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Sustainable Rangeland Management: Status of a Roundtable to Determine Criteria and Indicators

A Work in Progress

Proceedings of a Symposium Sponsored by the Sustainable Rangelands Roundtable

Annual Meeting of the Society for Range Management

Editors: E. T. Bartlett and John E. Mitchell

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The Purpose and Process of the Sustainable Rangelands Roundtable

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Abstract

The United States currently lacks consistent, standardized indicators for reporting the status of rangelands. This country needs a national information gathering process, based upon a comprehensive set of broadly accepted "Criteria and Indicators" (C&I) for future rangeland assessment and planning. Availability of such information at a national scale would foster informed, sound decision-making relative to the sustainability of the economic, social and ecological benefits derived from rangelands. The Sustainable Rangelands Roundtable (SRR), a multidisciplinary group, comprised of scientists (ecologists, soil scientists, economists, sociologists, etc.), conservation groups, industry, federal, state and local government representatives, and policy and legal experts, has been convened to address this need. However, the SRR is not, itself, a decision making body, but rather provides an opportunity for groups and individuals representing diverse interests and backgrounds to share information and perspectives on defining and describing C&I of rangeland sustainability. The inclusive nature of the process should lead to wider acceptance and adoption of the C&I by agencies, non-profit organizations and academia alike.

Introduction

Toward the end of the twentieth century, public concern about natural resource degradation increased, and environmental monitoring became more common. Interest in anthropogenic impacts and attendant ecosystem changes continues to grow, and governments now espouse sustainable development as an appropriate analysis paradigm (Shields, in press); trends in sustainability of numerous natural resources must be regularly assessed. For this reason, a group of stakeholders, including representatives from conservation groups, the livestock industry, local, state and federal government, and university partners, is involved in an ongoing series of meetings designed to identify a common set of factors for measurement of rangeland sustainability. This open, inclusive partnership operates as the Sustainable Rangelands Roundtable (SRR), and is working to distinguish a set of criteria and indicators (C&I), embodying social, economic, and ecological factors, to form a framework for national assessments of rangelands and rangeland use. Ideally, the C & I will describe individual elements that need to be assessed in order to determine trends in resource conditions, management, economic benefits, and social values derived from rangelands.

Sustainable Development

The term "sustainable development" was introduced in the 1980's as a modification of the term economic development. Sustainable development was popularized by the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, then the Prime Minister of Norway (WCED 1987). The description contained in their report, "Our Common Future," has become known as the Brundtland definition and states that sustainable development is, "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43).

The United Nations Conference on Environment and Development (the Earth Summit held in Rio de Janeiro in 1992), culminated in adoption of a plan for achieving sustainable development. Additionally, Earth Summit leaders endorsed the Rio Declaration and principles of sustainable forest management, which led to the creation of the Montreal Process (MP) Working Group in 1994.

The MP Working Group developed criteria and indicators (C&I) designed to achieve sustainable forest management. Their work resulted in creation of a set of seven criteria and sixty-seven indicators for the "conservation and sustainable management of temperate and boreal forests," which was

endorsed by the United States and nine other countries in the Santiago Declaration in 1995.

Four years later, this endorsement led the USDA Forest Service to initiate the Roundtable on Sustainable Forests (RSF). One of several significant issues identified at their initial meeting was the need for development of a C&I effort to focus specifically upon the nation's rangelands. This idea merited additional attention, and, within a year, a meeting was convened in Denver to investigate the utility of a roundtable for sustainable rangeland management. Due to the efforts of dedicated Forest Service personnel, the first meeting of the Sustainable Rangelands Roundtable was held in Denver in April 2001.

Sustainable Rangelands Roundtable

The SRR is not a decision making body, but rather provides an opportunity for groups and individuals representing diverse interests and backgrounds to share information and perspectives on defining and describing C&I of rangeland sustainability. SRR promotes shared leadership and responsibility for the participants. At the first two meetings held during 2001, SRR established trust and common understanding by adopting vision and mission statements, and guiding principles.

To ensure that opinions of all participants were equally represented, SRR has committed to two vision statements. The first regards SRR's ideal future condition for rangelands: "We envision a future in which rangelands in the U.S. provide a desired mix of economic, ecological and social benefits to current and future generations." The second vision statement describes how SRR views itself and the process through which it is working, stating, "we envision a future where we have widely accepted criteria and indicators for monitoring and assessing the economic, social, and ecological sustainability of rangelands."

SRR mission statement expands upon similar themes. Ultimately, "the Roundtable will identify indicators of sustainability based on social, economic, and ecological factors, to provide a framework for national assessments of rangelands and rangeland use."

The group further focused their efforts by collectively creating a set of guiding principles to assist with development of SRR procedure and process. A guiding principle is a fundamental truth, law or assumption (Romero 2001). More specifically, the guiding principles to which the SRR agreed are enduring rules or standards that guide roundtable practices and behaviors. The eight guiding principles developed by the SRR are as follows:

1. Collectively, indicators should guide monitoring efforts to measure rangeland sustainability in the U.S. at the national scale. Where possible, indicators should guide monitoring efforts to measure rangeland sustainability at multiple scales.
2. Ensure that the indicators employ the appropriate temporal and spatial scales for assessing the criteria.
3. Collectively, criteria and indicators will address social, ecological, and economic aspects of sustainability.
4. Use a criteria and indicator framework as a common language and operational framework for defining and assessing sustainability. Begin by considering the criteria and indicator framework of the SFR.
5. Review and consider, as appropriate, other indicator initiatives.
6. There are numerous policy questions related to rangelands. We will focus on the vision-mission agreed to by the SRR.
7. The Roundtable process will feature outreach to stakeholders, open dialogue, and respect for differing opinions.
8. The SRR will be supportive of and compatible with improved on-the-ground management of rangelands.

Benefits of Criteria and Indicators

The C&I that the SRR are developing will provide a common framework for monitoring and assessing progress toward sustainable rangeland management. Measurement of a valid, consistent, standardized set of indicators facilitates reporting on the full range of factors that affect the sustainability of rangelands. In addition to providing national baseline information, indicators also offer a method to accurately monitor changes in social, ecological, and economic aspects of rangeland sustainability. Wade and Reuwsaat present broader perspectives on the numerous benefits associated with having a comprehensive set of C&I for sustainable rangelands (see pp. 15-16), and Heintz (pp. 7-13) supplies an in-depth examination of the importance of sustainability indicators.

SRR Process

SRR Meetings

The SRR focuses its efforts through a series of working meetings, formal and informal electronic interaction between meetings, action-oriented working groups, and subject-oriented criterion groups. Physical meetings are two days in length, with the vision, mission, and guiding principles directing group thought and behavior. Mr. Lou Romero of Albuquerque, New Mexico, who is very familiar with natural resource management and

issues after a 32-year career with the USDA Forest Service, provides formalized, professional facilitation.

Agendas for each meeting are drafted at the previous session, revised, and provided to participants prior to the meeting. Meetings begin with two hours of informational presentations to introduce new participants to concepts of sustainable development, potential benefits of C&I for sustainable rangelands, and the logistics and principles of SRR. All participants receive updates from prior meetings and reports from various workgroups before undertaking tasks outlined for the current session.

Participants spend a majority of meeting time in small groups, moving forward with development, review, and revision of C&I. While the first few meetings emphasized drafting vision and mission statements and guiding principles, the groups subsequently identified major issues of rangeland sustainability. Categorical clustering of issues served as the foundation for the creation of five broad-based topic groups to further focus indicator development efforts. Consistency with C&I established by the RSF for sustainable forests emerged during the third SRR meeting, when the Roundtable combined issue clusters with RSF C&I sets. Efforts at the next two meetings concentrated on continued development of indicator sets specific to sustainable rangelands within five criteria groups. Six of the papers included in this symposium specifically address this indicator development process, utilizing the criterion group structure.

Collaborative Delphi

Time constraints associated with indicator development deadlines necessitate continued progress between meetings. To facilitate distance participation, SRR conveners created a modified electronic Delphi process to maintain communication and participant involvement. This process, informally dubbed Collaborative Delphi, offers opportunity via e-mail conversations for additional discussion and resolution of issues that emerge during SRR meetings. Collaborative Delphi is an effective tool for bounding differing positions, more clearly defining areas of agreement and conflicting opinion, and soliciting informed review of documents.

Additionally, because Collaborative Delphi emphasizes written, anonymous communications, individuals may further reflect upon subjects and voice concerns and opinions that they may be reluctant to enumerate at open meetings. For example, this procedure assisted with attaining agreement on variants of vision and mission statements, and guiding principles early in the SRR effort. It also increased SRR efficiency by saving time that then could be devoted to more pressing tasks at working meetings. For a more expansive discussion of Collaborative Delphi, see the article by Rowe (pp. 29-36).

Working Groups

As progress on development of C&I for sustainable rangelands continues, special projects and exigent concerns arise unexpectedly. To address these items efficiently, the SRR forms workgroups comprised of a small number of participants to perform specific tasks on behalf of the SRR, or to offer recommendations about how SRR ought to resolve emerging issues. Four of these special working groups have been formed, dealing with outreach efforts, questions of spatial and temporal scale, indicator development coordination across initiatives, and operational definitions.

Communication and enhanced public awareness of SRR efforts improves acceptance levels of SRR C&I upon project completion. For this reason, the Outreach Workgroup, chaired by Lori Hidinger of the Ecological Society of America, emphasizes involvement of additional organizations, development of effective outreach materials, coordination with outreach efforts of other roundtables, and maintenance of SRR momentum (see paper by Hidinger, pp. 17-19).

The Scale Working Group, chaired by Paul Geissler of the USGS Biological Resources Science Staff, focuses on identifying an interpretation of appropriate spatial and temporal scales for the SRR. Complex relationships among national, regional, and local scale indicators will be examined to determine whether spatial aggregation is suitable and/or useful. Situations where interpretation of indicators might change as scale changes, and instances when the metric (measure) varies among levels of scale will also be explored. A progress report is scheduled for the March 2002 SRR meeting.

The SRR Coordination Working Group formed to identify other ongoing indicator efforts dealing with issues relevant to sustainability and/or to rangelands. Tom Roberts, of the Bureau of Land Management in Denver, chairs this group. Coordination will avoid duplication of effort and indicator redundancy, while enhancing information sharing and cooperation. Currently, four roundtables are working on indicators of sustainability for various natural resources. These efforts include: the Roundtable on Sustainable Forests, the Sustainable Minerals and Energy Roundtable (SMR), the SRR, and the Sustainable Water Resources Roundtable (SWRR), which is still under organization. Additionally, numerous organizations have developed or are developing indicators specifically related to sustainable rangelands. These groups include the Heinz Center (see Patten pp. 63-65),

Environmental Protection Agency (EPA), and The Nature Conservancy (TNC), among others.

Most recently, the SRR formed the Definitions Working Group, chaired by John Tanaka of Oregon State University, to address the question - "Is it rangeland or is it forest?" Inclusive, consistent ecosystem classification will help to ensure that all vegetation communities are included in C&I efforts of various roundtables. Additionally, all relevant indicators for each ecosystem must be considered and, where possible, adopted, regardless of definitional classifications.

SRR Organization and Support

SRR activities require operational, intellectual, and participatory input. As a result, the SRR organization has several tiers of involvement, comprised of SRR core staff, SRR Steering Committee, aforementioned working groups, criterion groups, and participants (see below). The core staff, which consists of John Mitchell, Tom Bartlett, Kristie Maczko, and Helen Rowe, handle daily operations such as: finances and travel arrangements, meeting organization, coordination of participant efforts, and communications. The seven-person SRR Steering Committee meets between and immediately prior to SRR meetings to determine the group's general direction and identify milestones. This committee also finalizes the agenda proposed by the staff and facilitator; reviews and plans outreach efforts; and insures that participants continue to represent a wide range of interests and organizations. Steering Committee members include the co-chairs, Alison Hill and Larry Bryant of USDA Forest Service, Tim Reuwsaat of DOI Bureau of Land Management, Paul Geissler of USDI-USGS, and Evert Byington of USDA Agricultural Research Service. Additionally, the core staff and facilitator serve as ex-officio members.

Clearly, the participants are the most important components of the SRR structure. Organizations currently represented include: the USDA-FS, NRCS, USGS, ERS and ARS; the DOI-BLM, BIA, FWS, NPS, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, sixteen accredited universities, and eighteen local, state and national organizations. The latter range from professional groups such as SRM, Conservation Biology, and ESA, to producer groups such as the National Cattlemen's Beef Association, and conservation groups including the National Wildlife Federation and the Idaho Conservation League. Most participants attend numerous meetings, as schedules permit, with many attending all five SRR meetings, to date. Other participants represent groups that are active near SRR meeting locations. These individuals may attend only a single meeting, but add fresh perspectives to SRR's discussions and efforts; some ask to become regular participants. It is important to note that while most participants have been invited to attend meetings, the SRR is open to all those interested in sustainable rangeland management.

SRR attempts to subsidize travel expenses of all non-federal participants, but local participants typically do not require travel reimbursement. Additionally, SRR pays the salary of one staff member and time for one of the co-chairs. Funds to support SRR activities have come from several agencies, including USDA-Forest Service, USDI-Bureau of Land Management and the U.S. Geological Survey. Colorado State University also has contributed faculty and support staff, as has the Rocky Mountain Research Station of the Forest Service.

However, as previously stated, the most significant support has come from SRR participants. Depending on meeting location and requisite travel time, many individuals devote two to four days of effort to each meeting attended. Participants also contribute time and effort between meetings through the aforementioned Collaborative Delphi process, as well as through tasks assigned by working groups and criterion groups.

Time Line and Products

At its inception, the SRR effort was designed to adhere to a schedule that would allow it to make substantive contributions to a federal land status report in 2003. With that deadline in mind, the SRR held four meetings in 2001. One meeting has occurred during this calendar year, and others are scheduled in March, May, July and October of 2002. Three meetings also are tentatively scheduled in 2003.

In addition to regularly scheduled regional meetings, external review and professional feedback will also contribute to broad acceptance and adoption of SRR C&I. The SRM symposium is the SRR's first reporting effort, intended to inform rangeland professionals of ongoing SRR efforts and future plans. Similarly, a workshop proposal has been submitted for the ESA annual meeting, scheduled for August 2002. It is anticipated that the SRR will have a semi-complete set of draft indicators at that time, thus presentations are designed to solicit critical input from a wide sampling of stakeholders interested in rangelands sustainability. Ideally, the ESA Workshop will provide an opportunity for small group discussion of ecological related C&I, as well as a thorough evaluation of SRR indicator designation efforts.

Such focused critiques will contribute to the formal SRR report, due to be finalized early in 2003. Collaboration with other groups working on indicator sets - the Roundtable on Sustainable Forests, the

Sustainable Minerals and Energy Roundtable, the Heinz Group, The Nature Conservancy, the EPA, and the President's Council on Sustainable Development - also will enhance progress toward a robust, useable, commonly accepted and shared set of indicators for measuring sustainability. More practically, the SRR report will assist agencies in their respective resource management efforts through recommendation of a framework for a first approximation of sustainable development as applicable to U.S. rangelands. The candidate framework is intended to complement the 2003 national report on sustainable forest management.

Criteria and Indicators

As described earlier in the context of SRR meeting processes, identification of rangeland sustainability issues and compatibility review of RSF's work, culminated in creation of five criteria groups within the SRR. Organization of indicator identification and definition efforts under these five criteria categories minimizes existence of areas of gaps and overlaps within indicator sets. These Criterion Groups are:

1. Maintenance of Productive Capacity on Rangeland Ecosystems
2. Maintenance of Ecological Health and Diversity of Rangelands
3. Conservation and maintenance of Soil and Water Resources of Rangelands
4. Maintenance and Enhancement of Multiple Economic and Social Benefits to Current and Future Generations
5. Legal, Institutional, and Economic Framework for Rangeland Conservation and Sustainable Management

The SRR overview paper and presentation, and the following Criterion Group summaries included in the symposium proceedings represent status reports on all aspects of the SRR. Additionally, SRR participants presenting papers are intimately involved with ongoing indicator development and would greatly appreciate your feedback. SRR staff and Steering Committee members also are available to receive comments pertaining to participation and process. Please feel free to contact us in person, by telephone, or electronically.

Lastly, symposium coordinators have prepared a one-page questionnaire that you are asked to complete and return at the conclusion of the presentations. As you offer input, please remember that the SRR effort is a work in progress.

For more information see the SRR web page (http://www.cnr.colostate.edu/RES/srr/index.html), or contact Tom Bartlett at 970-491-7256, et@cnr.colostate.edu or Helen Rowe at 970-491-3908, ivy@cnr.colostate.edu.

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The Roles and Importance of Sustainability Indicators

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Abstract

We like to believe that the better information we feed decision makers, the better decisions they will make. Policy makers will argue about what actions will and will not promote sustainability. We need to be able to measure the impacts of these decisions within a feedback loop. In order for these measures to be used, there needs to be wide support that the measures are appropriate to assess sustainability. If we can agree on indicators of sustainability, then we build common understanding. In 1993, we embarked on developing the Sustainable Development Indicators, a national report that would organize existing governmental data into a body that could be used to assess national sustainability. This effort drew upon the work done on the Montreal Criteria. For future generations to be at least as well off as the present, the key is sustaining resources. Underlying capacities of systems must be maintained and increased if we are to grow. There is a common desire to boil down sustainability into one measure, one indicator. It is impossible to capture the complexity of sustainability into just one indicator. Through indicator sets, we can organize information in such a way that promotes ongoing conversations in relevant policy arenas.

Introduction

Substantial efforts are being made to develop sustainability indicators for natural resource systems such as rangelands and for the nation as a whole. These efforts reflect the beliefs that sustainability is an important long-range goal and that a system of regularly published indicators that can be used to monitor conditions and to assess trends relevant to sustainability will provide an effective means for making progress toward sustainability. This paper summarizes the history and concepts of sustainability and sustainable development. It then discusses the ways in which a system of sustainability indicators can be particularly useful in promoting sustainable development in America's multi-centric political and economic systems. Next it discusses the variety of roles and contexts in which sustainability indicators can be used including on-the-ground management, policy development, and social learning.

History and Concepts

Over the last 20 years, sustainability, achieved through sustainable development, has emerged as an important goal. In 1987, the Brundtland Commission Report, "Our Common Future," put forward the general concept of sustainable development that has become most widely accepted. It described sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

The commitment to maintaining opportunities for future generations is a central theme of sustainable development. The integration of the economic, environmental, and social realms is also an important theme. If we want future generations to have the same or better opportunities as present generations, then it is important that current efforts to progress in one realm not cause long run declines or unexpected collapses in other realms.

Sustainable development was the organizing theme for the U.N. Conference on Environment and Development in Rio de Janeiro in 1992 at which many countries adopted Agenda 21 as the basis for efforts to implement the concept (UNCD 1992). Sustainable development will, of course, be the theme for the World Summit on Sustainable Development in Johannesburg in September 2002.

The Matter of Definitions.

No paper on sustainability would be complete without an attempt to say what it means. Most generally, sustainability of large complex systems is a dynamic condition that enables them to endure for an extended period of time. The biosphere provides the best example of a system that has achieved this type of sustainability. In the context of human economic and social systems and their interactions within the biosphere, sustainability is the condition under which the patterns of interaction and the resulting satisfaction of human needs and wants can endure from generation to generation. In other words, sustainability is the condition achieved when our economic, environmental and social systems are operating in a manner that yields constant or

increasing human well being over the long run. This anthropocentric version of sustainability encompasses the sustainability of the biosphere on which the human population depends.

Indicators, for the purposes of this paper, are taken to be statistical measures of observed phenomena, or classes of phenomena, regularly published, and organized in ways that make them more understandable and more accessible than the data from which they are derived. Indicators are not one-time events or measurements and they are not forecasts or projections. They show past trends leading up to the present.

Roles of Sustainability Indicators in the American Context

Many are concerned that the burdens being placed on the biosphere by a large and growing human population threaten sustainability and portend declines in human well-being in the 21st century. Yet, it also seems possible that, through sustainable development incorporating new technologies, new management techniques, and new ways of living, we may achieve a transition to sustainability with high levels of well-being for astonishingly large numbers of people. The premise of this paper is that the ways in which we create, organize and use information on the consequences of human activity will play an important role in the processes of sustainable development through which we may be able to achieve this possibility.

A frequently heard justification for developing indicators is that they will be used by "decision makers," yielding better decisions, decisions that are more effective at promoting sustainability. It is often assumed that such decision makers are politicians, high level public officials or corporate executives who, because of their positions, make decisions affecting the behavior of large numbers of people and the uses of significant amounts of resources. Clearly, advocates of sustainable development hope that high level decision making becomes more "sustainable." And most people who work to produce information and develop indicators certainly hope that their efforts will improve decision making. In the American economic and political context, however, sustainability indicators can play a much broader role and achieve much greater importance.

To much of the world, sustainable development is a paradigm that relies heavily on central decision making, whether in the developing countries or in the social democracies of Europe. In the United States, however, our economic and political systems are multi-centric. We rely upon a mix of decentralized decision making, in households and small businesses, in communities and state governments, and centralized functions in the Federal government and large corporations. Even our "central" institutions exhibit many characteristics of decentralized decision making.

Thus, for sustainable development to occur most effectively in the United States, it will need to occur through decisions at many levels throughout our economic and political system. It will need to occur through on-the-ground management, through middle management, and through high-level government policy and corporate investment decisions. It will need to occur through management that affects production of commodities, goods, and services, and through the decisions we all make in our daily lives that affect the what and how of consumption and post consumption recycling or disposal of "waste."

Consequently, the importance of sustainability indicators is greater than is suggested by the mere hope that they will better inform high-level decision making. In a multi-centric economic and political system, information instead of plans and commands allows effective and coordinated choices to be made at many different levels. In our democracy, informed citizens use information in many contexts to exercise their freedoms and meet their responsibilities. In our markets, firms and consumers use information to make decisions that affect how resources are used in producing the goods and services we use.

Moreover, because sustainability is a new and overarching paradigm, successful sustainable development in the United States requires the emergence of a widespread understanding of the concept, its practical implications, and the consequences of a failure to make the transition to sustainability. Broad public acceptance of sustainability as a basis for decisions at all levels can legitimize and support the new kinds of actions that are needed to achieve sustainability. High-level decisions that are unacceptable to large numbers of people in the United States tend to be few and ineffective because of the many countervailing forces and processes within our multi-centric system. Actions that are understood and accepted by the public, however, tend to be repeated and strengthened.

Sustainability indicators are an important way to promote sustainability through the actions of well-informed citizens as they participate in our democracy and the economy. Thus, an important role of sustainability indicators is that they can be regularly broadcast to the public along with concise explanations, stories that tell people what has caused the conditions and trends the indicators portray. Consistent, regular reporting of sustainability indicators can contribute to a better, more widely shared understanding of the concept of sustainability and of the general causal relationships that affect its achievement.

The Roles of the Indicator Selection and Development Process

People who have been involved in the indicator development process, such as those participating in the Sustainable Rangelands Roundtable (SRR), sometimes feel some frustration at the seemingly endless discussion of what sustainability means and how to measure it. The participants include managers, scientists, and interested citizens. Because of the diversity of views and values among participants, the discourse often digresses into debates about what constitutes the good life, now and for our grandchildren. While it often seems that this delays progress in selecting indicators, in fact, it is an important benefit of the process.

The discussions inherent in the indicator development process contribute to a more broadly shared understanding of sustainability and of the human needs and wants our resources help satisfy. Maureen Hart, a consultant to many community sustainable development efforts, has as her motto, "We are what we measure. We need to measure what we want to be." I have suggested a somewhat more complex version: "We are more likely to become what we can agree to measure. We need to agree on what we want to become." Developing a broader consensus that we want to become a sustainable society and a broader, more specific agreement about what that means is an important part of the indicator development process.

Uses of Sustainability Indicators

Sustainability indicators can be used in a variety of ways in the decision contexts described above. One way is by analogy to the ways information is used in the delivery of medical care. A second can be drawn from the literature on policy and management processes. A third view of the uses of indicators can be developed from work on social values and objectives.

A Medical Analogy

A medical analogy is useful for understanding the different roles of information in our society. Information is used in four stages in the delivery of medical care:

1. Assessment
2. Diagnosis
3. Prescription
4. Treatment

Different types of information have different costs and contribute differently to what is useful to know at each stage. Thus, the type of information used in each stage tends to be different. We can illustrate how this applies to sustainable resource management by exploring the roles of information in the health care process.

A health assessment is designed to determine whether a patient has any health problems that need to be treated. Doctors use a relatively small set of indicators in a health assessment: vital signs and a few standard laboratory tests such as blood counts and cholesterol levels. Most of the information from a health assessment is used to determine whether the patient's various systems are functioning normally, whether they have the capacity to maintain life. If key indicators are outside of normal range, the result of the assessment is the conclusion that a problem may exist. Assessment is often a problem identification process. A health assessment also helps the doctor develop a shared understanding with the patient that legitimises further investigation leading to a diagnosis.

The information typically used in a health assessment has been selected on the basis of well-known relationships between a wide variety of diseases and a few easily measurable parameters. The information used in assessments usually does not reflect the specific cause and effect relationships of all diseases. Assessment indicators generally do not show the precise nature of the problem and its cause. They merely indicate whether or not a problem exists.

In the diagnostic phase, specific tests are used to determine the nature of the problem and its cause. The selection of diagnostic information is based on specific knowledge of the cause and effect relationships among symptoms, diseases and their causes. Diagnosis is a puzzle solving process, but as is the case with health assessment indicators, diagnostic information is also used to convince the patient to undergo treatment. An important role of diagnostic information is to legitimize treatment.

Once a diagnosis has been made, a treatment is prescribed. This involves the design of actions to be taken and a decision to take them based on the expected consequences. The prescription of treatment is based on information about future outcomes whereas assessment and diagnosis are based on information about the patient's current and past conditions. Information is also used in the treatment phase. Some information is needed to implement the treatment. Other information is needed to monitor its effects. Monitoring of the patient's progress sometimes shows that the prescribed treatment has failed, leading to a new cycle of diagnosis and prescription.

Sustainable resource management is analogous to health care in a number of ways. Sustainability indicators can be structured for use in assessment, diagnosis or monitoring treatment. At each stage, they can be used to legitimize the next step.

The Policy and Management Cycle

The use of performance indicators within a management organization is often described as a part of an adaptive cycle as shown in Figure 1. Monitoring is a key source of information used in measuring performance in management organizations. Performance indicators provide accountability, but they also promote the evolution of management practices that are more effective at achieving the goals and objectives of the organization. They provide the feedback that allows reviews by on-the-ground managers, by mid-level managers, and by policy-level decision makers. At each stage, indicators can be used to determine from the observed consequences, what works and what doesn't. Information feedbacks help shape the evolution of policies and management practices to better achieve goals and objectives. Adaptive management processes help our organizations to repeat what works and drop what doesn't.

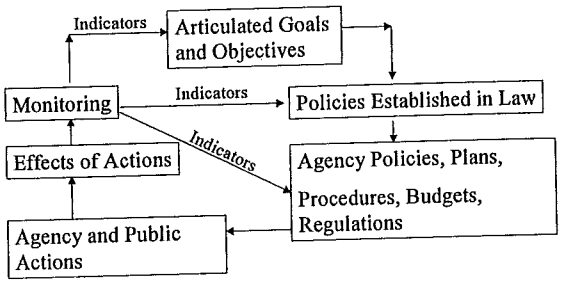

Figure 1. Use of Indicators in the Policy Cycle

Social Learning and Changing Societal Objectives

A similar evolutionary process occurs through the use of indicators by broader segments of the public. At this level, indicators are used by a variety of interested parties (often called stakeholders) in the public discourse that articulates the values, goals and objectives to be pursued in American society. Although basic values and fundamental goals are very slow to change, objectives, particularly those related to the means of achieving fundamental goals, change more rapidly. For example, the objectives of natural resource management change as people come to share a better understanding of resource conditions and the factors that cause them. In this process, indicators can be viewed as important contributors to social learning. As the public's understanding changes, people espouse new objectives for management organizations at all levels.

Figure 2 illustrates how information feedbacks affect society's objectives. It takes Underlying Human Nature as its starting place. This includes values inherent in, and common to, all humans. Next is the shared values in a society that flow from human nature, but are affected by the society's culture. These values differ among the individuals in a society, but are held by many. People have values about both the ends to be achieved in life and about the means through which they are to be achieved.

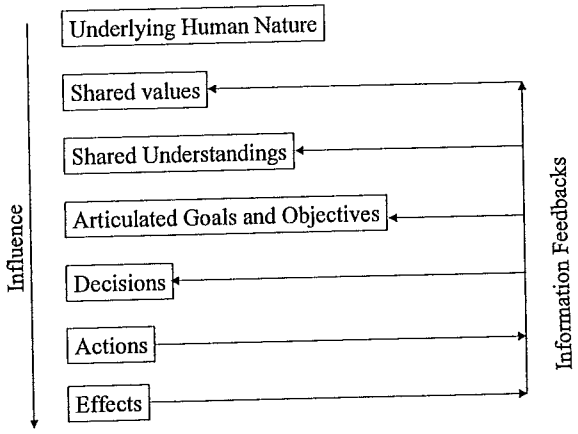

Figure 2. Information Feedback in Social Learning

The people in a society also have shared understandings about conditions and causal relationships. They have views about "how the world works" that include social and economic systems and the environment. People interact through a variety of social, political and economic processes in ways that articulate the goals and objectives in a society. Articulated goals and objectives tend to affect decisions and actions at many levels.

In the policy realm, the societal goals and objectives that emerge from the social learning process are often manifested in laws. For example, a number of the Federal laws affecting rangeland management have emerged from the social learning process in the past: The Federal Land Policy and Management Act, The National Forest Management Act, and The Resources Planning Act.

The downward arrow on the left of Figure 2 represents processes that influence objectives and the upward arrow on the right represents information feedbacks. In our social and political processes, information includes formal information such as indicators along with many forms of informal information.

Sustainable development can usefully be seen as a major transformation in human behavior patterns to be achieved through social learning. Shared understandings of conditions and causal

relationships are an important manifestation of the social learning process. Information, particularly well organized, relevant, well communicated formal information such as regularly reported indicators, can make an important contribution to social learning by promoting more widespread understanding.

Through social learning, people come to share changed and more effective understandings of conditions and causal relationships as realistic information feedbacks reinforce those understandings. This leads to actions that are more effective at achieving goals and objectives. Science formalizes much of the process of social learning, but does not, in itself, promote changes in understandings among non-scientists. The social learning process is assisted by science, but it occurs largely outside of the community of scientists through education and a variety of formal and informal communications processes.

A transition to long-run sustainability is not likely to be achieved merely by changing the formal information used by decision makers in federal agencies. It will also require the use of information to promote social learning, the gradual change in the values and understandings shared widely within our society and the objectives that become articulated to guide federal agencies.

This suggests that an important aspect of indicator development is the design of the means by which relevant information can be effectively communicated to millions of people, means by which they come to understand more realistically the current conditions and situations as well as the cause and effect relationships that are key to improving them.

Toward a National System of Sustainability Indicators

Several efforts are making it possible to develop a national system that will assemble information relevant to sustainability and provide access to the portions of that information that are suitable for use at different scales and in different contexts. In the long run, it may be possible to develop and report on a set of indicators at the national to local scales for governments, businesses, and individuals that are based on consistent measures. The sort of consistency that has been achieved in economic measurement, reporting, and indicators may eventually emerge in the environmental and social realms as well. The work of the Interagency Working Group on Sustainable Development Indicators (the SDI Group) can serve as an integrating framework, an umbrella under which the work of the SRR and the other Sustainable Resources Roundtables can be brought together along with indicators for other aspects of the economic, environmental and social realms.

The SDI Group began its efforts in 1994 to develop sustainability indicators that could be applied at the national level. In 1998, it published a report setting forth a framework for organizing indicators and a set of 40 experimental indicators covering the economic, environmental and social realms (IWGSDI 1998, also see www.sdi.gov).

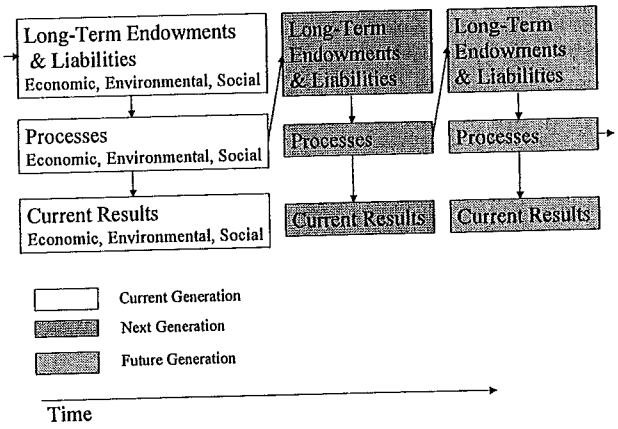

Figure 3. Sustainable development indicator framework.

The SDI Group's framework is shown in Figure 3. It was based on the Brundtland Commission concept of sustainable development, the Pressure-State-Response Framework being used for environmental indicator development in Canada, the Netherlands, OECD and the U.S. EPA, and the capital maintenance approach being developed by the World Bank and others. The SDI Group framework distinguishes three categories of indicators:

- Endowments, including productive capacities, stocks, capital assets.
- Processes, including particularly Driving Forces that cause changes in Endowments.
- Current Outputs and Results, including the goods and services humans use and the resulting satisfaction of human needs and wants.

The Endowment category contains indicators that facilitate sustainability assessment by focusing on measures of the productive capacities. The SDI Group chose the term "endowment" because it conveys the concepts of stewardship and trusteeship. Table 1 shows the Endowment indicators that were included in the experimental set of 40. Indicators in the Endowment category will facilitate assessments based on the capital maintenance approach. Declines in our Endowments would suggest that we are not passing sufficient opportunities along to future generations.

Driving Forces are processes that cause increases or decreases in Endowments. They build up or draw down stocks, capacities and capital. Driving Forces include many activities that are the focus of economic or resource management such as investment and environmental restoration. They also include pressures on environmental endowments such as pollution discharges and landscape alteration. Table 2 shows the Driving Force indicators included in the experimental set of 40. Indicators of Driving Forces can be used to assess sustainability by focusing on changes in endowments rather than the total capacities of endowments. For many aspects of our natural endowments, it is easier to get data on changes than on total capacity. If increases in Endowments are greater than decreases, it suggests that we are passing more capacity along to future generations than was passed to us by previous generations.

Current Outputs and Results indicators measure the goods and services produced in the current period and the extent to which their use satisfies human needs and wants. Table 3 shows the indicators included in the SDI Group's experimental set. Current Outputs and Results indicators are the most widely available and widely used, but are less useful in assessments of sustainability because it is possible to achieve high levels of output over a limited period at the expense of long run sustainability. Nevertheless, this category of indicators is useful for assessing how well we are meeting the needs and wants of the current generation. Long-run declines in Current Outputs and Results indicators would suggest the possibility of underlying sustainability problems.

The focus on Endowments in the SDI Group's framework is generally consistent with the approach evident in the Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests, often called the Montreal Criteria and Indicators for short (see Journal of Forestry, Vol. 93, No. 4 April 1995). Most of the seven criteria call for maintenance of capacities or other valued attributes of forest ecosystems. As a result, many of the 67 indicators could be included in either the Endowment or Driving Force categories of the SDI Group's framework.

The SRR is not using the SDI Group's framework nor is it following exactly the approach of the Sustainable Forest Criteria and Indicators. It appears, however, that there will be a substantial focus on the productive capacities and other valued attributes of rangelands and on the factors that cause them to change. This will make it possible for indicators selected by the SRR to be incorporated into the national framework. Thus, the work of the SRR will not only make indicators available for assessments focused on rangelands at various scales and in various contexts. It will also contribute rangeland indicators that can be used, along with those emerging in the parallel efforts on Forestlands, Minerals and Energy, and Water Resources, in sustainability assessments at the national level.

Table 1. Long Term Endowments & Liabilities

Economic	Environmental	Social
Capital Assets	Surface Water Quality	U.S. Population
Labor Productivity	Acres of Major Terrestrial Ecosystems	Children Living in Families with Only One Parent Present
Federal Debt to GDP Ratio	Contaminants in Biota	Teacher Training Level and Application of Qualifications
	Quantity of Spent Nuclear Fuel	
	Status of Stratospheric Ozone	
	Greenhouse Climate Response Index	

Table 2. Processes – Driving Forces

Economic	Environmental	Social
Energy Consumption (per Capita and per $ of GDP)	Ratio of Renewable Water Supply to Withdrawals	Contributing Time & Money to Charities
Materials Consumption (per Capita and per $ of GDP)	Fisheries Utilization	Births to Single Mothers
Inflation	Invasive Alien Species	Educational Attainment by Level
Investment in R&D (% of GDP)	Conversion of Cropland to Other Uses	Participation in the Arts & Recreation
	Soil Erosion Rates	People in Census Tracts with 40% or Greater Poverty
	Timber Growth to Removals Balance	
	Greenhouse Gas Emissions	
	Identification & Management of Superfund Sites	

Table 3. Current Outputs and Results

Economic	Environmental	Social
Domestic Product	Metropolitan Air Quality Non-attainment	Crime Rate
Income distribution	Outdoor Recreational Activities	Life Expectancy at Birth
Consumption Expenditures Per Capita		Educational Achievement Rates
Unemployment		
Homeownership Rats		
% of Households in Problem Housing		

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Value of Sustainability Indicators for Rangeland Management and Policy

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Abstract

The process we are currently using to develop criteria and indicators to measure rangeland sustainability involves a diverse group of individuals representing a wide-spectrum of values and interests. It is a cooperative process that incorporates ecological, social, and economic facets of rangelands. Agencies need to be able to provide a comprehensive and common language that is nationally consistent. This information is important to make decisions at the national policy level and for outlining resource management priorities. It will also: 1) lead to improved efficiencies by focusing measurements on what has been agreed to, 2) understanding the connection to what is measured and overall rangeland sustainability, 3) improve our accountability to the public, Congress, and other partners, 4) build a foundation of common understanding which will improve the debate on the management of our nation's rangelands.

Introduction

Currently it is difficult, if not impossible, to assimilate all the economic, social, and ecological information on the state of our Nation's rangelands. This is because of:

- Differing jurisdictions.
- Differing laws affecting those jurisdictions enacted at different times.
- Differing uses on different areas of the rangelands.
- Differing societal values.
- Differing scales.
- Changes over time (ecological, societal, economic).
- Data collections costs & budgets not always equal nor stable.

The result has led to some confusion and frustration on the public's part and, over time, a variety of policies by the different Federal agencies. If agencies were able to provide comprehensive, easily understood, and nationally consistent information on the social, economic and ecological status of rangelands, then comparisons could be made on a spatial and temporal basis. Accordingly, decision makers at the national level would have much better information with which to develop sound policy.

Indicators

Indicators for rangelands are objective and verifiable measurements that provide information about the criteria to which they pertain to help determine the economic, social and ecological status of the Nation's rangelands. Indicators should be value neutral, that is, the outcome of what we are measuring should not lend itself to any particular individual value. It should be noted, however, that we as individuals will interpret these measurements differently, each of us placing our own held values against this interpretation.

For instance, let's say indicators are colors. In general, we can all agree that blue is blue, red is red, and yellow is yellow. However, if we were each to paint a picture of the same object using these colors, we would probably mix them differently giving more weight to certain colors; thus, each of our pictures would look different. Given the opportunity, most of us will choose our own object to paint, but we all rely on the same basic colors.

As each of us use different sustainability indicators, similar to using the different colors as described above, we will mix them differently, and reach different conclusions. Just as individuals have held values, so do groups. Groups of people with a set of similar values range from a youth baseball team to a political party. This means that the interpretations of rangeland indicators may be different and therefore conclusions of what is sustainable on the rangelands may also be different when changes in administrations occur every four or eight years. What is foremost to the concept of using criteria and indicators to assess sustainability is the agreement among people and groups holding different values that these variables all deserve consideration when making evaluations or reaching conclusions.

Examples of Policy Change

Let's examine a few examples of policy changes. An indicator of production is *acreage of lands available for livestock grazing*. This acreage is decreasing over time. If we looked at only this one indicator, resulting policy options might be to de-emphasize the grazing program and perhaps shift dollars to other programs. Other potential policy changes might be opening more acreage to grazing through land use planning or reducing fees paid to graze livestock to stimulate the demand.

Let's look at another indicator in addition to a livestock grazing indicator. This ecological indicator is *acres of weeds occupying rangelands*. Over time, this has been increasing dramatically. A potential resulting policy is more dollars directed towards weed control and eradication, which results in native forage plant increases and increased livestock production over the long-term. The policy options indicated in the previous paragraph would not be necessary.

Now, let's consider a social indicator, which measures *accessibility to rangelands for a variety of uses*. Examination of this indicator finds that accessibility to public rangelands restricts livestock use due to land ownership patterns. This situation could trigger a policy to focus on land exchanges to realign lands ownership patterns and/or emphasize right-of-way and easement acquisition. When coupled with the second indicator above, weed control could be targeted to those areas being retained or acquired.

As illustrated, the resulting policies from the scenarios described above are dependent on which indicators are considered and in what combination. From the examples, it is demonstrated that, as we look at different indicators from the economic, social, and ecological criteria, our concept of what it takes to ensure rangeland sustainability changes and, along with it, what policy changes are needed. Therefore, it should be apparent that a comprehensive set of indicators can provide a great value to policy makers.

Other Important Uses of Indicators

In addition to the examples above which show how indicators could be used to modify policies, a common set of indicators can also improve efficiencies by federal and state land management agencies and other organizations interested in rangelands. These efficiencies would be accomplished by:

- Monitoring only what has been identified as important.
- Providing for the development of common techniques to avoid redundancy.
- Allowing agencies, universities, and organizations to focus research on developing accepted methodologies and protocols to measure these ecological, economic, and social indicators.
- Helping establish national workload priorities to those areas most at risk or in need of restoration. This could provide a basis for recommending funding for new appropriations or shifts in funding among agencies and departments.

In addition, a common set of indicators will improve accountability to our partners, stakeholders and Congress by:

- Setting the stage for multi-level coordinated data reporting which improves accountability.
- Helping to determine compliance with applicable laws. For instance, if an indicator was *number of watersheds with impaired waters*, and over time this number was decreasing, such a trend would indicate compliance with the Clean Water Act.
- Most importantly, criteria and indicators developed by a diverse group of individuals representing a wide spectrum values will provide for understanding the sustainability of rangelands now and in the future. Doing so will improve the debate on the management of rangelands.

Summary

Once the indicators are identified and information collected, the effects of current management strategies can be determined, thus becoming the catalyst for new rangeland policies and management actions to sustain rangelands. We might disagree about the interpretation or the conclusions derived from the different indicators: however, the roundtable process should ensure that we won't be arguing about the indicators.

Partnership Efforts in the Sustainable Rangelands Roundtable

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Abstract

Various stakeholders derive values (economic, ecological, and social/cultural) from rangelands. To develop criteria and indicators for sustainable rangelands that will be acceptable to a range of stakeholders, the SRR was established as a partnership of scientists, ecologists, economists, sociologists, policy and legal experts, environmental advocates, and public and private rangeland managers. To increase awareness of and participation in the SRR and its activities, the SRR is distributing news items, maintaining a website, coordinating with other sustainable resource roundtables, conducting symposia and workshops, and providing the opportunity for local participants to sit in on SRR meetings in various locations around the country.

Introduction

Rangelands affect the quality of life of every person in the United States. Rangeland ecosystems account for approximately 40 percent of the lands in the United States, including Great Plains grasslands, savannas in Texas and Florida, shrublands in the Great Basin, Alaska tundra, alpine meadows, Southwestern deserts, and wetlands across the country. This diverse and dynamic natural resource provides numerous goods and services, such as:

- wildlife habitat;
- high quality water, clean air, and open spaces;
- natural carbon sequestration systems;
- habitat for threatened and endangered species;
- recreation;
- food and fiber production, including livestock grazing; and
- a setting for social and cultural activities.

These goods and services provide values (economic, ecological, and social/cultural) to a suite of stakeholders from those who live on and derive their livelihoods from rangelands to those who derive joy from the knowledge that these ecosystems continue to exist and flourish. Many of these stakeholders are very passionate in their perspectives on the values rangelands should provide and to whom. These passions have often advanced different values and goals, resulting in conflicts over rangeland use.

The Partnership Approach

The significance and diversity of the goods and services provided by rangeland ecosystems underscore the importance of ensuring that rangelands are sustained for current and future generations. Advancing the sustainability of rangelands uses and values necessitates the ability to measure economic, ecological, and social/cultural conditions of U.S. rangelands using criteria and indicators (C&I).

To develop C&I for sustainable rangelands that will be acceptable to the suite of stakeholders that derive values from rangelands, the Sustainable Rangelands Roundtable (SRR) must consider various perspectives. The SRR seeks to promote understanding and support for the C&I under discussion among diverse interest groups including private and public organizations and agencies involved in the use and conservation of U.S. rangeland ecosystems. Towards this end, the SRR was established as a partnership of rangeland scientists, ecologists, economists, sociologists, policy and legal experts, environmental advocates, industry representatives, and public and private land managers (Table 1). SRR participants have made a commitment to collaborate on the goal of identifying indicators of sustainability, based upon social, economic, and ecological factors, to provide a framework for national assessments of rangelands and rangeland use.

Participants contribute to the development of C&I through working meetings, through e-mail discussions, and through the Delphi Process. In

Table 1: Organizations Involved in the Sustainable Rangelands Roundtable

Government Agencies	Universities	Non-Governmental Organizations
USDI Bureau of Indian Affairs	Arizona State University	American Farm Bureau
USDI Bureau of Land Management	Bradley University	Ecological Society of America
Chippewa Cree Tribe	Colorado State University	Gray Ranch and Malpai Borderlands Group
Confederated Tribes of Warm Springs	Montana State University	The H. John Heinz Center for Science, Economics, and the Environment
USDI National Park Service	New Mexico State University	Idaho Conservation League
Oak Ridge National Laboratory	Oklahoma State University	Lady Bird Johnson Wildlife Center
Pacific Northwest National Laboratory	Oregon State University	National Association of Counties
San Antonio Water System	South Dakota State University	National Association of State Foresters
USDA Agricultural Research Service	Texas A&M University	National Audubon Society
USDA Economic Research Service	University of Arizona	National Cattlemen's Beef Association
USDA Natural Resources Conservation Service	University of California, Berkeley	National Public Lands Council
U.S. Department of Interior	University of Colorado	National Wildlife Federation
U.S. Environmental Protection Agency	University of Idaho	Quivera Coalition
U.S. Fish and Wildlife Service	University of Nevada	Society for Range Management
USDA Forest Service	Utah State University	The Nature Conservancy
U.S. Geological Survey	Washington State University	Welder Wildlife Foundation
Wyoming State Grazing Board		Western States Land Commissioners
		World Wildlife Fund

addition to providing their personal and professional expertise, SRR participants also act as liaisons between the SRR and the organizations they represent. Other interested parties receive meeting notes and updates on SRR activities.

SRR Outreach Activities

The SRR Outreach Working Group was formed to:

- advise the SRR Steering Committee on ways to recruit and communicate with non-participating organizations;
- direct/develop outreach materials for the SRR;
- coordinate with outreach groups in the Roundtable on Sustainable Forests, the Sustainable Minerals Roundtable, and the new Sustainable Water Roundtable;
- review outreach efforts for the SRR Steering Committee; and
- maintain the momentum of the SRR.

The SRR Outreach Working Group includes representatives from Federal agencies, academia, non-governmental organizations, and industry.

To increase knowledge and understanding about the SRR and its activities, the Outreach Working Group helped develop a news item that announced the formation of the SRR and described its goals. This news item was sent to a number of relevant scientific societies, environmental organizations, and industry groups. Articles appeared in newsletters of the Society for Range Management, the Ecological Society of America, the Society for Conservation Biology, and others. In addition the story was posted to several listserves to increase its distribution. The news item was the first in a series that will hopefully provide updates on future SRR activities.

The SRR maintains a website (http://www.cnr.colostate.edu/RES/srr) which provides an introduction to the SRR, its mission and vision. The website is regularly updated with meeting notes and notices of upcoming meetings. It also has a place for stakeholders to contribute their ideas and comments. The initial question asked in the "Your Input" section was, "What is your one greatest concern about the state of U.S. rangelands?" Respondents have offered ideas regarding water quality and the complexity of rangeland ecosystems. The current question addresses the challenge of developing meaningful indicators on a national scale by asking for examples of relevant indicators used successfully on rangelands, shrublands, or grasslands.

Another way of increasing the understanding of and input to the SRR is through symposia, workshops, discussions, and presentations. For the Society of Range Management 2002 Annual Meeting, the SRR organized a symposium on "Sustainable Rangeland Management: Status of a Roundtable to Determine Criteria and Indicators."

The objective of this symposium is to inform SRM members and the rangeland science and management community of the SRR, its vision, mission, process, progress, and plans. To elicit input from symposium participants, a response questionnaire was developed and distributed at the symposium. Proceedings from the symposium will also be made available electronically to reach a larger audience. The SRR has submitted a proposal to hold a workshop in conjunction with the 2002 joint meeting of the Ecological Society of America and the Society for Ecological Restoration. This workshop will provide participants with a chance to become acquainted with the SRR, it vision, mission, process, progress, and plans, as well as allowing them to participate in small group work on developing C&I.

The SRR also participates in the Sustainable Natural Resources Roundtable Coordination Network (SNRRCN), a loosely-knit organization to provide coordination among the various natural resource sustainability roundtables. Through SNRRCN, the SRR hopes to be able to effectively coordinate and communicate with the other sustainable resource roundtables—the Sustainable Minerals and Energy Roundtable (http://www.mackay.unr.edu/smr/), the Roundtable on Sustainable Forests (http://www.sustainableforests.net/) and the newly-formed Sustainable Water Resources Roundtable.

The SRR provides the opportunity for local participants to participate in SRR meetings at various locations around the United States. Meetings have been held in Denver, Salt Lake City, Reno, San Antonio, and Tucson. At each meeting, 8 to 15 new participants have joined in SRR discussions, some only for that meeting. Others have continued their involvement through the listserves, Delphi Process, and other meetings. Future meetings will be held in Denver (March 2002), Washington, DC (May 2002), Billings (July 2002), and San Diego (November 2002).

Through these outreach efforts and the communication links that the SRR participants provide to their organizations, the SRR hopes to fully inform and encourage input from stakeholders. In this way, we can develop a partnership of individuals and organizations that consider U.S. rangelands valuable.

Sustainability Research for Rangelands

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Abstract

In the past, rangeland sustainability research and reporting focused upon condition and trend of range sites. Patterns like condition and trend estimated at local scales cannot be aggregated to the national level because processes existing at small scales often have no meaning at large scales. Scale refers to the extent relative to the grain of a variable within a space-time framework, and it is fundamental to hierarchy theory. Extent and grain limit the degree of data aggregation within nested hierarchies; aggregation in non-nested hierarchies is more difficult because the data do not capture the emergent properties of the broader system. SRM, the Ecological Society of America (ESA), and the Forest Service have led activities over the past decade to evaluate the scientific basis for sustainability. The ESA Sustainable Biosphere Initiative, begun in 1991, called for increased fundamental research in global change, biological diversity, and sustainability of ecological systems. ESA also conducted two forums on science and sustainability that underscored essential linkages among physical, biological, and socioeconomic systems, along with need to interface science and policy, in assessing sustainability. In 1993, the SRM Research Affairs Committee sponsored a symposium on research strategies for providing sustainability to a nation's rangelands. Among the goals enumerated in the symposium was the necessity to better understand societal values in relation to rangelands. The Rocky Mountain Research Station undertook an analysis of the 67 indicators of sustainable development of temperate forests included in the Montreal Process, and found most to be applicable to rangelands.

Introduction

The status of rangelands in the United States has long been of interest to the Congress and American people. Until two decades ago, however, perceptions of rangeland sustainability focused primarily upon range condition in relation to livestock grazing. Early scientists had documented that plant succession was an indicator of misuse (Sampson 1919), but a monitoring framework was not in place to document sustainable management. By 1934, our country was facing a grazing crisis on the public domain caused by drought, the depression, and conflicts between sheep and cattle interests that led to the first assessment of its rangelands. This assessment found that much of the U.S. public rangeland base outside of Forest Reserves, especially in the Southwest, was being persistently overgrazed. Nearly 600 million acres were estimated to be excessively eroding, thereby reducing soil productivity and watershed function. Nonetheless, the report stated that 99 percent of the western rangeland was "available" for livestock grazing (Secretary of Agriculture 1936). Three decades later, the Public Land Law Review Commission documented our country's continued interest in viewing rangeland use and sustainability primarily in terms of maximizing livestock grazing (Public Land Law Review Commission 1970).

In recent years, federal land management agencies and other organizations have started considering sustainability in terms of both amenity and commodity resources, involving ecological, economic, and social measures at multiple scales. This shift became socially acceptable, in part, when research demonstrated that future increases in demand for red meat could be largely met by private forage sources (Joyce 1989). At the same time, social scientists began to show how a region's sustainability must be linked to "communities of place" and the human, social, natural, and financial capital needed by these communities (Flora 1999).

The 1992 United Nations Conference on Environment and Development, held in Rio de Janeiro, first formalized the joint importance of environmental protection and economic and social development for achieving sustainability at a national scale (Johnson 1993). Specific criteria and indicators (C&I), founded on this triad, have been accepted for temperate and boreal forests through the Montreal Process (Coulombe 1995). C&I for rangelands are now being developed by the Sustainable Rangeland Roundtable (SRR). The purpose of this paper is to describe the research

basis for discerning the sustainable management of U.S. rangelands.

Scale Issues

Dealing with issues of scale may be the central research-related problem associated with deriving C&I for sustainable rangeland management. When trying to incorporate multiple scales in relation to indicators of sustainability, it is important to understand principles of hierarchy theory. According to this theory, three important scale-dependent attributes of data are grain, extent, and frequency behavior. The threshold between the smallest discernable data features and those that are too small to be observed is known as the grain of an observation. For example, a 5-ha meadow cannot be distinguished using remotely sensed AVHRR data having a pixel size of 1 km². The threshold between the largest describable feature and those that are too big is called the extent of an observation. As Allen and Hoekstra (1992) said, "That is why one cannot conduct a full study of trees through a microscope."

The cycle time of unperturbed behavior of a system is directly related to its level of organization. Thus, there is a continuum of natural frequencies from the top to the bottom of a hierarchy (see Fig. 1). An example of different natural frequencies would be the rapidity in which ecological sites can change their successional status in comparison to the slow changes vegetation undergoes at a national scale (Mitchell 2000). Such theoretical bases for scaling and integrating ecology makes it difficult, if not infeasible, to aggregate hierarchies from local to national levels.

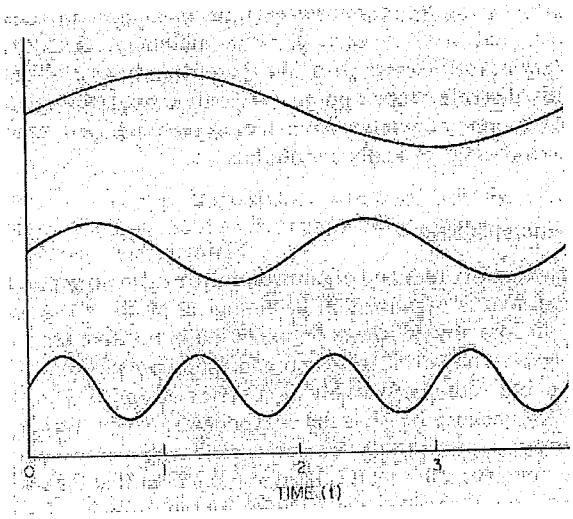

Figure 1. Relationship between systems scale and natural frequency distributions. Compare the relative changes of the lowest and highest scales between time 1 and time 3 (from Allen and Starr 1982).

Because of the importance of scale in developing and evaluating indicators of sustainable rangeland management, the SRR has created a Scale Working Group headed by Dr. Paul Geissler of the U.S. Geological Survey (see http://www.pwrc.usgs.gov/brd/srrscale.htm).

Biological Thresholds

Thresholds, or discontinuities, are manifested in a number of ecological indicators of forest and rangeland sustainability. The concept of thresholds declares that the state of an ecological system can change abruptly, and sometimes irreversibly, in response to a continuous and even change in some driving variable. Understanding threshold values adequately to relate them to sustainable management is difficult, at best, because of a number of uncertainties and limitations. Perhaps foremost, the delineation of a threshold depends upon the spatial and temporal scale in which it is considered (Levin 1992).

Ecological thresholds for ecosystem resilience and ecosystem function in response to biodiversity have been advanced by both theoreticians (May 1973) and scientists using empirical data (Tilman 1996). For example, the redundancy hypothesis maintains that ecosystems can lose a number of species because others will substitute for them as a result of niche overlap. However, at a certain point, the loss of another species can trigger a functional breakdown (Walker 1992). Tilman et al. (1997) later established that plant productivity and plant nitrogen are positively correlated with species diversity in a pattern consistent with this premise. A meta-analysis of 171 studies showed both non-linear and positive patterns between species richness and productivity to be more or less prevalent, depending upon scale (Mittelbach et al. 2001). However, no studies have verified a unmistakable discontinuity in ecosystem stability or function in relation to changing diversity, in part because the science of ecology is too complex to enable predictions of ecosystem-level outcomes of changing biodiversity. In addition, the idea of ecosystem resilience is imprecise as best, relating to two general concepts, the ability to recover to a pre-existing state following a disturbance and the ability to exist in the form of alternate ecosystem states (Grimm and Wissel 1997).

Ecosystem fragmentation has been studied at length in relation to biodiversity. Some authors have hypothesized a discontinuous correlation between these two variables, resulting in a threshold level of fragmentation, above which habitat suitability, and thus biodiversity, declines abruptly (Bascompte and Solé 1996).

Invasions by non-native plants are known to adversely affect both biodiversity and productive capacity at multiple scales (Vitousek et al. 1996). Whether a discontinuity or threshold mechanism applies to ecosystem responses to invasive species is not known; however, one would expect triggering nonlinear feedback mechanisms to be present (Gonzalez-Andujar and Hughes 2000). The interactions between alien annual grasses and fire constitute one well-documented altering ecosystem processes at local and, perhaps, regional levels (Young and Longland 1996). Their applicability to broader scales deserves investigation.

Sustainability as Expressed by Forms of Capital

In many ways, the concept of sustainable development and sustainable rangeland management at a national scale is tied to economic theory. Capital goods are entities existing in the present but which serve to provide a source of income or consumption opportunities in the future. In other words, capital has investment value. Capital has historically been considered in terms of goods and services having known market value, but recent advancements in ecological economics and sociology have led to consideration of other forms of capital, including natural capital and human/social capital (Flora 1999). Sustainability can be considered to be attained when the combination of all kinds of capital provide for the needs of present and future generations. An optimal level of sustainable development is achieved when no change in policy can make any group better off without causing another group to lose without just compensation, an economic condition called Pareto optimality. Regardless, one foundation of sustainability is that financial/built capital, natural capital, and human/community capital are all indispensable components.

The idea of substitutability represents a key provision for achieving and assessing the joint production of multiple forms of capital. A great deal of research has gone into both theoretical and applied aspects of substitutability. Collectively, economists have tended to stress the ability of markets to allocate resources efficiently, a process that requires a high degree of substitutability between natural and other forms of capital. Ecologists, alternatively, by and large contend that minimum thresholds of natural capital exist, and tradeoffs with financial/built capital become less and less feasible as risks of unsustainable, and potentially irreversible, outcomes from losing natural capital increase (Toman 1994). Unlimited substitutability is inclined to be viewed from an anthropocentric perspective while a total lack of substitutability is aligned with an ecocentric viewpoint. Some authors have called for those studying sustainable development to take a anthropogenic outlook, a more centrist condition where values of nature become overriding as they approach some minimum safe standard (Folke 1995). Thus, the notion of thresholds is not limited to biological criteria when it comes to considering sustainability.

Intergenerational equity comprises an crucial part of analyzing sustainability. The economics and social literature on this subject is long and complex, often including issues of fairness, ethics, and irreversibility. Authors have fiercely debated various discount rates and intergenerational social welfare functions (Vojnovic 1995). Ultimately, our understanding of equity is coupled to a hierarchy of social values and objectives, which in turn have purpose because of basic held values (Mitchell et al. 1995).

Previous Rangeland Sustainability Investigations

A number of research forums and reports concerning the sustainable management of rangelands have been conducted during the past decade. The Ecological Society of America's (ESA) Sustainable Biosphere Initiative (SBI) called for increases in basic research on sustainability of ecological systems to help improve the management of natural resources (Lubchenco et al. 1991). The SBI emphasized the importance of ecological knowledge in monitoring and evaluating ecosystems. It likewise recognized the importance of scale when it posed the same question facing the SRR Scale Working Group; that is, "How do patterns and processes at one spatial or temporal scale affect those at other scales?" Two national-level research items in the SBI are effects of changing land use patterns on ecological processes and feedbacks between ecosystem and atmospheric processes. Since it's establishment, SBI has served to fortify the link between science and policy through projects bringing together academics, agency representatives, local and tribal governments, and NGO's through various projects. Thus, ESA participation in the SRR falls logically within the purview of their SBI Project Office.

At least two forums on interrelations between environmental quality and economic growth have been published in *Ecological Applications*. The first forum (Ecological Applications 3:545-589), entitled "Science and Sustainability," was based upon a paper published in *Science* by Ludwig et al. (1993). Its contributors recognized that the term "sustainability" is not well understood, even though it has received a great deal of attention. What sustainability entails is the ability to manage ecosystems under uncertainty, while paying heed to

the linkages among physical, biological, and socioeconomic systems, as well as to the juncture between science and policy.

The second forum (Ecological Applications 6:12-32) was entitled "Economic growth and environmental quality." It, too, was prompted by a prior article in *Science*, one that examined feedbacks between measures of these two variables (Arrow et al. 1995). The conclusion that economic growth always leads to a country's environmental improvement was seen as inconsistent, at best. Ecologists do not commonly understand economic concepts like substitutability, but ecologists generally maintain that basic ecosystem services (natural capital), such as clean air and water, decomposition of wastes, etc., cannot be considered as substitutable. Several authors acknowledged difficulties associated with using thresholds as ecological indicators of carrying capacity and ecosystem resilience (see section above). Research was seen as needed to obtain models and other information upon which thresholds and limits could be based.

In 1993, the Society for Range Management (SRM) held a symposium sponsored by its Research Affairs Committee (Vavra 1995). The symposium examined research strategies for providing sustainability to U.S. and other rangelands. Speakers suggested that scientists need to build upon past successes and involve the public in forging new research programs. Participants identified six goals for future work: provide water, develop efficient and environmentally compatible livestock grazing systems, maintain/enhance riparian and wetland systems, develop vegetation management schemes that ensure ecosystem integrity, provide quality wildlife habitat, and understand the needs and direction of society in relation to rangelands. The symposium did not address scale issues or C&I for sustainability.

At about the same period, another SRM committee reported upon its work for evaluating rangeland sustainability at the management unit level (Task Group on Unity in Concepts and Terminology 1995). The Task Group concentrated upon the importance of soil as the basic resource, and sought agreement among land management agencies in defining ecological sites and site conservation ratings (sustainable and unsustainable). In doing so, it highlighted the importance given to thresholds in appraising ecological sustainability; in this case, site conservation thresholds of ground cover, below which unacceptable soil erosion rates will occur. Erosion has also been deemed as an important indicator of soil and water conservation at a national level; however, it will be much more complex to assess (unpublished SRR notes).

Applicability of Montreal Process C&I to Rangelands

A meeting of Rocky Mountain Research Station scientists was held in October 1997. Its goal was to advise the Station Director on the status of rangeland monitoring and priorities for future research on this subject. The participants recommended a mechanism for doing so that tied the need for new knowledge about rangeland monitoring to the issue of sustainable rangeland management. They reached this conclusion, in part, because the Forest Service had already adopted the seven Montreal Process criteria and 67 indicators as the means for assessing the sustainable management of forests at a national level. As a result of the meeting, the Station Director asked a group of scientists to prepare a series of papers, one for each criteria, examining the applicability of the Montreal Process C&I to rangelands. The papers addressed the following questions:

1. Are the indicators developed for assessing sustainability of temperate and boreal forests applicable for rangelands? If so, which ones are most critical?
2. Are approaches and data available to assess, monitor, and integrate the indicators?
3. What research is needed to implement the Montreal Process C&I on rangelands?

The papers were to be written for a refereed journal, in order that assumptions and conclusions contained therein would be subject to peer review. They were subsequently accepted by *The International Journal of Sustainable Development and World Ecology*. Papers covering the first five criteria were published in 2000, and the last two are in press (Appendix A).

In general, the authors found all seven Montreal Process criteria to be essential for evaluating rangeland sustainable management at a national scale. Many of the indicators were considered very important, while a number do not seem to apply to rangelands as they do to forests; for example, economic indicators dealing with production, consumption, and employment have surrogates among the other six criteria or they are not nearly as vital from a macroeconomics perspective as for forests.

A number of research obstacles were identified in the Montreal Process papers. Many definitions were seen as ambiguous. Data and methodologies were judged to be inadequate. Work to clarify definitions, design and validate monitoring systems, and test critical assumptions will be necessary to implement a comprehensive framework of rangeland indicators, according to most of the authors.

Sustainability Science: A New Discipline

An internet-based Forum on Science and Technology for Sustainability has been initiated. The Forum considers sustainability science to be an emerging discipline having a purpose of understanding the nature of interactions between nature (ecology) and society (social and economic factors). It grew from discussions at the Friibergh Workshop on Sustainability Science, held in Őrsundsbro, Sweden on 11-14 October 2000 and is now managed as an activity of the Initiative on Science and Technology for Sustainability (see http://sustsci.harvard.edu/). Like ESA's SBI, the Initiative has goals of expanding the role of science in considering and achieving sustainability, as well as improving the connection between science and policy.

The framers of the Forum have envisioned seven core questions that must be taken up under the banner of sustainability science (Kates et al. 2001). Four of these core questions directly apply to goals of the SRR. They are: What determines the vulnerability or resilience of the nature-society system in particular kinds of places and for particular types of ecosystems and human livelihoods? Can scientifically meaningful "limits" or boundaries be parameterized that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation? How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability? How can today's relatively independent activities of research planning, monitoring, assessment, and decision support be better integrated into systems for adaptive management and societal learning?

Conclusions

A number of common threads are woven among results from research directed at rangeland sustainable management. First, the concept of sustainable management or sustainable development is not precisely defined. However, broad agreement exists over its importance, and that the concept involves the confluence of biophysical, social, and economic elements.

Tenets of hierarchy theory are ingrained in sustainability research. Attributes and issues of scale have been a fundamental aspect of hierarchy theory. The scale of data, both spatially and temporally, must be consistent with the level and frequency dynamics of the system being monitored.

Understanding thresholds, although a key factor of several rangeland sustainability indicators, faces serious problems. The magnitude, sensitivity, and consequences of ecological and economic thresholds at a national scale are poorly understood.

Sustainability can be evaluated in the currency of human/social, natural, and financial/built capital. Taken collectively, assessments of sustainability will depend upon the values and perceptions of the beholder; therefore, no single "Dow Jones" of sustainable management can exist.

C&I for sustainable rangeland management fit within the larger R&D framework for monitoring rangelands by facilitating advances in national monitoring systems, thus promoting a feedback mechanism between monitoring and assessments.

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The "Collaborative" Delphi

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Abstract

Delphi is a method for the systematic solicitation and collation of informed judgments on a particular topic. Here, we introduce the "Collaborative" Delphi used as a conflict resolution and consensus building tool in the Sustainable Rangelands Roundtable (SRR). Traditionally the Delphi process involves a set of carefully designed sequential questionnaires interspersed with summarized feedback of responses. The Delphi strives towards consensus by obtaining opinion from a panel of experts and giving participants the opportunity to revise their opinion based on feedback from the group. The process is iterative and does not end until a pre-specified level of consensus is achieved. The Policy Delphi is issue or question driven; it strives to answer one question. In contrast, the Collaborative Delphi is process oriented; it works in conjunction with group meetings to develop consensus. The SRR can host only 4-5 meetings per year, but uses Delphi to make progress between meetings. We have found that the Collaborative Delphi has been an effective tool for establishing the range of differing positions, more clearly defining areas of agreement and conflicting opinion, and soliciting informed review of documents. Delphi allows for individual reflection on a subject and, because of its anonymous and written nature, gives voice to all concerns and opinions, even those wary of speaking at meetings. It has also been effective in keeping participants engaged in between meetings.

Introducing SRR

A cooperative effort to address issues associated with sustainable management and use of the United States' rangelands is being conducted by Colorado State University (CSU) in cooperation with several federal land management agencies. The Sustainable Rangelands Roundtable (SRR) is identifying a set of "Criteria and Indicators" (C&I), based on social, economic, and ecological factors. These C&I will provide a framework to assess rangeland sustainability in the United States. SRR is a multidisciplinary group, comprised of scientists, economists, sociologists, conservation groups, industry, state and local government representatives, and policy and legal experts.

At present, the United States lacks consistent, standardized indicators for assessing and reporting the status of rangelands. In the absence of an effective system for monitoring social, economic, and ecological aspects of rangeland ecosystems, measurement of progress toward sustainability remains difficult.

Thus, this country needs a national system of indicators for future assessment and planning. These C&I may help direct sampling protocols for national and regional monitoring systems like the National Resources Inventory. Ecological, social, economic, and legal indicators provide a framework for assessing the sustainability of the 240 million hectares of rangelands in the United States. Availability of such uniform information at a national scale would foster informed, sound decision-making relative to sustainable rangeland management in this country.

SRR was formally organized early in 2001 and is a multidisciplinary group that has gathered to identify C&I of sustainable rangeland management. Participants attend 4-5 meetings a year and contribute to the progress of a variety of working groups. They continue this work between meetings through communication with their indicator groups or with the group as a whole through a series of email surveys we call the "Collaborative" Delphi process.

The Delphi

The Delphi is a technique used for gathering and developing opinion. The process requires that, initially, experts be carefully selected. Once participants are chosen, the Delphi is an iterative process whereby questionnaires are sent out, individual responses are collated and returned to participants in the form of analysis and comments, and individuals are given the opportunity to revise their original answers in response to group feedback. In the conventional form, the Delphi process continues until a pre-determined level of consensus is achieved. In reality, the Delphi process tends to continue for three to four rounds (Turoff 1970, Crance 1987). Though it is important to let the group know that they are working with peers, individual anonymity is usually guaranteed. Delphi benefits include: increased participation by respondents who dislike speaking up in group situations for fear of saying something "stupid" or

contradicting superiors in public; the first round allows "fresh" input untainted by the opinions of others; and the process cannot be domineered by the few. The process allows one to freely change an opinion in response to group feedback without embarrassment. It is critical for the legitimacy of the survey that the design team remains unbiased and report the group summary as closely as possible to reflect individual opinions (Turoff 1970).

There have been various forms of Delphi since it was first established as a forecasting technique in the 1950s. The conventional Delphi technique has been used as a forecasting technique as well as a way to establish study results using expert opinion in areas where traditional research techniques are unavailable (Linstone and Turoff 1975). Policy Delphi was established in the late 1960s for application in the social sciences to aid in policy decision-making. The Decision Delphi was proposed in 1979 as a way of consciously developing a field of interest rather than allowing small, unrelated decisions to guide its development (Rauch 1979). In the late 1980s and early 1990s at least three papers introduced the use of Policy Delphi for environmental dispute resolution and economic planning (Miller and Cuff 1986, Smit and Mason 1990, Gibson and Miller 1990).

The Policy Delphi is used for policy questions for which there are no "experts" as there are for the questions targeted in conventional Delphi studies. The Policy Delphi makes use of advocates and referees to resolve issues. This process provides a way to gather differing opinions on a specific policy area for use in a small workable committee. In this way a small committee can use the input of many and, at the same time, have a less cumbersome decision making process (Turoff 1970). The dual purposes of this paper are to introduce a new variant to the Policy Delphi that I will call "collaborative" and to describe its use by the SRR.

Overview

The SRR has been using the Collaborative Delphi in conjunction with group meetings to accomplish its mission. The SRR can meet only 4-5 times per year, but expands its productive capability by using the Delphi between meetings. The SRR has used Delphi to: 1) develop vision and mission statements and guiding principles; 2) illicit feedback on documents produced at meetings; 3) develop a proposed classification system; and 4) allow work groups to obtain input from the larger group.

The main difference between Collaborative Delphi and Policy Delphi is that Collaborative Delphi is part of a larger process in which both meetings and the Delphi are used to establish consensus. The Policy Delphi is a self-contained process that produces a distinct set of results. Rather than doing as many Delphi rounds as needed to reach a pre-determined level of consensus on a specific issue, as in a Policy Delphi, the SRR chooses relevant Delphi questions to make progress on issues between meetings. Progress may occur through eliciting the full spread of opinion, getting feedback on a product or an idea, or from group learning. Delphi can be a powerful tool to inform at least part of the respondent group (Turoff 1970, Turoff 1975, Ludlow 1975). In the case of SRR, the Delphi can be used to inform and build agreement in the group and to allow participation by those unable to attend meetings.

Turoff (1975) describes six phases of the communication process that occurs in the Policy Delphi. "These are:

1. Formulation of the issues...
2. Exposing the options...
3. Determining initial positions on the issues...
4. Exploring and obtaining the reasons for disagreements...
5. Evaluating the underlying reasons...
6. Reevaluating the options..."

All of these phases should be covered to complete a Policy Delphi and can be done in three rounds with careful question design (Turoff 1975). The Collaborative Delphi approach occurs in conjunction with an ongoing process of regular meetings. Turoff's communication process may begin at a meeting and continue into a Delphi and conclude at another meeting. Roundtable work on the vision, mission and guiding principles gives a good example of this. During the first roundtable meeting, participants brainstormed the issues and discussed the options, producing a few draft options for review by Delphi. Two rounds of Delphi conducted between meetings requested reactions and feedback to these initial positions. New ideas were proposed and some reevaluation occurred. At the next meeting, the statements were revisited, but agreement was not reached.

Turoff (1970) notes that in the first few rounds, participants seem to believe that with a few casual comments, the other group members will change their views. By the third round, a profound shift occurs in which people either drop out or sharpen their arguments. After the second round of the mission/vision Delphi, people started to become frustrated with the impasse. The benefit of the collaborative process in this case was that the crux of the disagreement was pinpointed through the Delphi so that discussions on the issue could be more targeted to resolve fundamental issues.

While Collaborative Delphi might not bring the group into consensus, it can clarify the spread of opinion so that when the group re-assembles, compromise is more easily reached. At the meeting

clarification was made on which areas had sufficient approval by the group and which needed more focus through Delphi. Two more rounds ensued which set the stage for a compromise to be reached at the third meeting.

Linstone and Turoff (1975) warn that the Policy Delphi is not a substitute for committee deliberations or studies, but that it organizes views anonymously for these purposes. The Collaborative process is specifically designed to combine the collection of opinion and feedback into a group committee process to further the goals of the group.

Collaborative Delphi Procedures

Delphi seems simple on the surface, which has caused many individuals to try the technique without thoroughly learning the process or understanding its demanding nature (Linstone and Turoff 1975). It was this naiveté that the SRR embarked on employing the Delphi technique. Trial, error, and a great deal of patience on the part of the SRR members have allowed us to refine and define the Collaborative Delphi. What follows is a description of each of the basic aspects of Delphi coordination used by the SRR. Design questions in Turoff (1970) helped identify topics to cover.

Choosing the experts

In the case of a Collaborative Delphi, expertise is not chosen for the Delphi process alone, but for participation in the entire collaborative process. The SRR Steering Committee strived to include representation from all stakeholders in the field of rangeland management and science. Experts for the Roundtable were selected through recommendations and include academics in rangeland sociology, economics and ecology, livestock producers, non-profit environmental organizations, federal research and management agencies, and state and local government representatives. As a result, expertise is both varied and extensive and spawns the hope that products reached by this diverse group will receive widespread national support.

Anonymity

In a Collaborative Delphi, the respondent group cannot remain anonymous because, unlike other Delphis, it involves group meetings. This may not be a disadvantage, however. Knowing the expertise involved in the study can assure participants that they are working with peers which lends validity to the responses of others. Anonymity of individual responses is ensured and provides the participants with freedom in survey completion. To this end, any information that might expose an identity, such as reference to an agency, is changed. Because the surveys are sent and received via email, the person processing the emails will know whom the surveys are from, but this information is confidential, even from the rest of the design team.

Preparing the Delphi participants

In the Policy Delphi, it is crucial to explain to the experts involved how results will be used. The results of a Delphi can be used just to inform and influence the decision makers or actually determine the final decision or outcome. Different expectations of how results will be used might cause some participants to become disenchanted with the process (Turoff 1975). SRR is a participant driven process in which the group makes the decisions. The Collaborative Delphi is a means for helping the group as a whole make decisions and is thus one facet of the collaborative decision making process.

Participants are informed about the Delphi process through handouts and briefings given at each meeting. Respondents generally have at least a week to respond and reminders are sent out a day early to improve the response rate.

Choosing the topic

Topics for Delphi can be chosen on the basis of what will best continue the work of the previous meeting, help prepare for a future meeting, or resolve other needs. Some uses of Collaborative Delphi could be to make progress on a single contentious issue, brainstorm and prioritize issues, review and revise a document, or develop common goals. For the first three meetings, participants and the steering committee were asked for suggestions for Delphi questions. The Delphi design team chose the topics from these suggestions and from topics brought up in a previous Delphi round. At the fourth meeting, criteria groups of the roundtable were encouraged to submit Delphi topics. Allowing the criteria groups to suggest topics and use Delphi to further their criteria group goals increases its usefulness for the group. If a work group reaches an impasse or needs verification from the group on an issue, input can be received by the Delphi.

So far, eight rounds of Delphi had been completed for SRR. In Delphi 1 – 3 and 5, the group worked on finding common ground through developing mission and vision statements. In Round 3, a definition of rangelands proposed at the group meeting was also sent out for review. Delphi 4 gave input on a document listing the "most important issues" work produced at the second SRR meeting. Delphi rounds 6 and 7 were used to receive input on a system to classify indicators. Delphi 8 was the first to include suggestions by criteria groups. One group wanted agreement on whether to reject an indicator; another group requested that SRR consider the application of a "time zero".

Writing the survey

With the SRR, we strive to provide space for open-ended feedback at the same time as trying to limit the scope of the questions in order to keep the exercise focused. There is a balance between narrowing the focus to reach a conclusion and ensuring all sides of an issue are given space to be considered. Delphi designers must be careful in choosing questions. Once a question is posed, there is no way to control the outcome if it is to be an honest process (Turoff 1975). Therefore, questions must be carefully chosen to reflect group goals. It is important to be absolutely sure that group input is desirable. An open-ended question is always provided which allows respondents to challenge the nature of the question or introduce new issues or arguments.

The design team must be knowledgeable about the subject matter for both the writing and evaluation phases (Linstone 1975). Questions, as in any survey, must be phrased succinctly and clearly and target the question at hand; a poorly worded exercise will not produce useful information and will have to be redone. Designers must be able to interpret answers in order to collate them into a readable form. In cases where it is useful to summarize answers, understanding the responses is even more crucial. All answers must be reflected in the summary, otherwise participants might become discouraged because their input is not being considered.

Choosing a good design team is a necessary step in developing the Delphi. Linstone (1975) lists quality of questions (avoid vague, poorly written questions), lack of imagination (creativity to get the most from the participants), and poorly worded or repetitious statements as common pitfalls. Employing someone experienced in survey design is essential. Dr. Michael J. Manfredo, Department Head of Natural Resource Recreation and Tourism at CSU, provides the team with invaluable advice helping provide clear, concise, and interpretable surveys. The other design team members include E.T. Bartlett and John E. Mitchell who provide evaluation, proof reading, and topic definition support. Helen Rowe writes the surveys, compiles the results, and cooperates with the other team members to choose topics.

The survey instruments must be well defined. Each Delphi survey must be self-contained with directions to complete and return the Delphi. In addition, the rating scales must be clear (Turoff 1970). Only recently did the design team incorporate definitions of the scale to distinguish between levels of acceptability. This clarity greatly improves our ability to evaluate the responses.

Processing the responses

It is important to present the responses in a clear and organized manner so that even those who did not participate in the survey will understand the results. Generally, responses are read carefully for similar arguments and listed under common headings. These headings have the added benefit of giving those who only have time to skim the material the opportunity to ascertain the general thread of the debate. Responses are often reported verbatim, to keep the full meaning and intent of arguments intact. In these cases, only references that would give away the identity of the participant are changed. If the character of the responses is less emotional and more factual and concise, they may be summarized. In such a rewrite, it is crucial to retain the full meaning of the original statement. It is also important to organize the information without placing value or priority on responses. As an exception to this rule, the SRR summaries highlight minority opinions so that voices of dissent are heard.

Deciding on follow up questions

Ideally, a topic will be pursued for at least two rounds to get the benefits of a Delphi, although a one-round Delphi has been useful at times. In a second round, results from the previous round will be distributed along with follow up questions. The design team must carefully consider how to progress. Effort must be made not to be subjective in choosing ideas for further focus. An issue brought up by several persons may be explored further in the next round. A suggestion of compromise or a new idea that may lead to further consensus on a topic might also be a good candidate. All views, regardless of whether they are pursued in the next round, will be heard in the summary.

The number of iterations needed for each issue differs according to logistic parameters and the issue covered. In some cases, time between meetings is adequate to allow for three rounds of Delphi; however, some interludes permit only one or two rounds. The number can also depend on the contentiousness of a given issue. We spent four rounds of Delphi and discussion at three meetings to reach agreement on mission, vision and guiding principles. In contrast, reviewing a list of issues needed only one round of Delphi because most of the discussion took place during meetings.

Specifics on the SRR

In order to explain fully the Collaborative Delphi process used in the SRR, each round of the Delphi is described below along with relevant SRR meeting information.

SRR Meeting 1

The group proposed three alternative vision and mission statements and had a list of nine possible guiding principles.

Delphi Round 1

The purpose of the first Delphi was to narrow down the options. Respondents were asked to rate their level of acceptance for each of the guiding principles, the mission statements, and the vision statements. They were given a scale of four choices: unacceptable, slightly acceptable, moderately acceptable and highly acceptable. For each "unacceptable" response, respondents were asked for an explanation. Respondents were asked to choose their preferred vision and mission statement and explain why. At the meeting there was some discussion about the parenthetical addendum to one of the vision statements. We asked respondents if it should be included in the final vision statement, in order for it to be acceptable.

Delphi Round 2

The responses to Round 1 allowed us to eliminate one mission and one vision statement and propose adoption of the first seven guiding principles at the next meeting. Many respondents gave suggestions for rewriting the statements that the design team felt should be considered. The responses were collated and sent out with further questions. Based on the responses from Round 1, respondents were asked to select their preferences between the two remaining mission statements and the two vision statements. Proposed statements were listed for vision, mission, and guiding principles and respondents were asked if they preferred these to the original statements. An open-ended question allowed for additional comments.

SRR Meeting 2

Responses to Round 2 were distributed before the second meeting. Based on the results, a set of guiding principles was adopted easily. With a little discussion, the mission statement was modified slightly and accepted. A vision statement was crafted for review through the Delphi process. Also, one participant suggested a compromise to adopt two vision statements - one for rangelands and one for the SRR process. In addition, discussion about the definition of rangelands was deferred to the Delphi in the interests of time.

Delphi Round 3

The definition of rangelands written at the meeting and the Society for Range Management's (SRM) definition were presented in Round 3. Respondents rated their level of acceptance for each and stated their preference. Additional space was given for comments. Acceptance level was also rated for the rangelands vision statement, which was edited at Meeting 2. A new vision for SRR was presented, and respondents were asked whether it should be adopted (yes/no) and if so should it be adopted in conjunction with the rangelands vision (yes/no). An option for additional comments was also provided.

Delphi Round 4

At the second meeting, the group developed a list of important issues pertaining to rangeland sustainability. To help focus these issues, the design team decided to send out a Delphi with the list and ask, "What topics or issues that you feel are essential to evaluating overall rangeland sustainability are not included in this list?" The returned comments were collated with the notes into a document used at Meeting 3 to continue issue development.

Delphi Round 5

While a clear majority favored adopting the SRM definition of rangelands, there was enough dissent that a further round was felt to be desirable by the design team. Respondents were asked to review results from Round 3 and rate their level of acceptance on the SRM definition. Additional comments were also solicited. Round 5 also presented five alternative packages containing a mix of the suggested vision statements with the accepted mission statement. Presenting these together as packages was meant to give a clearer idea of how they would look together. For each "package," participants were asked to rate whether it was "acceptable (check all packages that you could live with)" or "not acceptable (check all packages not acceptable to you)" and to "chose only one package that you prefer". Room for comments was provided with a remark that comments on "not acceptable" items would be most useful.

SRR Meeting 3

The SRM definition was adopted for use by the SRR. Limited further discussion revealed lingering disagreement on the mission-vision package, but the group agreed to accept it for the time being with the possibility of revisiting the issue at a later time.

Delphi Round 6

At the end of the third meeting, an indicator classification system was introduced. This round of Delphi asked respondents to rate the level of acceptability for the system and asked for additional comments.

Delphi Round 7

Suggestions for rewording the classification system were incorporated and participants were

asked to re-rate the level of acceptability. Upon doing more research on the Delphi (Turoff 1970), the design team realized that to get a more reliable and specific feedback from the survey, the levels of acceptability should be specifically defined. Levels were defined as follows:

- Unacceptable = disagree fundamentally with this classification and oppose its adoption
- Slightly acceptable = acceptable only with further modification
- Moderately acceptable = acceptable, but there is room for improvement
- Highly acceptable = acceptable without modification

In Round 6, participants identified several new factors with which to categorize indicators. These factors were listed with the question, "What factors would be important to use to classify indicators?" The question was written to encourage more new ideas. As in every round, space was provided for other comments. Results from Delphi 7 were organized and sent out to the group to review in preparation for discussion at the next meeting.

SRR Meeting 4

Discussion on Delphi 7 results focused not on finding closure, but on widening the debate. Participants discussed the factors raised in Delphi 7 and presented some new ideas. The next step in developing this classification system will be done by trying to apply it to developed indicators at a future meeting.

Delphi Round 8

At the fourth meeting, criteria groups were given the opportunity to suggest Delphi topics. This Delphi was in response to two requests. The first topic was suggested by a criterion group that was grappling with an issue it felt should be decided by the SRR as a whole. They wanted to know what "time zero" should be used for the indicators; whether time zero would be the same for all indicators; and whether all indicators need a time zero. A second group had agreed that an indicator should be eliminated, but wanted to assess the SRR's level of support for this action (again levels of acceptance were defined) as well as support for incorporating aspects of this indicator into a new indicator. Space for additional comments was included.

Limitations

The SRR recognizes that there are limitations to Collaborative Delphi. "The strength of Delphi is, therefore, the ability to make explicit the limitations on the particular design and its application. The Delphi designer who understands the philosophy of his approach and the resulting boundaries of validity is engaged in the practice of a potent communication process. The designer who applies the technique without this insight or without clarifying these boundaries for the clients or observers is engaged in the practice of mythology" (p. 586, Linstone 1975).

One limitation of using the Delphi with this group is the specificity of expertise. That is, for responding to some questions, such as reaching agreement on vision and mission statements, participation in the SRR is sufficient expertise. Each roundtable participant should have an equal say in the outcome. However, there are certain technical questions for which there might be what Linstone (1975) calls an anonymity disadvantage, in which the credibility of a response might hinge upon the expertise of the respondent. The SRR participants have expertise in a wide array of areas. For certain technical questions, experts to these areas should be consulted. Opening up such questions to the wider SRR might dilute the true expert opinion, in which case, a Delphi would not be an appropriate forum for gathering input. The Delphi should be reserved for questions of a more general nature that involve consensus building and for gathering feedback from the SRR as a whole.

Some have questioned why Delphi leads to consensus (Kweit and Kweit 1984, Woudenberg 1991). The debate centers on whether it occurs due to group pressure or because of group learning and compromise. Woudenberg (1991) argues that the group pressure to conformity is strong in Delphi, stronger than accuracy. Linstone (1975, p.583) describes the problem well, "[in] a dogmatic drive for conformity the 'tyranny of the majority,' sometimes threatens to swamp the single maverick who may actually have better insight than the rest of the 'experts' who all agree with each other". Jones (1975) found this tyranny of the majority to be tied to the level of expertise. The more expert in their field participants were, the less likely they were to converge. Apparently experts have more confidence to stand their ground against other opinions. Brockhoff (1975) countered this study by looking at self-ratings by experts and found them to be an inaccurate reflection of expertise, based upon tests in their field. In Delphi studies seeking an accurate response to a technical question, this issue has greater ramifications. For questions of a non-technical nature, where agreement, rather than an accurate answer, is sought, conformity or compromise may not be a negative attribute, unless the compromise is superficial and not long lasting. Practitioners of the Delphi, should be aware of this limitation and avoid pushing respondents to agree where fundamental disagreement persists.

Advantages

The advantages for using the Collaborative Delphi on a consensus-building project are great. It saves valuable time in meetings for other work to be accomplished. The Delphi process may not resolve an issue fully, but it will bring the group closer to being able to make a decision during a meeting. Overall, it may reduce the number of meetings needed. It also allows the planners to involve more people in the process. That is, busy schedules may restrict meeting attendance for some critical players. These people may still participate through Delphi. Including Delphi in the process lends continuity and keeps participants engaged in the process. It also serves as an excellent tool for sharing ideas at the same time as gathering support and agreement.

Linstone (1975) lists "illusory expertise" as a possible pitfall in which full representation is hard to come by. The advantage of using the collaborative process is that being a part of a larger process, the project can pull together a larger pool of experts. SRR has successfully brought together a multidisciplinary group, comprised of ecologists, economists, sociologists, conservation groups, industry, state and local government representatives, and policy and legal experts.

Lastly, the Delphi appears to be representative. The eighth round of Delphi elicited responses from 22 participants, an average response rate, from a database that now includes 115 names. At the most recent meeting, held after Delphi 8, participants were given a three-question survey in which 41 responses were returned. The results showed that for 17 respondents that had read the results, but had not participated in Delphi 8, 13 felt represented by the results, 1 did not feel represented, and 3 responded n/a to whether they felt represented (they possibly did not understand the question). Although the Delphi does not illicit feedback from all of the possible respondents, the responses seem to represent views of a wider audience. Though some opinions are undoubtedly missing that would be included were larger numbers to participate, this representation nonetheless validates the notion of using the Delphi to identify a fairly representative spread of opinion on a given issue.

Summary

Over the past three decades of its use, Delphi has proven to be a highly malleable instrument, finding uses in a multitude of arenas. The Collaborative Delphi, as a new variation, has been integral to the SRR process. We will continue to use the Collaborative Delphi for the SRR and explore further application in other projects.

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Indicators for Ecological Health and Diversity on Rangelands

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Abstract

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

Introduction

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

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

Indicators

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

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

Biodiversity

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

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

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

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

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

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

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

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

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

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

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

Ecological Health

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

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

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

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

Challenges and Opportunities

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

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

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

Conclusions and Future Work with Criterion

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

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Indicators for Soil and Water Conservation on Rangelands

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Abstract

Rangelands and associated civilizations rely on conservation and maintenance of soil and water resources to maintain themselves over time. The Sustainable Rangelands Roundtable (SRR) has explicitly included conservation and maintenance of soil and water resources as a criterion under which indicators can be identified and by which sustainability can be assessed. To this point, 14 indicators - seven soil-based, six water-based, and one soil and water-based - have been identified by the Soil and Water Resources Criterion Group. Soil erosion from water and wind, soil organic matter, soil compaction, soil aggregate stability, bare ground, and soil food web structure are the current focus of soil-based indicators. Biodiversity of aquatic organisms, water quality, stream channel geometry, wetland geographic extent, and duration of flow in rangeland intermittent streams are the current focus of water-based indicators. Regarding several of these indicators, several challenging questions remain to be answered. For example, can an indicator detected over a small geographic portion of rangelands be a credible indicator for rangeland sustainability at the national level? The Soil and Water Resources Criterion Group has used the Collaborative Delphi to solicit interdisciplinary feedback from SRR members to these challenging questions. The identification and eventual quantification of rangeland indicators related to soil and water might provide an approximation of status of rangeland sustainability for our Nation.

Introduction

Soils influence hydrologic processes by providing the medium for the capture, storage, and release of water (Whisenant 1999). Flow of soil and water through rangeland ecosystems is related, because flow of water can cause soil erosion. Soil erosion is regarded as a major contributor to declines in human civilizations over the past 7,000 years (Lowdermilk 1953). Rangelands and associated civilizations rely on conservation and maintenance of soil and water resources to maintain themselves over time.

The Sustainable Rangelands Roundtable (SRR) has explicitly included conservation and maintenance of soil and water resources as a criterion–a category of conditions or processes that is an explicit goal of sustainable management by which sustainability can be assessed. As a criterion, conservation and maintenance of soil and water resources is too general to monitor directly, but it can be characterized by a set of indicators that can be monitored over time. Fourteen indicators have thus far been identified. To settle on this criterion, we began by considering issues related to rangeland sustainability that would focus our indicator identification. Sustaining fundamental ecosystem processes and components, including biodiversity, were issues that stimulated inclusion of soil and water resources. A soils criterion group was originally formed, members of which deemed soils to be the single most important issue affecting rangeland sustainability. We identified four initial soil categories to focus our identification of indicators: (1) soil amount or loss, (2) soil constituents, (3) soil physical properties, and (4) soil food web structure. The SRR then used the Collaborative Delphi to introspectively analyze the originally formed criterion groups, looking for missing critical issues. The water resource was identified as a missing critical issue. Water resources were then added to the soils criterion group, forming the conservation and maintenance of soil and water resources criterion group (hereafter referred to as the Soil and Water Resources Criterion Group).

Indicators

Indicators are quantitative or qualitative variables that can be assessed in relation to a criterion. An indicator describes attributes of the criterion in an objectively verifiable and unambiguous manner, and is capable of being estimated periodically in order to detect trends.

Our 14 indicators are nearly evenly divided with seven being soil-based, six being water-based, and one being soil and water-based (Table 1). These 14 indicators are the outcome of a screening of the conservation and maintenance of soil and water resources indicators identified in the Roundtable on Sustainable Forests (RSF), plus identification of new indicators that we believe pertain to rangeland sustainability. The Soil and Water Resources Criterion Group screened the eight RSF soil and water indicators for their relevance to rangelands. The outcome of this screening was the retention of seven of the RSF soil and water indicators (Table 1).

The Soil and Water Resources Criterion Group has applied a framework of questions to each of the 14 indicators to varying degrees of completion. These framework questions focus on: (1) what the indicator is, (2) what the indicator measures, (3) why the indicator is important to rangeland sustainability, (4) the degree of meaning of the indicator at various geographic and climatic scales, (5) the relation of the indicator to its ability to be monitored over time including issues of data availability, (6) the sensitivity of the indicator to changes over time, and (7) the degree of understanding the public has for the indicator. The most important information we have currently on answers to these framework questions is in "Current Status of Indicators" below.

Current Status of Indicators

Soil-Based Indicators

Area and Percent of Rangeland with Significant Current Soil Erosion:

We are currently pursuing the applicability of the Water Erosion Prediction Project (WEPP), a physically-based erosion model, for national and regional-level prediction of soil erosion from water.

Erosion and the risk of erosion are difficult to measure directly. Other soil properties that affect erosion and can change with management, including soil surface stability, aggregate stability, infiltration, compaction, and content of organic matter, can be measured (USDA, Natural Resources Conservation Service, 2001a and b). We are considering whether changes in aggregate stability, content of organic matter, and compaction, three indicators we have already identified, can be surrogates for potential water erosion. Similarly, for wind erosion, we are considering whether changes in aggregate stability and organic matter content can be surrogates for potential wind erosion.

Area and Percent of Rangeland with Significantly Diminished Soil Organic Matter:

Soil organic matter enhances rangeland sustainability because it: (1) binds soil particles together into stable aggregates, thus improving porosity, infiltration, and root penetration and reducing runoff and erosion; (2) enhances soil fertility and plant productivity by improving the ability of the soil to store and supply nutrients, water, and air; (3) provides habitat and food for soil organisms; (4) sequesters carbon from the atmosphere; (5) reduces mineral crust formation and runoff; and (6) reduces the negative water quality and environmental effects of pesticides, heavy metals, and other pollutants by actively trapping or transforming them (USDA, Natural Resources Conservation Service, 2001c). We are investigating the methodology and sampling issues associated with soil organic matter measurement. There is a possibility we will seek surrogates for soil organic matter that will facilitate the estimation of this indicator.

Area and Percent of Rangeland with Significant Soil Compaction:

Soil compaction is detected when soil particles are physically compressed, eliminating the air spaces, or pores between the soil particles. Soil compaction is problematic because the increased soil density and decreased pore space limits water infiltration, percolation, and storage, limits plant growth, and limits nutrient cycling (USDA, Natural Resources Conservation Service, 2001d).

We have concerns with this indicator relative to its applicability over broad geographic areas. An underlying basis for this concern is speculation that soil compaction can change drastically over very small distances; therefore, great spatial variability exists at a site level. In addition, speculation is that soil compaction is substantial only over very small portions of rangelands and therefore is not a widespread problem on rangelands. We are investigating these questions: (1) Can great spatial variability at a site level not compromise a broad geographic area characterization of soil compaction?, (2) Can an indicator detected over a small geographic portion of rangelands be a credible indicator for rangeland sustainability at a national level?

Table 1. The 14 soil and water resources indicators identified by the Soil and Water Group of the Sustainable Rangelands Roundtable (SRR).

Indicators	Originated with Roundtable on Sustainable Forests and Retained in SRR?	What the Indicator Describes
Soil-based		
Area and Percent of Rangeland with Significant Current Soil Erosion	Yes	Erosion and the risk of erosion from water and wind.
Area and Percent of Rangeland with Significantly Diminished Soil Organic Matter	Yes	Soil productivity, energy flow, nutrient cycling, and infiltration.
Area and Percent of Rangeland with Significant Soil Compaction	Yes	The physical properties of soils, including bulk density, infiltration. Measures effects on soil productivity and soil/water relations.
Area and Percent of Rangeland Experiencing Changes in Toxic Substances	Yes	Soil productivity; potential for groundwater contamination.
Area and Extent of Rangelands with Changes in Soil Aggregate Stability	No, a new indicator identified by SRR	Changes in soil erosion resistance to water and wind.
Area and Percent of Rangeland with Significant Variance in Diversity of Soil Organisms	No, a new indicator identified by SRR	Health of the soil food web structure, as a surrogate for soil productivity.
Change in Extent of Bare Ground	No, a new indicator identified by SRR	Erosion potential from water and wind.
Water-based		
Percent of Water Bodies in Rangeland Areas (e.g. stream kilometers, lake hectares) with Significant Variance of Biological Diversity from the Natural Range of Variability	Yes	Water quality and aquatic habitat conditions.
Percent of Water Bodies in Rangeland Areas (e.g. stream kilometers, lake hectares) with Significant Variation from the Historic Range of Variability in pH, Dissolved Oxygen, Levels of Chemicals (Electrical Conductivity), Sedimentation or Temperature Change	Yes	Water quality.
Quantifying Aquifer Change	No, a new indicator identified by SRR	Change in geographic extent of riparian and wetland ecosystems.
Area and Extent of Rangelands Occupied by Wetlands	No, a new indicator identified by SRR	Change in geographic extent of functional lotic or lentic wetlands.
Percent Stream Miles in Rangeland Catchments in which Stream Channel Geometry (W/D Ratio, Flood Plain Access, Substrate Composition, Sinuosity, etc.) Significantly Deviates from the Natural Channel Geometry	No, a new indicator identified by SRR	Watershed functioning, including sediment transport, sediment filtering and retention, substrate composition, flood amelioration, fish and wildlife habitat, aquifer recharge, water temperature, and season and duration of surface flow.
Change in Number and Duration of Dry Periods in Rangeland Intermittent Streams	No, an indicator identified by The H. John Heinz III Center for Science, Economics and the Environment	Aquatic and terrestrial biodiversity, watershed functioning.
Soil and Water-based		
Area and Percent of Rangeland Managed Primarily for Protective Functions	Yes	Conservation of soil and water.

Area and Percent of Rangeland Experiencing Changes in Toxic Substances:

We believe toxic substances might be an important indicator for rangeland sustainability, although we have yet to investigate this indicator in detail. Similar to the soil compaction indicator, we have concerns with this indicator relative to its applicability over broad geographic areas. An underlying basis for this concern is speculation that rangeland soils with substantial toxic substances exist only over very small portions of rangelands and therefore are not a widespread problem on rangelands. We are investigating the answer to the question: Can an indicator detected over a small geographic portion of rangelands be a credible indicator for rangeland sustainability at a national level?

Area and Extent of Rangelands with Changes in Soil Aggregate Stability:

Stable soil aggregates are critical to erosion resistance, water availability, and root growth. Soils with stable aggregates at the surface are more resistant to water and wind erosion than other soils. Aggregated soils hold more water than other soils and provide pores for root growth (USDA, Natural Resources Conservation Service, 2001e). A field soil aggregate stability kit (Herrick et al. 2001) is a method for measuring soil aggregate stability in the field without having to transport soil samples to the laboratory. Plans are to measure soil aggregate stability in the field with the stability kit method in the Rangeland National Resources Inventory (NRI) beginning in 2002 and periodically thereafter (J. Herrick, pers. comm. 2002). Therefore, the indicator will apparently be measured over broad geographic areas with a statistically valid sampling scheme.

Area and Percent of Rangeland with Significant Variance in Diversity of Soil Organisms:

This indicator would quantify the soil animals, including protozoa, nematodes, mites, springtails, spiders, insects, and earthworms, and soil microorganisms, including bacteria, fungi, and algae, and their changes through time (USDA, Natural Resources Conservation Service, 2001f). This indicator would assess the health of the soil food web structure, as a surrogate for soil productivity. Speculation is that this is an important indicator of rangeland sustainability, yet its large cost to measure at the present time, and its overlap with other indicators such as soil aggregate stability and soil organic matter in regard to indicating erosion resistance and infiltration, needs further investigation before it merits final consideration as an indicator. In addition, this indicator might appropriately be shifted to the Ecological Health and Diversity Criterion Group at a later time.

Change of Extent of Bare Ground:

Change in extent of bare ground, along with soil aggregate stability, have great potential to be indicators of erosion potential and rangeland sustainability. Change in extent of bare ground can be quantified over broad geographic areas of rangeland using remote sensing technology. However, the accuracy of the measured change is lessened by several factors that limit classification accuracy of bare ground, including soil moisture content, litter amount, organic matter content, and presence of biological soil crusts. The presence of biological soil crusts on the surface soil of otherwise bare ground confers some protection to the soil surface from water and wind erosion (Belnap et al. 2001). Therefore, bare ground with biological soil crusts will not equate to bare ground without biological soil crusts in its susceptibility to erosion from water and wind. The degree of influence of these accuracy-lessening factors needs further investigation by the Soil and Water Resources Criterion Group.

Water-Based Indicators

Percent of Water Bodies in Rangeland Areas with Significant Variation of Biological Diversity from the Natural Range of Variability:

Biodiversity of aquatic organisms is an indicator of water quality and habitat conditions. If water quality and habitat conditions change in streams, rivers, and lakes, some aquatic species might decline or disappear, whereas other species might increase. There could be a decline in biodiversity, with fewer species. Because water bodies are dynamic, some variability in biodiversity should be expected. We are concerned that using the historic range of variability as the standard for evaluation might not be appropriate, because we speculate there is not an accepted manner of ascertaining the historic range of variability of biodiversity within water bodies. We are investigating this issue and the substitution of natural range of variability, which conceivably can be measured, as the standard for evaluation.

Percent of Water Bodies in Rangeland Areas with Significant Variation from the Historic Range of Variability in pH, Dissolved Oxygen, Levels of Chemicals (Electrical Conductivity), Sedimentation or Temperature Change:

We have yet to expend effort applying the indicator framework questions to this indicator but intend to do so. Similar to the previous indicator on biodiversity in water bodies, the issue of using the historic range of variability as a standard for evaluation appears problematic, and we will be investigating the substitution of natural range of variability, which conceivably can be measured, as the standard for evaluation.

Quantifying Aquifer Change:

We have yet to expend effort applying the indicator framework questions to this indicator.

Area and Extent of Rangelands Occupied by Wetlands:

This indicator will measure changes in the extent of functional lotic or lentic wetlands through time on rangelands. We have yet to standardize what will be interpreted on-the-ground as functional lotic and lentic wetlands. This is imperative, because measuring wetland acreage alone without qualification can be problematic (e.g., man-made impoundments can obscure other changes occurring, such as reduced riparian flows and resulting changes in wetland/riparian communities). In regard to measuring and monitoring this indicator, wetland/riparian classifications exist. Remote-sensed imagery data are apparently available for some rangeland areas.

Percent Stream Miles in Rangeland Catchments in which Stream Channel Geometry Significantly Deviates from the Natural Channel Geometry:

This indicator measures changes in stream channel length associated with channel geometry that either deviates from a historic condition, or deviates from some other established baseline condition (on which we have not yet made a group decision). This indicator will represent departure of channel geometry from a baseline condition. Channel geometry is indicative of natural watershed functions of channels such as sediment transport, sediment filtering and retention, substrate composition, flood amelioration, fish and wildlife habitat, aquifer recharge, water temperature, and the season and duration of surface flow.

Change in Number and Duration of Dry Periods in Rangeland Intermittent Streams:

This is our most recently identified indicator. This indicator reports on the frequency and duration of intermittent stream flow within shrub/grassland regions. Specifically, this indicator presents the percent of streams that have some no-flow period in a year, and the percent of streams where the duration of zero-flow periods is substantially lesser or greater than the long-term average. We are seeking to obtain the analyses of U.S. Geological Survey's data conducted within Colorado to better understand the degree to which this indicator will be suitable at the national level.

Soil and Water-Based Indicator

Area and Percent of Rangeland Managed Primarily for Protective Functions:

The Soil and Water Resources Criterion Group recommended eliminating this indicator. Rationale for elimination was disseminated out to all SRR members through use of the Collaborative Delphi, to gauge the degree of agreement with our conclusions. Enough disagreement was presented such that we are revising this indicator rather than removing it from our list.

Rationale for elimination was based on these points: (1) this indicator is mostly a measure of societal valuation of protection areas and proper management, rather than a guarantee of rangeland sustainability (Neary et al. 2000); (2) if managing for protective function tends to imply a passive, hands-off management approach, a passive hands-off management approach will not ensure rangeland sustainability. Case examples exist (Sydoriak et al. 2000/2001; Pringle 2000). Rangeland areas that are now being managed primarily for protective functions, but in the past were subject to land uses that achieved commodity production, pose dilemmas for managers because the vegetation, soil, and water changes that have occurred and were attributable to the commodity production, can remain on-going subsequent to a change to a more passive management approach. Although there were several points of disagreement received through the Collaborative Delphi, a salient point was that active, hands-on management to achieve conservation of soil and water, rather than passive hands-off, should be the underlying premise. We are currently considering modifications to this indicator that might make it more suitable as an indicator of rangeland sustainability.

Challenges and Opportunities

The soil compaction and soil toxic substances indicators challenge our thinking relative to their applicability over broad geographic areas. These indicators appear to be extant only over very small portions of rangelands and therefore are not a widespread problem. We will be challenged with answering the question, "Can an indicator detected over a small geographic portion of rangelands be a credible indicator for rangeland sustainability at a national level?"

The Soil and Water Resources Criterion Group has embraced the opportunity to utilize the Collaborative Delphi to assist in answering challenging questions that arise (for example, see section above on Area and Percent of Rangeland Managed Primarily for Protective Functions). We will continue to do so, for the Collaborative Delphi permits our criterion group to solicit feedback on challenges we face with soil and water-based indicators.

Conclusion and Future Work

There are reasons to believe that the fourteen indicators identified to date will be reduced to a fewer number during the next year. First, a Sustainable Water Resources Roundtable is being created. There is a high likelihood that water-based indicators we have

identified, or indicators quite similar, will be identified by the Sustainable Water Resources Roundtable. The SRR is beginning to discuss internally the ramifications of potential overlap of indicators between the two Roundtables. Within SRR, there also exists some overlap in indicator identification currently between the Soil and Water Group, and the Ecological Health and Diversity Criterion Group. Integration, both within the SRR, and between the various Roundtables, is critical to minimize indicator overlap. SRR leadership is networking with other Roundtables and the next SRR meeting in late March 2002 will devote time to inter-criterion group discussion of indicator overlap. Second, in some cases, more than one indicator appears to be indexing the same rangeland component. For example, Table 1 shows that we have identified soil erosion, soil aggregate stability, content of organic matter, and soil compaction as potential indicators, yet they are all related to soil erosion. The question exists as to whether we need to retain all four of these indicators or if fewer will be adequate to indicate the soil portion of rangeland sustainability.

Soil and water remain as basic resources for rangeland sustainability. The identification and eventual quantification of rangeland indicators related to soil and water might provide an approximation of status of rangeland sustainability for our nation and provide a blueprint for evaluating rangeland sustainability worldwide.

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Indicators for Maintenance of Productive Capacity on Rangelands

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Abstract

This paper is a progress report outlining efforts of the Sustainable Rangeland Roundtable to develop standardized indicators for Maintenance of Productive Capacity for monitoring and assessing the sustainability of rangeland ecosystems. Conceptual challenges include identifying and defining indicators to include productive capacities for rangelands. To date, seven indicators have been identified to cover total acreage, livestock, wildlife, invasive plants, non-forage products, and biomass production. The current developmental status of these indicators is reviewed. Future work will concentrate on collaboration with other criteria groups to ensure all aspects are covered without duplication and assessing the viability of the indicator set.

Introduction

Sustainability has been broadly defined as providing goods and services for current and future generations. Rangeland has the capacity to provide the current generation with a wide variety of goods and services depending on the mix desired by society at any particular time. Maintenance of productive capacity then implies that future generations will also be able to obtain their desired mix of market and non-market goods from rangelands. Sustaining productive capacity requires that estimates of this criterion consider temporal and spatial scale issues for a wide variety of goods and services. It is important to understand that productive capacity includes more than forage based products such as livestock. It must include non-consumptive goods and services, for example, wildlife habitat and open space.

One of the difficulties that arises when evaluating the productive capacity of rangeland is the question, "Capacity for what?" One rangeland area can produce a wide variety of goods and services. Some of which are mutually exclusive while others are compatible to some degree. Seldom is there a linear exchange ratio between two different uses. Grazing of multiple species illustrates this concept.

The Productive Capacity Criterion Group has also discussed tradeoffs between non-productive and productive capacities. When the use of a given rangeland area changes in some permanent way, the question asked is, "Has the productive capacity changed as well?" For example, if the creation of a new wilderness area results in the elimination of domestic livestock grazing, has the productive capacity to produce livestock from that land changed? At the same time, has the productive capacity to provide recreational value increased? These are representative of the difficult questions being considered by the group.

This criterion group also raised and discussed the following questions:

- What are the important products, goods, and services that are being produced and which ones can be monitored?
- What products, goods, and services will potentially be desired and produced for future generations?
- How can issues of fragility and resiliency be considered?
- Is it important to assess the cost and benefits to society for producing these products?
- Should fire or other natural processes be monitored to account for change in productive capacity?

Indicators

Seven indicators have been identified to capture the diversity of the productive capacities of rangeland (Table 1). Some of these indicators will require close linkages with other criteria groups to prevent duplication. It will be especially important to coordinate with the Ecological Health and Diversity Criterion

Table 1. Indicators for productive capacity of rangelands.

Indicator	What it tells you
Total acres of rangeland within the context of physiographic regions.	Indicates major shifts in land use that disrupts the production of goods and services from rangeland.
Percent of available rangeland that is grazed by livestock.	Provides information on land use patterns on rangeland that may shift production from one commodity to another use.
Number of domestic livestock on rangeland by physiographic region. (Cattle, sheep, goats, horses, bison, wild horses?? and burros??)	A direct measure of a consumptive use of rangeland forage.
Number of wildlife harvested by physiographic region. (Need number of hunters and success ratios)	An indirect measure of wildlife numbers that derive some proportion of their food and habitat requirements from rangeland.
Acres of invasive and noxious plants by physiographic region.	A measure of the extent to which rangeland productive capacity is altered through changes in the composition of plant species.
Annual removal of non-forage products by physiographic region.	An estimate of the wide variety of other consumptive uses of rangeland.
Annual above ground biomass production by physiographic region	A measure that integrates the biotic and abiotic factors that determine the annual production from rangeland.

Group and the Socio-Economic Criterion Group. A brief description of the seven indicators selected for the Maintenance of the Productive Capacity on Rangelands criterion follow.

Indicator 1. Total acres of rangeland within the context of physiographic regions

This indicator provides the base information of how much rangeland there is. It has also been identified by the Ecological Health and Diversity Criterion Group. Total acres of rangeland is shown as the first indicator because of the importance of this indicator to the development of indicators relating to productive capacity.

Indicator 2. Percent rangeland used to produce livestock

This indicator tracks the ratio of net area of rangeland that is used to produce forage for livestock to the total area that is classified as rangeland within the context of physiographic regions (Indicator 1). Our group initially thought that ecological state or condition would be important as well, but the data required to do this was thought to be too difficult to obtain at the regional and national scale. Using this indicator for market and non-market goods other than domestic livestock was also considered and thought to not be feasible at this time. A concern was that the distribution of commodities and their extraction/use is not equally distributed; therefore, we must account for potential trends in disproportionate use.

Indicator 3. Number of domestic livestock (i.e., cattle, sheep, goat, horses) on rangeland by physiographic region

It is recognized that livestock do not spend their entire life in one area and that this indicator would require careful evaluation and use with other indicators. The number of head was used rather than using AUM's because the total number of head would be more easily understood by the general public. Conversion to AUM's could be accomplished for other analyses if required. After considerable discussion, it was decided that the number of feral horses and burros would not be included as livestock because their importance tends to be localized and not appropriate for use as a national indicator.

Indicator 4. Number of wildlife harvested by physiographic region

Similarly to issues faced with livestock in Indicator 3, most wildlife species do not spend their entire life cycle on rangeland and determining the actual time spent on rangeland would be an impossible task. A complete inventory of major wildlife species (e.g., elk, deer, pronghorn antelope, sage grouse) would be desirable. However, the availability of this information is highly variable from state to state. Most states collect data on the number of wildlife harvested, hunter success ratios, and the number of permits/licenses issued. These numbers might be used as an indicator of the long-term trends in wildlife numbers on rangeland.

Indicator 5. Acres of invasive and noxious plants by physiographic region

Changes in vegetation can impact the productive capacity of rangeland. This is especially true when very large areas are invaded and dominated by invasive and noxious plants. Their dominance can change the capacity for some uses of these rangelands. Most states inventory and track invasive plants at the county level. This indicator may overlap with the Ecosystem Health and Diversity Criteria Group.

Indicator 6. Annual removal of non-forage products by physiographic type

Traditional non-forage products from rangelands include seeds, medicinal plants, and firewood. More recently, landscape materials have been harvested from arid and semi-arid rangelands. Individual products are often important locally but the net effect of their removal may not be important regionally and nationally. One of the strongest messages that has come from our discussions thus far has been that productive capacity should consider the entire mix of market and non-market goods from rangelands. Details on how this will be done still remain to be worked out.

Indicator 7. Annual aboveground biomass production by physiographic type

Standing crop has traditionally been a measure of productivity. This indicator seems to be understood by the general public and has the potential to be monitored remotely. The working group is exploring options to develop this indicator.

Correlation with the Roundtable on Sustainable Forests Criteria and Indicators

Criterion number two, developed by the Roundtable on Sustainable Forests (RSF), *maintenance of productive capacity of forest ecosystems*, is the counterpart to this criterion. Five indicators were developed for forestlands as follows:

- Area of forestland and net area of forestland available for timber production.
- Total growing stock of both merchantable and non-merchantable tree species on forestland available for timber production.
- The area and growing stock of plantations of native and exotic species.
- Annual removal of wood products compared to the volume determined to be sustainable.
- Annual removal of non-timber forest products (e.g., fur bearers, berries, mushrooms, game), compared to the level determined to be sustainable.

The SRR Productive Capacity Criteria Group evaluated these RSF criteria and retained and developed relevant aspects into the seven indicators.

Challenges And Opportunities

There are two significant challenges and opportunities confronting the criterion group. The first challenge will be to maintain the momentum gained in the most recent SRR meeting held in January 2002. Work in this group began with a fury of ideas and enthusiasm during the first two meetings (April and June, 2001). However, progress slowed at the August and November 2001 meetings as the group recycled a myriad of new ideas and surfaced some new ideas. In the latest meeting, significant progress was made.

The second challenge and/or opportunity will be to link the work of this criterion group with the other groups. Essentially all of the proposed indicators have a significant linkage with other criteria or draw upon information that will be obtained from indicators developed to address other criteria. Developing clear and smooth connections between groups without duplicating efforts will require careful collaboration and an overall perspective of the criterion as a body.

Conclusions and Future Work

Seven indicators have been developed thus far. By comparing the current list of indicators with minutes taken at all five SRR meetings and with indicators developed in the RSF, the Productive Capacity Criterion Group found that these seven indicators address all issues raised to date. The next tasks will be to develop linkages with other criterion groups and to assess the feasibility of using these indicators.

Status of Economic Criteria and Indicators for the Sustainable Rangeland Roundtable

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Abstract

The economic set of criteria and indicators (C&I) for rangeland sustainability are being developed through the roundtable process. The purpose is to define the set of indicators about which data could be collected that will tell those interested whether certain economic goals are being met. At this point, in addition to the traditional commodity indicators, we are working through how to deal with noncommodity indicators. We are sorting through suggested criteria and indicators from other efforts and adapting them to the rangeland situation. A draft set should be ready for circulation in early 2002.

Introduction

The role of economic C&Is for rangeland sustainability is to identify what happens to economic systems as other systems (ecological, social, legal, and political) change and to find ways that we can measure those effects. The economic system underlies how society chooses to allocate scarce resources among competing uses. Thus, these indicators should tell us, over time, how those choices are reflected for specific criteria.

Process

We began the process of identifying the economic C&Is using the Roundtable on Sustainable Forests (RSF) interpretation of the Montreal Process Criterion 6 – Maintenance and Enhancement of Long-Term Multiple Socio-Economic Benefits to Meet the Needs of Societies. Each of the RSF economic indicators has either been adapted to rangelands for further evaluation or were rejected as not being useful for evaluating rangelands. We have supplemented the RSF C&Is with issues and additional economic indicators raised by the SRR at the Salt Lake City and Reno meetings. The current list of potential indicators presented below is the result this process. We also meet jointly with the social C&I group at Sustainable Rangeland Roundtable (SRR) meetings (see Brunson, pp. 55-58) so that overlap between the two reports is expected.

The Socio-Economic Criterion Group is also working on developing a better framework to understand the economic and social relationships in "rangeland counties." Most relevant economic data are collected at the county level and aggregated to the national level in reports such as the Census of Agriculture. At the same time, understanding the social implications of rangelands requires knowledge of the structure and function of communities that are tied to the land. We believe that the best way to understand the relationships among economic and social systems and the rangeland ecosystems to which they are tied is to use a monitoring framework. This framework should be based on a valid statistical design using indices that account for differences among counties (e.g., Clark County, NV, home of Las Vegas, vs. Owyhee County, ID, a large rural county in the extreme southwestern corner of the state).

Indicators

Table 1 shows the potential economic indicators being considered. Some of the indicators such as livestock AUMs and their values are more easily obtained than others which will require extensive research before they are useful. The final suite of economic indicators will be useful for showing how rangelands are used and how decisions about their use are being made. At this point there is likely to be significant overlap among the economic indicators and those being identified by other criterion groups.

Challenges and Opportunities

There are several challenges related to developing the economic C&Is. These can be grouped into definitional, relationship, and scale questions. The definitional questions, while vexing, are perhaps the easiest challenge to address. For each of the indicators we must decide what is being measured and how it is going to be measured. The second level of question is the relationship among economic indicators and ecological and social indicators. For example, if a soil indicator shows a change is occurring, will that eventually show up in

Table 1. Potential economic indicators for sustainable rangelands.

Potential Indicator	What it tells you
Total ecologically available AUMs on rangeland and rangeland AUMs actually used or harvested and/or number of rangeland AUMs used and number of AUMs represented in total livestock production.	Measure of % utilization and/or dependence on rangeland for livestock production.
The amount and value of forage harvested from rangeland by livestock.	Shows one of the uses of rangeland. One of the few indicators that will tie together the social, economic, and ecological indicators via grazing impacts to range ecology and rural communities dependence on livestock production income.
Value and quantities of production of non-livestock products produced from rangeland.	Measures the economic value of non-livestock AUMs, wildlife, open space, and other amenities.
Supply and consumption/use of non-livestock forage rangeland products.	Direct measure of the number of people using rangelands for numerous non-production uses
Area and percent of rangeland managed for hunting recreation, dispersed recreation, tourism, and wilderness, in relation to the total area of rangeland.	Demonstrates society's desired uses of rangelands as areas become managed for different uses.
Number and type of facilities available for general recreation and tourism, in relation to population and rangeland area.	Adequate facilities are required to promote recreational rangeland use.
Number of visitor days and fees collected (in total, per capita, and per unit of rangeland area) for rangeland related recreation and tourism activities.	Shows how rangelands are being used for recreation.
Value of investment, including investment in rangeland, rangeland improvements, and recreation and tourism.	Indicates how much demand there is for new structures for a variety of uses.
Level of expenditure on rangeland research, development, and education.	Indicates long-term commitment to future activities.
Extension and use of new and improved technologies related to rangeland improvement (including "best management practices") and livestock production.	Shows how new technologies are being adapted as pressures increase.
Rates of return on investment for range livestock enterprises.	Indicates the ability of ranchers and other business enterprises to remain in business and provide stewardship.
Direct and indirect employment in the ranching sector, and ranching sector employment as a proportion of total employment.	Measures the importance of the ranching sector to the employment base.
Number of conservation easements purchased.	Measures the willingness of people to contribute to the conservation of open space and as a way to help ensure land is not developed.
Acres of rural land purchased by non-governmental organizations.	Measures the willingness of people to contribute to the conservation of open space and as a way to help ensure land is not developed.
Contributions to restoration activities.	Measures the willingness of people and organizations to invest in a variety of rangeland activities.
Trade flows (regional economic modeling information).	Measures how economic goods and services are traded between rural and urban areas. Important to know where investment of income is occurring.

an economic indicator and can they be linked into a statement of overall sustainability? Lastly, the question of scale arises continuously as we discuss economic indicators. What is relevant to an individual rangeland owner or user may or may not be relevant at the community, county, region, or national level. Furthermore, when we aggregate up or disaggregate down the results may become meaningless, especially if we want to make any kind of assessment of rangeland sustainability. For example, if we consider national data from "rangeland counties" (generally the level that data are collected), large urbanized county data can overwhelm data from lightly populated and less economically diverse counties.

While the list of indicators above will address the first two questions to some degree, we do not think they will tell us what we want to know about

rangeland sustainability on the national level, especially if we seek to link this economic information with social, ecological, and institutional indicators. The opportunity here lies in taking the time to develop a statistically valid method of sampling "rangeland counties" throughout the nation to draw inferences about the sustainability of rangelands from the economic and social perspectives and to tie those inferences into the ecological and institutional perspectives.

Conclusions and Future Work with Criterion

Developing usable economic indicators that can be combined with social, ecological, and institutional indicators to assess rangeland sustainability in the United States remains a work in progress. There is no nationally accepted framework to determine relationships to make such an assessment. We propose that developing one upon the concept of national data sets will not work for economic (or social) indicators. A new framework for making national assessments based upon statistical sampling of "rangeland counties" may be a better model. While we will continue to work on a rational set of economic indicators, we intend to pursue a parallel track of defining this alternative model. We recognize that this statistical model may not be useful until research has validated essential relationships. Nevertheless, we believe that the time to develop economic indicators that can be interpreted in relation to other indicators is now upon us and should be pursued.

Status of Social Criteria and Indicators

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Abstract

Sustainable rangelands are defined as those "that provide a desired mix of benefits to the present generation without compromising their ability to provide benefits for future generations." Implicit in that definition are assumptions that rangeland ecosystems must remain healthy (a condition judged primarily in biophysical terms), and that they must continually produce goods and services people desire (judged mainly in socioeconomic terms). Unfortunately natural resource managers have much more experience measuring and monitoring biophysical criteria than socioeconomic ones, and generally better economic measures than social measures. Thus, the social criteria and indicators in the Sustainable Rangelands Roundtable are problematic. For example, "social acceptability" is often cited as a key goal of rangeland ecosystem management, yet the acceptability of rangeland policies, practices, and conditions is most often detected by its absence. In other words, we are typically spurred to action when citizens tell us something is wrong with what we are doing, but by that time we are reacting to correct an unsustainable direction rather than managing proactively to maintain a sustainable direction. This paper will discuss this and related problems, and describe the Roundtable's progress toward enhancing the current state of social monitoring for rangeland sustainability.

Introduction

Perhaps the most fundamental tenet of sustainability is that it requires attention to biophysical, economic and social systems (World Commission on Environment and Development 1987). Within the field of rangeland science and management, the system we've given the least attention is the social system (Vavra 1995). For that reason, it may take even more work to find social indicators of rangeland sustainability than for the other two aspects.

The importance of monitoring the social component of sustainability grows more obvious each time we hear about difficulties faced by those who guide rangeland management initiatives. The literature on grazing in the developing world contains many examples of rangeland degradation brought on by the failure of Western-influenced programs and governments to incorporate long-standing social and cultural orientations to pastoral systems (Niamir-Fuller 1996, Scoones 1996). In the United States and other developed nations, projects intended to improve the ecological sustainability of rangelands – e.g., Mexican wolf reintroduction in the Southwest, chaining to enhance post-fire rehabilitation success in the Great Basin, weed control efforts in the northern Great Plains – have been delayed by lawsuits or administrative appeals from persons who believe the practices to be unacceptable. Accordingly land management agencies seek to build collaborative partnerships with multiple publics while monitoring citizens' acceptance of range management practices and conditions (Brunson 1999).

Process

The task of identifying criteria and indicators (C&I) of social sustainability for the Sustainable Rangelands Roundtable (SRR) has fallen to the criterion workgroup for Maintenance and Enhancement of Multiple Economic and Social Benefits to Current and Future Generations (subsequently referred to as the Socio-Economic Criterion Group). We have responsibility not only for the social indicators, but also for the economic indicators described by John Tanaka and Allen Torell in this symposium (pp. 51-53). Our discussions have included persons trained in academic disciplines both within and outside the social sciences, including sociology, anthropology, social psychology, cultural geography, economics, ecology, and forest and range management.

As others within the SRR have done, we used the Sustainable Forest Roundtable's list of C&I as a starting point for our discussions, along with a list of issues developed by the entire SRR at meetings in Salt Lake City and Reno in summer 2001, and refined for the purposes of considering socio-economic indicators at our fall meeting in San Antonio. Subsequently we examined each of the indicators using a framework developed by the SRR as a whole: What does it measure? Why is it important for social sustainability? Can it be monitored with existing data and models? Can it be reported adequately over time? And most

importantly, does it make any sense for social sustainability in a rangeland context? In that fashion – considering both social and economic indicators – we were able to eliminate several sustainable forest indicators that depend on the specific nature of timber production and timber-dependent communities. Others are being recast to be most relevant to rangelands and their management. The social indicators that remain are described in the next section.

Indicators

Our list of social indicators of sustainability is most definitely a work in progress (Table 1). For some we have been able to clearly articulate their importance, monitorability, and measurability. Others we are just beginning to explore.

Challenges and Opportunities

Perhaps the most useful – but also the most problematic – of the indicators is the final one listed above: "Viability and adaptability of social systems in range-dependent communities." At the core of the idea of social sustainability is the notion that human communities are better off if rangelands are both healthy and productive. Because maintaining the balance between rangeland health and productivity is at the core of most debates over rangeland policy, it is critically important that we develop methodologies for assessing how social conditions are affected by policies and practices. And while rangelands support both urban and rural communities, we believe rural communities are an appropriate focus for sustainability assessment because they are likely to be more sensitive both socially and economically to changes that have negative consequences.

Table 1. Potential social indicators of rangeland sustainability.

Potential Indicator	What It Can Tell Us
Area and percent of rangeland (relative to total rangeland area) managed to protect cultural and spiritual needs/values.	Extent to which rangeland management objectives continue to support these values. (E.g., can people gain access to places that offer spiritual benefits? Are there changes in protection of cultural resources?)
Non-consumptive-use rangeland values.	Extent to which values other than commodity outputs are supported by management. (E.g., is there an increase in actions that protect or diminish the scenic quality of rangelands?)
Area and percent of rangeland used for subsistence purposes.	Extent to which subsistence users, including but not limited to Native Americans, retain access to food, fiber, and shelter resources.
Land tenure and ownership patterns, including length of tenure and disposition of lands for which tenure has changed.	Extent to which changes in ownership, tract size, etc., occur that can affect sustainability. (E.g., are state trust lands being privatized, and if so, do new uses affect sustainability? Are ranches being fragmented? Aggregated?)
Extension and use of new and improved technologies related to rangeland improvement and protection.	Extent to which state-of-the-art practices such as riparian protection, rotation grazing, etc., are being adopted and implemented.
Viability and adaptability of social systems in range-dependent communities.	Extent to which changes in rangeland uses and conditions affect social conditions in rural rangeland-dependent communities.

There are great opportunities for measuring viability and adaptability because the federal government already monitors many social conditions at county levels. It is possible that several of these indicators can be incorporated into a defensible index of community sustainability. A highly abridged list of available data include:

- Demographic data such as in- and out-migration, percentage of population in certain age or gender categories, average education levels (critical to many economic diversification strategies);
- Data on community well-being including morbidity/mortality, poverty, water quality status, and availability of medical services; and
- Government/social services data such as property tax rates, social service expenditures and enrollments per capita (welfare, schools, school lunch program, public child care, etc), public safety expenditures, and municipal incorporations or disincorporations (an indicator of community viability).

We believe there are fundamental questions about such social indicators that have not been adequately addressed in research, at least as they pertain to the sustainability of rangelands. Most importantly, we're not convinced that we understand the linkages between social and ecological sustainability. Do breakdowns in ecological sustainability necessarily lead to loss of social sustainability? Not if one believes that cities such as Denver, Salt Lake, Las Vegas or Boise are sustainable. The rapid growth of these cities may be due partly to the fact that they are located on rangelands – not solely because of the values citizens can obtain from rangelands, but also because the economic value of rangelands is low enough to facilitate rapid urban sprawl, for better or worse.

It seems likely that the linkages are clearer in rural rangeland-dependent communities, but even in these cases, we are unsure whether a change in ecological sustainability necessarily leads to a change in social sustainability. Some associations seem obvious – for example, subdivision of ranches into 5- or 10-acre "ranchettes" has been linked not only to reduction in ecological sustainability (Knight et al. 1995) but also to breakdowns in the social fabric of ranching areas (Brunson and Wallace, in press). Other links are less obvious – e.g., if poor socio-economic conditions cause people to leave a rangeland setting, as has happened in parts of the Great Plains, is that occurring *because of* a loss of ecological sustainability or *independent of* changes in ecological sustainability? And does the change in population affect the ecological condition of those landscapes positively, negatively, neither or both?

Some methodological and theoretical challenges pertain to the nature of relationships between indicators and sustainability, the lack of (or difficulty in identifying) reference conditions, and the potential skewing of indicators by a few high-population areas.

Relationships between social indicators and sustainability are not always straightforward. One example is with the indicator, "Area and percent of rangeland used for subsistence purposes." Reduced access to rangelands for subsistence purposes may indicate a loss of social sustainability if there remains constant demand for such uses, or it may indicate improved sustainability if demand is lower due to increased availability of alternative sources of food, fiber, and shelter. Similarly, having fewer acres of rangeland available for subsistence uses may indicate improvement in ecological sustainability if such uses posed a threat to ecosystem components, or it may indicate a reduction in ecological sustainability if subsistence uses are concentrated to the extent that they become a threat.

While reference conditions provide important targets or thresholds for biophysical indicators, it may be impossible to identify reference conditions for some social indicators. For example, how much rural poverty is sustainable?

National-level measures of social conditions are often determined by conditions in population centers. For example, if there is an increase in the number of children enrolled in school lunch programs in rangeland regions, it may reflect a general downturn in the economy that is unsustainable, or it may reflect local economic conditions in the few large cities of the West that may not be found in smaller communities.

For that reason and because most social data are reported at the county level, we believe it will be important to identify what is a "rangeland county." Social indicators should be sampled from a subset of those counties that are representative of relevant rangeland characteristics, rather than measuring all counties. In so doing and by measuring as many indicators as possible relative to county populations, we can avoid the pitfall of a few localities dominating the statistics.

Conclusion

As can be seen, the Socio-Economic Criterion Group still has much work ahead of it. We need to fine-tune all indicators and to identify which measures are best for characterizing several of those we have listed. However, we are encouraged by the long history of using broad-scale indicators in

social research. We are further encouraged by the sheer number of social indicators that are already gathered by federal agencies, long-standing social surveys, the U.S. Census Bureau, and other entities. If we can identify which indicators are most indicative of social sustainability in rangelands, it seems likely that monitoring is possible without development of a major new infrastructure as may be needed for other aspects of rangeland sustainability.

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Status of Institutional Criteria and Indicators

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Abstract

The mission of the Sustainable Rangelands Roundtable is to identify indicators of sustainability based on social, economic, and ecological factors, to provide a framework for national assessments of rangelands and rangeland use. In order to identify such indicators, the SRR has chosen five larger categories called criteria, which encompass soil and water; social and economic factors; capacity of systems; health and diversity; and legal-economic-institutional framework. Indicators within the legal-economic-institutional framework criteria seek to define the extent to which the U.S. legal (laws, regulations, guidelines), institutional, and economic framework supports the conservation and sustainable management of rangelands. This paper will describe progress and challenges for this particular aspect of the Sustainable Rangelands Roundtable.

Introduction

The criterion on the legal, institutional, and economic framework assesses how the overall policy framework of the United States does or does not facilitate the long-term conservation and sustainability of rangelands. Issues about the legal, institutional, and economic framework for sustainable rangeland management complement those of a bio-physical nature. Within this criterion, matters of fairness and equity, economic efficacy, cultural traditions, legal rights and obligations, advancing management theories and skills, and overall national interests greatly influence the long term sustainability of our Nation's rangelands.

Indicators

The criterion on the legal, institutional, and economic framework asks whether mechanisms are in place to support conservation of rangelands, and does so by breaking the criterion into five (5) subparts with a total of twenty (20) separate indicators (Table 1). Participants in the Framework Group realized that the implementation of on the ground management alterations designed to promote the sustainability of rangelands would depend on whether there were institutions that encouraged management alterations, and whether rangeland managers had the training and resources to understand the need for appropriate management, and the tools to assess the effectiveness of varying management.

For example, the willingness of the private owner of rangelands to take action that would rest rangelands from livestock grazing for a period of time might well depend on the state and national tax policy which could provide economic incentives for resting the land. For publicly owned rangelands, the ability to manage them for some commodities that might promote sustainability of certain resources might depend on whether there were public planning processes in which interested citizens could participate, and whether decisions made in those public planning processes were implemented and reliable. Finally, the willingness of users of rangelands to live with changes in management could depend not only on whether they could have their day in court, but also on whether markets existed to allow them to take advantage of changes in management (e.g. if a federal grazing permittee is required to reduce his stocking level, can he make up the income loss by selling access across his private lands to adjacent federal lands for hiking, backpacking, hunting, and fishing).

The criterion subcategories and their indicators were drawn almost verbatim from work done by the Roundtable on Sustainable Forests (RSF).

Challenges and Opportunities

We have discussed the issue of scale as it relates to assessing these sub-criteria. For assessing institutions within the United States, the scale question turns on whether the institutions arise from national, state, or local (or county) governments. For rangelands, all three scales must be assessed in most instances.

The data exist (for the most part) which allow description of the institutions, mechanisms, and capacities in the United States. For example, on the web and in a law library, you can record laws, cases, and regulations governing rangeland management; can inventory mechanisms, which encourage or require planning for rangelands; and can access information on educational and research institutions which train people to use information to manage rangelands.

Table 1. Subgroups and indicators of the criterion on the legal, institutional, and economic framework for rangeland conservation and sustainable management.

Criterion subcategory	Indicator	Purpose
1. Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of ranges, including the extent to which it:	Indicator 48: Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process. Indicator 49: Provides for periodic range-related planning, assessment, and policy review that recognizes the range of rangeland values, including coordination with relevant sectors. Indicator 50: Provides opportunities for public participation in public policy and decision making related to rangelands and public access to information. Indicator 51: Encourages best management practices for rangeland management. Indicator 52: Provides for the management of rangelands to conserve special environmental, cultural, social and/or scientific values.	This sub-criterion is based on the premise that rangelands can only be sustained if there are institutions that support activities which allow for and enhance sustainability.
2. Extent to which the institutional framework supports the conservation and sustainable management of rangelands, including the capacity to:	Indicator 53: Provide for public involvement activities and public education, awareness and extension programs, and make available rangeland related information. Indicator 54: Undertake and implement periodic rangeland-related planning, assessment, and policy review including cross-sectoral planning and coordination. Indicator 55: Develop and maintain human resource skills across relevant disciplines. Indicator 56: Develop and maintain efficient physical infrastructure to facilitate the supply of rangeland products and services and support rangeland management. Indicator 57: Enforce laws, regulations and guidelines.	The first sub-criterion looks at the mechanisms needed for sustainability, while this describes whether there are resources & opportunities to support those mechanisms.
3. Extent to which the economic framework (economic policies and measures) supports the conservation and sustainable management of ranges through:	Indicator 58: Investment and taxation policies and a regulatory environment which recognize the long-term nature of investments and permit the flow of capital in and out of the range sector in response to market signals, non-market economic valuations, and public decisions in order to meet long-term demands for range products and services. Indicator 59: Non-discriminatory trade policies for range products.	This sub-criterion looks only at economic policies which might be important to rangeland sustainability.
4. Capacity to measure and monitor changes in the conservation and sustainable management of ranges, including:	Indicator 60: Availability and extent of up-to-date data, statistics, and other information important to measuring or describing indicators associated with criteria 1-7. Indicator 61: Scope, frequency, and statistical reliability of range inventories, assessments, monitoring, and other relevant information. Indicator 62: Compatibility with other countries in measuring, monitoring and reporting on indicators.	This sub-criterion looks at whether data are available to measure and compare the condition of rangelands.
5. Capacity to conduct and apply research and development aimed at improving range management and delivery of range goods and services, including:	Indicator 63: Development of scientific understanding of range ecosystem characteristics and functions. Indicator 64: Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies, and to reflect range related resource depletion or replenishment in national accounting systems. Indicator 65: New technologies and the capacity to assess the socioeconomic consequences associated with the introduction of new technologies. Indicator 66: Enhancement of ability to predict impacts of human intervention on rangelands. Indicator 67: Ability to predict impacts on rangelands of possible climate change.	This forward looking sub-criterion looks at the system's ability to incorporate new information and discoveries.

However, despite the availability of the data, there will be no way to know how that institution is actually affecting rangelands, other than occasional anecdotes. For example, we can list various economic policies affecting the use of rangelands, both public and private, but cannot isolate what actual difference a particular policy may have made in the management of a parcel.

Conclusion and Future Work

The Framework Criterion Group is attempting to assemble a "First Approximation Report" for these twenty indicators as the next step before trying to actually polish (compress) the indicators in this criterion. This report will provide an introduction of the extent of a legal, institutional, and economic framework for sustainable management, a discussion of the indicators, and a summary that highlights major points and identifies indicator gaps. Indicator discussions will describe them, provide salient background information, including information needs, and interpret their capacity to assess the criterion. The criterion group felt it prudent to go through the exercise of a first approximation report before attempting to edit the indicators. In our first attempts at "first approximation" materials, we discovered the exercise was most valuable in helping understand the kinds of information that the indicator should attempt to assess, as well as the many limits on the ability to do so.

Linkages between Rangeland Indicator Efforts: Sustainable Rangeland Roundtable and Heinz Center Programs

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Abstract

The indicator concept is widely used and accepted, especially the use of selected attributes to demonstrate condition of ecosystems of concern. Recently, use of indicators has been elevated to regional and national scales. Two parallel and complementary programs are developing indicators of rangeland condition. The Sustainable Rangeland Roundtable (SRR) program is building an extensive foundation of indicators with emphasis on western rangelands. The Heinz Center program on "The State of the Nations Ecosystems" is developing indicators for many ecosystems including forests, grassland/shrublands (rangelands), farmlands, freshwater, coastal waters, and urban/suburban systems. Consequently, the Heinz Center program has limited its number of indicators for each ecosystem, while the SRR is developing an extensive list of indicators. Both the SRR and Heinz Center program have used an iterative process to identify indicators. The Heinz Center program emphasizes state or condition and attempts to show change using sequential time data. SRR indicators are being selected to show present conditions while using sets of indicators for evaluating sustainability of rangelands. The SRR program will be helpful to rangeland managers and resource agencies, while the Heinz program is to be used by national decision-makers and resource managers. The difference in emphasis of the two programs makes them complementary. Details of the Heinz Center are presented at a forum titled "Rangeland Indicators from the State of The Nation's Report" on Monday at this meeting.

Introduction

Resource managers as well as local and national decision-makers often want to know how well we are managing our natural resources and whether their condition is improving or declining with time. Many agencies (e.g., NRCS) sample the condition of the ecosystems under their management, reporting changes in status in nationally available reports. However, no one agency manages or reports on the national coverage of any one ecosystem type, for example, forest or rangeland. Consequently, there is a need for national status reports of these systems, reports that can be used as guidance for long-term management decisions or for decisions on resource funding. Although extensive amounts of information may be developed by the resource agencies, these data need to be filtered and reduced to a manageable level of comprehension and usability. Additionally, data may be incomplete and data compatibility among agencies for similar resources is often poor. One approach for reducing and presenting large amounts of information is to identify attributes of the ecosystem of concern (e.g., rangelands) that will illuminate changes in condition of that ecosystem over time. These attributes that show change are often called indicators.

The indicator concept is widely used and accepted. Recently, use of indicators has been elevated to regional and national scales. For example, the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) has developed the concept of indicators as "measurable characteristics of the environment, both abiotic and biotic, that can provide quantitative information on ecological resources". This approach is also being used internationally for forests (e.g., Montreal Process).

Program Comparison

Two parallel and complementary programs are presently developing indicators on rangelands. The Sustainable Rangeland Roundtable (SRR), one of several sustainable roundtable programs (others address forests, minerals, and water), is building an extensive foundation of indicators with emphasis on U.S. rangelands. The H. John Heinz III Center for Science, Economics, and the Environment program on "The State of the Nations Ecosystems" is also developing indicators for six major ecosystems that encompass the United States. These include forests, grassland/shrublands (rangelands), farmlands, freshwater, coastal waters, and

urban/suburban systems. The Heinz Center program has limited the number of indicators for each ecosystem to 18 to enable production of a "user-friendly" report for upper-level resource managers and decision-makers. The SRR, like the other roundtables, is developing an extensive list of indicators. Both the SRR and Heinz Center program have used an iterative process to identify indicators. Each of the Heinz Center working groups had 12 to 18 members which met several times to identify and parse a set of indicators. The Heinz Center program also had an oversight Design Review Board that set basic guidelines for the working groups and helped identify indicators arising from the working groups that had national significance. In contrast, the SRR has held a number of roundtables with up to 55 attendees working in subgroups to identify and winnow a list of indicators of rangeland sustainability. The products of these subgroups have been presented in the preceding papers.

The difference in approach between the two programs, that is, use of small working groups compared to a large, multifaceted roundtable may result in quite different quality sets of indicators and reports. To overcome the deficiency of not using large numbers of participants and many meetings, the Heinz Center indicator program has depended on both an extensive internal and external review process. This process has improved descriptions of indicators and caused the working groups to rethink indicator selection.

Heinz Center Program

The Heinz Center program indicators fall within four general categories designated by the Design Review Board. These are systems dimensions, chemical and physical conditions, biology, and human use. A few overlapping indicators were identified by most work groups within the Heinz Center program. Because these had common roots, they were elevated to "national indicator" status and were in addition to the 18 allowed for each group. Briefly, these are: area of the six major ecosystems, fragmentation of natural lands, exportation of nitrogen from watersheds to coastal waters, chemical contamination and exceedance of national standards, fraction of U.S. species at risk, fraction of U.S. lands that are highly managed, trends in plant growth regionally and in different ecosystems, quantities of key ecosystem-related commodity goods, recreational activities, and ecosystem services. It is important to realize that these national indicators should also be considered indicators of each of the ecosystems. Recreational activities, for example, are important within forests and rangeland ecosystems, as are ecosystem services. Review of indicators within an ecosystem will seem incomplete unless one considers the "national indicators" as part of the set of indicators for the ecosystem.

The Heinz Center indicators by general category are:

A. Indicators of System Dimension: area of land covered by grass and shrublands; acres used for various human activities such as mining, rural residence and recreation; and patch sizes of grass/shrubland types.

B. Indicators of Chemical and Physical Conditions: amount of nitrate in groundwater; carbon stored in grass/shrubland; fraction of streams with intermittent flows; depth to shallow groundwater; condition of riparian areas; and changes in frequency of fires.

C. Indicators of Biological Condition: fraction of grassland/shrubland species rare or at risk; percent of cover occupied by non-native plant species; and non-native bird populations.

D. Indicators of Human Use: number of livestock fed on grasslands/shrublands; and harvest of game animals.

Description of these indicators in the "State of the Nation's Ecosystems" report include: (a) indicator description, (b) importance of the indicator, (c) data if available, (d) what the data show, (e) why data aren't available if they are not, and (f) what should be done to acquire appropriate data. These indicators were presented to the SRR at a roundtable session. It was obvious from the presentation that many of the Heinz Center indicators and those of the SRR have similar foundations and justifications for selection. In some cases, Heinz Center indicators were considered as additional indicators by the SRR.

The Heinz Center program has been concerned that adequate and reliable data for an indicator are not commonly available. Rather than discard the indicator for this reason, the indicator description points out the quality or inadequacy of the data and then suggests how sufficient data of high quality might be achieved and developed for a national evaluation of ecosystem state. In several cases, the Heinz Center contracted with external scientists to develop comprehensive data sets for an indicator. The subgroups within the SRR are also considering the availability of data when selecting indicators. Availability of data, especially if data are incomplete, although an important criterion, is not being used to select or discard a potential indicator in the SRR program.

Conclusions

The Sustainable Rangeland Roundtable and the Heinz Center program have similar goals; however, the Heinz Center program differs in that it emphasizes state or condition using primarily bio-physical values and attempts to show change using sequential time data. The Heinz Report will not explain cause-effects, nor use "drivers" or "stressors"

as indicators. SRR indicators are being selected to show present conditions while using sets of indicators for evaluating sustainability of rangelands. This means the indicators relate to present and continued ecological and human benefits and services and thus emphasize socio-economic values as much as biophysicial conditions. The SRR criteria and indicators will be helpful to state and national resource agencies and rangeland managers at all levels, while the Heinz program is aimed at decision-makers and resource managers primarily at the national level. The difference in emphasis of the two programs makes them complementary. Details of the Heinz Center program and indicators will be presented at this SRM meeting on Monday afternoon February 18 at a forum titled "Rangeland Indicators from the State of The Nation's Report".

Future Plans and Milestones for the Sustainable Rangelands Roundtable

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Introduction

The primary objective of the Sustainable Rangelands Roundtable (SRR) is to create a suite of criteria and indicators (C&I) that will provide a framework for national assessments of rangelands and rangeland use and that will be acceptable to a broad cross-section of agencies and organizations interested in rangelands. SRR has met five times, starting in April 2001. As shown in the papers of this symposium, the SRR has accomplished a great deal in a short time, but there is much to be accomplished in order to meet our primary objective.

Future Meetings

We presently have four meetings planned for 2002 and have tentatively scheduled three more in 2003. The next several meetings will be reviewing and critiquing the strengths and weaknesses of the indicators and critiquing their relevance to sustainability of rangelands. SRR will meet March 26 and 27 in Denver, Colorado. Our objectives for this meeting are: 1) to initiate a rotating criterion group review and critique of draft indicator sets, 2) to review the indicator framework to discuss its utility and to make modifications, and 3) to identify potential external reviewers for indicator sets. Additionally, the SRR Soil and Water Resources Criterion Group will meet with its counterpart from the Sustainable Minerals and Energy Roundtable.

SRR is scheduled to meet May 29 and 30 in Washington, D.C. and July 30 and 31 in Billings, Montana. At both of these meetings, criterion groups will review indicator sets, discuss and refine those indicators, and finalize the lists of reviewers. In October, SRR will meet in San Diego and finalize the indicator lists. These meetings will be in the expansion and contraction phase, which Romero describes as a period when candidate indicators are added for consideration and sorting of indicators occurs. Sorting of indicators will identify a core group of strong indicators meaningful to a large population and a narrower set of indicators that are useful to more specific interests.

The meetings in 2003 are tentatively scheduled for Florida, Albuquerque, and Washington, D.C. in January, March and May, respectively. These meetings will primarily be focused on drafting and revising the SRR report. The Washington, D.C. meeting will be a joint meeting with other roundtables to review the entire natural resource sustainability effort.

Overlaps and Gaps

One of the concerns evolving in SRR is that multiple criterion groups have identified the same indicator or similar indicators. In the same vein, the SRR also wants to ensure that all important indicators are identified. This symposium and its proceedings serve as a mechanism to initiate the review of indicator efforts by all criterion groups. In fact, as individual authors prepared manuscripts for these proceedings, they noticed some indicators that had been identified by more than one criterion groups. Some of these indicators, although outwardly similar, were defined in a different context. At the Denver meeting in March, we will start a formal process for review and critique through a rotating procedure of all the criterion groups. This review process will be repeated at future SRR meetings.

Other Roundtables

The SRR invited the leadership of other natural resource roundtables to meet in conjunction with the last SRR meeting in Tucson. The purpose of this meeting was to initiate a forum for collaboration on shared issues and coordination of common tasks. The co-chairs of the Roundtable on Sustainable Forests (RSF) and Sustainable Minerals and Energy Roundtable joined us for a productive discussion on the importance of communication between the various roundtables. An informal organization has been formed, called the Sustainable Natural Resources Roundtable Coordination Network (SNRRCN). SNRRCN will provide an opportunity for more efficient progress, while minimizing conceptual and implementation inconsistencies.

Issues

Numerous issues remain to be resolved during the next few meetings. Included in these issues are

the question of scale, a preliminary definition of rangeland in relation to one for forests, the protocol for evaluating indicators, and protocols for identifying data sets, their usefulness, and addressing whether an indicator actually relates to changes in rangeland sustainability. All criterion groups have been asking relevant questions related to scale, and our Scale Working Group will report on the scale issue at Denver.

Some ecosystems are considered as rangeland and forests, depending upon the classification system. For example, the pinyon-juniper woodlands and the oak woodlands have been classified as both. SRR has a Definition Working Group developing a strategy to resolve this issue, and the issue is being addressed by SNRRCN. We want to insure that, regardless of how an area is classified, data are recorded on all of the relevant indicators.

The SRR has addressed the question of how to classify indicators with respect to their strengths, weaknesses, and relevance to sustainability. Again, we are working through the roundtable network to learn from the forest and minerals efforts so that we can gain efficiency in developing the protocol for evaluating indicators.

Finally, the Socio-Economic Criterion Group raised a very relevant issue. Even if an identified indicator can be measured, does the indicator, and particularly changes of the indicator, relate to rangeland sustainability? Several SRR participants are developing research proposals to address this question.

Outreach

The SRR Outreach Working Group has been vital to addressing outreach questions and strategies, as has the SRR Steering Committee. This symposium is one result of their efforts. Our purpose here is to provide the range profession information on what SRR is, what it is not, what it has done, and the current status of social, economic, and ecological indicators of rangeland sustainability. A larger task of how to inform all rangeland sustainability stakeholders about SRR efforts still remains. We will continue to produce white papers and press releases, as salient information becomes available. We will also continue to speak to groups on rangeland sustainability and to host workshops or symposia where the opportunity arises.

The Ecological Society of America (ESA) has accepted a proposal to hold a working symposium at their 87th annual meeting to be held next summer in Tucson. The workshop will be held Sunday afternoon, August 4, 2002. Its purpose is to gain feedback from ESA members on the indicators that SRR has developed applying three criteria: 1) soil and water resources conservation, 2) ecological health and diversity, and 3) productive capacity of rangelands.

Reports

. A report on Criteria and Indicators for Rangeland Sustainability, to be drafted this year and completed in 2003, will be the summation of our current work. This report will document the status of the indicators and relevance of each to monitoring and assessing rangeland sustainability. The SRR report will be comparable to the First Approximation Report of the RSF, published in 1997 (see <www.fs.fed.us/global/pub/links/report/candi.htm>) and will be useful to all natural resource agencies responsible for assessing rangelands. The SRR first approximation report will very likely form the basis for the 2005 Assessment update required of USDA Forest Service by the Forest and Rangeland Renewable Resources Planning Act of 1974.

Final Thoughts

Let us first make the bold assumption that SRR will be successful in creating a suite of C&I that will be acceptable to a broad range of agencies and organizations. There will still be the need for land management agencies to have adequate resources to commit their agencies to long-term monitoring programs that adequately assess the C&I recommended by SRR. Unfortunately, we cannot predict when or how that might occur.

This uncertainty about the final outcome of the SRR's efforts may affect some of our efforts, but generally this reflects the adventure in which we are involved. Even though we have been able to benefit from the lessons and work of the RSF, we have seen the C&I of the SRR develop in an independent fashion. Thus, we do not know what the final report will contain at this point in time. The uncertainty and developing nature of SRR's efforts emphasize a statement of Phil Janik, co-chair of the RSF, "Sustainability is not a destination, but a journey; no deadlines are set, but work progresses towards a goal over time."

Participant List for the Sustainable Rangelands Roundtable

The following list includes participants who have attended one or more meetings:

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