosystems. Fragmentation of community types is particularly critical for wildlife and some plant populations; sufficient habitat and niche size is required to sustain breeding, rearing, feeding, and shelter needs. Specific agents of fragmentation, such as intensive land uses, roads, and concentrations of exotic species, may affect the overall impact this process has upon rangeland ecosystem function.

What are the data and what do they show?

Some data sets exist at the regional-national level, but methods and procedures are not standardized at this scale. Data sources include federal agency repositories such as USGS (satellite imagery, digital elevation models, GAP analysis map data layers of land ownership, vegetation, and species distribution, the NLCD), USEPA, USDA, and the Census Bureau. A large suite of metrics have been developed that measure fragmentation.

🟧	Extent and condition of riparian systems.

🟦	Population status and geographic range of rangeland-dependent species.

What is the indicator and why is it important?

This indicator will measure the status of riparian systems on a linear basis measured in kilometers for 1st to 6th order streams within U.S. rangeland regions. Condition may be evaluated on a quantitative basis using a numeric value or it may be an ordinal descriptor with classes such as "fair condition." No quantitative indicator has yet been developed, although several riparian researcher teams are working on such an approach that should be ecologically based and include geomorphic, hydrologic, and biotic parameters.

Riparian ecosystems respond to changes in associated, upstream watersheds, but are very resilient and can recover readily if perturbations are removed. They function as buffers between the upland and stream, helping maintain water quality. Riparian areas are used as habitat by a wide variety of animals and are known for supporting high biodiversity.

What are the data and what do they show?

Some data sets exist at the regional-national level, but methods and procedures are not standardized at this scale. Several protocols exist that may be used on a local basis (e.g., a hydrogeomorphic index developed by Army Corps of Engineers), and some are generally used by several resource management agencies, e.g., Proper Functioning Condition (PFC) <http://www.or.blm.gov/nrst/Tech_Reference s/tech_references.htm>. The subjective nature of ordinal data, such as PFC categories, could result in inconsistencies when aggregated and implemented at regional or national levels.

What is the indicator and why is it important?

This indicator measures the population levels (abundance) and the geographic ranges of rangeland-dependent plant and animal species, monitored across their known range. One cannot generally use information about one species to reliably infer traits about another species; so single species are not always useful as representatives of other species or communities. However, it is not possible to monitor the population levels and ranges of all species of animals, plants, and microorganisms, so some species must be selected for monitoring. If the selected species include keystone species and those that are sensitive to particular threats, such as overgrazing, irreversible soil erosion, or fire, and if the species are diverse with respect to their taxonomy, habitats, and life strategies, the indicator will have a higher likelihood of detecting trends in range ecosystems.

What are the data and what do they show?

Data are available for a wide variety of vertebrate and vascular plant species that could be selected as representative species. The data are primarily in the form of either local focused research or as regular counts of species abundance, such as the USGS Breeding Bird Survey, the Christmas Bird Count of the Audubon Society <http://www.audubon.org/bird/cbc/bb.html>, North American Waterfowl Breeding Survey <http://www.mp2-pwrc.usgs.gov/bbs. Less is known about other groups, including invertebrates, reptiles, small mammals, bryophytes, fungi, algae, and bacteria. Lichens are well known to respond to air pollution, and extensive research on their uses as indicators is available.

	Area of infestation and presence/absence of invasive and non-native plant species of concern.

What is the indicator and why is it important?

The proposed indicator is designed to track the area of infestation and presence/absence of invasive or non-native species on rangelands over time, thus providing information for developing strategies to address resultant problems. Invasive species are defined in Executive Order 13112 <http://www.invasivespecies.gov> as an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health. Species of concern can include natives that are overly dominant to the extent they can impact normal ecosystem processes, species that are poisonous to livestock, etc.

Invasive species, typically, have high growth rates and reproductive potential with dispersal mechanisms that allow them to move readily across a landscape. As the extent of these invasions expand across the landscape, changes within functions and/or processes may result in an irreversible decline in the overall productivity of the rangeland system.

**What are the data and what do they show?**

Some data sets exist at the regional-national level, but methods and procedures are not standardized at this scale. There are presently a multitude of invasive species data systems; however, most of these only represent a listing of the species with some kind of distribution information at various scales. The proposed metric would require an effort be put forward to develop a national framework of data collection (for example, FIA and NRI) or at least national data standards and consistent species in databases that could be aggregated across scale. A multi-agency task force is now developing a scale-sensitive standardized monitoring system that is planned for implementation within the next five years.

Data Gaps and Related Issues

At this time, there are no centralized databases that provide extensive information for all invasive species throughout the United States. Many individual states or regional collaborations collect data and maintain databases on specific species, especially plants (see the illustrations). Databases are maintained by organizations such as NRCS (National Resource Conservation Service), NatureServe, HEAR (Hawaii Ecosystems at Risk). International efforts are supported by organizations such as GISP (Global Invasive Species Program), IUCN, IABIN and NABIN. Efforts at making the existing databases interoperable have led to limited success. However, efforts being led by FICMNEW, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, (comprising agencies from within USDA, USDOI, USDOT, USDOD, USDOE, USEPA) are working towards the development of more thorough and centrally located data that would be a significant source of information in the application of the indicator. NISC (National Invasive Species Council) maintains the invasivespecies.gov website that serves as a centralized location for information on invasive species. Further actions should be made to expedite the development of a national database for invasive species.

Example: The following provides an illustration using two species; however, ultimately, the indicator will be based upon available datasets providing information for all species classified as invasive.
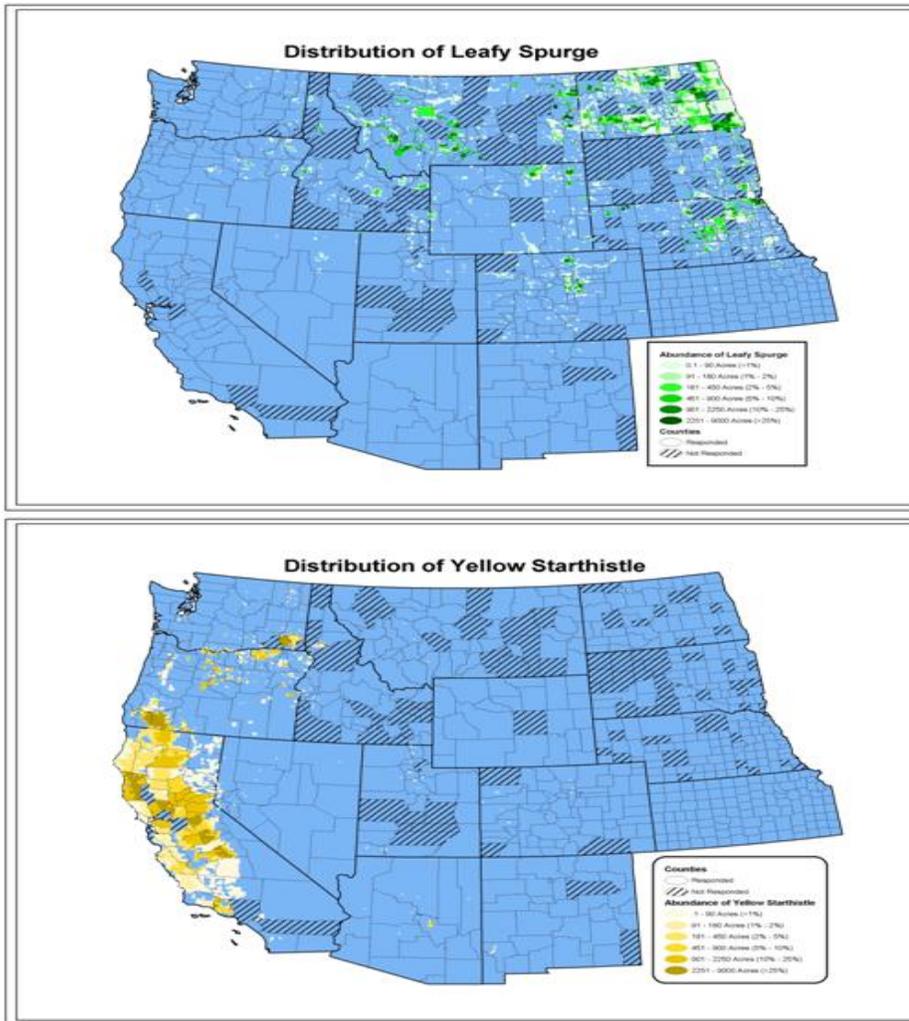
Maps Depicting the Distribution and Abundance of Leafy Spurge (Euphorbia esula) and Yellow Starthistle (Centaurea solstitialis) in the Western United States.
Eric Lane - Project Leader: Western Weed Coordinating Committee - organization running the project, Lakewood CO

Criterion 3: Maintenance of Productive Capacity on Rangeland Ecosystems

|	
🟩	Rangeland aboveground phytomass.

What is the indicator and why is it important?

Phytomass is the mass of plants, including dead attached parts, per unit area at a given time. Phytomass is commonly measured in units of pounds per acre or kilograms per hectare on a dry weight basis. It is a direct measure of biomass production available to potential grazers and users of rangelands, to product the soil surface, and to serve as a fuel source for fire. These data provide a valuable tie to past management actions, giving trends in biomass production through space and time. In addition, phytomass can be used to estimate residual forage supplies in regions where browsing or grazing by livestock or wildlife is not in equilibrium with NPP.

What are the data and what do they show?

Aboveground phytomass data is collected both directly and indirectly. Direct methods require destructive sampling of aboveground biomass through clipping and weighing plant material. Indirect methods involve weight-estimate procedures, where mass per unit area is estimated visually or in some other manner, such as correlating it with canopy cover. Indirect methods involving remote sensing show great promise. Analysis of data (LAI, EVI, NDVI) from the MODIS (Moderate Resolution Imaging Spectrometer) on the Terra satellite has been demonstrated to accurately predict of above-ground biomass at different scales.

NDVI data from MODIS, 2001 and 2003: Running, S., Nemani, R., Heinsch, F., Zhao, M., Reeves, M.C. and Hashimoto, H. (2004) A Continuous Satellite-Derived Measure of Global Terrestrial Primary Production. BioScience 54:547-560.
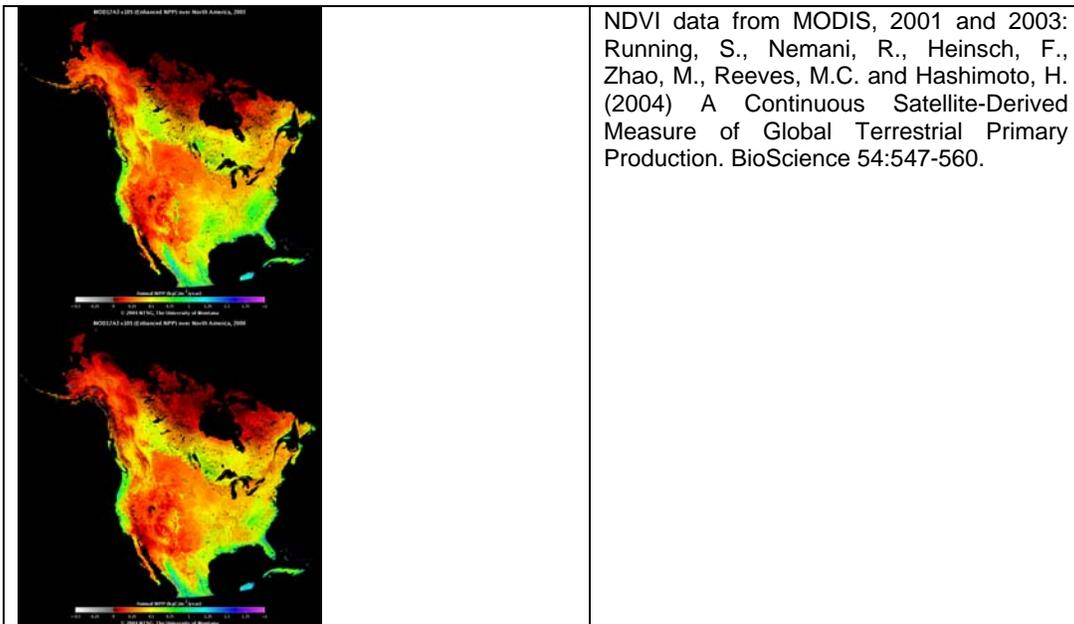
	Number of domestic livestock on rangeland.

What is the indicator and why is it important?

The number of livestock on rangeland is the quantity of livestock (cattle, sheep, horses, and goats) that spend part or all of the year on rangeland. It is an index of secondary productive capacity by a major category of primary consumer. Livestock do not spend their entire life on rangeland, so an inventory at any one time will underestimate their extent of rangeland use.

What are the data and what do they show?

The number of cattle may be determined at a scale necessary for regional and national assessments. We recommend that appropriate questions be incorporated into surveys used by USDA National Agricultural Statistics Service for developing these estimates. Presently, a direct estimate of the number of cattle (or sheep) that spend a part of the year on rangelands is not determined. Indirect estimates (total number of cattle less cattle on feed) require unacceptable assumptions concerning inadequate and incompatible data sets.

This indicator will be most useful with both cattle and sheep numbers on rangeland. It will be necessary to work closely with USDA NASS to acquire the requisite data for both.
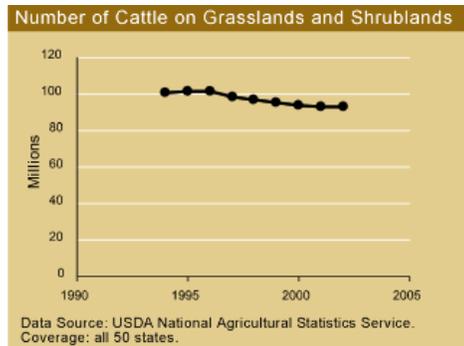

Figure on left is from The State of the Nation's Ecosystems, updated in 2003 by The H. John Heinz Center for Science, Economics and the Environment, http://www.heinzctr.org/ecosystems/grass/cattle.shtml.

Criterion 4: Maintenance and Enhancement of Multiple Economic and Social Benefits to Current and Future Generations

Value of forage harvested from rangeland by livestock.

What is the indicator and why is it important?

Livestock grazing is the historical economic use of rangelands and continues to be an important use on both public and private lands. Changes in the value of forage used by grazing animals can indicate change in rangeland sustainability because they suggest increased (or decreased) pressure to harvest vegetation as forage to the exclusion or detriment of other uses or values.

What are the data and what do they show?

The USDA National Agricultural Statistics Service (NASS) collects data on private non-irrigated grazing fee rates for the western states. The rates are published annually in the Agricultural Prices Report. These are rangeland leases used in the public land grazing fee formula. They are an indication of how the value of forage changes through time as reflected in the marketplace.

Private land grazing fees showing nominal fees and those adjusted for inflation using the index for prices paid for feed from the NASS report (1990-1992=100).

	Rate of return on investment for range livestock enterprises.

What is the indicator and why is it important?

This indicator shows trends in whether ranch families are making a competitive rate of return from producing livestock on rangelands. If the rate of return on rangeland-based livestock operations is not competitive, it might indicate that other (on-ranch) forms of economic returns and/or lifestyle values are important, other (off-ranch) sources of income are important, or that the ranch is likely to be converted to other uses.

What are the data and what do they show?

Data from the USDA National Agricultural Statistics Service, Agricultural Resource Management Survey (ARMS) include rates of return for all cattle ranches in the U.S. While this includes non-range livestock enterprises, the data do give an indication of how the cattle sector is performing as a whole. At this point, data are not reported for cattle operations in different regions of the country or for more specific types of cattle operations. It does appear that the data are available to make some estimates by region, but it would require data manipulation for that express purpose.
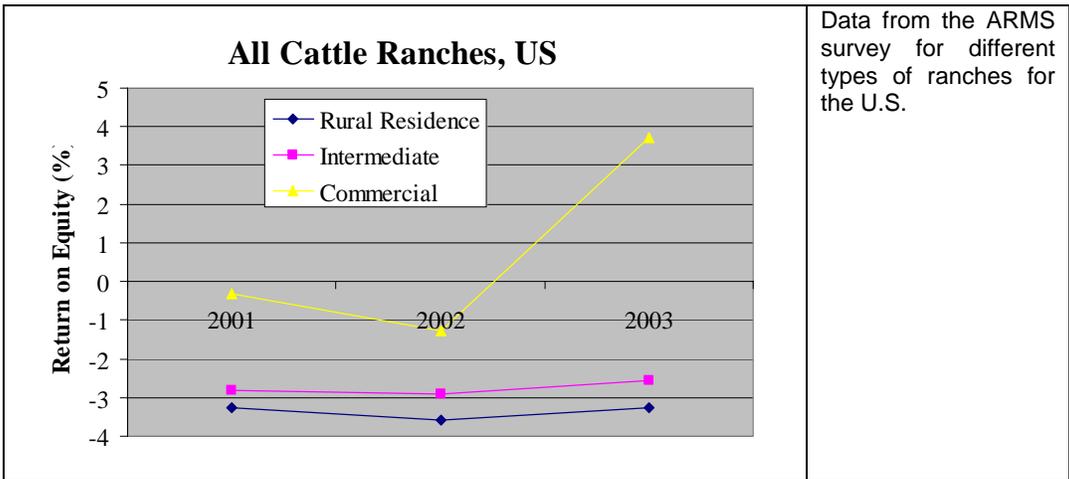
All Cattle Ranches, US Return on Equity (%) Rural Residence Intermediate Commercial 2001 2002 2003	Data from the ARMS survey for different types of ranches for the U.S.

	Area of rangelands under conservation ownership or control by conservation organizations.

What is the indicator and why is it important?

This indicator measures the number of acres protected under conservation easement. The indicator is a measure of the presence and trend of open-space or other undeveloped or minimally developed land areas for purposes of promoting conservation and biodiversity. It is an amenity availability measure and speaks to the desirability, adaptability, and resilience of communities, and the community perception of the importance/value of that land use or asset to some extent.

What are the data and what do they show?

No comprehensive data bases exist that account for all lands under various categories of legal protection by conservation easement or similar instruments. Individual conservation organizations, as well as associations promoting land trusts and conservation easements, keep track of data. The Land Trust Alliance <http://www.lta.org> conducted a "census" of non-profit groups in 2003 and found a 100% increase in area of land trusts during the preceding 5 years.

| Local, State and Regional Land Trusts Total Acres Conserved by Region, 2003		
Region	Acres Conserved	% Increase '98 to '03
Northeast	2,982,513	60%
Pacific	1,521,007	147%
Mid-Atlantic	1,419,539	91%
Southwest	1,412,689	116%
Northwest	933,528	109%
Southeast	648,895	123%
Midwest	416,428	92%
Total	9,361,001	100%

🟧	Index of social structure quality.

What is the indicator and why is it important?

Extensive data on social and economic conditions exist at the county level. Social science literature often addresses the multidimensionality of concepts that are being measured using indexes–the merging of multiple indicators to create a single broad-based measure. The index, once developed, will provide a summary of the social structure quality by county across the nation.

What are the data and what do they show?

While indices of this type are frequently constructed to rate quality of life in different places, there is little basis in social theory for most such indexes. Given that decisions about specific variables to include, units of measure, and weighting can strongly influence the values and sensitivity of such an index, we believe use of this indicator should come only after considerable research and model testing. Such an index was developed for forest-dependent communities that combined population, employment diversity, and economic resiliency.

	Example from Haynes, R.W. 2003. Assessing the viability and adaptability of forest-dependent communities in the United States. Gen. Tech. Rep. PNW-GTR-567. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.
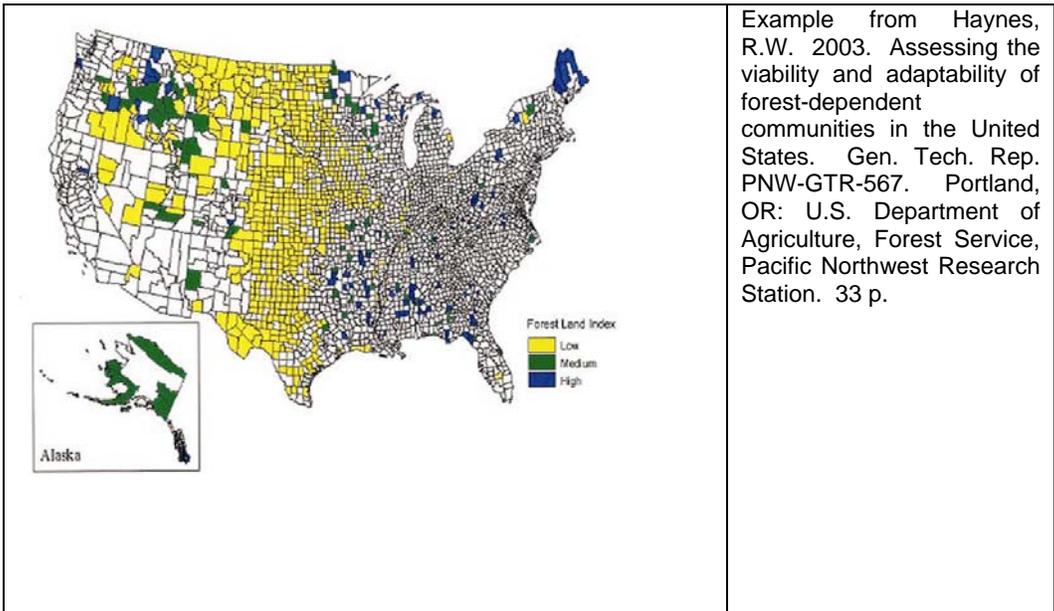
Sources of income and level of dependence on livestock production for household income.

What is the indicator and why is it important?

This indicator measures the degree of dependence of ranch families on livestock production for household income. Recent surveys have shown few ranchers rely totally on the ranch for family income. Measuring how the livestock part of disposable income varies and the percentage of ranchers highly dependent on livestock for income may both be useful measures. Higher dependence on the ranch for income may relate to the level of grazing during drought and the ability (or inclination) to follow sustainable grazing practices. As income dependence increases, ecological indicators of rangeland sustainable management may thus be affected.

What are the data and what do they show?

The USDA Economic Research Service administers the Agricultural Resource Management Survey (ARMS). Within this data set are estimates of farm and off-farm income for cattle producers on a national (1996-2003) and selected state (2003) basis. Because the data are for all beef cattle producers, it is unknown what this would look like for just those producers that use rangelands. We may be able to glean additional information from the regional estimates that are available.
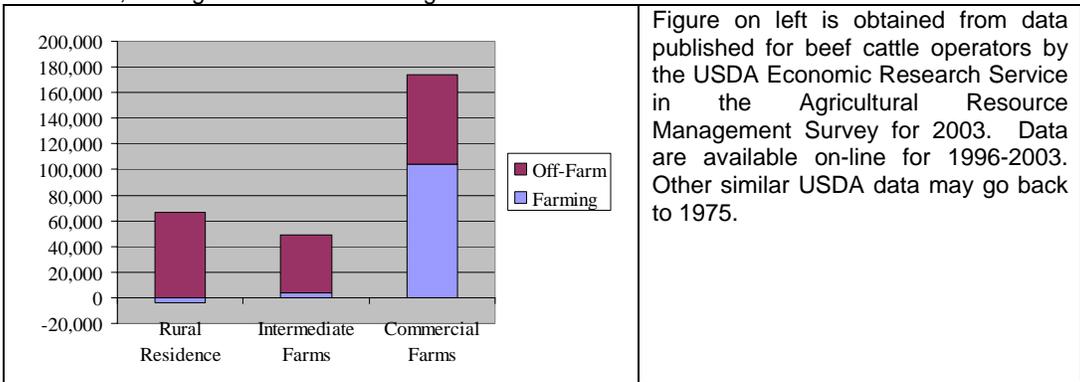

Figure on left is obtained from data published for beef cattle operators by the USDA Economic Research Service in the Agricultural Resource Management Survey for 2003. Data are available on-line for 1996-2003. Other similar USDA data may go back to 1975.

	Employment diversity.

What is the indicator and why is it important?

An economic diversity index can be developed related to the industries/sectors present in an economy. If economic diversity is defined as "a large number of different types of industries being present in an area" or "the extent to which the economic activity of a region is distributed among a number of industrial sectors," a summary statistic can be used to describe the diversity of an area and compare it to other areas. The Shannon-Weaver index measures diversity of employment (or other economic activity in a region) against a uniform distribution where employment is equi-proportional across all industries. We hypothesize that economic diversity is related to economic resiliency and the ability of an economy to respond to and adapt to changes in conditions.

What are the data and what do they show?

Actual measures need to be calculated to provide full and consistent coverage of this indicator, but background data needed to calculate an index are available at the county level from the Bureau of Labor Statistics. The Shannon-Weaver index can be calculated for all counties; however, knowing which counties are rangeland counties has not been determined.
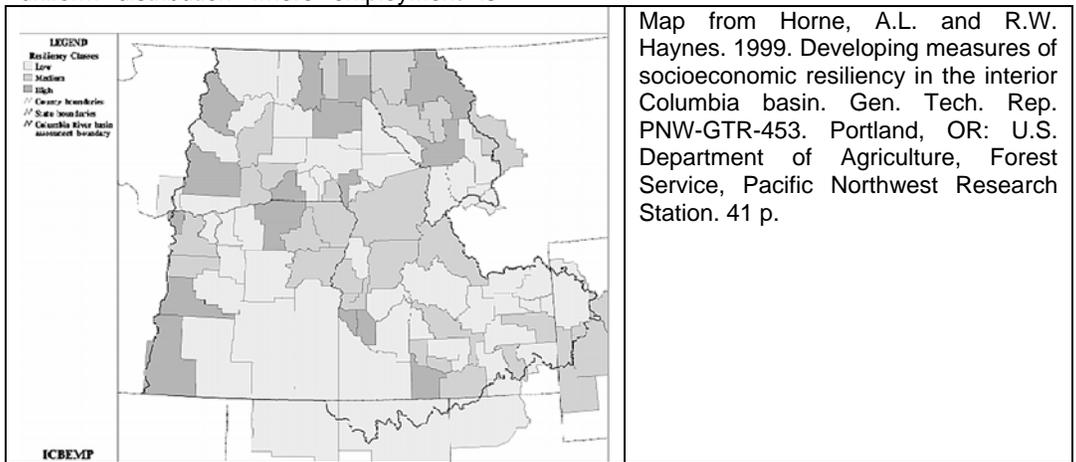
Map from Horne, A.L. and R.W. Haynes. 1999. Developing measures of socioeconomic resiliency in the interior Columbia basin. Gen. Tech. Rep. PNW-GTR-453. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 41 p.

| Value produced by agriculture and recreation industries as percent of total.

What is the indicator and why is it important?

Agriculture and recreation-based industries appear to be two of the primary sector groups of the economy related to rangelands and their long-term stewardship. While neither occurs exclusively on rangelands, tracking what happens to them in rangeland-dominated counties should indicate the pressures being placed on rangelands. The values that comprise this indicator will only reflect production values that flow through the economy. Nonmarket values that accrue to people from such things as recreation (beyond that captured in markets) and ecosystem services provided by rangelands will be missed by this indicator.

What are the data and what do they show?

Data on gross sales by North American Industrial Classification System are available from the Bureau of Economic Analysis for every county. Identifying the agricultural and recreational sectors to be included in the numerator and the rangeland counties to use in the calculations should be a relatively simple task. As population grows and economies change, we expect there to be a differential effect on rangelands and this indicator will show how those pressures change.
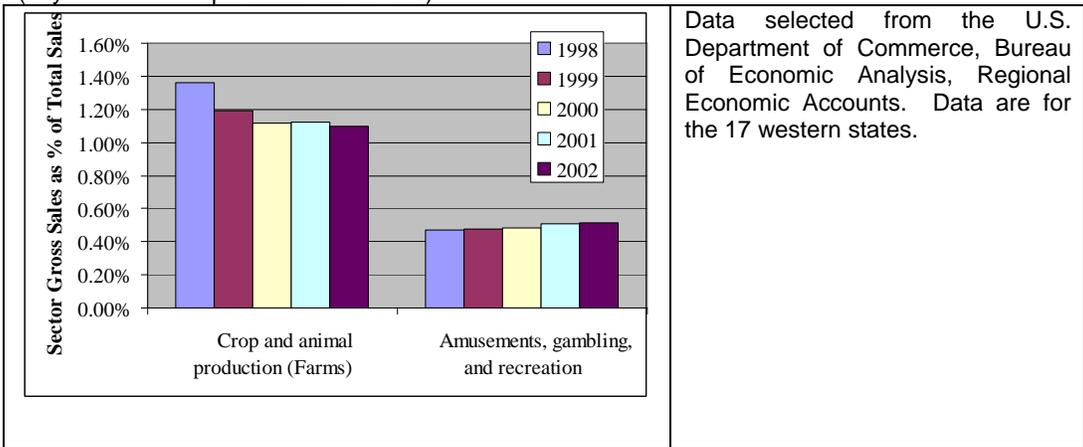
Data selected from the U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Accounts. Data are for the 17 western states.

Employment, unemployment, underemployment, and discouraged workers by industrial sector.

What is the indicator and why is it important?

Data on these variables provide information on the vitality of the local economy. High numbers in the unemployed, underemployed, and discouraged worker categories would indicate an economy in trouble and a community under stress. Such high numbers in rangeland-related industries (e.g., livestock production, recreation, tourism) would provide an indication of the pressures on rangeland-dependent livelihoods and lifestyles.

What are the data and what do they show?

Employment data are reported by the Bureau of Labor Statistics on a county basis. The relevant data need to be extracted from the existing database in the form required. The BLS data are only for covered employment and do not include much of the agricultural sector employment. The Census of Agriculture provides additional hired labor statistics for beef cattle ranches. These data will show how the industries are changing in rangeland-dependent counties.

Data were obtained from the U.S. Department of Labor, Bureau of Labor Statistics, Quarterly Census of Employment and Wages. Data presented here are for the U.S. as a whole. Similar data can be obtained for the different unemployment categories.
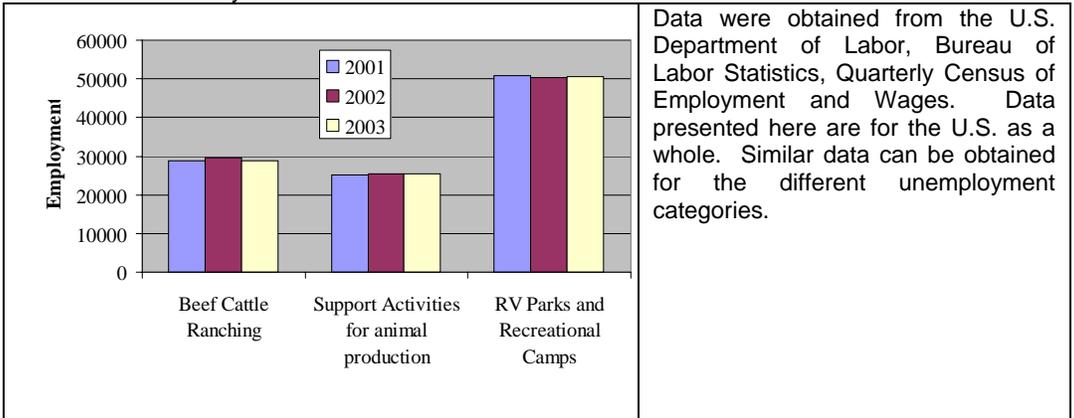
	Land tenure, land use, and ownership patterns by size classes.

What is the indicator and why is it important?

This indicator monitors changes in ownership (e.g., public vs. private, production agriculture to residential lots), ownership stability, and how the land is being used. It will measure how quickly rangelands are turning over (i.e., converting from one owner to another and one use to another). It is important to sustainability because conversions of rangeland to other uses can have both ecological and socio-economic impacts, e.g., loss of open space, habitat fragmentation, noxious weeds, as

well as diminishing future options for the land.

What are the data and what do they show?

Data for this multi-part indicator are available in the Census of Agriculture that is conducted every 5 years. Over time, the data will show how the ranching industry is changing. At present it is not possible to obtain these data for different size classes of beef cattle operations in rangeland dependent counties. However, the census does report both values and we believe that the relevant data series can be combined to provide the information for this indicator.

Data from the 2002 Census of Agriculture, USDA National Agricultural Statistics Service, Table 59.
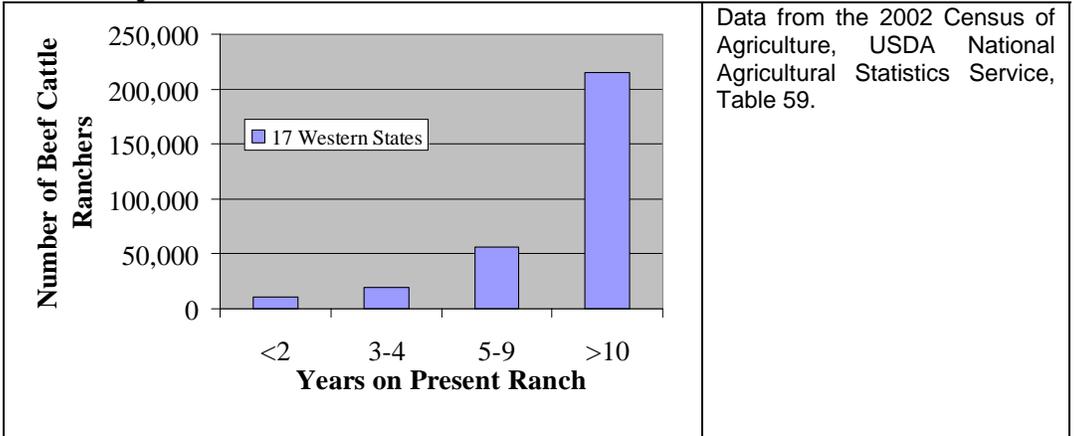
	Population pyramid and population change.

What is the indicator and why is it important?

Population pyramids are commonly used to describe a population's basic structure. They require actuarial data on gender and age. Data are organized into 5-year age cohorts. This measure provides evidence of community sustainability. A population pyramid that varies little from the youngest to the oldest cohorts is considered to be stable. Widely different proportions of population in general age classes indicate differing needs over time with respect to social and economic infrastructures that may be more/less likely to be derived from rangeland activities. Expanding and contracting needs for social services puts more stress on community infrastructure than does a situation in which they are fairly constant.

What are the data and what do they show?

Data to construct population pyramids are available from the U.S. Census Bureau for every county in the U.S. Developing the pyramids for rangeland counties would be relatively easy once those counties were designated. The population structure and rates of change in populations in the rangeland counties will show which are more or less likely to be maintained into the future and may give some indication of population pressures on rangeland resources.
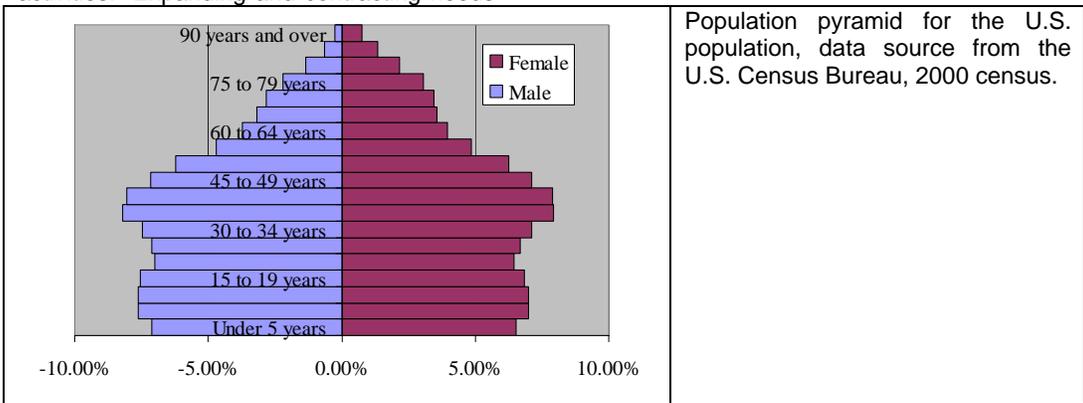
Population pyramid for the U.S. population, data source from the U.S. Census Bureau, 2000 census.

Criterion 5: Legal, Institutional and Economic Framework for Rangeland Conservation and Sustainable Management

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Professional education and technical assistance.

What is the indicator and why is it important?

This indicator describes the extent to which laws, regulations, and guidelines, institutions, and organizations provide for professional education and the distribution of technical information and financial assistance related to the conservation and sustainable management of rangelands. Periodic assessments of the relevance and changing needs of range management education have guided the evolution of rangeland-related programs in the United States for years. The Society for Range Management offers accreditation to schools that meet its criteria for professional education in range sciences. Professional societies also offer certification programs for their members and require some type of continuing education for certification maintenance. Most government agencies require professional development training for their employees. These extent and effectiveness of these programs vary with budgets and the interest and commitment of each organization's management team. Nationally, conservation education or environmental education programs are offered by NGO's that focus on nature, wildlife, forests, natural resources, conservation biology, biological diversity,

ecology, and a variety of other topics

What are the data and what do they show?

The only data presently available follows the number of students majoring in rangeland management and natural resource management at U.S. universities offering degrees in rangeland-related disciplines. Relevant data sets are maintained by the Society for Range Management for colleges and universities which they have accredited, and individual university departments. See the examples chapter for data on two rangeland science departments.

Example

The number of students majoring in rangeland-related disciplines varies for a number of reasons. The following data are from rangeland management departments at Oregon State University and Texas A&M University, respectively. Although no causal effects can be ascribed with certainty, the enrollment data from these two universities seem to reflect a more pronounced decline in students enrolling in large universities in public land states, like Oregon, compared to similar-sized universities in states with little public lands, like Texas. Moreover, student numbers are apparently increasing more rapidly in smaller, farm-oriented colleges and universities than in the large universities. If graduates from public land universities are more likely to seek employment from federal agencies, these trends could impact recruitment of qualified technical employees to replace those retiring from federal land management agencies.

Undergraduates and graduate students majoring in rangeland management, Oregon State University

Bar chart showing Undergraduate and Graduate students from 1993 to 2005.

Year	Undergraduate	Graduate
1993	33	20
1994	36	22
1995	41	27
1996	40	24
1997	32	17
1998	22	17
1999	29	15
2000	29	16
2001	31	14
2002	25	17
2003	28	18
2004	27	16
2005	23	12
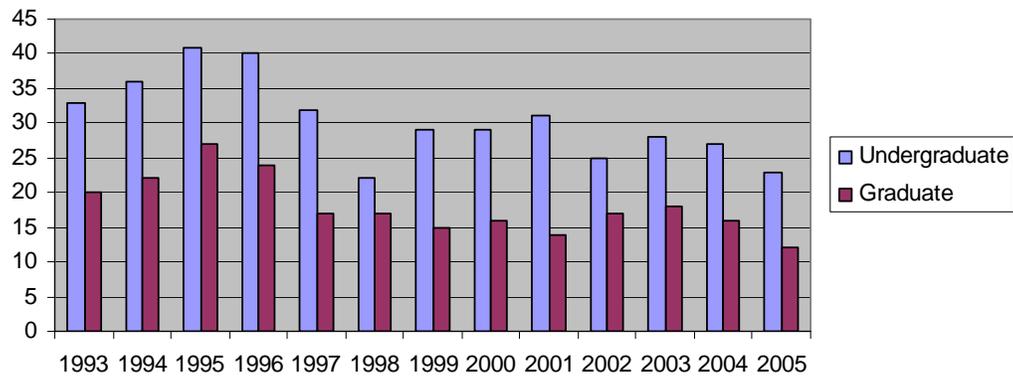
Undergraduates and graduate students majoring in rangeland management, Texas A&M University

Bar chart showing Undergraduate and Graduate students from 1990 to 2004.

Year	Undergraduate	Graduate
1990	85	54
1991	72	44
1992	98	51
1993	112	52
1994	107	63
1995	125	65
1996	117	67
1997	103	64
1998	94	60
1999	109	54
2000	107	55
2001	152	54
2002	155	67
2003	180	67
2004	190	64

🟥	Land management.
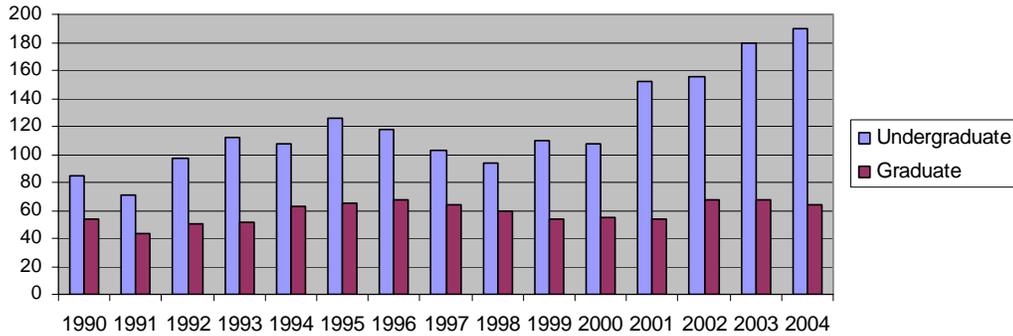
🟧	Research and Development.

What is the indicator and why is it important?

This indicator examines the various land management programs and practices, and measures the degree to which agencies and organizations carry out laws, regulations, and management opportunities pertaining to good rangeland management. Federal agencies that manage rangelands are faced with growing obligations to apply laws and monitor the conditions of the rangelands, but often are constrained in their ability to accomplish this by limited budgets and staffs. State land management agencies collectively manage an estimated 146 million acres of land – much of it for livestock grazing. Most of the laws relating to the management of state-owned rangelands are directed toward the process and procedures for issuing leases for grazing and other uses. Forty-one of the states have some requirement for agencies to assess the environmental impact of their actions. Of these, 14 states have "little NEPA" laws fashioned after the federal act and 27 states have scattered impact assessment requirements. Good management on private rangelands is best achieved through voluntary programs where private landowners are encouraged, advised and assisted to develop stewardship programs.

What are the data and what do they show?

Methods and procedures are not standardized for monitoring and reporting about the extent of rangeland management at the regional-national level. Information on private rangeland owners and managers who participate in USDA conservation technical assistance, environmental improvement, and stewardship programs may be privileged at local levels, and unavailable at broader levels.

What is the indicator and why is it important?

This indicator measures the extent of research and development programs that improve scientific understanding, develop new technologies, and assess the impacts of naturally occurring and human disturbances on the conservation and sustainability of rangelands. Essentially, this indicator looks at the extent to which government agencies, universities, and NGOs spend time and money spent on research and development activities related to rangelands. Historically, research pertaining to rangelands has emphasized ecological and grazing-related problems. Within the socio-economic research arena, studies have primarily dealt with tradeoffs derived from rangeland improvements, federal grazing policy considerations, and economic returns from different management practices. Little work has taken place to evaluate the socio-economic indicators in Criterion 4. Moreover, methods have not been established to monitor this indicator

What are the data and what do they show?

Some data sets exist at the regional-national level, but methods and procedures are not standardized at the regional-national level. During the past 30-40 years, the extent of research funding organizations supporting research about rangeland systems has expanded well beyond the historical USDA sources prevalent in the first half of the 20th Century. In addition, the backgrounds and disciplines of those undertaking rangelands-related research has become more diverse and less concentrated. All this makes a comprehensive measure of a R&D indicator more difficult. The USDA Current Research Information System (CRIS) documents its ongoing agricultural, food, and forestry research; see < http://cris.csrees.usda.gov/star/crisfin.htm>.

	Measuring and monitoring.

What is the indicator and why is it important?

This indicator measures the extent to which government agencies and NGOs spend time and funds to monitor indicators of sustainable management on rangelands. The United States has a large, but fragmented, capacity to measure changes in the conservation and sustainable management of rangelands. About one-thirds of the Nation's rangelands are held by the federal government and managed by the various agencies, primarily within the Departments of Agriculture and Interior. These agencies have the ability to monitor land under their jurisdictions, but currently do not measure the same variables, nor do they use the same protocols to ensure consistent, reproducible results. States, tribes and private landowners holding the majority of U.S. rangelands do little formal monitoring. Opportunities and problems associated with monitoring various indicators are spelled out in this chapter.

What are the data and what do they show?

All federal agencies report upon their monitoring programs in various ways. However, because different agencies monitor different indicators, and monitor the same indicators using different protocols, it is difficult to describe the extent of monitoring across administrative boundaries and across time. In addition, no data exist on the degree of monitoring that takes place on private rangelands. An example of how BLM reports the area of rangeland it monitors annually is shown below:

Percentage of BLM rangelands inventoried by two methods (Ecological Site Inventory, Soil Vegetation Inventory Method), 2004

AZ	CA	CO	ID	MT, ND, SD	NV	NM	OR, WA	UT	WY	All Lands
52%	15%	46%	73%	67%	38%	76%	55%	60%	59%	52%

Table 1. Six-point evaluation framework of indicators.
_____

1.   Indicator: What is the indicator (descriptive title)?

2.   Importance: What does it measure and why is it important to sustainability?

3.   Geographic variation: Is the indicator meaningful in different regions?

4.   Scale: Is the indicator meaningful at different spatial and temporal scales?

5.   Data: Categorize the availability of data sets for this indicator:

   - Methods and procedures for data collecting and reporting; and data sets of useable quality exist at the regional-national level.

   - Standardized methods and procedures for data collecting and reporting exist at the regional-national level, but useable data set(s) do not exist at the regional-national level.

   - Some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level.

   - Conceptually feasible or initially promising, but no regional-national methods, procedures or data sets currently exist.

6. Clarity: Is the indicator and indicator unit understood by stakeholders?

Table 2. Data matrix used by Sustainable Rangeland Roundtable to populate indicators with known data sets.

Data Matrix for Indicator #___

	Data set #1	Data set # 2	Data set # 3	Data set # 4
Response from #5 of 6-point evaluation framework (A-D)				
Brief description of Data Set (including source and content):				
Contact Person (email, phone, address):				
Website (if available):				
Additional information on data set:				
What is the most recent year of reported data?				
In what format is the data available? (map only, data point, …)				
Are data nominal, ordinal, or interval?				
What will be the approximate cost of collecting data?				
What barrier(s) prohibit access or use of data? (Restricted use, exorbitant cost, technical or legal barriers, confidential barriers, etc.?) Or are data easily accessible?				
What is the spatial grain of the data?				
What is the spatial extent of the data?				
At what spatial scales can these data be aggregated and reported?				
What is the temporal grain of the data?				
What is the temporal extent of the data?				
At what temporal scales can these data be aggregated and reported?				
Quality: can data be adequately reported over time in a consistent form? (Consistent methodology.)				
Quality: are existing data repeatable? (Estimates of independent observers not significantly different p<.2)				
Quality: is the sampling method biased?				
Quality: are existing data precise? (Standard error <20% of the mean?)				
Quality: are existing data valid?				
Quality: are existing data responsive?				
Quality: how well does this data set meet the data needs for this indicator?				

Table 3. Categorized availability of data for 64 Sustainable Rangeland Roundtable indicators.

Indicator	Data Set Availability[1]
Criterion 1: Conservation and Maintenance of Soil and Water Resources of Rangelands	
1. Area and percent of rangeland with significantly diminished soil organic matter and/or high Carbon:Nitrogen (C:N) ratio	D
2. Area and extent of rangelands with changes in soil aggregate stability	B
3. Assessment of microbial activity in rangeland soils	D
4. Area and percent of rangeland with a significant change in extent of bare ground	C
5. Area and percent of rangeland with accelerated soil erosion by water and wind	B
6. Percent of water bodies in rangeland areas with significant changes in natural biotic assemblage composition	A
7. Percent of surface water on rangeland areas with significant deterioration of their chemical, physical, and biological properties from acceptable levels	A
8. Changes in groundwater systems	A
9. Changes in the frequency and duration of surface no-flow periods in rangeland streams	A
10. Percent stream miles in rangeland catchments in which stream channel geometry significantly deviates from the natural channel geometry	B
Criterion 2: Conservation and Maintenance of Plant and Animal Resources on Rangelands	
1. Extent of land area in rangeland	B
2. Rangeland area by vegetation community	C
3. Number and extent of wetlands	A
4. Fragmentation of rangeland and rangeland vegetation communities	C
5. Density of roads and human structures	A
6. Integrity of natural fire regimes on rangeland	C
7. Extent and condition of riparian systems	C
8. Area of infestation and presence/absence of invasive and non-native plant species of concern	C
9. Number and distribution of species and communities of concern	A
10. Population status and geographic range of rangeland-dependent species	B
Criterion 3: Maintenance of Productive Capacity on Rangeland Ecosystems	
1. Rangeland aboveground phytomass	A
2. Rangeland annual productivity	A
3. Percent of available rangeland grazed by livestock	D
4. Number of domestic livestock on rangeland	B
5. Presence and density of wildlife functional groups on rangeland	C
6. Annual removal of native hay and non-forage plant materials, landscaping materials, edible and medicinal plants, wood products, and native hay	D

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[1] Availability of data sets is categorized by: A – methods and procedures for data collecting and reporting, and data sets of useable quality exist at the regional-national level; B – standardized methods and procedures for data collecting and reporting exist at the regional-national level, but useable data set(s) do not exist at the regional-national level; C – some data set(s) exist at the regional-national level, but methods and procedures are not standardized at the regional-national level; D – conceptually feasible or initially promising, but no regional-national methods, procedures or data sets currently exist.

Criterion 4: Maintenance and Enhancement of Multiple Economic and Social Benefits to Current and Future Generations

1.	Value of forage harvested from rangeland by livestock	A
2.	Value of production of non-livestock products produced from rangeland	D
3.	Number of visitor days by activity and recreational land class	C
4.	Reported threats to quality of recreation experiences	B
5.	Value of investments in rangeland, rangeland improvements, and recreation/tourism infrastructure	D
6.	Rate of return on investment for range livestock enterprises	B
7.	Area of rangelands under conservation ownership or control by conservation organizations	B
8.	Expenditures (monetary and in-kind) to restoration activities	D
9.	The threat or pressure on the integrity of cultural and spiritual resource values	D
10.	Poverty rate – general	A
11.	Poverty rate – children	A
12.	Income equality	A
13.	Index of social structure quality	C
14.	Community satisfaction	A
15.	Federal transfers by categories (individual, infrastructure, agriculture, etc.)	A
16.	Presence and tenure of natural resource non-governmental organizations at the local level	D
17.	Sources of income and level of dependence on livestock production for household income	C
18.	Employment diversity	A
19.	Agriculture (farm/ranch) structure	A
20.	Years of education	A
21.	Value produced by agriculture and recreation industries as percent of total	A
22.	Employment, unemployment, underemployment, and discouraged workers by industrial sector	A
23.	Land tenure, land use, and ownership patterns by size classes	C
24.	Population pyramid and population change	A
25.	Income differentials from migration	A
26.	Length of residence (native, immigrant more than 5 yrs., less than 5 yrs.)	A
27.	Income by work location versus residence	A
28.	Public beliefs, attitudes, and behavioral intentions toward natural resources	C

Criterion 5: Legal, Institutional, and Economic Framework for Rangeland Conservation and Sustainable Management

1.	Land law and property rights	B
2.	Institutions and organizations	D
3.	Economic policies and practices	C
4.	Public information and public participation	C
5.	Professional education and technical assistance	C
6.	Land management	D
7.	Land planning, assessment, and policy review	C
8.	Protection of special values	C
9.	Measuring and monitoring	C
10.	Research and development	C

Chapter 4: Utility of Criteria and Indicator-Based Monitoring by Federal Government Land Management and Research Agencies

USDA - Forest Service

The Forest Service has a legal mandate under the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) to produce a decennial assessment of the status in supply, demand, and trends of renewable resources coming from all forests and rangelands of the United States. The Agency also has a legal requirement for monitoring for purposes of research, planning, and management embedded in several laws, including the Forest and Rangelands Research Act of 1978.

The first comprehensive RPA Assessment was published in 1980. The chapter on rangelands focused upon range condition and the future supply and demand for rangeland forage. The Assessment estimated that about one half of all rangelands in the 48 conterminous states were in fair to good condition. It projected that a 46 percent increase in demand for forage between 1980 and 2030 would increase pressures to expand livestock grazing on both publicly and privately owned rangelands. The 1990 Rangeland Assessment technical document, alternatively, concluded that private rangelands could satisfy demands for increased forage over the next 50 years, thus allowing public land managers to accommodate an expanding public interest in natural and other amenity values. The 2000 Assessment also examined rangeland health and productive capacity, showing that rangeland health, although measured differently over the 20 years, had clearly improved during this time in most regions. All three Assessments relied upon a patchwork of data and models available at the time from various agencies and other sources.

Complicating both the RPA and the SRR, no U.S. national plot-based monitoring system is in place to allow the estimation of biotic and abiotic indicators of rangeland sustainable management not obtainable by remote sensing. The Forest Service collects data under its Forest Inventory and Analysis (FIA) Program from a sampling grid that includes all forests and woodlands on both federal and non-federal lands. The FIA grid does not extend onto non-forested lands, however. The only U.S. national-level sampling program on rangelands is the National Resources Inventory (NRI). Carried out by USDA-NRCS, the NRI grid does not extent onto federal rangelands, leaving a large monitoring gap. Until this gap is somehow closed, monitoring trends on all rangelands will be problematic.

USDA - Natural Resources Conservation Service (NRCS)

The primary emphasis of the USDA Natural Resources Conservation Service (NRCS) is to conserve, maintain, and improve our natural resources, particularly on private lands. Some of the SRR criteria and indicators are identical or similar to those in use by NRCS while other criteria and indicators are not used. Historically, the NRCS framework for conservation planning and natural resource management has been soils, water, air, plants, and animals (SWAPA). This effectively skews the mission and efforts of NRCS towards the first three of the SRR criteria: "Conservation and Maintenance of Soil and Water Resources of Rangelands", "Conservation and Maintenance of Plant and Animal Resources on Rangelands", and "Maintenance of Productive Capacity on Rangelands". For the indicators of these three criteria, the primary NRCS inventory and monitoring program is the National Resources Inventory (NRI). Of current note, NRCS is in the midst of a special three-year NRI specifically on rangelands. Other minor inventories are

conducted as part of traditional conservation planning.

NRCS also collects data on indicators not currently accepted by SRR. Significant among these is a sizable amount of climate data. Fairly unique to NRCS are programs addressing soil climate (SCAN data network) and snow-pack (SNOTEL data network). However, there are many other sources for climate and weather data, especially for precipitation and temperature. Many of SRR's criteria and indicators are directly affected by climate. By following weather and climate trends (relatively low-cost and available) as a surrogate, the correlated trend of other indicators (potentially high-cost or currently undeveloped) can be predicted.

USDI - Bureau of Land Management (BLM)

The BLM has been entrusted with stewardship responsibility for the multiple-use management of natural resources on nearly 262 million acres of public land, much of which is rangeland. The BLM has legal mandates for national-level (BLM-wide) reporting of rangeland condition and trend in rangeland condition. These legal mandates are The Federal Land Policy and Management Act (FLPMA) of 1976, and the Public Rangelands Improvement Act (PRIA) of 1978.

How does BLM comply with FLPMA and PRIA regarding national-level reporting of range condition and trend? BLM reports percent of rangeland acreage by ecological status, by state, in two publications: USDI-BLM's annual Public Land Statistics, and BLM's Annual Report. If looked at over a series of years, the ecological status data in these reports have been interpreted as trend in rangeland condition over time. Several problems with BLM's way of reporting rangeland condition have surfaced, relating to the scientifically-obsolete concept of ecological status, the lack of rangeland condition data on all BLM-administered rangelands, and the old (more than 20 years) age of much of the data.

Given these problems, BLM is considering a "course correction". Two courses are being considered. The first course is identifying a minimum set of aquatic, riparian, and upland rangeland indicators which could be quantitatively reported nationally for land health. SRR indicators are being seriously considered here. For example, bare ground, invasive plants, and aquatic macroinvertebrates, 3 indicators from SRR, will likely be in the final minimum set. BLM will have a need for data sets and data collection methods for these indicators. SRR will serve BLM's need here because SRR has been identifying the currently available data sets for all of its 64 indicators, and SRR is sponsoring a workshop in May 2005 on indicator data sets and data collection methods.

The second course is a roll up of BLM's Land Health Standards data from the field office level to the state office level to a BLM-wide level, resulting in a qualitative report of land health at the national level. Land Health Standards are ecologically-based goal statements that BLM gauges resource conditions against, to identify needed changes in land uses such as livestock grazing. Suites of indicators are associated with each Land Health Standard and are measured to evaluate whether Standards are being achieved. Although these suites of indicators were identified prior to SRR, many of these indicators are the same as those identified by SRR. BLM field offices currently have discretion to measure select indicators out of the suite available, but BLM is considering requiring at least a minimum set of aquatic, riparian, and upland indicators be part of all Land Health Standard assessments and in all land use plans. Some SRR indicators will likely be included in the minimum set.

In summary, BLM regards SRR indicators as credible. BLM currently is in the process of f making course corrections for future national-level (BLM-wide) reporting of land health. For quantitative reporting using a minimum set of aquatic, riparian, and upland indicators, and for qualitative reporting using

Land Health Standard assessments, BLM intends to use some SRR indicators.

USDI - US Geological Survey (USGS)

The USGS has a long history of collecting and interpreting data on water and wildlife resources throughout the USA. Water data collected by states include stream flow, ground water and water quality data. These three aspects of water status relate directly to indicators for assessing the Conservation and Maintenance of Soil and Water Resources on rangelands.

Within the National Streamflow Information Program, the USGS maintains nearly 7,000 stream gages that provide long-term and accurate data on stream flow and timing. Ground water sustains stream and river flows while providing the source that maintains riparian and wetland ecosystems. The USGS Ground-Water Resources Program maintains 10 to 20 years of ground water levels in 25 aquifers in the USA, many of which are in rangeland ecosystems. These data provide some information on the interactions between ground water and surface water of lakes, ponds, streams and wetlands. The National Water Quality Assessment Program evaluates 50 major river basins for water chemistry, hydrology, land use, stream habitat and aquatic life. These data provide information on changes in water quality within many rangeland ecosystems.

Monitoring and interpretation of selected animal groups has become an area of emphasis in the USGS Status and Trends program. The main groups are birds and amphibians. The Breeding Bird Survey monitors bird populations for nearly 400 species in the USA and Canada using consistent methods throughout the area. The Amphibian Research and Monitoring Initiative is establishing two databases for tracking the status of amphibian populations throughout the nation. These animal-monitoring programs will contribute indicator information useful for indicators relating to the Conservation and Maintenance of Plant

USDA - Agricultural Research Service (ARS)

The Agricultural Research Service (ARS) is the in-house research arm of the USDA. The ARS mission includes providing knowledge and technologies to farmers, ranchers, and other land managers to help manage the Nation's land in a productive and fully sustainable manner. Core to these developing technologies is an in-depth understanding of ecological processes as they relate to the management and conservation of rangeland, pasture, and forage resources. New understandings and technologies being developed at over 35 ARS locations include an array of indicators within SRR Criterion 1 (Soil & Water), 2 (Plant & Animal Resources), and 3 (Productivity Capacity).

Specific to Criterion 1 are new technologies and advanced understandings that are being developed for inventorying and monitoring changes in soil organic matter content (Indicator 1) and soil microbial activity (Indicator 3). This is important because both of these "soil quality/health" indicators are believed to be tied closely to the ecological sustainability of rangelands. Extensive efforts are also being expended to understand and accurately assess the effects that varying amounts of bare ground/foliage cover (Indicator 4) have on long-term sustainability as well as the impact that varying management tactics have on rates and amounts of water and wind erosion (Indicator 5), water quality (Indicator 7) and overall hydrologic function (Indicator 9).

Developmental technologies related to Criterion 2 include refined use of remote sensing and other rapid, broad based technologies for monitoring changes in amount (Indicator 1), type (Indicator 2), and landscape level distribution patterns (Indicator 4) of rangelands, riparian areas within rangelands (Indicator 7), and rate, extent, and pattern of invasive weed infestations (Indicator 8). Likewise, similar technologies are being used to monitor

sustainability as it relates to changes in Criterion 3 indicators such as aboveground biomass (Indicator 1) and annual productivity (Indicator 2).

The linkages between ARS and SRR are more subtle than the linkages between SRR and the Nation's premier land management agencies such as the US Forest Service (FS), Bureau of Land Management (BLM), and the Natural Resource Conservation Service (NRCS). This is because ARS research efforts are focused on developing new understandings and technologies for use in inventorying and monitoring the ecological health and sustainability of the Nation's rangeland ecosystems at a variety of scales, whereas FS, BLM, and NRCS are charged with actually inventorying, monitoring, and assessing the ecological health and well-being of our Nation's rangelands. Thus, the linkage between these land management agencies and SRR is obvious, direct, and critical to accomplishing like-minded land management goals and objectives. But these linkages are no more compelling than those between ARS and SRR as manifested through the continual exchange of ideas relative to: 1) the scientific merits of varying criteria and indicators, and the challenges associated with the technical capacity required to; 2) accurately inventory and monitor changes in varying indicators in a timely manner; and 3) accurately summarize and precisely interpret said monitoring data. These linkages SRR are critical as new rangeland inventorying and monitoring challenges emerge and new understandings and associated technologies are developed to effectively meet these challenges.

U.S. Environmental Protection Agency (EPA)

The U.S. Environmental Protection Agency's Environmental Monitoring & Assessment Program (EMAP) has been developing a set of spatial or landscape metrics for a 12-state area (Arizona, Colorado, California, Nevada, Utah, Wyoming, Montana, Idaho, North Dakota, South Dakota, Oregon, &

Washington) with the aim of assessing ecological conditions of terrestrial ecosystems across this large region. One of the primary goals of this project is to link observed conditions of terrestrial systems to surface water conditions, as well as to measure potential stressors and biophysical conditions that might account for observed conditions. The project includes all terrestrial biome-types, including forests, woodlands, and rangelands.

Data on surface water conditions come from EMAP stream survey samples, the USGS NAWQA program, and from STORET. Additionally, the US EPA Landscape Ecology group in Las Vegas, in collaboration with the USDA Agricultural Research Service in Tucson, Arizona, has developed user-friendly GIS extensions that generate landscape metrics at different scales (Analytical Tools Interface for Landscape Assessments or ATtILA) and that run spatially distributed watershed models to evaluate run-off and sedimentation (Automated Geospatial Water Assessment or AGWA tool). Results of these models are then combined with landscape metrics and compared against observed stream water quality at a range of scales (watershed, riparian zone, near-site) using multivariate and Bayesian statistical techniques.

Metrics and indicators generated by the Western EMAP project relate primarily to Criterion 1 of the Sustainable Rangeland Roundtable Criteria and Indicators for Sustainable Rangelands, and in particular, indicators related to: (1) Area and percent of rangeland with a significant change in extent of bare ground, (2) percent of surface water on rangeland areas with significant deterioration of their chemical, physical, and biological properties from acceptable levels, and (3) area and percent of rangeland with accelerated soil erosion. The group has focused on the surface water aspect because of EPA's role in protecting and enhancing the Nation's water resources, and because there are few studies that have linked terrestrial ecosystem conditions to surface water conditions in the western US.

Chapter 5: Conclusions and Next Steps

The vision of SRR is clear. We envision a future in which 1) rangelands in the U.S. provide a desired mix of economic, ecological, and social benefits to current and future generations, and 2) criteria and indicators (C&I) for monitoring and assessing the economic, social, and ecological sustainability of rangelands are widely accepted and used. The difficult part will be in reaching agreement on how we in the rangeland community will achieve this vision, and in the allocation of scarce resources to take the steps leading to the broad use of ecological, economic, and social indicators in rangeland monitoring and assessments.

Agencies and NGO's have a number of overriding reasons for incorporating C&I into the way they conduct business. First, they serve as a mechanism to clarify national and regional strategic planning goals and objectives, as well as management goals and objectives in the field. Second, the C&I process can promote collaboration for the stewardship of mixed-owner landscapes at local, state, and regional levels. Two other purposes of using C&I are to improve resource monitoring and assessments at all scales, and to help identify research needs for better monitoring and interpretation of monitoring results.

The highest priority for ascertaining how satisfactorily U.S. rangelands are providing a desired mix of goods and services to society is to complete a national report on sustainable rangelands.

Implementing Interagency Ecological and Socio-Economic Monitoring

At a recent workshop on SRR indicator implementation, held in Ardmore, Oklahoma and sponsored by The Samuel Roberts Noble Foundation, participants identified SRR as being at a critical juncture. Progress towards developing protocols for monitoring SRR indicators, as well as their acceptance by agencies, was seen as an essential next step. Some indicators, which are collected at a more local scale, cannot be reported upon at regional or national levels without having common data characteristics across administrative boundaries. Reaching the goal of common data will require formal collaboration among agencies and organizations that will collect it.

Several subjects will have to be addressed if useful national-scale data sets are to be achieved. For ecological indicators that rely upon on-the-ground measurements, the Natural Resources Conservation Service and the Forest Service and their stakeholders must work collaboratively to close the "federal rangeland" NRI/FIA gap. This will require direction and support from Congress because of the needed funding to collect statistically valid samples from such large landscapes.

Presently, a number of indicators relating to productive capacity and socio-economic criteria cannot be monitored on the basis of rangelands. Changes are needed, for example, in the way the National Agricultural Statistics Service collects data if these kinds of information are to be gleaned from censuses of all farmers and ranchers. Research is required to define rangeland dependent counties on a scientific basis.

Finally, in order to consolidate and facilitate research needed to report upon key indicators, universities are being asked to organize a Western Regional Committee that integrates the strengths of all rangeland-focused academic institutions.

2010 National Report on Rangeland Sustainability

Development of a 2010 National Report on Rangeland Sustainability is a significant undertaking if it is to be consistent across established boundaries that define ownerships and types of land. It will not be completed without the support from the

Administration, the Congress, and the leadership of multiple federal agencies and NGO's. Due to the magnitude of this effort, success will require coordination and oversight of data collection and analysis by all agencies and organizations involved.

For a 2010 Rangeland report to become reality, unprecedented and vocal support from state and local governments, professional, conservation, environmental and agricultural organizations will be vital. On the other hand, given the hundreds of millions of dollars spent by the federal government, alone, on monitoring and reporting, it is quite likely that a consolidated and coordinated rangeland monitoring and reporting system will actually save money in the long run. SRR serves as the catalyst for a 2010 Rangelands Sustainability Report.

The need for a national assessment tool for the Nation's rangelands has been at the forefront of discussion for many years. Recommendations for reporting rangeland condition at the national scale have been independently presented by the National Research Council in 1994, the Society for Range Management Task Group on Unity in Concepts and Terminology in 1995, and university academia. In 1995, the Society for Range Management recommended that all USDA and USDI agencies having requirements to report on the condition of the Nation's rangelands establish a consistent methodology using the latest scientific techniques to provide the public and Congress with an accurate assessment of the condition of rangelands.

A 2010 National Report on Rangeland Sustainability will be a fundamentally more focused and comprehensive effort than another ongoing national report on all U.S. ecosystems being undertaken by The H. John Heinz III Center for Science, Economics and the Environment, called The State of the Nation's Ecosystems. Although the 14 Heinz Center indicators for rangelands (called grasslands and shrublands in their 2002 report – http://www.heinzctr.org/ecosystems/) are similar to SRR indicators, they only constitute a synopsis of the status of rangelands within the context of all U.S. lands. The Heinz Center report also focuses almost exclusively upon the ecological and production indicators found under the first three SRR criteria, thus making its report more of a "one-legged stool."

Currently rangeland is inconsistently defined in the federal government both among and within departments. The majority of rangelands under federal management, however, are controlled by the Departments of Interior, Agriculture and Defense. Additional rangelands are under state and local ownership or under the private ownership of individuals, corporations or NGO's. Federal assistance is provided to non-federal rangelands through multiple agencies of the Departments of Agriculture and Interior.

The current lack of a consistent definition(s) of rangeland as an ecological type of land or a land use will need to be overcome to by all responsible parties. An ongoing endeavor between the Departments of Agriculture and Interior to develop and adopt Ecological Sites promises to ensure a compatible land classification system at the local level. The Vegetation sub-committee of the Federal Geographic Data Committee (FGDC) is currently developing federal standard for existing plant communities that will aid in correlation and consistency of describing plant communities.

The development of a rangeland sustainability report will require the collection of data at a minimum of a national scale. Limited national-level ecological data are currently available for this report. Where such data do exist, they often reside in multiple agency data sets that are inconsistent for various reasons, and, thus, cannot be aggregated to a scale suitable for national reporting. Rangeland vegetation data provide one example. As mentioned above, agencies responsible for collecting vegetation data must develop standard protocols – protocols that are scientifically defendable and provide answers to the questions being asked.

There are close to 800 million acres of rangeland in the United States. Of this area, almost half requires a soil survey and ecological classification. More than three-fourths of all U.S. rangelands still need field work done to develop ecological site descriptions. Completing soil survey and ecological classification of the Nation's rangelands to support local land use planning, resource management and monitoring would require an annual budget of $137 million over a 10-year period. During an interval of federal budget deficits, this important goal can only be achieved over time. Regardless of the length of time required, the stewardship of America's rangelands requires current soil and ecological classification information. Land, vegetation, and soil classifications are critical components of indicator-based monitoring systems at all scales. It is of the utmost importance to continue and reinforce the federal agencies' efforts to complete soil and land classification.

Establish an Interdepartmental Steering Group

A federal Interdepartmental Steering Group at the Senior Executive Service level is needed to provide oversight and direction to rangeland monitoring and assessment issues at both the local and national scales. Such issues include establishing consistency in methods used to collect and interpret monitoring and assessment information among Agencies and Bureaus, ensuring compatibility of data across jurisdictional boundaries. A Working Group, consisting of senior agency resource professionals, could be established to provide the Steering Group with technical expertise.

Conclusion

The adoption and monitoring of key indicators of sustainable rangeland management in the United States remains the highest goal of SRR and its stakeholders. Producing a national report on U.S. rangelands, comparable with the 2003 National Report on Sustainable Forests <http://www.fs.fed.us/research/sustain>, completed by 2010, remains an associated goal of nearly equal importance. Ultimately, other related goals and objectives will be enhanced, and perhaps made possible, by their supporting roles in local, regional, and national rangeland monitoring and our resultant improved capability for assessing the contributions of rangelands and rangeland communities to our Nation's well-being.

The Sustainable Rangelands Roundtable will promote social, ecological, and economic sustainability of rangelands through development and widespread use of the criteria and indicators for rangeland assessments, and by providing a forum for dialogue on rangeland sustainability.