

Ecologic, Economic, and Social Considerations for Rangeland Sustainability: An Integrated Conceptual Framework

Daniel W. McCollum, economist, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO

H. Theodore Heintz, Jr., economist, US Dept of the Interior and Council on Environmental Quality, Washington, DC

Aaron J. Harp, self-employed sociologist, Ann Arbor, MI

John A. Tanaka, economist, Eastern Oregon Agricultural Research Center, Union, OR

Gary R. Evans, College of Natural Resources, Virginia Polytechnic Institute & State University, Northern Virginia Center, Alexandria, VA

David Radloff, Sustainable Development, State & Private Forestry, USDA Forest Service, Washington, DC

Louis E. Swanson, Chair, Dept. of Sociology, Colorado State University, Fort Collins, CO

William E. Fox, III, rangeland ecologist, Texas Water Resources Institute, Texas A&M University, College Station, TX

Michael G. "Sherm" Karl, Inventory and Monitoring Specialist with the Bureau of Land Management, Colorado State Office, Lakewood, CO

John E. Mitchell, rangeland scientist, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO

Abstract—Use and sustainability of rangelands are inherently linked to the health and sustainability of the land. They are also inherently linked to the social and economic infrastructures that complement and support those rangelands and rangeland uses. Ecological systems and processes provide the biological interactions underlying ecosystem health and viability. Social and economic infrastructures and processes provide the framework or context in which rangeland use occurs and continues. All these systems and processes interact and feedback on each other over time and space. To look at rangeland sustainability exclusive of any of the three basic components, ecologic, economic, and social, is to look at an incomplete picture. Such an incomplete picture misinforms and misguides decision makers as they seek sustainable management. This paper proposes a conceptual framework providing for interactions between ecologic, economic, and social aspects of rangeland use and sustainability. While the specific example relates to rangelands, the framework is generalizable to any natural resource.

Introduction

Ecological systems and processes provide the biological interactions underlying ecosystem health and viability. Social and economic infrastructures and processes provide the framework or context in which rangeland use and management occurs and rangeland health increases or deteriorates. All these systems and processes interact and feedback on each other over

time and space. To focus only on ecological aspects of rangeland use, management, and sustainability is to look at an incomplete picture. Likewise, the picture would be incomplete if one looked only at economic aspects of use, management, and sustainability. The latter has been recognized in recent years (McCollum and others [1993] summarize the arguments and propose one solution). In order to adequately assess and monitor rangeland sustainability, an integration of ecologic, economic, and social perspectives is needed.

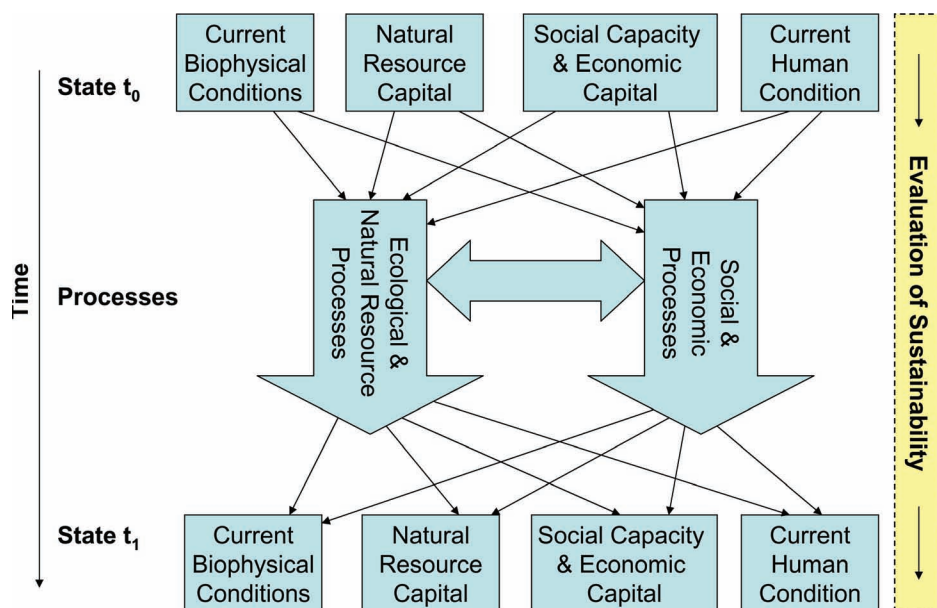


Figure 1. Tier 1 Rangeland Sustainability Evaluation Framework.

An Overview of the Framework

This framework links ecological factors and social/economic factors related to rangelands. In Tier 1 (fig. 1), the world is categorized into: (1) Current Biophysical Conditions (of air, water, soils, plants/animals, minerals), (2) Natural Resource Capital (the stocks of total biomass—including both plants and animals), (3) Social Capacity & Economic Capital (consisting of economic assets & liabilities and social opportunities & constraints), and (4) Current Human Condition (values and norms, income, health, security, etc.). The four boxes are acted upon by processes, represented by the large downward arrows. There are ecological and natural resource processes. These consist of reproduction, growth, death, decomposition; and include water cycles, nutrient cycles, carbon cycles, succession, migration, adaptation, etc. On the other side are social and economic processes. These consist of demand, investment, depreciation, management, social regulation, production, consumption, social interaction, institutional processes, etc. The processes change the conditions and capitals existing at time t_0 and result in a new set of conditions and capitals at time t_1 .

Integration of ecological factors and social/economic factors is introduced into the framework as the horizontal arrow linking “ecological & natural resource processes” and “social & economic processes.” This represents an explicit recognition that ecological and natural resource processes affect and are affected by social and economic capitals/capacities and conditions, and by social and economic processes. Likewise, social and economic

processes affect and are affected by biophysical conditions and natural resource capital, and by ecological and natural resource processes.

A Tier 2 framework (fig. 2) details those interactions, focusing on three primary points of contact: (1) extraction, (2) waste discharge, and (3) ecosystem services. Humans extract natural resources. Extracted resources are used by humans and affect biophysical conditions and natural resource stocks. In the process of extraction, processing, and use of those resources, wastes are generated and discharged. Ecosystem goods and services are generated that are used by humans (whether they are aware of the ecosystem goods and services they use or not). One set of such ecosystem services involves detoxifying and decomposing waste discharges. Other ecosystem services include climate regulation, soil formation, biodiversity, among many others.

A Tier 3 framework proposes indicators with which to assess and evaluate rangeland condition and sustainability over time. Those indicators are represented in both the Tier 1 and Tier 2 frameworks (figs. 1 and 2) by the box labeled “Evaluation of Sustainability,” on the right side of the diagrams. Indicators provide measurements of key variables that inform as to the condition and functioning of relevant stocks and flows.

Further Details on the Framework

Natural Resource Capital

The intent is to capture the stock of resources existing in the biophysical environment. Included in Natural

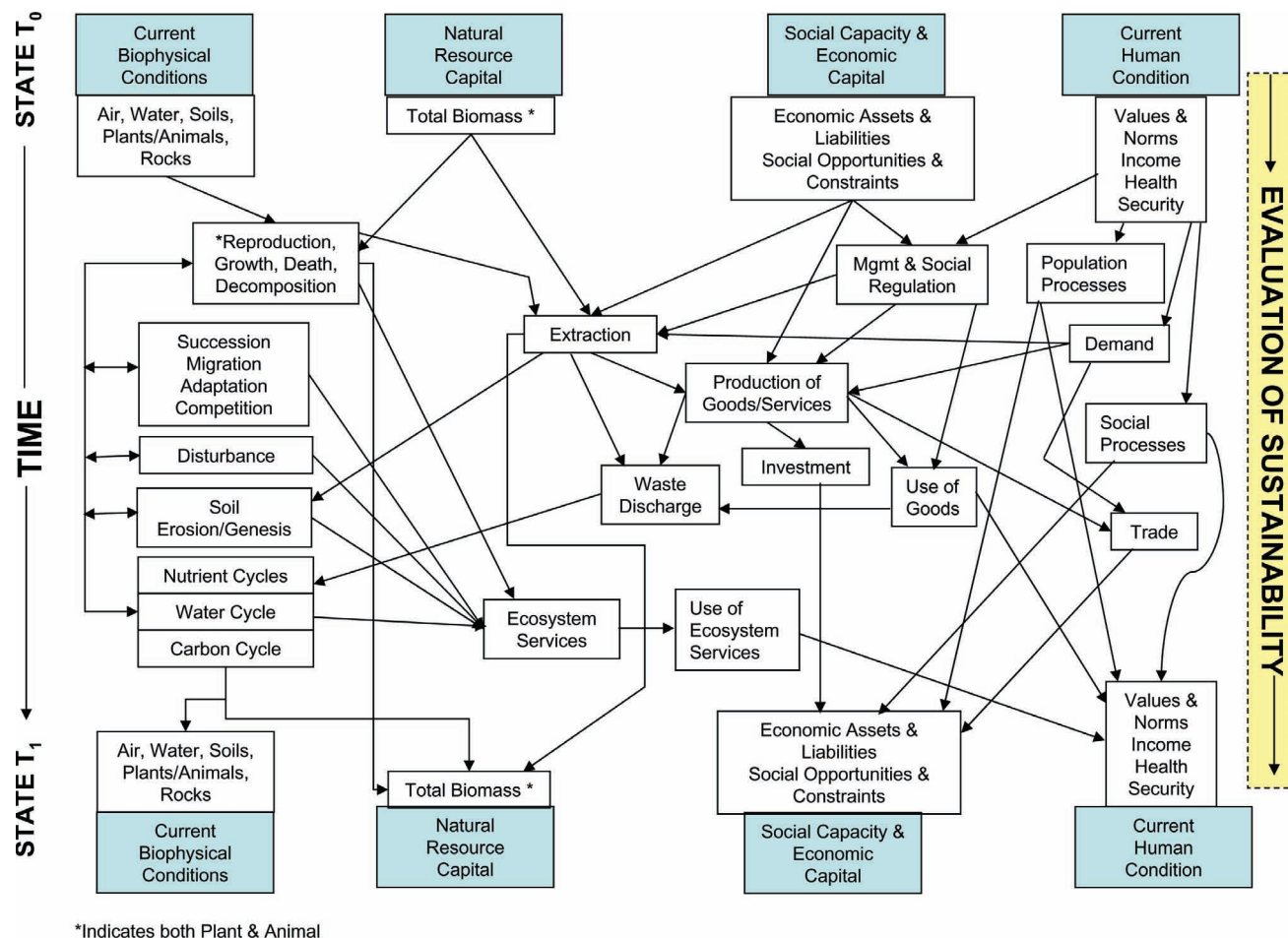


Figure 2. Tier 2 Framework – Rangeland Example.

Resource Capital is the total biomass present in the ecosystem—both plants and animals.

Current Biophysical Conditions

This includes the state and status of all the biota comprising rangelands, as well as the environmental conditions that influence and are influenced by the biota—in other words, the rangeland ecosystem. This includes all the biotic and abiotic entities that are specifically identified as comprising natural resource capital—plus others. Into this category would go things like air and water pollution, holes in the ozone layer, etc., along with the level of biodiversity of the rangeland ecosystem, conditions of the soils, etc.

Social Capacity and Economic Capital

This category includes the traditional economic notion of capital—all the assets and liabilities present in the economy, from buildings and machinery to inventories of raw materials to the productive capacity of the economy. The category is broadened to include the idea of social

capital or social capacity. This represents the opportunities and constraints afforded by the existing organization of society. Included in this category are people's or community social and support networks, and the institutional structures of society—the legal system, the education system, etc. It also includes human populations. This is intended to represent a social and economic stock or capacity present in the society.

Current Human Condition

This box represents the state and status, or condition of people and society—human well-being. It includes values and norms present in the society. It includes economic conditions—employment and unemployment, income distribution within society, and growth rate of the economy, etc. It also includes broader social conditions—poverty, educational status, health status, security, etc. Another aspect of human well-being in this category would be conditions of society in terms of social interactions, community cohesiveness, social integration and stratification.

The Ecological Processes

This series of boxes represents all the processes that produce biomass, either by primary production such as photosynthesis, or by consumption and conversion of other biomass. It also includes the variety of processes that continuously cycle the finite elements that are entrained in the biologically active layer of the earth. They include the carbon cycle, water cycle, and nutrient cycles. The processes are performed or mediated by the rangeland biota, and they in turn set the conditions for the functioning of the biotic world. This cycling of matter results in some of the natural resource stocks present in the next period in time.

Other processes in this series of boxes include dynamics like succession, migration, adaptation, and competition; they include soil erosion and genesis. Disturbances like flood, drought, fire, etc. are envisioned as one of the series of ecological processes. As indicated by the double-headed arrows on the diagram, the ecological processes interact and feedback on each other. The processes are driven and controlled by current biophysical conditions, and the outcomes become the “new” current biophysical conditions in the succeeding time period.

The ecological processes are influenced and modified by various intentional human activities such as extraction of products like range forage and other biomass and water; and investment in management practices. They are also influenced by unintended consequences of human actions such as the release of waste products into the environment or by careless behaviors, etc.

The Social and Economic Processes

Economic processes include production of goods and services, demand, investment, consumption or use of goods and services, trade, etc. Production of goods and services is broadly conceived, so it includes “household production” as well as manufacturing processes. For example, people use natural resources and access to natural resources to produce a variety of recreation and leisure goods that then affect human condition. Also included are management and social regulation. These are envisioned to include social policy and management of natural resources, among other things. Just as there are population processes on the ecological side of the framework, so too are there population processes on the social/economic side of the framework. These processes include birth, death, migration, aging, morbidity, etc. Finally, there are social processes, which include social integration, stratification, extra-local ties, social differentiation, governance, etc. These are the processes that form the organization of society. Taken together, all

these processes result in “Social Capacity & Economic Capital” and “Current Human Condition” at the next point in time.

The Interactions between Ecologic, Economic, and Social Factors

A shortcoming of many previous efforts to address natural resource sustainability has been the failure to adequately consider social and economic factors at all; and when they have been considered there has been no integration of social and economic considerations with ecological considerations. A typical effort to assess rangeland sustainability might include an analysis of relevant ecological factors. Toward the end of the effort there might be recognition that there should be some discussion of social and economic factors so a (separate) social/economic analysis is tacked on at the end. No real thought is given to the dynamic two-way interaction between ecological factors related to use and sustainability and social/economic factors. That is not to say that this effort and this conceptual framework solve all those problems. Rather, the Sustainable Rangelands Roundtable (SRR) and the efforts represented by this conceptual framework are a beginning. From its beginning, the SRR recognized the importance of thoroughly integrating ecological factors, social factors, and economic factors. All three are important to a well-informed assessment of rangelands and rangeland sustainability; and one cannot stand without the other two. Because it represents only a beginning, this conceptual framework and the thinking behind it are still evolving. By no means is this paper the final word on the subject.

We envision three primary points of interaction: extraction, waste discharge, and ecosystem services.

Extraction

In the case of rangelands the traditional extraction occurring is the removal of forage by livestock and wildlife. But, these are not the only extractions going on. Various plants are extracted from rangeland ecosystems for a variety of purposes. There are herbal and medicinal uses of some rangeland plants, there are landscaping uses, among others. Water is extracted from rangeland ecosystems for a variety of uses such as irrigation and human consumption. Animals are extracted by hunters and others. Such extracted products are demanded by people and enter into the production of goods and

services. From there, they are used, consumed or traded and contribute to Social Capacity and Economic Capital or to the Current Human Condition. Also, as part of the extraction process, biomass is removed affecting the stock of Natural Resource Capital. Byproducts of extraction and the extraction process factor into the Biophysical Condition through such mechanisms as soil erosion, succession of species, etc.

Beyond those relatively straightforward extractions from rangeland ecosystems, there are extractions of habitat and rangeland itself. Such extractions are a primary way in which humans directly impact rangeland ecosystems. Some extractions are positive or neutral as far as their effect on the environment; others have negative effects. Increasing and migrating human populations encroach on rangeland. Use changes from grazing and open space to residential development and subdivision. Results include fragmentation of habitat, basic changes in the composition of species as development occurs and landscaping replaces many of the native plants, exotic and invasive species might be introduced and spread, and native wildlife species might become pests and nuisances leading to their removal from parts of the ecosystem, among other effects.

Another form of extraction is related to recreation and “spiritual” or “aesthetic” services. Natural environments produce services that are extracted not as commodities but as perceptions or opportunities. Such extracted services affect the human condition in ways such as experiences of wonder and majesty, scenic beauty, or as a backdrop to life activities. They can also enter into a household production process and contribute to leisure and recreation activities. This overlaps with “ecosystem services,” which are discussed below.

Waste Discharge

Wastes are discharged into the ecosystem at several points and from several processes. Such wastes can have both positive and negative effects. We have already alluded to the byproducts of extraction. Grazing animals discharge wastes as they digest forage. Extraction of plants might leave “slash piles,” such as one might expect at the interface between rangeland and forest ecosystems. In some cases, those wastes support microorganisms and other life cycles. In other cases, they lead to water pollution and adverse effects on human and non-human species, or they increase the likelihood of disturbances like fire. Waste discharge can contribute to the spread of invasive species, among other effects.

Perhaps the greater effects of waste discharge, though, result from humans and human use of goods and services. In this vein would be discharges from productive and

manufacturing processes, wastes created by consumption and use of goods and services such as discarded packaging and other byproducts of human society. Some of those wastes get recycled back into productive processes while others get released into the ecosystem in a variety of ways and forms. Those wastes are acted upon by (or interrupt and otherwise alter) natural processes, and result in changed conditions of Natural Resource Stock and Biophysical Condition.

A more subtle effect of human society that might be included in a broad conception of waste discharges is human behavior or byproducts of human behavior that adversely affect the environment. Included in this vein would be behaviors such as burning fossil fuels, introduction and spread of exotic and invasive species, among others. Also included might be careless or malicious behaviors that result in environmental or ecosystem damage. While it could be argued that these are not truly “waste discharges,” they are byproducts of society that affect ecosystems.

Ecosystem Services and Use of Ecosystem Services

Broadly defined, ecosystem services refer to a wide range of conditions and processes through which natural ecosystems, and the species that are part of them, help sustain and fulfill human life. These services maintain biological diversity and the production of ecosystem goods, such as seafood, wild game, forage, timber, biomass fuels, natural fibers, and many pharmaceuticals, industrial products, and their precursors. In addition to the production of goods, ecosystems support life through such things as: purification of air and water, mitigation of droughts and floods, generation and preservation of soils and renewal of their fertility, detoxification and decomposition of wastes, pollination of crops and natural vegetation, control of many agricultural pests, protection from the sun’s ultraviolet rays, partial stabilization of climate, opportunities for recreation and leisure activities, provision of aesthetic beauty and intellectual stimulation that lift the human spirit, among others (Daily and others n.d.). Many ecosystem goods enter into our framework through extraction and productive processes, as alluded to above. The primary focus of this “process/interaction box” is to capture those services not explicitly entering by way of extraction and productive processes—such as those listed above as contributing to life support. These ecosystem services are used by humans, whether they know it or not, and contribute to the Human Condition.

Obviously, ecosystem services also have feedback mechanisms to the ecological side of the framework.

We recognize those feedbacks, but include them in the ecological processes such as decomposition, soil genesis, nutrient cycles, water cycles, carbon cycles, etc.

Completing the Framework: Tier 3

The stated purpose of the SRR, and the context in which this conceptual framework was generated, is to develop and refine indicators of sustainability, based on social, economic, and ecological factors, to provide a framework for national assessments of rangelands and rangeland uses. Hence, completion of the framework requires Tier 3. Tier 3 is a set of indicators covering five criteria: (1) Conservation and Maintenance of Soil

and Water Resources of Rangelands; (2) Conservation and Maintenance of Plant and Animal Resources of Rangelands; (3) Maintenance of Productive Capacity on Rangelands; (4) Maintenance and Enhancement of Multiple Economic and Social Benefits to Current and Future Generations; and (5) Legal, Institutional, and Economic Framework for Rangeland Conservation and Sustainable Management. These indicators are intended to provide measures of key variables that will inform and facilitate monitoring and periodic assessment of the condition and functioning of rangeland ecosystems over time.

The indicators associated with each of these criteria are shown in figure 3. Further information and descriptions of the indicators can be found in a special issue of *Rangeland Ecology and Management* (formerly the *Journal of Range Management*) forthcoming in 2005. That special issue is comprised of papers by Mitchell

Criterion 1: Conservation and Maintenance of Soil and Water Resources of Rangelands **Soil-based Indicators**

1. Area and percent of rangeland soils with significantly diminished organic matter and/or high carbon:nitrogen (C:N) ratio.
2. Area and extent of rangelands with changes in soil aggregate stability.
3. Assessment of microbial activity in rangeland soils.
4. Area and percent of rangeland with significant change in extent of bare ground.
5. Area and percent of rangeland with accelerated soil erosion by water or wind.

Water-based Indicators

6. Percent of water bodies in rangeland areas with significant changes in natural biotic assemblage composition.
7. Percent of surface water on rangeland areas with significant deterioration of their chemical, physical, and biological properties from acceptable levels.
8. Changes in ground water systems.
9. Changes in the frequency and duration of surface no-flow periods in rangeland streams.
10. Percent of stream length in rangeland catchments in which stream channel geometry significantly deviates from the natural channel geometry.

Criterion 2: Conservation and Maintenance of Plant and Animal Resources on Rangelands

11. Extent of land area in rangeland.
12. Rangeland area by plant community.
13. Number and extent of wetlands.
14. Fragmentation of rangeland and rangeland plant communities.
15. Density of roads and human structures.
16. Integrity in natural fire regimes on rangeland.
17. Extent and condition of riparian systems.
18. Area of infestation and presence/absence of invasive and other nonnative plant species of concern.

19. Number and distribution of species and communities of concern.
20. Population status and geographic range of rangeland-dependent species.

Criterion 3: Maintenance of Productive Capacity on Rangelands

21. Rangeland aboveground biomass.
22. Rangeland annual productivity.
23. Percent of available rangeland grazed by livestock.
24. Number of domestic livestock on rangeland.
25. Presence and density of wildlife functional groups on rangeland.
26. Annual removal of native hay and non-forage plant materials, landscaping materials, edible and medicinal plants, and wood products.

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

27. The value of forage harvested from rangeland by livestock.
28. Value of production of non-livestock products produced from rangeland.
29. Number of visitor days by activity and recreational land class.
30. Reported threats to quality of recreation experiences.
31. Value of investments in rangeland, rangeland improvements, and recreation/tourism infrastructure.
32. Rate of return on investment for range livestock enterprises.
33. Number of conservation easements purchased.
34. Expenditures (monetary and in-kind) to restoration activities.
35. The threat or pressure on the integrity of cultural and spiritual resource values.
36. Poverty rate (general).
37. Poverty rate (children).

Figure 3. SRR Criteria and Indicators for Sustainable Rangelands.

and others, Karl and others, Joyce and others, Evans and others, McCollum and others, and Hamilton and others. Further refinement and testing of those indicators will occur over time. Like this conceptual framework, work on the indicators is an evolving process.

Absent from Tiers 1 and 2 is any notion of scale, either spatial or temporal. Rangeland ecosystems can be considered at several spatial scales. One might think in terms of a particular river drainage. Alternatively, one could think of rangelands at the national scale; or anywhere in between the two. Life histories of the various biota are highly diverse, so that significant changes in natural resource capital occur with very different frequencies, from years to decades to centuries. Issues of scale become important in Tier 3 when one begins to develop and collect data on indicators.

Discussion and Conclusions

We have laid out a set of basic ecological processes that act upon and maintain or alter rangeland ecosystems. We have also laid out a set of basic social and economic processes that act upon and maintain or alter people and communities. On the surface, there are some interactions between the two—economic processes depend on rangeland ecosystems for some raw materials, some people depend on rangeland and rangeland products for their livelihood—but the two components are largely independent. If that's all we did, we would be like everyone else—nice frameworks, but tell us something we don't already know.

The contribution of this effort is in the integration of the ecologic component and the social and economic components. Three primary points of interaction were suggested—three points of integration between ecologic, economic, and social factors related to rangeland sustainability. Human impacts on the condition of the ecosystem are filtered through ecological processes. Ecosystem effects on human condition are filtered through economic processes and use of ecosystem services. Are these the “be all and end all” of a truly integrated framework? No, but they are a beginning.

Acknowledgments

This conceptual framework was developed in the context of the Sustainable Rangelands Roundtable (SRR). The SRR is an inter-disciplinary collaborative partnership involving federal and state resource management agencies, tribal governments, academia, environmental organizations, resource user groups, and professional societies working to develop and refine

indicators of sustainability, based on social, economic, and ecological factors, to provide a framework for national assessments of rangelands and rangeland uses. Similar roundtable groups exist for Forests, Minerals, and Water. Development of this framework benefited from discussions and contributions by the “Integration and Synthesis Group,” made up of representatives from all four of the Roundtables and from the H. John Heinz III Center for Science, Economics and the Environment which produced a report on sustainability and the state of the nation's ecosystems in 2002.

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