Sustainable Rangelands
Ecosystem Goods and Services

Photo courtesy USDA ARS

Sustainable Rangelands Roundtable Mission and Vision

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

SRR envisions a future in which rangelands in the United States provide a desired mix of economic, ecological and social benefits to current and future generations; and criteria and indicators for monitoring and assessing the economic, social and ecological sustainability of rangelands are widely accepted and used.

http://sustainablerangelands.warnercnr.colostate.edu/

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Sustainable Rangelands Ecosystem Goods and Services

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Photo courtesy USDA Forest Service

Executive Summary

The Sustainable Rangelands Roundtable (SRR) recognizes the unique contributions rangeland resources make to the nation's well-being. To communicate the importance of these commodity and amenity values, SRR participants developed this primer on rangeland ecosystem goods and services. It summarizes the history of the nation's relationship with and reliance upon rangeland resources, as well as the evolution of SRR's contribution to current concepts about advancing rangeland stewardship and conservation.

We discuss not only extractable goods derived from rangelands, but both tangible and intangible rangeland ecosystem services and the core ecosystem processes that underlie these goods and services. One section outlines an applied evaluation method suitable for use by ranchers, technical service providers and other private and public land managers who seek to identify and consider the income potential of rangeland ecosystem goods and services provided by their lands. We use a hypothetical ranching operation in Montana to highlight relevant questions and conversations between a rancher and a conservation technical service provider to determine such potential.

Thinking more broadly, we present a conceptual framework developed by SRR to illustrate integration of social, economic and ecological elements of rangeland sustainability via a bridge built upon the rangeland goods ands services that society values. The Texas Leon River Restoration Project illustrates the utility of SRR's model for successfully addressing multiple desired uses associated with traditional ranching operations, national security military uses and critical species habitat requirements.

Sustainable management of rangelands requires not only that derived goods and services satisfy the desires of current generations, but that these resources are conserved to meet the needs of future generations. Including standardized, periodic monitoring as part of the management and policy-making processes allows us to responsibly manage for ecosystem goods and services in both rural and urban/suburban systems. Conservation of the Katy Prairie near Houston, TX, integrates ecosystem services associated with stormwater management, provision of wildlife habitat and preservation of increasingly rare coastal prairie rangeland resources.

Coordinated, comprehensive monitoring is the foundation for successful rangeland management. To establish useful objectives, managers and scientists need baseline data to detect changes on the land that may be due to management actions, disturbances, or longer term processes like climate change. Actions and reactions in social and economic systems also must be monitored to obtain a complete picture of sustainability. The SRR's ecological, social and economic indicator set offers a useful framework for comprehensive rangeland inventory, monitoring and assessment at multiple spatial scales. Using the Idaho Murphy Complex fires as an example of affected ecosystem services, we illustrate potential applications of indicators to track fire regimes, changes in productivity and vegetation patterns and impacts on critical sage grouse habitat.

While rangeland amenity values matter to many people, profit potential may motivate many others to pay greater attention to conservation and provision of rangeland ecosystem goods and services. We consider and present criteria for evaluating public and private programs that offer conservation incentives, specifically conservation easements and credit trading. For example, conservation easements are being used to protect California's Ridgewood Ranch, historic home of the famed racehorse Seabiscuit, from development.

We conclude by discussing future research needs to better inform management and conservation of the nation's rangeland resources, as well as the goods and services that these valuable lands provide. The Oregon Multi-Agency Pilot Project highlights the evolving interest in comprehensive rangeland resource monitoring to track trends in natural capital and core ecosystem processes supporting these resources. Federal land management agencies recognize the commodity and amenity values of rangeland resources and are coordinating efforts to better align their rangeland monitoring capabilities to inform rangeland conservation policies and programs. Better information will lead to better decisions, culminating in sustainable management of rangeland ecosystem goods and services to satisfy the wants of current populations while also conserving the nation's rangelands for future generations.

Photo courtesy NPS

Table of Contents

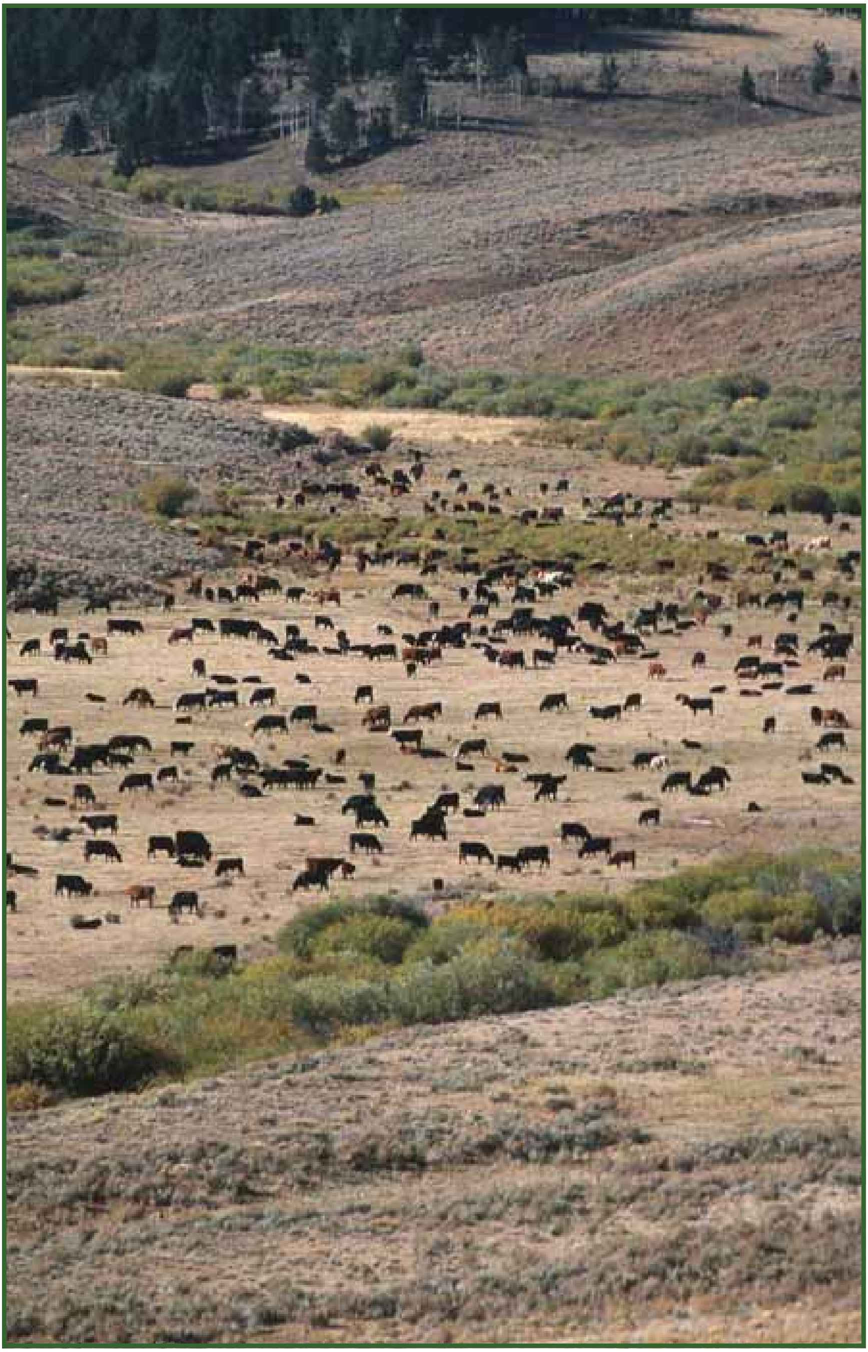

Photo courtesy USDA NRCS.

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Ecosystem Goods and Services from Sustainable Rangelands: A Primer

The United States Department of Agriculture's (USDA) 2005 public commitment to use market-based incentives for environmental stewardship and cooperative conservation focused land managers' attention on concepts of ecosystem services. However, this was not a new idea. In the early 20th century, Aldo Leopold embraced the value of open space and urged Americans to espouse a 'land ethic,' recognizing the unique contributions of wildlands and agricultural landscapes to the American ethos. Theodore Roosevelt preserved millions of acres of the American West as national forests and monuments, to be administered for the greatest good for the greatest number and as a constant source of valuable production commodities, in today's jargon, ecosystem goods. Similarly at the turn of the century, America recognized recreation and relaxation opportunities as marketable services. Period publications, such as *The Nation's Business,* ran articles recommending "Making a Business of Scenery," referring to the parks as economic assets of inestimable value.

Although considering benefits derived from natural rangeland systems in terms of goods and services is not novel, it has particular relevance in the 21st century as populations become increasingly urban and subdivision, development and altered ecosystem processes threaten rangeland sustainability. Reconnecting people with lands that provide the food, fiber, clean water, biofuels, cultural heritage and recreation opportunities that they value, by increasing their understanding of their use of these benefits upon which their lifestyle depends, is critical to mitigating threats to rangeland systems.

The development of a more formal ecosystem services approach to rangeland resource conservation and management is relatively recent; however, numerous instances of its efficacy already exist.

- Juniper removal and ecosystem restoration has allowed partners in the Leon River Restoration Project (LRRP) near Fort Hood in Texas to enhance the delivery of a suite of ecosystem goods and services. Since the 1940s, the Central Texas Cattlemen's Association historically leased as much as 162,000 acres of the Fort Hood military reserve for livestock grazing. During the 1980s, Endangered Species Act prescriptions associated with the black-capped vireo and golden-cheeked warbler began impacting this arrangement. In response, a private public partnership initiated the LRPP to improve water quality, habitat for the warbler and vireo and livestock forage supplies through removal of juniper. LRPP partners are achieving varying goals, enhancing the provision of rangeland goods and services through comprehensive, coordinated collaboration around a single management practice.

Removal of juniper at the Leon River Restoration Project, Texas. Photo courtesy Urs Kreuter.

- Texas' Katy Prairie Conservancy, The Center for Houston's Future, Texas A&M University and the Harris County Flood Control District are collaborating to research flood control and stormwater retention issues in the context of rapid urbanization and loss of open space. Seven hundred thousand acres of wetlands, creek corridors and coastal grasslands comprising the Katy Prairie provide critical wildlife habitat, supporting outdoor hunting and birding. Many ecosystem goods and services are derived from the preservation efforts of this partnership. Estimates suggest that waterfowl hunting in Texas alone brings in over a billion dollars annually. In addition, these efforts provide the potential for flood mitigation that may save millions in protection costs for chronically flooded homes.

- Idaho minimizes degradation of private and public lands following fire disturbance by re-seeding native sagebrush steppe plant communities that don't naturally re-sprout. Restoration efforts safeguard core ecosystem processes to support provision of rangeland goods and services including livestock forage, native plant populations and wildlife habitat critical to species such as the sage grouse.

Cattle grazing in Oregon. Photo courtesy of USDA NRCS.

- Efforts are underway across federal land management agencies to coordinate and standardize monitoring in the Oregon Multi-Agency Pilot Project to generate comprehensive, consistent rangeland information from coast to coast and border to border. In order to track available supplies of various goods and services and their condition in conjunction with anticipated demands, standardized monitoring is a key component in prioritizing conservation incentives for provision of rangeland ecosystem goods and services.
- Emerging credit trading systems encourage provision of ecosystem goods and services by financially supporting carbon sequestration, water quality and habitat conservation. These systems also

complement existing programs that reward landowners for maintenance of grasslands and shrublands and enhancement of environmental quality. Alternative income sources from ecosystem services, such as fee permits for hunting, fishing, hiking, bird watching and rock collection on private lands, now help ranchers augment their income from livestock production. While there is considerable debate about potential impacts of these traditional and emerging activities, research documents that larger ranches are more effective than subdivisions or ranchettes at preserving intact rangeland ecosystems.

Rangelands provide recreation values such as birdwatching. Photo courtesy NBII

Ecosystem Goods and Services on U.S. Rangelands

At present, U.S. rangelands comprise approximately 770 million acres (approximately 1/3 public and 2/3 private lands) of grasslands, savannas, deserts, shrublands, alpine meadows, wetlands and tundra. Rangelands are defined by the Society for Range Management as lands characterized by self-propagating plant communities, predominately grasses, grass-like forbs, shrubs and dispersed trees. These lands are often associated with grazing and managed by ecological, rather than agronomic, methods. They provide commodity, amenity and spiritual values vital to the well-being of humans. Worldwide, rangelands cover nearly 70 percent of the earth's surface and contribute significantly to the production of ecosystem goods and services.

Recognizing the importance of diverse rangeland resources, federal agencies funded the establishment of the Sustainable Rangelands

Roundtable (SRR; http://SustainableRanglands.cnr.colostate.edu) in 2001. The SRR is a collaborative partnership process with participants from federal land management and research agencies; tribal, state and local government; non-governmental organizations; scientific societies; and academic and other research institutions. Initially, SRR focused on development of a rangeland monitoring and assessment framework applicable at regional and national levels. However, more recently, SRR acknowledged critical linkages between monitoring and tracking trends in supplies of rangeland ecosystem goods and services (REGS). To better understand these relationships, participants considered associated values and applicable valuation methods, as well as potential for improved cooperative rangeland conservation through traditional markets, conservation easements, or credit trading.

With this in mind, the SRR convened a special workshop to address these issues. Forty-seven participants from 14 states, nine agencies, 10 universities and nine non-governmental organizations gathered to develop information pertaining to rangeland ecosystem services. Outcomes included lists of rangeland core ecological processes, goods and services and more explicit acknowledgement of these entities in SRR's conceptual framework.

SRR defines ecosystem goods as tangible outputs from ecosystems that are provided to humans through human activities that begin with extraction. Once they enter the economic system, they are transported and usually transformed and combined with other goods and services to yield value to humans. The social and economic processes needed for extraction and subsequent processing and use of rangeland ecosystem goods are structured by our legal, institutional and economic frameworks, particularly those affecting markets for such goods and the products to which they contribute. Ecosystem services may be intangible or tangible but their value to humans arises through direct experiences or indirect opportunities rather than through extraction and processing. Intangible services yield value to humans through

SRR Criteria and Indicators

SRR originally sought to develop and report on a set of criteria and indicators for sustainable rangeland management. SRR has published its initial list of 64 indicators (27 core indicators) and continues to work with potential users on refinement. A criterion is a category of conditions or processes that is an explicit goal of sustainable development or by which sustainable development can be assessed. A criterion is too general in scope to monitor directly, but can be characterized by a set of indicators that can be monitored over time. An indicator is a variable that can be assessed in relation to a criterion. It should describe attributes of the criterion in an objectively verifiable and unambiguous manner and is capable of being estimated periodically in order to detect trends.

experiences that are primarily perceptual, such as visual or kinesthetic experiences, rather than organic, such as eating or breathing. Tangible services are direct interactions with the ecosystem that occur in situ, such as breathing air or being exposed to the warmth of the sun or the chill of snow, a light breeze, or a gentle rain.

Ecosystem goods and services (EGS) are supported by rangeland ecological processes. These processes include succession, migration, adaptation, competition, disturbance, soil formation and erosion, nutrient, water and carbon cycling. Human systems interact with rangelands ecosystems through a variety of social processes (population, cultural, education, governance, markets, legal, social interactions, family, etc.). Social processes provide the mechanisms through which ecosystem goods and services are valued by society. They also provide the economic and institutional frameworks to maintain ecological processes through management and regulation.

To visually depict these relationships, SRR developed a conceptual framework (the Integrated Social, Economic and Ecological Concept for Sustainable Rangelands or ISEEC; see Fox et al, in press) to illustrate interactions among rangeland resources and the human communities that depend upon rangelands for their well-being. Ecosystem services act as the primary bridge between ecological and social/economic systems (see Figure 1). Production and delivery of ecosystem goods and services depends on properly functioning ecological processes and social processes.

Integration of ecological and social/economic factors is introduced into the framework as a horizontal arrow linking "ecological & natural

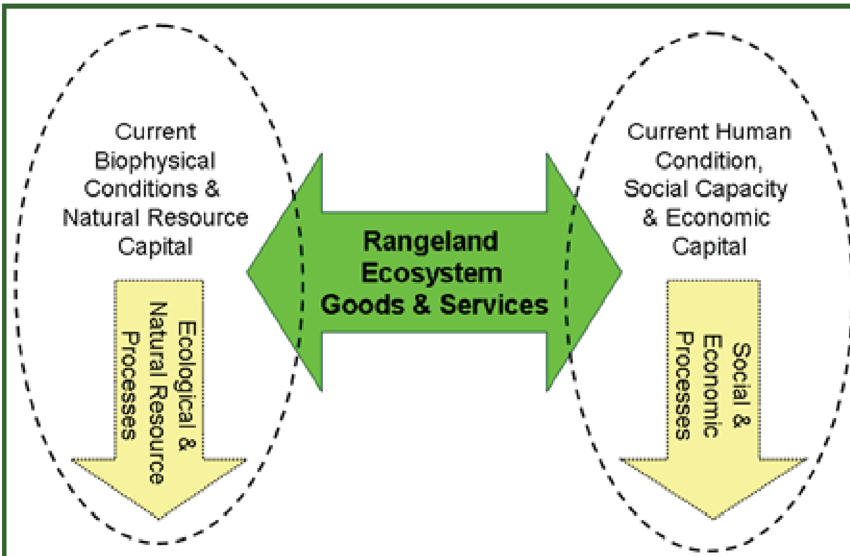
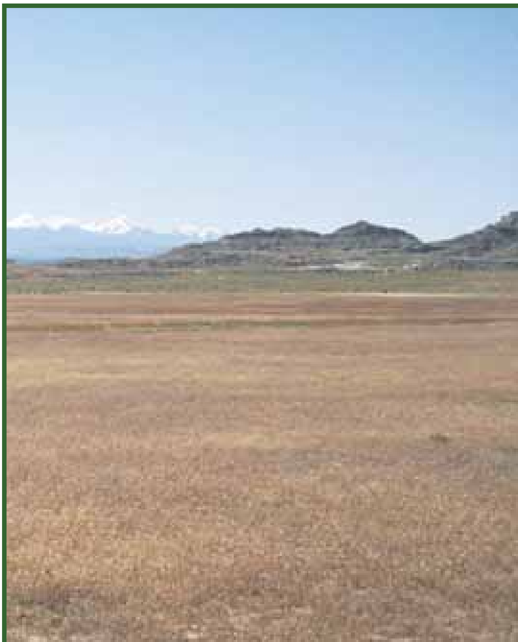


Figure 1. Rangeland Ecosystem Goods and Services provide the link between environmental systems and socio-economic systems.

resource processes" and "social & economic processes." This integration recognizes that ecological and natural resource processes affect and are affected, by social and economic capital stocks, capacities, conditions and processes. The framework asserts that those interactions occur by way of extraction and use of resources, waste discharge and ecosystem services. Interactions between the ecological and social/economic systems can lead to both positive and negative consequences. Human use of rangelands may produce benefits such as food and fiber, recreation and a sense of well-being. Human use can also result in alterations of the ecosystem and its processes so that rangelands no longer provide the desired goods and services. For example, invasion of cheat grass following natural or human disturbances changes the frequency and intensity of fires in an area, thus changing the vegetation communities and affecting wildlife habitat and forage productivity because cheat grass is inferior forage for grazing. Feedbacks between ecosystem goods and services and ecological and social/economic processes are usually complex and nonlinear.



Invasive species, like cheat grass, diminish the capacity of rangelands to produce ecosystem goods and services. Photo courtesy USGS.

Perceived benefits of a particular ecosystem will vary from person to person or from time to time based on individual and social values. For example, the value that society has placed on open space and recreation has increased in the last 60 years with an increase in leisure time, resources for recreation and environmental awareness. The Federal government responded by promoting the use of public lands and passing legislation mandating that agencies increase opportunities for recreation. Uses of ecosystem goods and services often result in trade-offs between various goods and services and ecological and social processes. For example, riding ATVs in an ecosystem can increase soil erosion and reduce soil stability.

Due to the interactions, feedbacks and trade-offs associated with human use of rangeland ecosystems, it is imperative to track trends in supplies of ecosystem goods and services and ecological and social processes. To this end, the SRR promotes the use of its indicators to monitor rangeland sustainability, including the associated goods, services and processes.

Ecosystem goods and services have value because they satisfy human needs. Value arises from human interactions with ecosystem goods and services, which may be positive or negative. Interactions vary to include eating a good steak or lamb chop, watching a sunset from a high butte, galloping a horse over open range, meditating in wilderness and fishing in a mountain stream.

Value is personal and subjective, but there are commonalities in basic human needs and experiences that make it possible to measure collective values realized by various populations. Values people place on

Rangelands can provide optimal sites for windmills to generate renewable energy.
Photo courtesy of USDA ARS.

goods and services are closely related to the preferences revealed by the choices they make. Value can be signaled by prices in market transactions or revealed by other behaviors, such as distance traveled to a favorite fishing hole.

Using prices derived from market transactions for goods and services is part of the economic system's means of creating incentives that shape economic behavior, generally yielding greater production of goods and services that produce profit. Values revealed or expressed through non-market processes also influence behavior, often through institutions of collective action. In general, allocation of resources to production of goods and services through collective institutions is less dynamic and often less efficient. Such goods and services tend to be under-produced because they depend on taxes or government regulation, which are limited by governance processes. In addition to interactions normally considered as uses, value can result from exchange of ownership, maintenance of the option for ownership or use, the desire to make something available to future generations, or the simple existence of the good or service. The first is generally more amenable to market transactions, while option, bequest and existence (i.e., non-market) values are less frequently subject to transactions. Non-market values may be estimated by methods such as travel cost or contingent valuation.

In principle, all entities, conditions and processes in rangeland ecosystems that contribute to valued ecosystem goods and services also have value, though in many cases that value will not be signaled by market prices or be measurable through methods revealing peoples' preferences. The fact that so many ecological processes interact to produce rangeland ecosystem goods and services also makes it more difficult to estimate the value of a specific process.

Societal values for rangeland resources and ecosystem goods and services can lead to the development of conservation incentives that might be used to accomplish rangeland management objectives or promote sustainable management practices. A basic tenet of economic theory is that people respond to incentives. If one wants to encourage a particular behavior, one provides some kind of incentive. Incentives might include direct payments, preferential tax treatment, or cost share opportunities, among others. If one wants to discourage a particular behavior, one provides some kind of disincentive. Disincentives might take the form of taxes or regulations, among other mechanisms.

Knowledge of linkages among ecological and natural resource processes and social and economic process, as well as their interactions, as depicted in the SRR conceptual framework, can inform design of incentive-based policies and programs to facilitate production, maintenance, or restoration of ecosystem services.

Importance of Rangeland Ecosystem Goods and Services

By definition, ecosystem goods and services (EGS) are important to the extent that they satisfy human needs. Goods and services have been grouped in various ways. For example they have been grouped into provisioning, regulating, cultural and supporting services by the Millennium Ecosystem Assessment (2005; see also Havstad et al 2007). Another approach is to group them into tangible goods, tangible services and intangible services—the last of which are primarily perceptual in nature.

Rangeland EGS affect people across economic, social and cultural and environmental boundaries. For example, people profit from the sale of ecosystem goods such as food and fiber, biofuels feedstocks and biochemicals extracted from plants. Rangelands also generate intangible benefits such as the pleasure that people take in observing plants and wildlife, studying natural systems and hunting and fishing. These intangible benefits include the sense of wonder and spiritual connection that many people feel when immersed in rangeland landscapes.

Environmental perquisites may result from co-occurring products and processes. For example, some forage species produced for biofuels feedstock may also help reduce the net addition of carbon dioxide to the atmosphere. This activity may also increase energy security by providing alternatives to imported oil.

Social perquisites stem from a broad view of ecosystem services, dividends they provide and how the provision of ecosystem services (by ecosystem functions) is perceived and realized. Recognize first that economic dividends of ecosystem services are a subset of social dividends. They are merely particular outcomes of ecosystem functions that are recognized as valuable inputs to processes that result in specific interactions and transactions in an economy—typically this would be a market economy, but it could also be a non-market economy. Those ecosystem services considered to provide economic dividends are generally commodity-type ecosystem services such as fish, timber, or wildlife and the habitats that support those ecosystem commodities. However, they also include non-commodity products such as berries and mushrooms harvested for personal use and precursors to a variety of chemicals and pharmaceuticals. Perception and realization of dividends provided by such ecosystem commodities is relatively straightforward.

Other social dividends stem from outcomes of ecosystem functions that are more difficult to specifically define and measure. These are largely the "life support services" (Millennium Assessment, 2005; Dailey, 1997) and "backdrop services" against which everyday life proceeds. When such ecosystem services (resulting from a variety of ecosystem processes) are functioning "correctly" we might not perceive that they are there. Nonetheless, they are critical to human life.

Although a comprehensive accounting of the economic, social and environmental perquisites of rangeland EGS is not practical, Table 1 offers some examples of these dividends.

Table 1. Examples of rangeland ecosystem goods and services and their potential dividends

Rangeland Ecosystem Good or Service	Dividend
Forage production (for livestock consumption)	**Economic** • Sale or lease of feed for grazing • Hay production **Environmental** • Landscapes for biodiversity, native species • Soil stability • Clean air and water • Some crops, e.g. nitrogen fixers, enrich soil **Social/Cultural** • Open space • Rangeland-dependent rural communities
Beef and lamb production (food for human consumption)	**Economic** • Sale of meat and fiber products • Ranching operations • Economic base for ranching communities **Environmental** • See forage production above **Social/cultural** • Satisfaction people enjoy in ranching as a way of life • Open space
Fishing and hunting	**Economic** • Sales of licenses, gear, guide services • Access rights (to fish or hunt) on private or public lands **Environmental** • Promotion of healthy wildlife populations • Biodiversity maintenance • Control of hunted populations, e.g. deer, elk **Social/Cultural** • Pleasure involved in fishing and hunting • Watchable wildlife

Rangeland Ecosystem Good or Service	Dividend
Clean water	<u>**Economic**</u> • Satisfaction of household, agricultural and industrial needs • Sale of bottled water • Income from water-based recreation—swimming, boating, fishing <u>**Environmental**</u> • Habitat for fish and other aquatic organisms • Drinking water for wildlife • Rejuvenation of channels and riparian areas via sediment transport and deposition, creating bare soil for germination, etc. <u>**Social/Cultural**</u> • Aesthetic qualities of unpolluted water bodies • Pleasure people derive from water-based recreation
Wind	<u>**Economic**</u> • Capture and sale of wind energy <u>**Environmental**</u> • Dispersal/dilution of pollutants • Pollination of wind-pollinated plants • Seed dispersal <u>**Social/Cultural**</u> • Sense and smell of gentle breezes
Wood	<u>**Economic**</u> • Sale of fuelwood and fence posts <u>**Environmental**</u> • Wildlife habitat • Spatial diversity in litter, soil nutrients, etc. <u>**Social/Cultural**</u> • Warmth, sight and smell of campfires
Seeds and plant materials	<u>**Economic**</u> • Seeds and cultivars for forage and land restoration <u>**Environmental**</u> • Genetic diversity <u>**Social/Cultural**</u> • Human values relating to restored rangelands

Rangeland Ecosystem Good or Service	Dividend
Floods	**Environmental** • Maintenance of soils via sediment deposition • Maintenance of aquatic habitats via sediment removal and reworking, creation of snags over streams, etc. • Rejuvenation of channels and riparian areas
Biofuels feedstocks	**Economic** • Sale of the feedstock and the resulting biofuel **Environmental** • Depending on feedstock (e.g. natural grasses): – biodiversity maintenance – soil enrichment – carbon sequestration in soil (itself an EGS) – reduced release of carbon to the atmosphere
Sites to observe (e.g. landscapes)	**Economic** • Income from tourism **Environmental** • Maintenance of biodiversity in protected sites **Social/Cultural** • Aesthetic and spiritual satisfaction • Intellectual satisfaction from study of sites

Rangeland EGS ultimately depend upon core processes that are fundamental to ecosystems, but are not themselves goods or services. Almost all EGS result from complex interactions among these processes and almost all these processes contribute to numerous categories of goods and services. These processes fall into several general categories:

- edaphic (e.g., soil formation, recycling of nutrients),
- biological (e.g., primary production, maintenance of biodiversity),
- hydrological (e.g., water cycling, soil erosion, sediment transport),
- atmospheric (e.g., weather events, climate change) and
- physical (e.g., fires).

These processes collectively create the current biophysical conditions and natural resource capital that are the bases of the EGS provided by rangelands.

The fundamental challenge in valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structures and functions of natural systems, the benefits (i.e., goods and services) derived by humanity and their subsequent values. Ecosystems are complex and the translation from ecosystem structure and function to ecosystem goods and services (i.e., the ecological production function) is difficult. In many cases, the lack of markets and market prices and absence of other direct behavioral links to underlying values makes the translation from quantities of goods and services to value (and direct translation from ecosystem structure to value) quite challenging. For some ecosystem goods and services, it is even difficult to express quantities of the good or service.

From an ecological perspective, the challenge is to interpret basic research on ecosystem functions so that service-level information can be communicated to economists and others. For economics and other social sciences, the challenge is to identify the values of both tangible and intangible goods and services associated with ecosystem functions and (recognizing that not all ecosystem services can be valued completely or at all) to address the problem of decision making in the presence of partial valuation. The combined challenge is to develop and apply methods to assess the values of human-induced changes in ecosystem functions and services (National Research Council 2005, p. 4).

The values people place on goods and services are closely related to the preferences revealed by the choices they make. Looking back at U.S. history, basic categories of values have remained somewhat the same while particulars within these categories have changed as illustrated in Figure 2. Monitoring the outcomes of these choices through the indicators created by the SRR can help us understand society's preferences and priorities or values for rangelands ecosystem goods and services, thus highlighting the importance of rangeland resources and giving managers information to use to evaluate trade-offs.

Sustainability of rangelands implies availability of a full suite of goods and services for future generations, which requires that we ensure the proper functioning of core ecosystem processes. The linkage of management actions and policy decisions to EGS outcomes and effects on ecological processes and functions is of critical importance. Monitoring, with a core set of indicators that reflect the importance of rangeland EGS, is key to meeting current and future human needs.

Subsequent sections include a more detailed discussion of linkages between indicator-based monitoring and ecosystem goods and services. Building on information provided by these indicators, SRR has developed a simple tool to assist land managers in evaluating EGS on their lands.

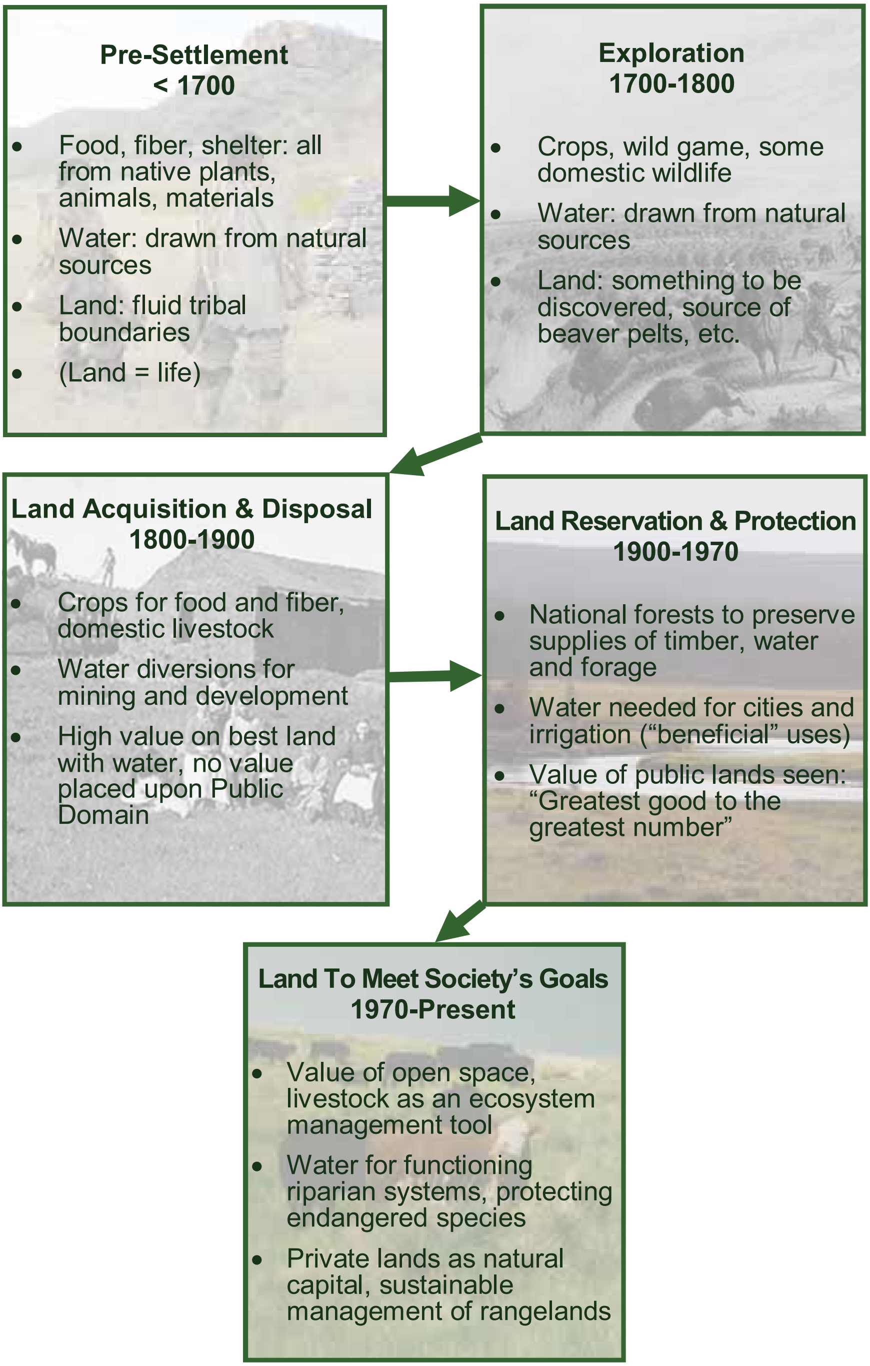


Figure 2. Timeline showing how society's values for rangeland goods and services have changed (based on unpublished presentation by Fee Busby, Utah State Univ.)

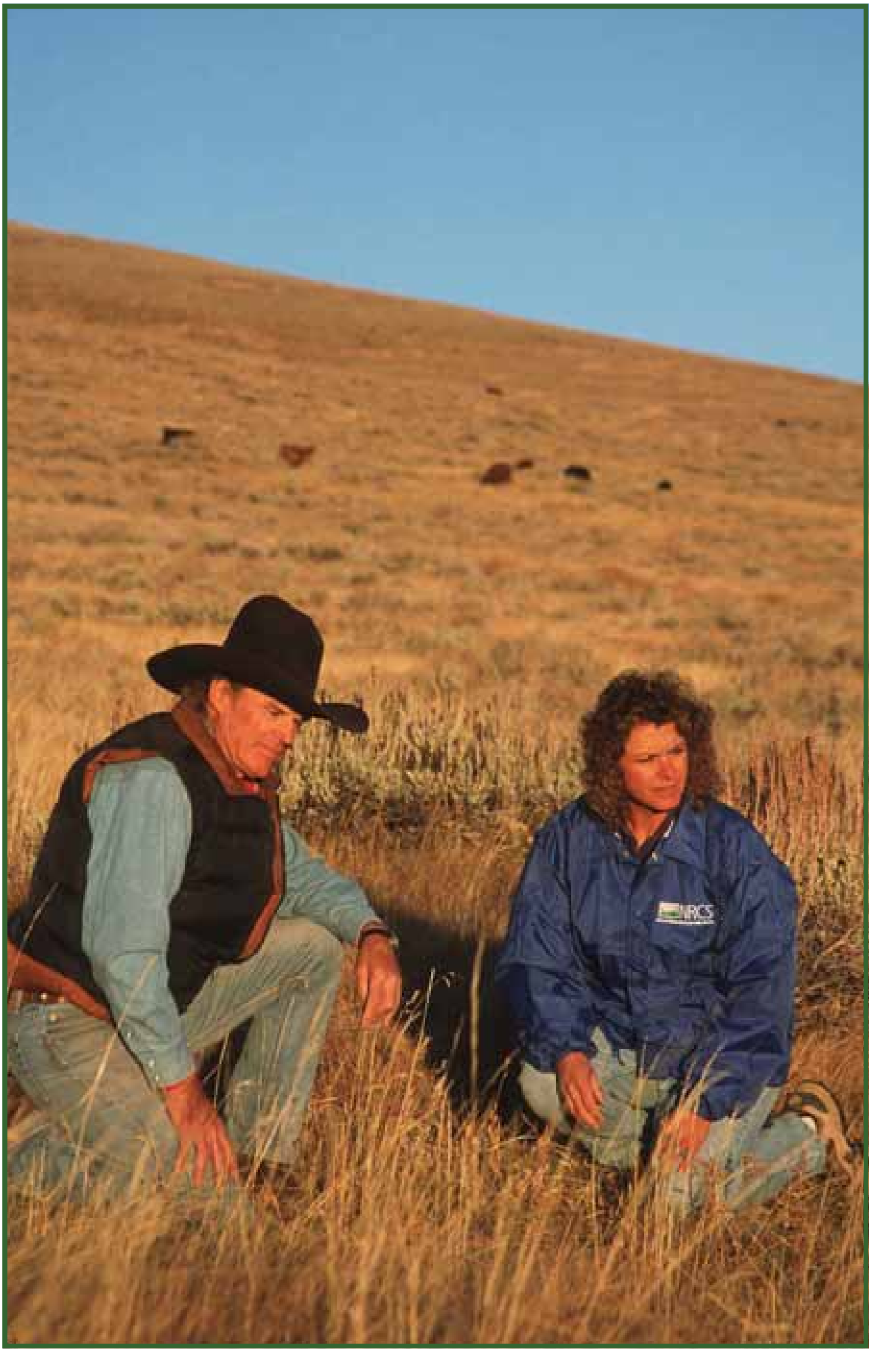


Photo courtesy of USDA NRCS.

Evaluating Ecosystem Goods and Services

Ecosystem goods and services are as varied as is their importance to different users. To address the importance of EGS for public and private lands, SRR proposed a consistent set of questions to evaluate each good or service. While responses to the questions are important, it is the evaluation and discussion process that provides the most useful information. Using an example of a private landowner consulting with an NRCS rangeland conservationist or other technical service provider, SRR shows how these questions can be used to inform their EGS objectives.

Consider a 2,000 acre ranch in Montana with a commensurate public land grazing allotment. Several streams run through the ranch, which also has some stock water ponds and many developed and undeveloped springs. The ranch sits in the foothills of the Absaroka Mountains. The country is wide open with picturesque views, within an hour's drive of Bozeman. More and more people are discovering the area for outdoor recreation—hunting, fishing, off-highway vehicle use, bird watching, etc.

The ranch is a mosaic of sagebrush-dominated rangelands with native and introduced grasses in the understory. Lowlands are used for hay production and a public land grazing permit allows the ranch to graze its cattle for much of the spring and summer. Recently there has been pressure to adjust cattle management on public lands away from springtime use due to conflicting resource concerns.

The rancher worries about several issues that will affect the ecosystem goods and services that his land can produce. Table 2 provides a list of different potential ecosystem goods and services that could be considered, but please note that there may be more.

While the list in Table 2 is not comprehensive, it does represent many of the EGS that could be produced from rangelands to provide economic value to the landowner. We have listed them according to whether they are derived from biological, hydrological/atmospheric, or miscellaneous processes simply as a way to organize the information. Each of these EGS could be considered by the rancher for focused management and development as he goes through business planning processes.

Our rancher, in visiting with the local NRCS rangeland conservationist, looks at each EGS as a potential income source or as a way to enhance conservation. During the debate, it becomes apparent that a more rigorous way to evaluate the potential income sources is needed. After much discussion, the rancher and rangeland conservationist agree on a set of questions to frame the evaluation process. The questions are divided by the relative importance they may want to place on the answer (Table 3). Appendix A provides some blank worksheets for evaluating the different types of EGS.

Table 2. Ecosystem goods and services derived from rangelands.

Biological	Hydrological/Atmospheric	Miscellaneous
Domestic Livestock	Drinking Water	Views and Scenes
Other Food for Human Consumption	Water for Economic Benefit	Cultural or Spiritual Resources
Forage for Livestock	Floods for Channel and Riparian Area Rejuvenation	Historical/ Archeological Sites
Fiber	Flood Mitigation	Scientifically Significant Sites
Biofuels	Water Bodies for Recreation / Tourism	Recreation and Tourism Sites
Fishing, Hunting and Viewing Wildlife	Minimizes Contributions of Chemicals and Particulates	Ornamental Resources
Biochemicals	Contributes to Clean, Fresh Air	Ceremonial Resources
Genetic Material	Hydrologic Energy Potential	
	Solar Energy Potential	
	Wind Energy Potential	

The first two questions (Must Haves) are meant to determine if the EGS is rangeland-related and whether it is a good or service about which society cares. If the answers to both of these questions is "yes," the second set of questions (Wants) evaluates the potential goods and services. Following is a discussion of how the rancher and range conservationist could use each question to evaluate one rangeland ecosystem good, for example the **production of biofuels**. For this discussion, we will assume that the rancher is considering converting a significant portion of native rangeland to biofuels feedstock production. In this case, in-depth discussions of trade-offs are necessary to understand implications of this decision in terms of impacts to other EGS produced on the ranch.

The Must Have questions can be answered "yes" since we are talking about using rangelands to produce plant materials that can be used as feedstock for biofuels production. Biofuels are important for human well-being to the extent that they may replace other sources of fuels. Many states are passing legislation requiring that a certain percentage of their energy comes from renewable sources. The more ambiguous discussions are related to the "Wants" questions.

Does the EGS provide a basic human need? Is it important to society? While biofuels do not necessarily provide a basic human need, they are deemed to be important to society. Ethanol is being used as a substitute for fossil fuels based gasoline. They agree to rate this as Medium.

What is the current level of demand for the EGS? Demand for ethanol products is increasing and new technologies are being developed to produce it more efficiently and from different feedstocks. With the state-driven legislative mandates, demand for such energy sources can only be expected to increase over the next few decades. They agree to rate this as Low-Medium.

How responsive is the EGS to management? Once the plant material desired for biofuel production is selected and demonstrated to be cultivated on rangelands, it will be very responsive to management.

Table 3. Questions used to evaluate ecosystem goods and services.

Must Haves (Yes / No)
• Does the EGS exist on or is derived from rangelands? • Is the EGS important to rangeland ecosystem processes and/or human well-being? *Both questions must be answered YES to continue.*
Wants (High/ Medium/ Low/ NA)
High Importance • Does the EGS provide a basic human need? Is it important to society? • What is the current level of demand for the EGS? • How responsive is the EGS to management? **Moderate Importance** • How easily is the EGS measured? • How important is the EGS over local, regional and national spatial scales? • How important is the EGS over different temporal scales? • How resilient is the EGS? • How much does human activity impact the EGS? • How important are rangelands to this EGS? • How unique is the EGS to rangelands? **Low Importance** • For this good, are there no potential substitutes? **Consequences** • Is the EGS impacted by local, state or federal regulations?

Switchgrass, a potential biofuel feedstock, can be grown on rangelands to provide additional income streams to ranchers. Photo courtesy USDA ARS.

In discussions about the trade-offs, the rancher comes to understand that there will be a net loss in other EGS, such as reduced forage and changes in wildlife habitat, erosion potential, or the landowners viewscape. Each of those would have to be evaluated using this same set of questions. They agree to rate this as High.

How easily is the EGS measured? Measurement of the amount of biofuel feedstock produced is relatively easy and predicted ranges would become known for this specific area over time. Estimating prices for the feedstock is more uncertain depending on where a processing facility is built and the number of those that participate in the market. They agree to rate this as High.

How important is the EGS over local, regional and national spatial scales? Feedstock production and processing is important at the local scale. The location of the processing facility in relation to the ranch is a critical factor in determining whether the alternative is economically feasible. The demand and hence prices received, for the feedstock are probably more important at the regional and national scales where demand for the final product (ethanol) is set. They agree to rate this as High for local, Medium for regional and Medium for national.

How important is the EGS over different temporal scales? Production and demand for the feedstock is expected to increase over time. Demand will be driven by higher crude oil costs and the legislatively driven desire to reduce dependence on fossil fuels. They agree to rate this as Moderate.

How resilient is the EGS? Once established, the feedstock may be resilient. However, rangelands as a whole will become less resilient due to the loss of biological diversity and alternation from a native, intact system to one that resembles a monoculture. They rate this as Low.

How much does human activity impact the EGS? Fuel consumption impacts the demand for feedstock. They rate this as Medium.

How important are rangelands to this EGS? National rangelands will probably never produce a significant portion of biofuels compared to what can be produced on crop and forest lands. However, for specific locations, rangelands could produce significant amounts. They agree to rate this as Low.

How unique is the EGS to rangelands? Production of feedstocks from rangelands is not unique. They agree to rate this as Low.

For this good, are there no potential substitutes? There are numerous alternative sources of biofuel feedstocks from crop and forest lands. They agree to rate this as Low.

Is the EGS impacted by local, state, or federal regulations? At this point in time, biofuel feedstock production is not impacted any more or less than any other crop. Regulations on clean air, clean water, product safety, worker safety, etc. affect its production just as any other agricultural production activity. They agree to rate this as Low.

Discussion. At the end of the discussion, the rancher and rangeland conservationist enter the agreed-upon responses into the worksheet from Appendix A. Table 4 shows their responses for biofuels and a few other ecosystem goods and services. The rancher, in consultation with the rangeland conservationist, now must interpret the results and decide how the information can be used in conservation planning and decisions regarding investing in one activity or another.

After the rancher has evaluated all the EGS potentially available on his ranch, as well as the trade-offs of selecting different mixes, he can decide how to proceed. The rangeland conservationist can provide advice on management and investment options. The results in Table 4, combined with the landowner's goals, can eliminate some options and highlight others for further examination.

This example is used to show one use of the evaluation questions and associated discussions. We believe it can be used at a variety of other decision making and analysis scales in addition to the private property level. Questions may need to be adjusted for the scale at which the evaluation is occurring, but the questions can lead to fairly thorough discussions.

The previous example illustrates a tool for evaluating the importance of rangeland EGS on a local scale. In the following sections, we use the SRR conceptual framework as a tool for evaluating their importance at a broader policy analysis level to guide regional and national decisions.

Table 4. Example responses for biofuels and other ecosystem goods and services on the example Montana ranch.

	Domestic Livestock for Human Consumption	Biofuel Feedstocks	Fishing, Hunting and Viewing Wildlife	Recreation and Tourism Sites
Must Haves (Yes / No)				
Does the EGS exist on or is derived from rangelands?	YES	YES	YES	YES
Is the EGS important to rangeland ecosystem processes and/or human well-being?	YES	YES	YES	YES
For each column, both questions must be answered YES to continue.				
Wants (High/ Medium/ Low/ NA)				
High Importance				
Does the EGS provide a basic human need? Is it important to society?	H	M	M	L-M
What is the current level of demand for the EGS?	H	L-M	M	M
How responsive is the EGS to management?	H	H	H	L
Moderate Importance				
How easily is the EGS measured?	H	H	L	H
How important is the EGS over different spatial scales?				
Local	H	H	M	M
Regional	M	M	L	L
National	L	M	L	L
How important is the EGS over different temporal scales?	M	M	M	L

H = high; M = medium; L = low

Table 4 (continued). Example responses for biofuels and other ecosystem goods and services on the fictional Montana ranch.

	Domestic Livestock for Human Consumption	Biofuel Feedstocks	Fishing, Hunting and Viewing Wildlife	Recreation and Tourism Sites
Wants (High/ Medium/ Low/ NA)				
How resilient is the EGS?	M	L-M	M-H	H
How much does human activity impact the EGS?	H	M	H	L
How important are rangelands to this EGS?	M	L	M-H	H
How unique is the EGS to rangelands?	M	L	M-H	M
Low Importance				
For this good, are there potential substitutes?	L	L	M	L
Consequences				
Is the EGS impacted by local, state or federal regulations?	L/M	L	M-H	L

H = high; M = medium; L = low

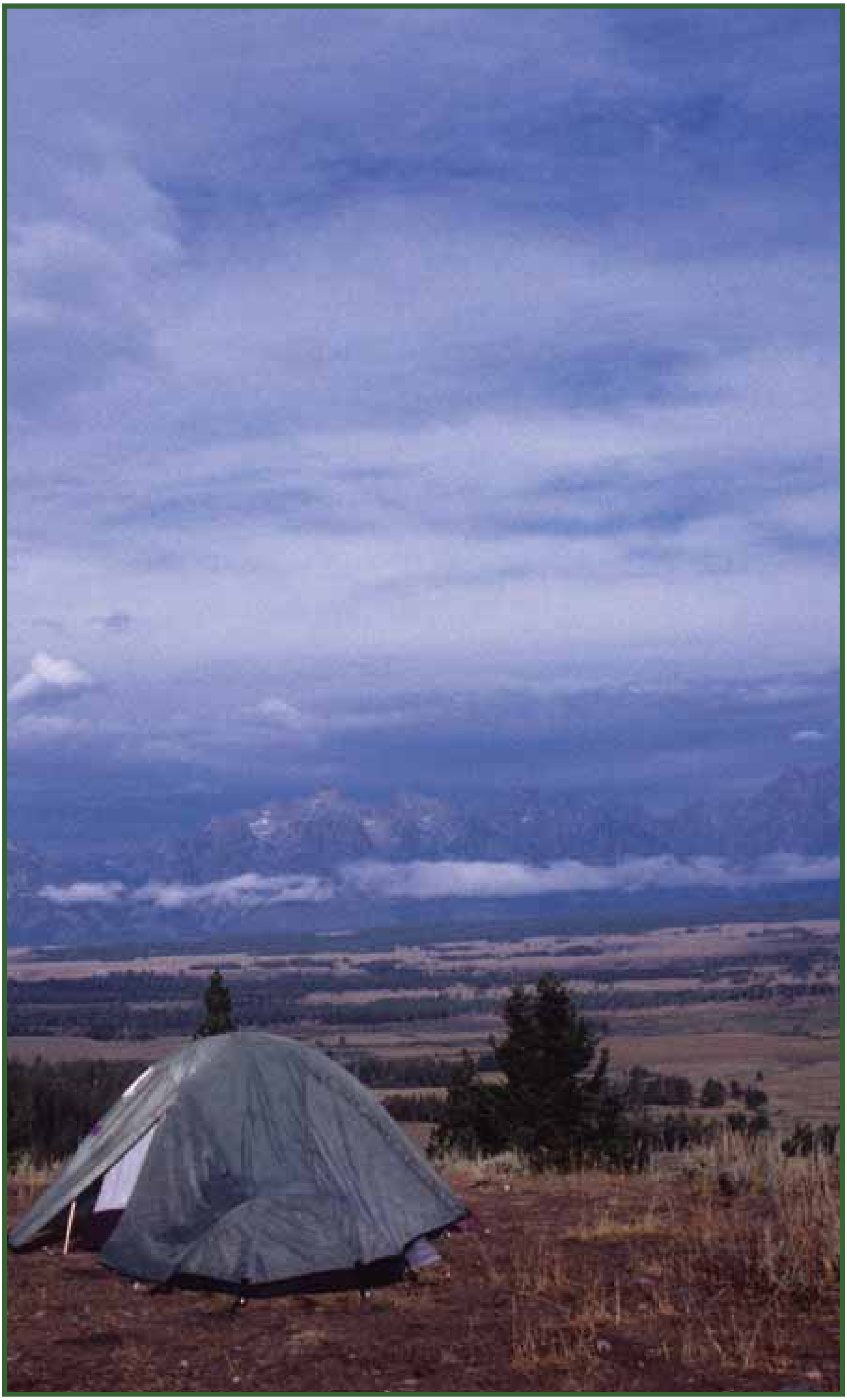


Photo courtesy NBII.

Conceptual Framework for Assessing Ecosystem Goods and Services

SRR recognized a need for an interdisciplinary framework in which to consider rangeland sustainability issues. Practitioners representing several disciplines cooperated to develop indicators for assessing and monitoring rangeland sustainability and subsequent indicator lists addressed ecological, social and economic perspectives.

Although participants explicitly acknowledged the importance of integrating all three disciplines, SRR indicator lists (Appendix B) retain individual disciplinary focuses. Proposed indicators represent two relatively separate sides of a conceptual framework for rangeland sustainability evaluation and assessment. This framework has the dual purposes of providing a logical and consistent structure to evaluate rangeland sustainability indicators, as well as to provide the context for considering interactions between ecological processes and indicators and social and economic processes and indicators.

The resulting SRR conceptual framework (the Integrated Social, Economic and Ecological Concept for Sustainable Rangelands or ISEEC; Fox et al, in press) facilitates discussion of ecosystem services and their uses as the primary interface between people and the environment. They are the "bridge" across which impacts move between the ecological realm and the social/economic realm. Ecosystem services depend not only on ecosystems and ecological processes, but on a functioning society and economy and social and economic processes.

Ecological systems and processes provide the biological interactions underlying ecosystem health and viability. Socio-economic infrastructures and processes serve as the context in which rangeland use and management occurs and rangeland health improves or deteriorates. These systems and processes interact across time and space.

The ISEEC depicts changes over time, identifying linkages among system components to illustrate forces of change. Integration of ecological and socio-economic processes within a conceptual framework provides a holistic means for "seeing through the complexity to the underlying structures generating change" (Senge 1990). The ISEEC allows SRR to organize rangeland ecosystem complexity into a logical "story."

The basic, Tier 1 ISEEC (Fox et al, in press), is illustrated in Figure 3. The current state of the world is categorized into four component states: (1) Current Biophysical Conditions, (2) Natural Resource Capital, (3) Social Capacity & Economic Capital and (4) Current Human Condition. As shown by the large vertical arrows in the diagram, the four component states are acted upon by Ecological & Natural Resource Processes and Social & Economic Processes. These processes, acting independently and in combination on the states in time period 0, result in the states in time period 1. Integration of ecological/natural

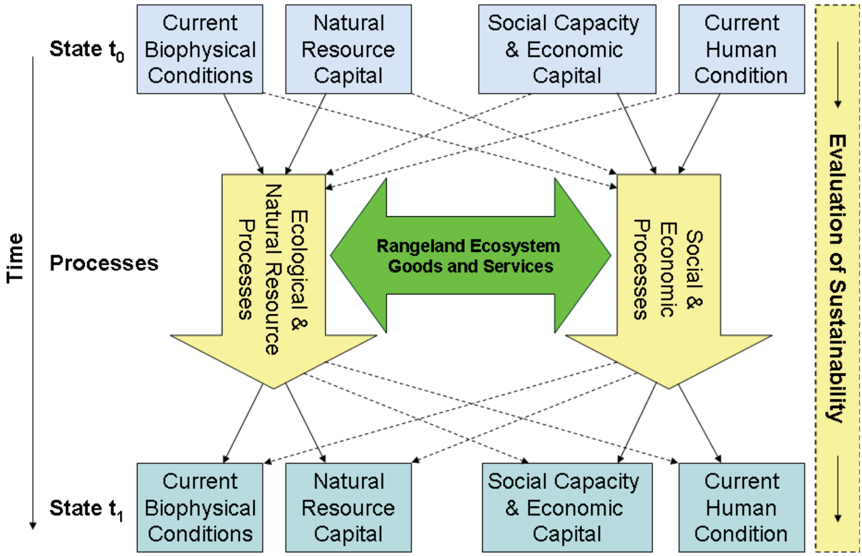


Figure 3. Tier 1 Integrated Social, Economic and Ecological Concept (ISEEC) for Sustainable Rangelands (Fox et al, in press)

resource and social/economic factors is represented in the Tier 1 conceptual framework by the large horizontal arrow. This explicitly recognizes and illustrates that the processes affect and are affected by each other. The smaller, solid arrows in Figure 3 show direct effects and impacts between states and processes. The dashed arrows show indirect effects and impacts to other processes.

Current Biophysical Conditions include the state and status of rangelands biota, as well as the environmental conditions that influence and are influenced by the biota—in other words, the rangeland ecosystem. It includes biotic and abiotic characteristics that constitute a particular rangeland, such as air and water pollution, chemical composition and condition of the soil and level of biodiversity in the rangeland ecosystem. Natural Resource Capital is the total biomass present in the ecosystem—both plants and animals.

Social Capacity & Economic Capital refer to the capacity of society and social networks to maintain or transform social systems, which represents both opportunities and constraints afforded by a society's existing organization. This category includes individual and community social and support networks and the institutional structures of society that encompass regulatory, educational, governance and legal systems. It also includes human populations as human capital. Economic capital represents the physical capital present in the economy. Current Human Condition represents human well-being—the state and status of individuals, groups and society. It includes cultural orientations associated with values and norms present in a society, as well as economic conditions such as employment and unemployment, income distribution within society and growth rate of the economy. The distribution of factors affecting societal well-being (e.g., population structures, educational status, poverty, quality of social interactions, community cohesiveness and stratification) can maintain or change a social system.

The processes shown in Figure 3 comprise the actions taking place in the ecological and socio-economic subsystems between points in time.

Ecological and Natural Resource Processes include functions that produce biomass, either through primary production via photosynthesis or by consumption and conversion of other biomass. They also include the variety of processes that continuously cycle the finite elements found in the biosphere as a result of the carbon, water and nutrient cycles. Such processes are performed or mediated by the rangeland biota and, in turn, set the conditions for the functioning of the biotic world.

Other ecological processes include dynamics like succession, migration, adaptation, competition and soil genesis and erosion. Disturbances such as flood, drought and fire are also considered ecological processes within our framework. Ecological processes interact with and affect each other. The processes are driven and controlled by Current Biophysical Conditions and Natural Resource Capital and the outcomes become the Current Biophysical Conditions and Natural Resource Capital in the next time period.

The Valle Caldera Preserve has been set aside to conserve properly functioning rangeland ecosystems and provide recreation opportunities. Photo courtesy Lori Hidinger.

Economic Processes include demand, production of goods and services, trading, investment and consumption or use of goods and services. Production of goods and services is broadly defined to include "household production" (such as meals, a residence and recreation) (Becker 1965, 1974; Lancaster 1966), as well as manufacturing processes. Social Processes include management and social regulation, reflecting social policies pertaining to natural resource use and management. Human population processes on the socio-economic side of the framework include birth, migration, aging and morbidity. Other elements occurring on the right side of the framework include cultural resources, education, governance structures, markets, legal system, social interaction and family. These processes determine the organization of society. Taken together, economic and social processes act on existing conditions and result in Social Capacity & Economic Capital and Current Human Condition in the next period.

Moving on to Figure 4, we envision three primary points of interaction between the ecological and social/economic sides of the framework: ecosystem goods and their extraction, tangible and intangible ecosystem services and their use and waste discharge and alterations of landforms and water flows. That "interface" is shown in the circle between the process arrows.

Ecosystem Goods and Their Extraction: On rangelands, the traditional extraction that occurs is consumption of forage by livestock and wildlife. In addition, various plants are extracted for purposes such as fuel, construction materials, herbal and medicinal uses and landscaping (Kane 2006). Increasingly important is the extraction of water from rangeland ecosystems for irrigation and consumption. Such extracted ecosystem goods are demanded by people and enter into the production of consumable, tradable, or otherwise usable goods and services, which then contribute to Social Capacity & Economic Capital or to the Current Human Condition. Extraction obviously also affects the stock of Natural Resource Capital. By-products of extraction and the extraction process factor into the Current Biophysical Conditions through mechanisms such as soil erosion and vegetation dynamics.

Tangible and Intangible Ecosystem Services: Ecosystem services refer to a wide range of conditions and processes through which natural ecosystems and their constituent species help sustain, support and fulfill human life. These services can be tangible or intangible, but they are nevertheless critical for sustaining human well-being. Examples of these services are trees and grasses cooling streets and buildings, rangelands reducing stormwater runoff and lakes adding recreational opportunities and aesthetic beauty. Ecosystem services maintain biological diversity and support the production of ecosystem goods such as forage, timber, biomass fuels, natural fibers, precursors to many pharmaceuticals and industrial products and wildlife. Ecosystem services also support and enhance life through core ecosystem processes that help purify air and water, mitigate droughts and floods, generate

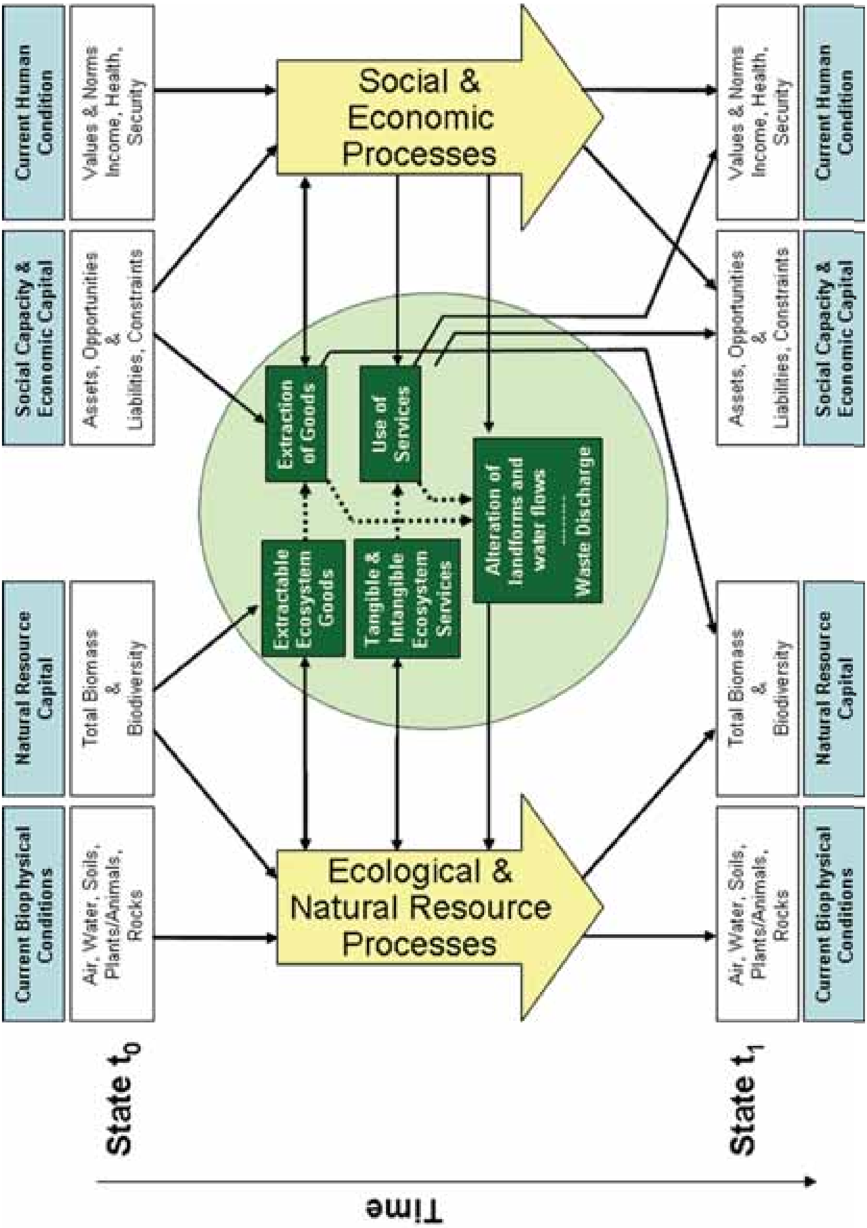


Figure 4. Tier 2 Integrated Social, Economic and Ecological Concept (ISEEC) for Sustainable Rangelands (Fox et al, in press).

Purple coneflower (*Echinacea purpurea*) is valued for its medicinal properties. Photo courtesy NBII.

soils and renew their fertility, detoxify and decompose wastes, pollinate crops and natural vegetation, control many agricultural pests, protect from the sun's ultraviolet rays, partially stabilize climate and provide opportunities for recreation and leisure activities, aesthetic beauty and intellectual stimulation (Daily et al. 1997).

More subtle uses of ecosystem services are related to recreation and "spiritual" or "aesthetic" services. Natural environments produce services that are not extracted as commodities but as perceptions or opportunities. Such services affect the human condition by promoting experiences of wonder, majesty and scenic beauty, or as a backdrop to life activities. They can also contribute to leisure and recreation activities. Such uses have by-products that can affect, positively or adversely, the natural environment—appreciation may lead to protection or restoration, overuse may lead to degradation of habitat and careless use may lead to wildfire.

Many ecosystem goods enter into the framework through extraction and productive processes, as described above. Such ecosystem goods are more commodity-oriented. The focus of the Tangible & Intangible Ecosystem Services and Use of Ecosystem Services boxes is to represent those services that do not explicitly enter by way of extraction and productive processes.

Waste Discharge and Alteration of Landforms and Water Flows: Wastes are discharged into the ecosystem as byproducts of several processes and they can have both positive and negative effects. For example, release of biosolids onto rangeland has been shown to increase primary production (Jurado and Wester 2001); however, nitrogen contained in biosolids can have adverse effects on plants and aquatic biodiversity through acidic leaching and nitrate losses can be problematic for maintaining water quality (Dalton and Brand-Hardy 2003). Waste discharge can also contribute to the spread of invasive species.

Perhaps the greater effects of waste discharge result from humans and human use of goods and services. These include discharges from production and manufacturing processes, byproducts of burning fossil fuels and wastes resulting from consumption and use of goods and services (such as discarded packaging). Some of the wastes are recycled back into productive processes while others are released into the ecosystem. Wastes released back to the ecosystem are acted upon by (or interrupt and otherwise alter) natural processes and result in changed conditions for Natural Resource Capital and Current Biophysical Conditions. Careless or malicious behaviors can also result (either intentionally or unintentionally) in environmental or ecosystem damage. Such byproducts of society affect both Current Biophysical Conditions and Natural Resource Capital.

Additionally, humans and human behavior can directly affect rangeland ecosystems by altering landforms and water flows. Some alterations are positive or neutral regarding their effect on the environment and others have negative effects. Increasing and migrating human populations encroach on rangeland. Rangeland uses have changed from

Urban sprawl extends development into rangelands impacting ecosystem services including wildlife habitat and forage production. Photo courtesy Marine Biological Laboratory.

grazing and open space to subdivision and residential development (Mitchell, Knight and Camp 2002), resulting in habitat fragmentation and basic changes in the composition of species. Exotic and invasive species may be introduced and spread. Native wildlife species may also become pests and nuisances, leading to their removal from parts of the ecosystem.

As an example, consider briefly how a rangeland invasive weed infestation works its way through social and economic systems and ecological and natural resource systems to impact the lives of ranchers. At what points in the progression through the systems are other ecological processes affected and how are they affected? How do effects on ecological and natural resource processes translate into effects on social and economic states and status? Similarly, how do changes generated in social and economic processes affect the ecological and natural resource state boxes in Figure 4, which in turn provoke changes in ecological and natural resource processes as the framework cycles through time? Given knowledge of ecological and natural resource processes and social and economic processes, as well as some linkages defining how and when each affects and is affected by others, can interventions be made that might mitigate adverse impacts on the rangeland resource and on ranchers?

Linking Ecosystem Goods & Services to Core Ecosystem Processes: Fort Hood and the Leon River Restoration Project

Origins of a Challenge in Central Texas

Following the attack by Japan on Pearl Harbor in 1941, the U.S. military initiated plans to develop a new training facility that could be more easily protected against external attacks. This led to the acquisition in 1942 of 108,000 acres of privately owned land through eminent domain in Bell and Coryell County near Killeen, Texas, for the establishment of Camp Hood. This camp was officially opened on September 18, 1942 and on April 15, 1950 it was designated the permanent status of Fort Hood. Following the initial land procurement, more private land was acquired to expand the area of Fort Hood to a total of 340 square miles (217,600 acres).

While farmers and ranchers whose land was seized to establish Fort Hood were compensated for their loss, they did not receive fair market prices. To offset the public relations problem, the Army began granting renewable five-year cattle grazing leases in 1954 to the Central Texas Cattlemen's Association (CTCA), which now consists of 83 descendants of the "original landowners" of Fort Hood (Keddy-Hector 2001). The current grazing lease involves 162,000 acres and 3,500 "animal units" (a single bull or a cow/calf unit) and is allocated to CTCA members based on the acreage their families owned or the area they have accumulated through membership buyouts. Since the late 1980's,


Fort Hood, Texas, 1944. Photo courtesy National Archives.

the collaboration between Fort Hood and the CTCA has, however, been affected by prescriptions of the Endangered Species Act (ESA) of 1973.

Specifically, the ESA forbids all federal agencies from authorizing, funding, or carrying out actions that may "jeopardize the continued existence of" endangered or threatened species (ESA Section 7(a) (2)). It also forbids any government agency, corporation, or citizen from taking endangered animals without written permission from the U.S. Fish and Wildlife Service (USFWS). Furthermore, once a species has been listed, the ESA also requires that “critical habitat” for the species must be designated, including areas necessary to recover the species (ESA Section 3(5) (A)) and federal agencies are forbidden from authorizing, funding, or carrying out any action that "destroys or adversely modifies" such critical habitat (ESA Section 7(a) (2)).

Due to the unequivocal prescriptions of the ESA, the listing of the black-capped vireo (*Vireo atricapilla*) and golden-cheeked warbler (*Dendroica chrysoparia*) on 6 October 1987 and 4 May 1990, respectively, had immediate repercussions for Fort Hood and the CTCA, as well as landowners in surrounding areas with land that contains critical habitat for these species. Tank maneuvers, the primary training activity on Fort Hood, can directly affect the habitat of these species through fires that may be initiated by live ordinances. By contrast, livestock grazing indirectly impacts them because cattle attract cowbirds, which are brood parasites that lay their eggs in the nests of songbirds, including those of the black-capped vireo and golden-cheeked warbler.

The USFWS commissioned a study to determine how problematic the cowbird was for endangered species. This resulted in the exclusion of cattle from 24,000 acres for the duration of the research period. The CTCA members contended that the endangered species were being used as an excuse to evict them. This reaction, combined with supportive political pressure from one of the Texas senators and the governor's office, eventually resulted in the removal of cattle from a smaller area and greater efforts to trap cowbirds on Fort Hood. It also led to the initiation of the Leon River Restoration Project (LRRP).

Leon River Restoration Project

Golden-cheeked warbler. Photo courtesy Austin Wildland Conservation Division.

The LRRP has three primary objectives: (1) improve water quality in the Leon River watershed, (2) improve habitat for golden-cheeked warbler and black-capped vireo in the areas adjacent to Fort Hood and (3) improve forage supply for livestock. The primary approach for accomplishing these objectives is the selective removal of native Ashe's juniper (*Juniperus ashei*), that has increased in abundance to impair forage supply, habitat and water quality. To meet the second objective (the focus of this case study), juniper management was used to promote native vegetation growth beneficial for the endangered birds. For example, mature juniper trees are critical for golden-cheeked warblers because they provide the stringy bark used by these birds for nesting material, while invasive re-growth juniper competes with other hardwood species and invades interstitial open spaces, both of which are key components of their habitat. In addition, invasive juniper trees have also been identified as key factors for declines in stream flow in the Edwards Plateau and forage production.

Four factors were responsible for the success of the LRRP with respect to all three objectives. First is the provision of technical and financial assistance to apply conservation measures, such as large scale removal of re-growth juniper, subject to the development of an approved Wildlife Management Plan with Texas Parks and Wildlife (TPWD) or a Resource Management Systems Conservation Plan with the Natural Resources Conservation Service (NRCS) (NRCS 2007). The second is effective collaboration between important stakeholders.

These include landowners who are members of CTCA and other non-affiliated landowners who are community leaders; federal agencies, especially the NRCS and USFWS; state agencies including the TPWD; and Non-government Organizations (NGOs) including Environmental Defense. The third criterion for success is effective and politically connected project leadership. This catalyzed trust among participating landowners and collaboration among participating agencies, NGOs and researchers. Finally, the credibility of the project was enhanced by participating Texas A&M University researchers who undertook research to address questions about the effects of juniper removal on water and forage supply and endangered species populations in the Leon River Watershed.

The LRRP represents an ideal case study for applying the SRR conceptual framework (ISEEC) to link bio-physical and socio-economic systems in the provision of rangeland ecosystem goods and services. The ecosystem service that is addressed in the case study is the enhancement of biodiversity through the provision of endangered species habitat. The Tier 2 ISEEC (Figure 4) is used to work through these linkages represented by this case study.

Bio-Physical and Human Subsystems

The bio-physical and human subsystems and their interactions with respect to the ecosystem service at the center of this case study are depicted in Figure 5. The relevant bio-physical condition is the population size of black-capped vireos and golden-cheeked warblers. The natural capital needed to sustain these endangered species is represented by the amount of habitat at the start of the evaluation period (t_0). For the human subsystem, the relevant condition is the concern over biodiversity loss, in this case, population decline in the two endangered bird species.

This concern is affected by the economic capital and social capacity of stakeholders, including landowners upon whose land the habitat occurs. The greater their disposable income, the greater their capacity to respond to concerns that are not related to their immediate survival, such as protection of endangered species habitat. Social capital relates to this issue because members of societies that are concerned about maintaining biodiversity and characterized by strong community links are more likely to respond to the plight of declining species than members of societies that do not exhibit such attributes. Measures of social capital include general and interpersonal trust, reciprocity and community networks (Hofferth and Iceland 1998; Putnam 2000).

Clearly, bio-physical and human sub-systems do not independently affect the fate of endangered species. Rather, they interact in their effect on the ecological processes that affect the maintenance of critical habitat elements. These interacting effects, over a given time period, will lead to new bio-physical/natural capital and human/socio-economic conditions at the end of the time period (t_1). Through positive

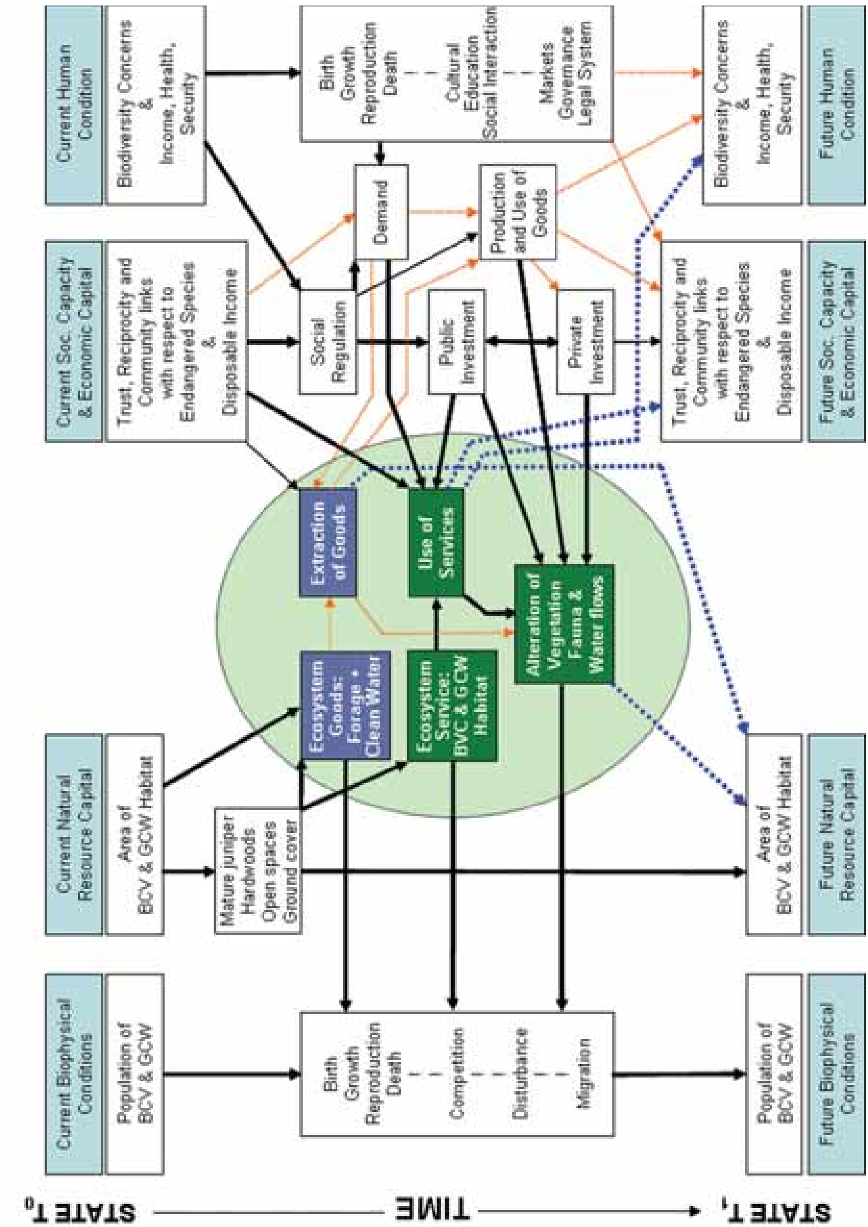


Figure 5. Linkages between the bio-physical and human subsystems with respect to endangered species habitat restoration for black-capped vireo and golden-cheeked warbler in the Leon River Watershed, Texas. (Interactions with respect to delivery/use of this ecosystem service are reflected by the heavy solid lines; feedback effects are represented by heavy blue dotted lines; and interactions with respect to extraction of ecosystem goods are represented by the thinner orange dotted lines.)

interactions, the natural resource capital (greater amounts of endangered species habitat) and the bio-physical conditions (larger endangered species population size) will both improve. Also, the human condition is likely to improve with endangered species population increases because previously concerned people will be psychologically better off. Furthermore, economic capital may increase if endangered species habitat improvement has positive side effects, such as improved forage supply for livestock or habitat for economically valuable wildlife species. Similarly, multi-stakeholder participation in a program that focuses on an issue of common interest, such as endangered species habitat improvement, is likely to enhance trust, reciprocity and community involvement among participants and, therefore, increase social capital.


Black-capped vireo. Photo courtesy Society for Conservation Biology.

Interactions

Interactions between elements of the bio-physical and human subsystems that influence the amount of endangered species habitat and the population size of the two endangered birds can be organized as: (1) the effect of bio-physical interactions, (2) the effects of use of ecosystem services represented by biodiversity with respect to the two endangered bird species and (3) the effects of extraction of ecosystem goods provided by rangelands that support the habitat of the two endangered birds.

***Bio-physical Interactions*:** The populations of both bird species are affected by factors that directly influence population dynamics, as well as factors that affect the amount and quality of habitat. These interactions are represented by the left hand side of Figure 5. The first set of factors (birth, growth, reproduction and death) affect the population dynamics of a species. However, these four factors do not operate independently of other factors. Rather, they are influenced by competition from other species, disturbances of habitats associated with various land uses and disruptions of resting roosts along migratory routes.

Inter-specific competition for both species of birds is associated primarily with the brood parasitism from cow birds. These populations may grow when cattle numbers increase, but can be controlled using bird traps. The transformation of habitat to alternative land uses can negatively impact the population dynamics of these endangered birds, although this is prohibited under the ESA's prescriptions. Conversely, an increase in the area that includes all of the elements of critical habitat for these species can lead to an increase in the population sizes of these two species. In the case of the golden-cheeked warbler, an increase in the amount of mature Ashe's juniper trees in conjunction with other hardwoods (especially oaks used as foraging substrate) and

Removal of juniper enhances habitat for endangered birds at Leon River. Photo courtesy Urs Kreuter.

the existence of intermittent open flyways would likely lead to larger populations. This component of the bio-physical subsystem represents the natural resource capital with respect to the endangered species and is affected by the human subsystem.

Effects of Use of Ecosystem Services: High levels of biodiversity are generally not associated with maximum extraction of goods from an ecosystem (as exemplified by the production of high-yielding monocultures), but rather with higher resilience of ecosystems to external shocks and the maintenance of opportunities for future discoveries of new ecosystem goods such as extracts for pharmaceuticals. Therefore, the value of biodiversity, reflected by the recovery of endangered species, is represented by the left center box in the oval in Figure 5. In this case study, the ecosystem service valued may be the mere existence of these birds, even though many people may never see them. A more direct use is the enjoyment birders derive through spotting these endangered birds.

Since the survival of these birds is valuable to humans, maintenance of their habitats is directly linked to the human subsystem. In Figure 5, the interactions between the bio-physical and human subsystems with respect to the delivery and use of this ecosystem service are reflected by the heavy solid lines, while feedback effects are represented by heavy dotted lines.

The human subsystem affects the endangered species habitat ecosystem service in numerous ways. Direct effects include the demand for such ecosystem services, which in turn is driven by the demographic, socio-cultural and economic, institutional and political factors included in the right-hand box. Demand is also influenced by social regulatory factors, such as social norms and sanctions, that are in turn driven by economic capital and social capacity. For example, societies that are financially secure and exhibit strong community linkages are more likely to strongly demand the maintenance of endangered species habitat and the control of detrimental land use practices than societies that are driven by the need to survive. In addition, such societies may also be more willing to invest public resources to enhance endangered species habitat through increased protection. In the LRRP, this element is represented by the cost-sharing program underwritten by the NRCS to improve endangered species habitat. Participation by private landowners in such cost-sharing programs requires private matching funds. Because the LRRP incorporated the participation of a wide array of landowners and representatives from federal, state and non-government entities that share common interests (improving wildlife habitat, water quality and rangeland productivity), it enhanced trust and community networks and therefore, social capital. This cascading series of interactions is reflected by the three boxes to the right of the oval in Figure 5.

The feedback effects of these links are reflected by the arrows associated with the bottom center box in the oval of Figure 5. These arrows reflect the acceleration of the treatment of regrowth juniper as a result of the LRRP, which has, in turn, led to the expansion of black-capped vireo and golden-cheeked warbler habitat and a concomitant increase in the sizes of their populations. Additional benefits have included increased water quality and forage production. All three of these benefits have resulted in an increase in natural resource capital. The LRRP has also affected the socio-economic subsystem by enhancing social capital by being a major catalyst for increasing landowner interest in improving endangered species habitat, an objective that many previously resisted due to the coercive nature of the ESA.

Effects of Extraction of Ecosystem Goods: Endangered species habitat is an ecosystem service rather than an ecosystem good because it provides value *in situ* rather than by being extractable and its "use" by one individual does not detract from use by another member of society. Nevertheless, the existence of endangered species may be linked to other ecosystem goods and services and associated feedback loops. Such linkages are illustrated in Figure 5 via the arrows connecting the boxes labeled extraction of goods, private and public investment and alteration of vegetation and water flows.

In the case of black-capped vireo and golden-cheeked warbler habitat, associated goods provided by the ecosystem include forage in the open spaces between clumps of mature juniper and other hardwood trees, habitat that is suitable for economically valuable wildlife (e.g., white-tailed deer benefit from premium black-capped vireo habitat) and

Leon River Restoration Project has returned these rangelands ability to provide multiple ecosystem goods and services. Photo courtesy Urs Kreuter.

extractable clean water in streams that flow through or are adjacent to well managed endangered species habitat. There also may be associated ecosystem services such as soil genesis, which can be accelerated when there is productive vegetative cover and carbon sequestration. Although these associated goods and services are not the focus of this case study, they may provide feedbacks that directly benefit endangered species. For example, if extractable goods associated with the increased provision of ecosystem services create opportunities for landowners to generate additional income, it is possible that there will be more private resources available for investment in endangered species habitat improvement. In turn, this may increase the public funds invested in endangered species habitat protection through cost-sharing programs.

Conclusion

Systematically identifying linkages between bio-physical and human subsystems that affect the delivery of goods and services from rangeland ecosystems upon which human well-being depends is not an easy task. Such linkages are frequently multifaceted and complex. The use of a general framework may simplify this task and the ISEEC is such a framework for rangelands. The LRRP case study illustrates the usefulness of ISEEC for identifying linkages in a systematic manner. The establishment of such linkages also facilitates the identification of research gaps with respect to such linkages. Research that properly links the natural and human systems is complex and has been lacking (Liu et al. 2007).

In the LRRP case study, research has been conducted with respect to both the bio-physical and human subsystems including: endangered species population and habitat evaluation both pre- and post-juniper treatment; pre- and post-treatment water supply evaluation; and factors affecting landowner interest in cost-sharing programs aimed at enhancing endangered species habitat. While this is a more integrated research initiative than many that attempt to link natural and human systems, several research gaps can be identified using the conceptual framework for sustainable rangelands. For example, questions regarding potential feedback effects of improving endangered species habitat on the human subsystem have not been addressed. Developing a comprehensive set of research questions can be simplified by using a generally applicable ecosystem goods and services evaluation framework to identify linkages between the bio-physical and human dimensions of systems that affect the delivery of such ecosystem goods and services critical for future human well-being.

Research has been done as part of the Leon River Restoration Project on endangered species habitat, both pre– and post juniper removal. Photo courtesy Urs Kreuter.

Photo courtesy NPS.

Using Indicators to Inform Management for Ecosystem Goods and Services

Within government, monitoring provides essential information used to measure and assess agency performance. The Government Performance and Results Act of 1993 (GPRA) requires all federal agencies to review annual performance and strategic plans to ascertain how well their objectives are being met. Indicators of sustainable rangeland management, as proposed by the SRR, provide a mechanism for accountability, promoting advances in effective public land management practices to achieve strategic plans and annual performance goals – both locally and nationally.

As shown in Figure 6, the use of indicators within public land management organizations can be described as part of an adaptive management cycle. Information gathered through suites of indicators allows land managers to evaluate strategies and plans and provides an objective basis for making adjustments to the management design initially proposed. Adaptive management is a recursive process in that the system continues to be monitored after adjusting the management design, ultimately providing evidence about the effectiveness of the change.

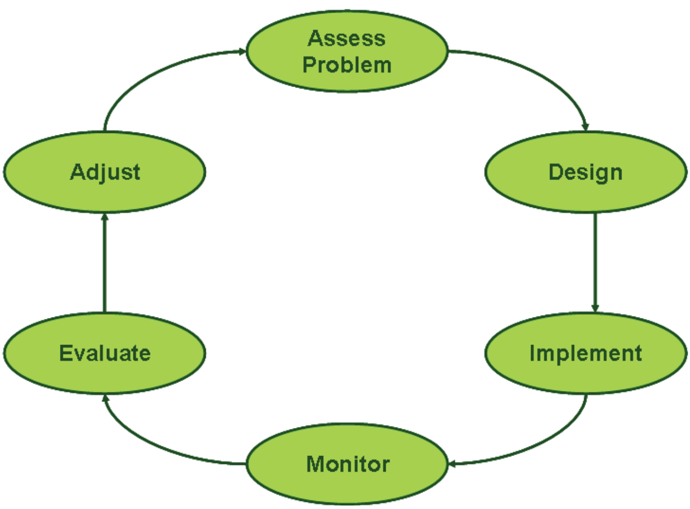


Figure 6. Adaptive Management Cycle. Adapted from Williams, B. K., R. C. Szaro and C. D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC .

Monitoring for rangeland sustainability entails repeated observations of various indicators with the goal of tracking changes in ecosystem, economic, or social variables in relation to management objectives and activities.

Federal land management agencies are responsible for administering multiple uses including protection of wildlife habitat. Photo courtesy U.S. Fish and Wildlife Service.

There are a number of challenges to monitoring, in general, as well as specific obstacles to monitoring for rangeland ecosystem goods and services within an adaptive management framework. Objectives can be lacking, ambiguous, or not measurable; data sources can be inadequate in quantity and/or quality; the links between indicators, management objectives and associated EGS may be unknown or not accepted by stakeholders; thresholds in data trends are often not known; and monitoring results can take too long to affect decision making.

Other challenges to monitoring for EGS include inadequate feedback linkages between monitoring and management, a lack of long-term commitment by monitoring agencies, a reflection of annual budget limitations and the inability to build into monitoring designs the flexibility needed to respond to the dynamics of adaptive management.

However, approaches exist to mitigate challenges to effective monitoring within an adaptive management framework. Collectors of indicator data must make it clear how data will be safeguarded and that sensitive information must be kept confidential. Managers must show how data will be incorporated into planning and other documents dealing with data use in order to make decisions. Involving interested stakeholders in the design of monitoring protocols can help avert future conflicts. Above all, networking and communication are essential during all phases of the adaptive management cycle.

Policymaking, like management, can be deemed an adaptive process. Society's values, which change slowly over time, are manifested in beliefs and objectives. Beliefs and objectives, in turn, drive laws and policy. The public, for example, places high value on environmental protection. Consequently, public policy tends to promote objectives such as protecting watersheds, promoting ecosystem health and providing resources to forest and rangeland dependent communities.

The policy cycle, Figure 7, starts with articulated goals and objectives. The goals must be translated into specific objectives that can be measured and assessed. Laws are generally written to address an objective, but they nearly all contain provisions for determining whether, or how well, the objective is being met. Laws can only be carried out after agencies write policies and regulations, create plans and receive budgets that allow them to do so. Monitoring, then, is necessary to provide information to those who write laws and policy in order to comply with reporting provisions engrained in these statutes. Monitoring, in turn, provides information that can be used to draft future laws and revise policies.

Monitoring EGS must also be flexible within an adaptive framework. The correlations between indicators and some EGS, such as forage, fresh water and soil formation, are fairly straightforward. For others (e.g., climate regulation, genetic resources and cultural amenities), relationships with measurable indicators are ambiguous at best.

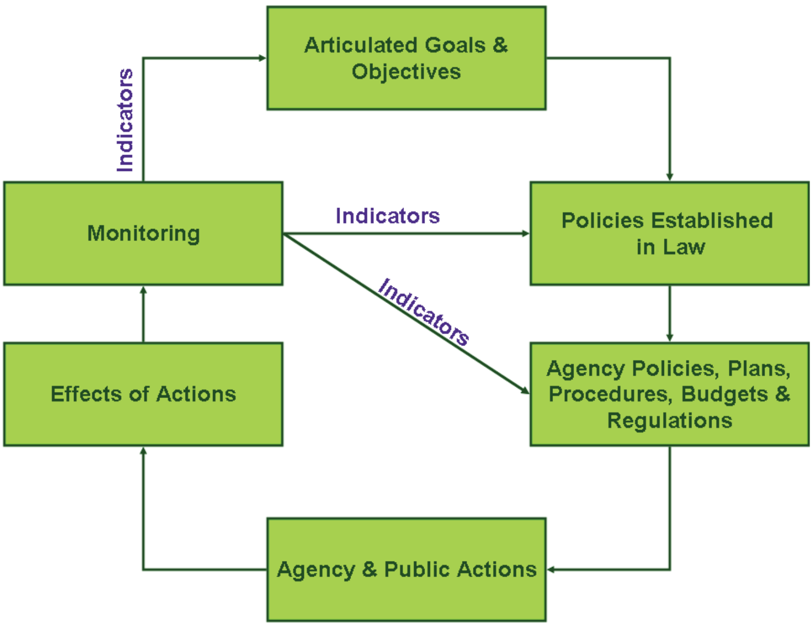


Figure 7. The Use of Indicators in the Policy Cycle (adapted from Heintz, H.T. 2002).

Public land managers are called upon to consider natural resource-dependent communities when making plans that might affect them. The three forms of capital tied to community welfare – economic, human/social and natural – and their relationship to each other, define another reason why managers must take ecosystem services into account during this process. Natural capital includes the resources we consume, the processes that sustain us and the aesthetics of nature we enjoy – all EGS.

Human capital consists of people's skills, training, values, education, etc. Social capital is the way humans interact in a community. Considered within the framework shown in Figure 8, ecosystem processes provide the foundation for all community capital.

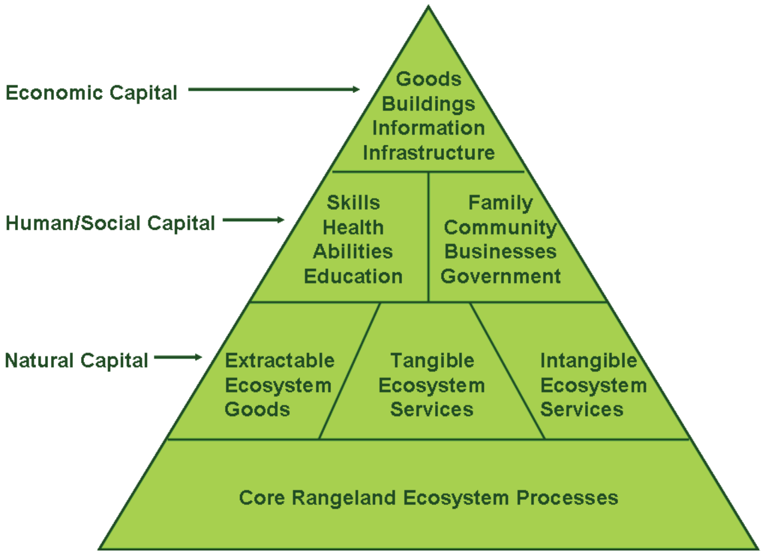


Figure 8– Rangeland ecosystem goods and services are the natural capital upon which human/social capital and economic capital are built. Adapted from Hart, M. 1999. *Guide to Community Indicators*. Hart Environmental Data. Andover, MA.

As more is learned about the relationships between ecosystem services and ecological and socio-economic conditions, managers will be able to make informed decisions about how to administer lands under their jurisdiction. A good example can be found in the Baltimore County Sustainability Project (Coehlo 2007), where an analysis of key ecological issues showed the County would not be able to provide required ecosystem services if the area of intact undeveloped land and natural riparian buffers continued to decline because of urban and exurban development. The problem has been exacerbated because residents in Baltimore County are much more aware of issues such as housing, education and economic development than environmental values provided through EGS. Thus, even urban land managers need to understand the values of ecosystem services, as is demonstrated further in the Texas open space and stormwater management example that follows.

Rangeland Open Space for Stormwater Management

The maintenance and active management of open space at the interface of urban, suburban and rural areas can provide numerous ecosystem goods and services for surrounding communities. The Katy Prairie encompasses over a thousand square miles, ranging from flat coastal plains to gently rolling pastures. Situated in the Texas Coastal Plain, it is bounded by the Brazos River to the southwest, pine-hardwood forest to the north and the city of Houston on the east (Wermund, 1994). The soils and vegetation are typical of native prairies along much of the upper Texas Gulf Coast. This poorly drained, tall-grass prairie was historically subject to periodic fires and contained a considerable amount of wetland areas.

Snow geese are one of the species of migratory birds who rely on coastal rangelands for habitat. Photo courtesy U.S. Fish and Wildlife Service.

Rice farming in the area, coupled with open-water habitat, created prime wintering grounds for snow geese that moved inland to this new habitat in the 1950's (Lobpries 1994). The habitat was increasingly used by migratory birds and waterfowl as other areas along the Gulf Coast diminished in size or were lost to development. At this same time, the City of Houston experienced a huge growth spurt and began spreading to the west and northwest. Rice farms decreased and 100,000 acres of the Katy Prairie were converted to urban uses (residential, industrial and retail).

Urbanization continues to have consequences for the future of the Prairie but a partnership between the Katy Prairie Conservancy, Harris County Flood Control District, Texas A&M University and the Center for Houston's Future is studying the impacts of managing this open space for flood control and stormwater detention. Perhaps this approach will provide a new "value" to maintain goods and services the prairie has provided for over a century.


Houston continues to expand, encroaching on Texas coastal prairie.

Current Biophysical Condition & Natural Resource Capital: The Katy Prairie is comprised of a variety of habitats, including agricultural wetlands, depressional wetlands, creek corridors and coastal grasslands. Grasslands, distinguished by grasses with extensive root systems, are maintained by periodic drought, grazing and wildfire (Chadwick 1995). Wetlands are areas subject to periodic or constant flooding that saturates the soil. Wetland vegetation is adapted to tolerate these inundated soils. Both prairies and wetlands are threatened ecosystems that provide habitat for a wide variety of wildlife, including migratory birds and endangered species. Prairies may also be important sinks of carbon dioxide, a possibly important ecosystem service with increasing concern over global climate change. Wetlands can provide buffers against flooding and storm surges and filter pollutants, improving water quality. They also serve as spawning and nursery areas for fish and shellfish.

The Texas coastal prairies extend from the marshes along the Gulf of Mexico inland 30-80 miles. They are flat, with elevations from sea level to 75 m (250 ft) (Hatch et al., 1990). Less than 2 percent of the 13 million acres of native coastal prairies of Texas and Louisiana remain, mostly under private ownership. Much of the rest is threatened by aggressive invasive species, such as the Chinese Tallow (*Sapium sebiferum*), which have little value to native wildlife and can out-compete native plant species.

Over the course of American history, more than 115 million acres of wetlands have disappeared (over 50% of the original 221 million acres), with over 30 million acres of this remaining acreage too contaminated to be ecologically useable. In Texas, 600,000 acres of coastal wetlands (52 percent of the total wetland acreage) have been lost and losses of these prairie wetlands and coastal marshes continue (Tacha, 1994).

Open spaces such as the Katy Prairie provide multiple ecosystem goods and services, including maintaining the quality of rural life, supporting outdoor activities such as hunting and hiking and providing habitat for wildlife species. The Katy Prairie supports a tremendous amount of wildlife including 196 different species of birds. Texas coastal prairie ecosystems originally supported alligators, bullfrogs, white-tailed deer, American bison, pronghorn antelope, black bear, eastern turkey, red wolf, grey and fox squirrels and muskrat (Stutzenbaker, 1994). Beaver, alligator, deer, coyote, bobcat and squirrels still can be found on the Katy Prairie. Waterfowl hunting in Texas brings an estimated $1.7 billion dollars and impacts over $3.6 billion dollars for the region (IAFWA, 2002).

Coastal prairies and wetland systems play a vital role as filter systems for most of the outputs from the cities in coastal regions. Bio-filtration of material from waterways before they enter coastal estuaries and wetlands has a significant impact on the health and economies of coastal communities.

Katy Prairie was once home to the Attwater's Prairie Chicken and still provides habitat for 196 different species of birds, including the American Golden Plover. Photos courtesy U.S. Fish and Wildlife Service.

Biophysical Processes: Many factors currently influence the core ecological processes occurring on coastal prairies, but most center around hydrology, soils and vegetation dynamics. The prairie's flat topography has led to unique hydrologic characteristics centralized on the slow movement of water across the landscape. This water retention has had a significant impact on the development of soils and thus the vegetative species composition.

With the reduction of rice farming on the Katy Prairie, much of the area is dominated by fallow fields left to revegetate on their own or developed into improved pasture dominated by introduced grasses such as Bermuda grass or Bahia grass (*Cynodon dactylon, Paspalum notatum)*. Competition driven by the invasion of non-native species continues to alter vegetation dynamics throughout the system. This competition has led to changes in the natural disturbance regimes including a near complete removal of fire. Secondary succession following agriculture use has not returned the system to its original prairie species composition, but instead, a biological threshold has been crossed due to species introductions and changes in the hydrologic cycle that has favored managed pasture and non-native species. The active management of hydrology, vegetation dynamics and community structure influences ecosystem goods and services such as flood mitigation and stormwater detention, along with wildlife habitats and recreation.

Ecosystem Goods & Services: The Katy Prairie ecosystem provides numerous goods and services that can include, but are not limited to forage, clean water, agricultural commodities, wildlife habitat, recreation opportunities, flood mitigation, stormwater detention, water quality improvement and carbon sequestration.

These goods and services can be maintained and enhanced by active management. A partnership between the Katy Prairie Conservancy, Harris County Flood Control District, Texas A&M University and the Center for Houston's Future has identified benefits related to flood mitigation and stormwater management. The partnership is investigating whether managing for open space in the headwater regions of Houston's western bayous and creeks can influence potential flood damage, such as that from Hurricane Allison in 2001.

For example, the headwaters of Cypress Creek are on lands currently under management of the Katy Prairie Conservancy. These lands, protected from development through a land trust, will be retained as open space. Reduction of peak stormflow in the Cypress Creek watershed has significant impact on Houston's urban areas. If Cypress Creek floods more than eight inches, the waters overflow into the Buffalo Bayou watershed that enters directly into downtown Houston.

Economic benefits of flood mitigation and stormwater peak flow reductions may be derived from open space management if doing so reduces the need to buy out homeowners in areas of significant flood risk. Since 1989, the Harris County Flood Control District has purchased and removed approximately $214 million worth of homes and structures that were chronically flooded.

In 2001, Houston was flooded by Hurricane Allison as stormwater exceeded natural prairie and man-made Harris County Flood Control capabilities. Photo courtesy NOAA.

Social Capacity/Economic Capital & Current Human Condition: Managing to increase the ecosystem services of flood mitigation and stormwater peak flow reduction through restoration and sustainable management of prairie rangeland systems on the outskirts of Harris County and Houston could impact the social capacity and economic capital of these communities, as well as their quality of life. Impacts on social capacity and economic capital could include reductions in flood insurance and taxation, standardization of floodplain restrictions and development ordinances and a reduced need for engineered flood control infrastructure. Quality of life could be improved with a reduction in loss of property and life due to flooding. A corresponding benefit is the addition of more open space that could be utilized for recreation such as hiking, birding and other outdoor activities.

Clearly, land managers need a coordinated planning and management approach that considers a wide variety of ecosystem goods and services and adapts as society's values shift. A comprehensive monitoring program to provide integrated social, ecological and economic data to support management analyses and decisions is also necessary.

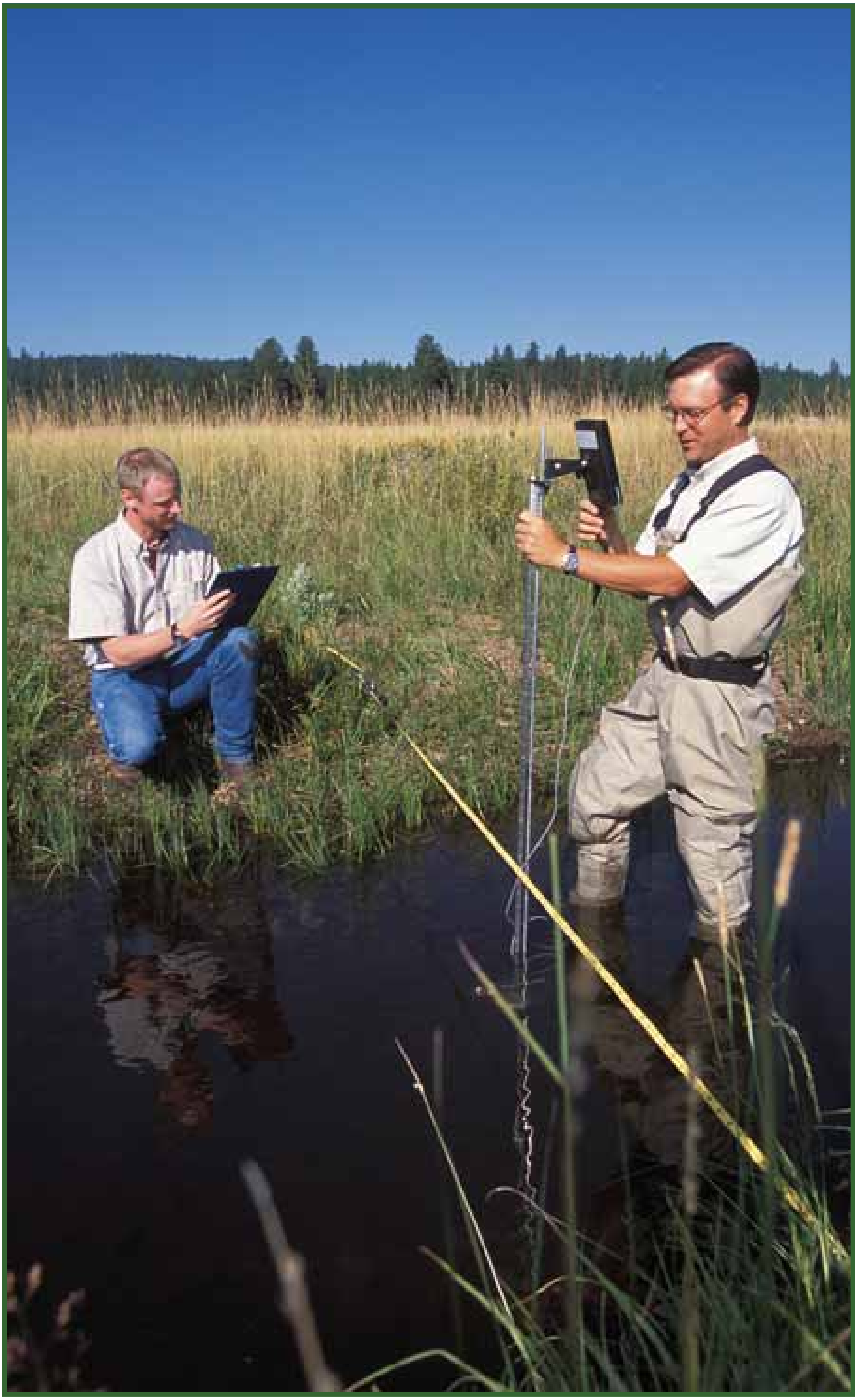


Photo courtesy USDA ARS.

Using Indicators to Assess Ecosystem Services

The nature and importance of ecosystem services have been established in preceding sections. However, in order to understand the consequences of maintaining ecosystem services in the face of increasing human populations and their ever enlarging ecological footprints, we must be able to monitor trends in specific goods and services that ecosystems provide. One approach for doing so, is through the use of key indicators developed by the SRR.

When it comes to monitoring ecosystem services, most people limit their consideration of indicators to those associated with the three SRR biophysical criteria: Plant and Animal Resources, Soil and Water Resources, Productive Capacity. Such limitation is inappropriate because it undermines a basic tenet of sustainable development – sustainable ecosystems can only be enhanced or maintained when the human conditions and economic capacity of societies that rely upon them are, themselves, sustained. Therefore, indicators tied to multiple economic and social benefits and the legal, institutional and economic framework for sustainable rangeland management also must be considered.

Indicators Tied to Core Processes

In the National Research Council Committee on Rangeland Classification's report "Rangeland Health: New Ways to Classify, Inventory and Monitor Rangelands" (NRC 1994), the Committee defined rangeland health as "the degree to which the integrity of the soil and ecological processes are sustained." Thus, core ecological processes are key to maintaining healthy ecosystems, which, in turn, provide the foundation for all ecosystem goods and services. Similarly, core social and economic processes provide the mechanisms for valuing and managing EGS. SRR indicators allow us to track trends in these core processes, as well as EGS.

***Biophysical Processes*:** Four fundamental biophysical core processes are essential for the functioning of rangeland ecosystems. They are soil formation and retention, photosynthetic or productive capacity, nutrient and water cycling and the maintenance of intact plant communities across the landscape. A number of indicators, described below, are tied to these four processes.

<u>Bare ground</u>. The percentage of bare ground varies naturally with the kind of plant community and seasonal climate and it also responds to management actions that tend to remove biomass and litter, such as livestock grazing. Bare ground serves as an indicator of erosion potential. By affecting rates of infiltration and incorporation of organic matter into the soil, bare soil can act as an indicator of functioning water and nutrient cycles. Bare ground can be easily estimated using various point sampling methods.

Accelerated erosion. Soil serves as the basic resource upon which all terrestrial life depends. Thus, preserving soil can be considered the ultimate ecosystem service. Quantitative indicators of actual soil erosion are not commonly available, but estimates of erosion effects (e.g., plant pedestals, debris dams, rills) have been developed.

Net primary production. Trends in primary production can serve as an integrator of multiple ecosystem processes. They can also provide evidence of declining or improving productive capacity during years favorable to plant growth. Net annual primary production is generally approximated from plot-based estimates of biomass taken after seasonal growth periods. Productivity is more directly estimated from "greenness" indices available from satellite multi-spectral images, although such measures must commonly be ground-truthed in order to obtain actual production estimates.

Nutrient and water cycling. Nutrient cycling is closely related to the soil-water relationship on rangelands. Generally, the greater the amount of precipitation that falls and is captured and stored for later use by plants, the greater the total primary production. Sites with higher productivity can more effectively capture and cycle nutrients essential for plant growth. Obviously, erosion causes nutrients contained in the soil to be lost from rangelands.

Given the complex nature of factors influencing nutrient and water cycling, it is apparent that multiple indicators are needed to determine whether rangeland processes are functioning properly. Among these are the core indicators described above. In addition, the SRR indicator dealing with no-flow periods in ephemeral streams may be useful to demonstrate the effectiveness of rangelands in retaining precipitation in the watershed.

Socio-Economic Processes: The literature recognizes a number of core processes in society. They include health care, the ability to network or communicate, education, religious faith, care of the young, old and infirm and a legal system to maintain order and resolve conflicts. Economic core processes involve open markets, tax structures and housing. SRR indicators address several of these social and economic core processes.

Poverty rates – general and children. Poverty rates reflect basic community well-being. With greater poverty, communities and people are less likely to have the resources and hence the ability, to adapt to socio-economic changes. Impoverished societies have overriding concerns for basic human needs (shelter, food, employment) and consequently pay less attention to environmental problems threatening sustainable management. About 13 percent of the people living in the United States are considered to live in poverty. However, children represent a disproportionate number of these poor; i.e., the U.S. child poverty rate is 18 percent. Thus, child poverty may exacerbate hardships relating to nutrition, housing and healthcare found in the general population. The states with the highest poverty rates (> 20 percent) reach from Arizona to Georgia along our southern border and extend through the Appalachians as far north as West Virginia. Consequently, the Southwestern rangeland states of Arizona, New Mexico and Texas all have poverty rates exceeding 20 percent (DeNavas-Walt et al. 2007).

During the Dust Bowl years, overuse impacted core ecosystem processes, resulting in erosion and loss of ecosystem services, which plunged many resource-dependent communities into poverty. Photo courtesy USDA NRCS.

Population and population change. The importance of population structure is fairly well understood by most Americans. Effects of the "Baby Boom" surge on Social Security, Medicare and jobs are being increasingly headlined on television and in print. But the potential impacts of an aging farm and ranch population is much less known or understood. The average age of farmers and ranchers is about 55 years (versus 37 years for all Americans) and it continues to climb, while the percentage of young (< 35 years) farm and ranch operators has declined from 15 percent to 5 percent since 1982 (Allen and Harris 2005). One possible outcome from an inverted population pyramid is the consolidation of ranches from family operations into larger corporate ones.

Land law and property rights. Various forms of property rights (e.g., private, public, common and regulatory) exist across the globe. The classic 1968 paper by Garrett Hardin, *The Tragedy of the Commons*, sounded a warning that the sustainable management of rangelands is unattainable without some consideration of property rights. The United States has comprehensive sets of laws and regulations at the national, state and local levels that help keep property rights issues from causing "tragedy" consequences when it comes to land management. However, conflicts can exist between traditions whereby the state intervenes through taxes or regulations and those based upon private property rights and market-based solutions. This is particularly true for resolving issues related to water pollution and protection of endangered species. Property rights and the way different landowners interpret them, can influence social factors affecting sustainability. For example, when values and perspectives about property rights differ between existing land-owners and newcomers or neighboring communities, conflicts impacting rural community vitality may arise.

Economic policies and practices. Sustainable management practices can be directed by both private and public landholders. Moreover, the nature of public policies and practices ranges from strategic, affecting the entire Nation, to local, affecting individual ranches and rural communities. Thus, they are broadly important and constitute a core indicator of socio-economic processes that impact the availability of ecosystem services in a myriad of ways.

Recent years have seen a gradual, but inexorable, shift from economic policies and practices furthering productive capacity to those encouraging ecosystem health and restoration. For example, the policies of the Conservation Reserve Program, contained in multiple Farm Bills of the past 20 years, have provided new and increased emphasis on improving soil stability, water quality and wildlife habitat, along with a reduction in crop production.

At the local ranch level, production strategies commonly employ goals of profit maximization; however, this is not always the case. Research has shown that important ranch outputs are not easily incorporated into conventional economic analyses. In other words, factors such as family, tradition and rural way of life also impact economic practices.

In addition to affecting ranchers, economic policies influence rural communities and regions. The National Environmental Policy Act of 1969 contains provisions requiring economic analyses to assess how policy alternatives can affect local economies. Monitoring to track supplies of rangeland goods and services is fundamental to assessing economies of resource-dependent communities.

Indicators Tied to Extractable Ecosystem Goods

Rangeland aboveground phytomass. Forage is defined as the plants or parts of plants consumed by grazing or browsing animals. The amount of forage available for consumption varies according to a number of factors. Some plant species are unpalatable. Certain parts of many plants are not consumed. Moreover, only parts of plants can be consumed if they are to maintain vigor and keep their place in the plant community. Some areas of rangeland are not suited for grazing by livestock because of steep slopes, fragile soils, distance to water, poisonous plants, etc. Nonetheless, a measure of biomass serves as a good indicator of forage available for both livestock and wildlife.

Allocation of forage to wildlife is generally only limiting to critical seasons, e.g., winter ranges for elk and deer.

Aboveground phytomass can be used to monitor another ecosystem good that shows promise of becoming an important alternative energy source – biofuel. Although the actual mass of biofuel sold at market will be directly measured, a phytomass indicator will be helpful for identifying areas of potential value for raising biofuels.

Number of domestic livestock on rangeland. Monitoring the proportions of different classes of livestock found on rangeland gives a measure of how important rangelands are in providing red meat, wool, hides and other products needed by consumers. Presently, the significance of rangelands in supplying these goods is open to dispute because of a lack of data. To truly assess the contribution of rangelands to meat and other animal products, one cannot merely consider the number of animals (or AUM's) on rangeland at any one time; rather, it is the number of livestock that spend any part of their lives on rangeland that gives a valid estimate.

Presence and density of wildlife functional groups on rangeland. Wildlife and fish harvested by hunters and anglers constitute an obvious good coming from rangelands. The type of monitoring system employed to estimate the extent of wildlife and fish populations varies. By law, the states act as stewards of wildlife and fish and control their

Well-managed rangelands provide forage for beef cattle, horses and other livestock. Photo courtesy NBII.

harvest. One of the challenges for undertaking regional and national assessments of wildlife and fish comes from the different, often incompatible, techniques used by different states to monitor them. At the local level, land managers marketing wildlife hunting or fishing use this indicator to monitor populations.

Ranchers in New Mexico supplement their income by providing outfitting services for elk hunters. Photo courtesy James Bernard.

Annual removal of native hay and non-forage plant materials, landscaping materials, seeds, edible and medicinal plants and wood products. This indicator is actually a catch-all for a number of measures having different units and degrees of abundance on rangelands. It is quite likely, however, that these forms of biomass are, or have the potential to become, much more significant as tangible ecosystem goods than seems to be warranted by the lack of data available for the indicator. The actual measures that may fall under this indicator will probably develop as demands and/or controls are implemented by local and state governments.

Changes in ground water systems. Many communities and individual family units rely on ground water for irrigation, household and other uses. Shallow water tables that provide water for livestock and households can be especially critical for the sustainable management of rangelands. As with other SRR indicators, the degree to which ground water levels are monitored varies across scale. Areas where ground water is being depleted by agricultural uses, such as the Ogallala aquifer (ranging from Texas to Nebraska), lend themselves to more intensive monitoring.

Indicators Tied to Tangible and Intangible Ecosystem Services

Rangeland areas by plant community and fragmentation of rangeland and rangeland plant communities. The extent and spatial distribution of rangeland, whether nationally, regionally, or locally, jointly serve as a critical indicator for a number of ecosystem services. These include things as fundamental as the air we breath, moderated climate, open spaces for all types of recreation, wilderness experiences, observable wildlife, research study sites and historic, religious and cultural sites. It should be noted that another SRR indicator, *density of roads and human structures*, also provides an indicator of rangeland fragmentation.

Much work needs to be done in order to correlate rangeland area and spatial distribution with some of these ecosystem services. Nonetheless, a monitoring system that tracks these two indicators will be essential if progress is to be made in quantifying ecosystem services, particularly those which are intangible.

Number and distribution of species and communities of concern and population status and geographic range of rangeland-dependent species. These two indicators collectively survey species that are of particular value to humans, act as keystone indicators of rangeland health, help promote biodiversity, or are classified as threatened or endangered. Aspen serves as an excellent example of a species of concern across much of the interior West. Not only do aspen stands provide islands of biodiversity and enhance viewscapes for rangeland visitors, but they tend to be highly productive.

The Mendocino Land Trust works to preserve native rangeland vegetation such as the coastal prairie at Navarro Point, CA. Photo courtesy James Bernard.

Extent and condition of riparian systems. Riparian ecosystems in properly functioning condition provide several ecosystem services to humans. They store water longer during the growing season, thereby increasing plant growth and providing irrigation water for longer time periods. They mitigate excessive runoff during flood periods and provide quality habitat for native fish populations. Riparian areas help filter water, resulting in higher water quality of streams transiting them.

Number and extent of wetlands. Wetlands are now protected from damage and destruction by federal legislation. The reason they are so valued can be expressed in terms of the ecosystem goods and services they supply. Among these are waterfowl and other wildlife habitat,

Properly functioning riparian areas provide wildlife habitat for elk, bison, trout and others, as well as runoff control. Photo courtesy NPS.

which give both tangible hunting and intangible viewing benefits, increased biodiversity, improved water quality, reduced severity of floods and conduits for recharging ground water. (Floods from Hurricane Katrina, which catastrophically struck New Orleans in 2005, would have been much less severe if the wetlands standing between the city and the Gulf of Mexico had not been so depleted.)

Social, Economic and Legal/Institutional Indicators Promoting Management of Ecosystem Goods and Services

Two thirds of U.S. rangelands are privately held. If these lands are to be managed for the EGS portrayed in this report, those owning them must have incentives for doing so. In addition, laws and regulations are needed to encourage rangeland management and conservation. Transcending both the economic and legal/institutional situations are values and beliefs held by society. Even though SRR indicators pertaining to socio-economic and legal-institutional criteria are not directly linked to rangeland EGS, their overriding relationship to the biophysical indicators warrants their inclusion in this discussion.

Visitor days by activity. Recreation activities on rangeland are providing ways for landowners to diversify their business enterprises. In Texas, for example, ranchers are able to undertake restoration practices that enhance wildlife habitat, retard erosion and increase forage for

Rangelands offer scenic vistas and recreation opportunities for thousands of tourists each year. Photo courtesy NPS.

livestock using income derived from hunters, birdwatchers and other visitors.

On public lands, agencies are only now starting to monitor the extent of recreation on their forests and rangelands. Since visitor day data are collected at campgrounds, trail heads and other point locations, the problems associated with determining where people actually recreate are not trivial. Regardless, an understanding of trends in recreation use on both private and public rangelands will be useful to researchers and managers as they consider actions that may or may not affect ecosystem services.

Value of investments in rangeland and rangeland improvements. On both private and public rangelands managed for livestock grazing, physical features such as fences and other structures are necessary to support proper grazing and maintain rangeland health. Investments for improvements and restoration are essential over the long term. An indicator that monitors investments in basic infrastructure for rangeland management may be able to provide an early indication of changes in ecosystem services, even before the associated biophysical indicators changed.

Area and distribution of rangeland under conservation ownership or control. During recent years, a growing number of NGO's and local governments have purchased conservation easements or enacted other conservation measures in order to protect open space, biodiversity, endangered ecosystems, etc. A number of ecosystem services are benefited by large, intact areas of rangeland – increased biodiversity, protection from improper grazing, etc. This indicator also reflects changes in societal values and beliefs because some conservation investments are made with public funds.

Expenditures for rangeland restoration. Expenditures to restore rangeland with non-functional ecosystem processes are related to much more than the need for restoration. Even when needs are clearly

Land trusts, such as the Mendocino Land Trust in California, use conservation easements to protect intact rangeland landscapes, like this oak woodland, from development. Photo courtesy Mendocino Land Trust.

documented, land managers often do not have the resources to carry out the work. Thus, this indicator reflects the intersection of both ecological and economic factors. Obviously, rangelands in unsatisfactory condition cannot produce the kinds and amounts of EGS desired by society.

The USDA Natural Resource Conservation Service provides technical assistance to landowners on rangeland management, including wetland protection. Photo courtesy USDA NRCS.

Professional education and technical assistance. Superficially, one would not expect to see a relationship between one or more measures of professional education/technical assistance and the supply of EGS coming from rangelands. However, advances in ecology, economics, rural sociology, range management, geography, computer science and other disciplines have provided the basis for the gradual improvement in rangeland health and productivity during the 20th century. There is no reason to expect technological and scientific progress to abate during the 21st century. Monitoring our Nation's commitment to professional education to train new generations of scientists and managers, as well as the commitment to providing technical assistance to rangeland managers on the ground, could well serve as an informative indicator of EGS.

Research and development. Just as education and technology transfer are necessary to a society that strives for sustainable development, so is an active research and development (R&D) program. Increasing human populations and their attendant ecological footprints will slowly, but incessantly, intensify pressures on the ecosystem and socio-economic processes that provide ecosystem services. A likely means for mitigating these pressures are through advances in technology – a product of R&D.

Monitoring Ecosystems Goods and Services in a Sagebrush Steppe Ecosystem

Rangelands are under increasing pressures from multiple users for goods and services, including forage, wildlife, water and recreational resources. Disruption of historical fire patterns and proliferation of invasive weeds, such as juniper and cheatgrass, have caused a widespread reduction in rangeland condition and productivity. Fire may act as a natural disturbance factor as well as a valuable management tool for rangelands. It is a key ecological driver in many ecosystems, facilitating nutrient cycling and promoting the growth of grasses and forbs over woody species. Periodic fire maintains a number of major grassland, shrub steppe and savanna ecosystems.

Sagebrush communities in Idaho's Big Desert have been studied to evaluate their resilience to fire. Long-term monitoring and assessment help detect fire impacts on EGS in these sagebrush steppe rangelands. Indicator-based monitoring can be used to track trends in both supplies of rangeland goods and services and the core processes impacting them.

Background

Over the last decade, an average 235,000 acres of Idaho rangelands have burned annually. Historically, these rangelands were dominated

Researchers study sagebrush steppe ecosystems in Idaho to identify factors causing their declines and to help guide restoration of habitats in the Great Basin. Photo courtesy USGS.

The greater sage grouse is threatened by declines in its critical habitats in sagebrush steppe ecosystems. Photo courtesy USFWS.

by big sagebrush (*Artemisia tridentata),* which does not re-sprout after fire. Fire, like invasive species and other disturbances, ignores political, administrative and land use boundaries. Consequently, assessing how natural fire regimes and prescribed burning transform ecosystems and rangeland-dependent communities requires standardized protocols for measuring how the spatial and seasonal distributions of fire vary over all land management categories.

For example, the Murphy Complex fires burned more than 650,000 acres of critical sagebrush habitat in Idaho and northern Nevada in the summer of 2007. Since sagebrush provides critical habitat for sage grouse (*Centrocercus urophasianus*), a species proposed for listing under the Endangered Species Act, the Bureau of Land Management, as well as other rangeland managers, such as the Idaho National Laboratory and private parties, must now decide whether to augment habitat restoration in burned areas with stabilization and rehabilitation treatments to prevent soil erosion and inhibit the invasion of exotic species, such as cheatgrass (*Bromus tectorum*).

Some of the important EGS impacted by the Murphy Complex fires include livestock forage production, watershed values and wildlife habitat, specifically sage grouse habitat. In the last three years, approximately 70 percent of the sage grouse habitat in eastern Idaho's Big Desert has been burned by wildfire. This part of Idaho and Nevada is one of the few remaining places with large areas of unfragmented sagebrush habitat. Seeding sagebrush within the burned area will speed the return of suitable habitat for sage grouse and other wildlife dependent on sagebrush. Significantly, 75 sage grouse leks fell within the fire's perimeter, 39 of which were known to be active in the past five years.

With the accelerating loss of native sagebrush communities and sage grouse habitat, sagebrush reseeding following fire has become important, as has the issue of livestock grazing impacts on recovering native vegetation and seeded areas. Fire suppression and rehabilitation costs are rising and the threats to human life and property are increasing. An advantage of indicator-based monitoring, applicable at multiple scales, is the emphasis on standardizing data collection programs across different agencies and organizations that monitor the status and trends of individual indicators. Whether looking at fire patterns in a county, state, region, or for all U.S. rangelands, a consistent set of agreed-upon indicators will make monitoring easier and more effective for researchers and land managers.

Presently, at regional and national levels, some data are available on acres burned, but data collection methods and procedures are not standardized. Data about the precise location and seasonality of fires are largely unavailable in a standardized format. Remote sensing technology has high potential for monitoring the extent and spatial distribution of fire across administrative borders. For example, scientists at the Goddard Space Flight Center are mapping fire activity

Satellite image of the Murphy Complex fires in southern Idaho and Nevada, which consumed over 650,000 acres of sagebrush steppe habitat during the summer of 2007. Photo courtesy NASA MODIS Rapid Response.

worldwide using the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's TERRA satellite. Digital remote sensing data are especially useful because of its applicability at multiple spatial scales, including local management units. Thus, information about the area, spatial distribution and seasonality of fires across administrative and political boundaries is uniformly collected by satellite and made available for analysis and incorporation into management plans and practices.

One SRR indicator specifically addresses fire. Integrity of natural fire regimes quantifies the area of rangeland burned each year, describing burned acres in terms of location, season and fire intensity. Whether the area of rangeland burned is within the historic range of variation for the ecological sites and landscapes where fires occur is a researchable question. However, it is also necessary to relate the extent of rangeland burned to other metrics. SRR indicators affected by fire include:

- Rangeland annual productivity
- Number of livestock on rangeland
- Fragmentation of rangeland and rangeland plant communities
- Presence and density of wildlife functional groups on rangeland
- Area of infestation by invasive and other non-native rangeland plant communities
- Number and distribution of species and communities of concern
- Population status and geographic range of rangeland-dependent species
- Area and percent of rangeland with accelerated erosion
- Area and percent of rangeland with significant change in extent of bare ground
- Area and percent of rangelands with significantly diminished soil organic matter and/or high carbon-nitrogen (C:N) ratio
- Annual removal of native hay and non-forage plant materials, landscape materials, edible and medicinal plants and wood products
- Extent and condition of riparian systems
- Value of forage harvested from rangeland by livestock
- Value of production of non-livestock products produced from rangeland
- Number of recreation days by activity and recreational land class
- Threats to and pressures on the integrity of cultural and spiritual resource values
- Expenditures to restoration activities

Data provided by indicator-based monitoring can improve management's understanding of how fire can impact EGS and assist in developing mitigation strategies for landscapes degraded by wildfire and invasive weeds. More specifically, the NRCS Conservation Effects

Assessment Project (CEAP) for rangelands could benefit from improved information about efficacy of conservation practices for fire prevention and restoration and USFS and BLM Burned Area Emergency Response teams could use this data to improve fire rehabilitation planning.

Ecosystem Processes, Goods and Services Impacted

Monitoring SRR indicators, in turn, supports tracking supplies of rangeland goods and and services, as well as the core processes that produce these goods and services. In addition to budgetary and property loss concerns manifested in social and economic processes, fire can impact a number of important ecosystem processes that SRR's indicator-based monitoring will capture. These core ecological processes, monitored by SRR indicators, include:

- Nutrient cycling
- Succession
- Primary production/photosynthesis
- Carbon cycling
- Soil formation and retention
- Wildlife species immigration and emigration

The ecosystem processes that are impacted by fire can affect EGS, many of which are also tracked directly or indirectly by SRR indicators. These EGS include, but are not limited to, the following:

- Food for livestock production
- Food for humans
- Wildlife habitat
- Viewsheds
- Watersheds
- Atmospheric transport of chemicals and particulates
- Native plant use

<u>Food for livestock production.</u> Fire can reduce the amount of vegetation that is available for livestock and wildlife grazing, thus reducing the extraction of goods (beef, lamb) and services (hunting and watchable wildlife opportunities). SRR indicators track rangeland annual productivity, value of forage, wildlife density and number of livestock. Reduction in forage, associated livestock production and wildlife numbers negatively affects ranching communities and, by association, the human condition in these resource-dependent economies. If fire can be managed so that only selected parts of the rangeland are impacted, then the overall impacts to the social capacity and economic capital, current human condition, natural resource capital and biophysical condition can also be managed. However, if large uncontrolled fires like the Murphy Complex Fire occur, impacts to EGS will be uncontrollable, as will the ecological, economic and social outcomes tracked by SRR indicators and identified in the ISEEC. The linkage between public and private land is also important in this discussion. If a rancher looses his

Following disturbances like fire, ranchers may need to move their cattle to other sources of forage. Photo courtesy USDA NRCS .

public grazing allotment for two or more years due to a large uncontrolled fire, he will have to find another option. If the use of private land increases, the quality of the EGS from the private lands will be impacted in the short-term and the sustainability and natural profit potential of the rangelands will be diminished in the long-term. SRR indicators tracking rangeland annual productivity, invasive plant infestations and value of forage and non-livestock products will capture these changes.

Understanding the linkages between fire, other ecological processes and EGS allows ranching communities to better understand fire's impacts not only on traditional products like forage and livestock, but upon supplies of nontraditional goods and services that the land can produce. These effects can also influence communities via alteration of social interactions, education, governance and family interactions. Thus, information generated by indicator-based monitoring can enhance understanding about linkages among rangeland EGS and fire management to improve profit margins and provide stability in the social, economic and human systems. It can also stabilize biophysical and natural resource capital conditions.

Wildlife habitat. SRR indicators can also track both the positive and negative impacts of fire on wildlife habitat. Short term impacts are usually negative due to lost cover and related habitat. The conversion of vegetative cover from shrub-dominated to grass-dominated communities (often exotic grasses) is a concern. Long term impacts may include new growth of desirable forages. SRR indicators tracking rangeland plant communities, riparian condition and invasive species infestations capture these changes.

It is important to understand how fire impacts biophysical conditions and natural resource capital as well as social capacity, economic capital and human condition. SRR indicators allow for evaluation of how fire impacts not only the habitat, birth, growth and reproduction of wildlife, but also changes in EGS value resulting from shifts in public demand to view or hunt the wildlife in the area. Understanding the demand can also influence how social processes (e.g., cultural, education, social interactions) are impacted. A school or nature group that once valued an area for its wildlife habitat can alter capital flows if they are forced to find alternate locations to enjoy wildlife viewing. SRR indicators monitoring presence and density of wildlife functional groups, recreation days by activity, population status of rangeland-dependent species and number and distribution of species of concern inform these assessments and evaluations.

Native plant use. One of the greatest concerns following a fire is the recovery of native species and minimization of exotic vegetation. SRR indicators track changes in extent of native and non-native rangeland plant communities. EGS related to native plants are recognized by a wide variety of groups. Native Americans seek native plants for the spiritual, medicinal and subsistence values. Biologists seek native plants for their genetic and habitat values, among others. Watershed scientists

Regrowth following fire can provide nutritious forage for bison and their young. Photo courtesy NPS.

value native plants for their ability to capture and store energy and water. Ranchers seek native plants for the forage value, wildlife habitat, ability to retard invasive species, and ability to enhance soil conditions. SRR indicators monitoring rangeland plant communities, invasive plant infestations and threats to the integrity of cultural and spiritual resource values capture some of these trends.

Native plant recovery enhances nutrient, water and carbon cycling, tracked by SRR's soil, water, plant and animal indicators. In some cases, native plants produce higher forage yields than exotics. Native plants also produce over a longer period, enhancing total biomass. SRR's productive capacity indicators dealing with native hay and non-forage plant materials, numbers of livestock and wildlife presence and density are impacted by changes in biomass. Recovery of native plants is also central to Native American cultural heritage, in addition to being economically important. Economic outcomes impact the social context within the ranching community, as evidenced by SRR's socio-economic indicators dealing with value of forage and non-livestock products.

Photo courtesy USDA ARS

Incentives for Production of Rangeland Ecosystem Goods and Services: Conservation Easements and Credit Trading

Clearly there is a wide range of valuable ecosystem goods and services that are produced by adequately functioning rangelands, but historically, only a few have dominated the management goals and use of resources, including livestock grazing, fishing and hunting. Property rights, social rules and norms and markets have evolved to provide incentives to manage rangelands to produce these services. But for many others, incentives do not exist and landowners have tended to allow degradation of the capacity to produce such services in the process of responding to the incentives for the few dominant uses. Recognition of the wider range of ecosystem services that are of value has motivated an examination of incentives for their production to equalize their standing with the traditional uses incentivized by markets. (For a good survey of market-based approaches for providing incentives for ecosystem services, see Kroeger and Casey 2007.)

From basic economics we know that if one wants to discourage a particular behavior, tax it. If one wants to encourage particular behavior, subsidize it. The notions of tax and subsidy used here are broad: tax connotes some sort of negative feedback or penalty for engaging in the behavior while subsidy connotes positive feedback or reward. The feedback or reward could take many forms—direct payment is one, but not the only example. There are existing government programs from a variety of agencies that provide subsidies for provision or enhancement of ecosystem services. Examples include the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Wildlife Habitat Incentives Program (WHIP), Wetland Reserve Program (WRP) and Environmental Quality Incentives Program (EQIP). For the most part, they apply to private landowners. Such programs provide incentives for things such as reduced soil erosion, reduced sedimentation in streams and lakes, protection of wildlife habitat and wetlands, floodplain restoration, and various management practices for enhanced conservation and reduced ecosystem degradation. The extent to which these programs specifically target ecosystem services on rangelands can be debated. The point is that the mechanisms are well-established and accepted and they are applicable to ecosystem services—they could be tailored to target any given set of ecosystem services on any type of land. A factor, perhaps not in their favor, is that they are government programs. In an era of government deficits and perennially tight agency budgets, broad use of these types of programs might be constrained.

Of greater interest in recent years are incentive mechanisms that are more private sector-oriented. Two potentially key approaches for providing the desired outcomes are conservation easements and credit

The Natural Resources Conservation Services Wetlands Reserve Program provides incentives to restore wetlands. Photo courtesy USDA NRCS.

trading. The first has been used widely to conserve high-value ecosystem resources of many different types. The second has been studied, but not widely applied. Both have the potential to provide income to landowners willing to maintain or expand capacity to produce ecosystem services.

Because costs are incurred in establishing and administering these incentive systems, successful application to rangeland ecosystem services requires that several conditions be present:

1. The social and economic benefits from the flow of the ecosystem services must be perceived as being greater, usually significantly greater, than the costs of establishing and operating the incentive system and the management practices needed to produce the ecosystems services.
2. There must be both willing buyers and willing sellers of the ecosystem services or the ecological capacity to produce them.
3. It must be possible to define and measure the characteristics of the desired ecosystem services or capacities.
4. Rules to protect the property rights that are created, as well as their transferability, must be enforced.
5. Information about the condition and availability of various units of the capacities to produce ecosystem services must be available to both buyers and sellers.

We will consider these conditions in examining conservation easements and credit trading.

Conservation Easements: Conservation easements allow government agencies or private organizations, such as land trusts, to acquire the rights to certain uses of land from a landowner without buying the land outright. Usually the landowner forfeits the rights to uses that would cause degradation of the capacity of the land to produce ecosystem services for which other incentives do not exist. The terms of an easement pass along with title to the land in all future transactions. Thus a conservation easement provides essentially permanent conservation of the ecosystem capacities that would have been degraded by the uses restricted by the easement.

The legal and institutional frameworks for conservation easements are well established and the mechanisms for their enforcement are a part of the application of real estate laws. Easements are usually applied to lands able to produce well-recognized, high value ecosystem services whose capacity faces an imminent threat of degradation, usually in the form of residential or commercial development.

In some cases, the landowner donates the easement in return for tax benefits. In other cases, government or private funds are used to purchase the easement. Government agencies desiring to acquire easements must raise funds through taxes and thus require the expression of the perceived value of the resulting ecosystem services through the political process. Private land trusts generally raise the funds they use to acquire conservation easements from philanthropic sources. Those sources are motivated by their perceptions of the values of the ecosystems services, both in general and in the cases of the particular easements involved. In either case, an accurate description of the ecosystem conditions and the value of the services they produce are key elements in motivating willing buyers and sellers.

It is important to recognize that the more imminent the threat of development, the more costly an easement tends to be because the land owner would be foregoing the financial returns from development that would occur in the near future. Present value has a higher value of return than does development that is decades in the future, which has a more uncertain and lower present value. On the other hand, it is often the case that the imminent threat of development is a primary motivation for the buyers or funders of the easement purchase. Thus, the timing of the transactions involving conservation easements tends to be a balance between these two factors.

The application of conservation easements to the preservation of rangeland ecosystems is well established. For example, in California's Mendocino County, Ridgewood Ranch owners have collaborated with the Mendocino Land Trust to establish the Ridgewood Ranch Conservation Area, covering 4,636 acres. The ranch is the final resting place of Seabiscut, the 20th Century's most celebrated racehorse. Without the opportunity for the owners of Ridgeway Ranch to obtain a conservation easement, these valuable historic and natural resources would likely have been lost forever to development. Taking advantage of the easement option protects historic buildings that once housed the horse whose rags to riches racing career inspired a nation during the Great Depression. It also protects grazing lands, redwood and fir forests, oak woodlands, seasonal wetlands and streams and scenic viewsheds.

It is important to note that the ranch contains highly developable tracts that were instead placed under conservation easements at prices below fair market value. Maintaining the Ridgewood Ranch provides for public appreciation while enabling landowners to continue agricultural stewardship and ensure the operation's economic sustainability. Tours, conservation research, school and youth group activities and community gardening projects will continue, providing alternate income streams.

The Ridgewood Ranch Conservation Area was established by easement to protect the historic home of Seabiscuit, as well as the ranch's oak-woodland ecosystems. Photo by John Birchard, courtesy Mendocino Land Trust.

The Wyoming Stock Growers have created a statewide land trust focusing on easements for agricultural lands (WSGALT). Since its inception, WSGALT has received 34 conservation easements on close to 80,254 acres of ranchland.

With much of Yellowstone National Park, Grand Teton National Park and the Rockefeller National Parkway within its bounds, Wyoming is revered around the world for its open spaces, abundant wildlife, scenic beauty and ranching heritage. When considering rangeland ecosystem services and social and economic benefits generated by consumptive and non-consumptive recreation in terms of travel and tourism, $120 billion flow into Western economies and approximately

20 million jobs in the West are generated. Ranches occupy the most agriculturally productive rangelands in the state and are critical habitat for Wyoming's wildlife, with strategic sites near valleys and waterways necessary for winter range, reproduction and wildlife travel corridors. Rangelands' benefits extend far beyond the borders of ranches due to Wyoming's mosaic of public and private land ownership.

However, development is displacing ranches and open rangeland throughout the West. Studies predict that 26 million acres of open space will be converted to residential and commercial development by 2050 at a rate that has been increasing since the 1940's. A U.S. Government Accountability Office report issued in 2007 stated that homes built in the wildland-urban interface have caused firefighting costs to triple

A conservation easement of 2000 acres in northwest Wyoming preserves sagebrush habitat for sage grouse, mule deer, pronghorn antelope and elk, as well as stream habitat used for spawning by brown trout. Photo courtesy WWNRT.

since 2000, costing over $3 billion annually as a result of development of rural areas.

In Wyoming, private lands provide important habitat for big game species. The Wyoming Wildlife and Natural Resource Trust (WWNRT), created by the Wyoming Legislature in 2005, uses conservation easements to enhance wildlife habitats and protect the natural resource heritage of Wyoming. Nationally, 90 percent of protected species have some portion of habitat on private land and 37 percent are entirely dependent on private land for survival. Clearly, partnerships to protect rangeland ecosystem goods and services must include private lands.

No matter the drivers, as rangeland is fragmented, persistence of important rangeland ecosystem goods and services such as wildlife habitat, watersheds and scenic viewsheds is threatened. According to USDA NRCS Natural Resource Inventory (NRI) data from 1982 to 2008, 10.4 million acres of U.S. rangelands were lost (NRCS 2008). Experts predict between 50 and 75 percent of ranches in the West will change hands in the next 10 to 15 years. Recognizing this threat, WSGALT and other Western state land trusts formed the Partnership of Rangeland Trusts (PORT). Members currently include the California Rangeland Trust, Colorado Cattlemen's Agricultural Land Trust, Kansas Livestock Association Ranchland Trust, Montana Land Reliance, Oregon Ranchland Trust and Ranch Open Space of Nevada. Rangeland conservation easements held by PORT members surpassed the one million acre mark, with 900 easements on over 1.3 million acres of rangeland.

Easements ensure that a balance between the natural and productive value of the land will endure while needed flexibility is provided to the landowners for daily operations. Conservation easements are completely voluntary agreements, limiting the amount and type of development permitted on a property in order to preserve its productive capacity. Although all conservation easements prohibit development that impacts land's value for ranching, the specific terms are individually tailored in accordance with landowner concerns and the unique property features. Conservation easements can be donated or sold and can be granted during the owner's lifetime or through a bequest. The easement may be placed on an entire property or a portion of the property. Conservation easements typically are assigned in perpetuity. This means the agreement runs with the title, regardless of ownership, ensuring that the land will be maintained as ranchland and open space for future generations.

Credit Trading: Environmental credit trading is an incentive mechanism whereby government regulation establishes a requirement for an environmental practice or action that can be satisfied by entities subject to the regulation, either by taking the required actions or by purchasing credits from entities that take credit-earning actions. In other words, a market for a specific type of credit is established by a government agency through definition of the nature of the credits, establishing conditions under which some entities become willing sellers of the credits and some become willing buyers.

For example, U.S. Environmental Protection Agency required firms to meet certain air quality emission standards and allowed firms that exceeded the requirement (i.e., by meeting a higher standard of air quality and discharging even fewer pollutants into the atmosphere than they would be permitted to discharge under the regulation) to sell credits based on the extent to which they exceeded the emission standards (EPA 2007, Joskow et al. 1998). Firms that were unable to meet the emission standards, or able to meet them only at very high cost, could purchase credits in lieu of meeting the requirement themselves.

In effect, firms could pay someone else to meet the emission standard in their place. In the economics literature, these transactions are referred to as marketable permits or transferable discharge permits. They have been proposed as economically efficient mechanisms for pollution abatement.

Although credit trading has been studied and advocated by economists for decades (Dales 1968, Montgomery 1972, Krupnick et al. 1983, Hartwick and Olewiler 1986, Cropper et al 1992), it has only recently been applied as an environmental management tool and has seen limited application to ecosystems services or capacities. However, because of its high visibility and acceptance as a possible mechanism for limiting the emissions of greenhouse gases and encouraging the sequestration of carbon in proposals to reduce the human factors driving global climate change, it is an important incentive mechanism to consider for management of rangeland ecosystem services capacities.

Water Quality Trading Credits: Keys to Success

Every trading program should strive to be:

Transparent

Keep the public informed at every step of the process by:

- Involving stakeholders in design of the trading program
- Communicating to the public necessary information to maintain stakeholder confidence

Real

Show pollutant reductions and water quality improvement by:

- Measuring reductions
- Verifying BMP installation and maintenance, e.g. through a third-party

Accountable

Manage the program effectively by:

- Including trade tracking mechanisms in the program design
- Periodically reviewing the program's process and results

Defensible

Base the program on sound science and protocol by:

- Using dynamic water quality models
- Requiring credit generators to certify credits
- Developing scientifically-based trading ratios

Enforceable

Establish responsibility for meeting or exceeding standards by:

- Incorporating clearly-articulated trading provisions in permits

Adapted from the U.S. Environmental Protection Agency WQT Toolkit for Permit Writers, August 2007. 833-F-07-005

Credit trading could be applied directly to actions degrading or creating the rangeland ecosystem conditions that produce valuable ecosystem services (McGartland and Oates 1995). A similar approach has been applied to the regulation of activities degrading or creating wetlands (EPA 2008). Under federal regulations, wetland mitigation banks can be established by creating wetlands at a specific site. Such banks can earn compensatory mitigation credits that can be purchased by entities that are undertaking actions that destroy wetlands, such as the construction of highways or commercial development. Ecological assessment methods are used to certify the ecological functions provided by the newly created wetlands in order to ensure that the credits provide the required mitigation for the wetlands being destroyed. Entities taking actions affecting wetlands purchase the credits, thus providing income to the entities creating the wetlands. A major advantage to this credit trading system is that it allows firms that specialize in creating and maintaining new wetlands to absorb the developers' liability to mitigate the effects of their activities.

Credit trading can also be linked to conservation easements, as with preservation of the New Jersey Pine Barrens (Lilieholm and Romm 1992). In that application, landowners who voluntarily accepted easements on their property earned tradable development credits that could be purchased by developers who could then use the credits to develop at higher densities in designated development areas in New Jersey. Here, credit trading was designed to maintain valuable eco-

In addition to traditional livestock benefits, ranchers may be able to sell carbon credits associated with carbon storage in rangelands soils through the National Farmers Union on the Chicago Climate Exchange. Photo courtesy USDA ARS.

system conditions in the Pine Barrens area of New Jersey while allowing some development in response to economic pressures.

Rangeland managers may have an opportunity to participate in a carbon credit trading system if one is implemented in the United States as a result of future national climate policy. In this case, the definition of credits and the requirement that they be purchased to offset carbon emissions would be established by federal law. Rangeland owners would earn credits for undertaking or continuing management practices that sequester carbon in vegetation and soil organic matter. Measurement and certification methods would need to be developed in order to support the award of credits for specific management practices on specific sites. Such methods have a clear relationship to the indicators developed by the SRR.

The National Farmer's Union (NFU) currently brokers rangeland carbon credits on the Chicago Climate Exchange (CCX), hinting at potential profitability of these transactions should government regulations be promulgated. Currently no such government regulation of carbon emissions exists. The NFU Carbon Credit Program allows agricultural producers and landowners who practice no-till crop production, conversion of cropland to grass and sustainable management of native rangelands to earn income by storing carbon in their soil. The CCX has recognized the NFU as a broker permitted to aggregate carbon offsets (carbon credits) and sell them on behalf of producers. In order to aggregate carbon offsets, the NFU enrolls producer acreage into blocks of marketable offsets that are then traded on the CCX, similar to sales of other agricultural commodities. Profits are transferred to producers as each aggregation of carbon credits is sold. During its first year of operation, producers earned more than $2.5 million dollars from this program. Proceeds could be expected to increase if government regulation becomes a driver in sales of offsets.

This approach has the advantage of having the rules and enforcement mechanisms needed for trading and the contributions of rangeland ecosystems to the carbon balance as the service most directly supported by the resulting incentives. In effect, the questions of benefits and costs and the need for willing buyers and sellers and rules for trading, will all be dealt with by climate change policy. This will relieve rangeland managers of these difficult tasks. However, this form of credit trading has the disadvantage that carbon sequestration may or may not be the most important ecological process relative to production of other valuable rangeland ecosystem services (see Havstad et al. 2007 for further discussion on issues related to carbon sequestration as a rangeland ecosystem service).

Photo courtesy USDA ARS.

Future Directions: Rangeland Ecosystem Goods and Services Research

Previous sections outline general opportunities and highlight specific examples of how application of the EGS paradigm can improve conservation and sustainability of private and public rangelands. They also point to the need for research on the ecological, social and economic bases of EGS production and rangeland sustainability. This section identifies overarching questions and specific opportunities for research and development of monitoring tools and technologies to facilitate research and management of rangeland EGS.

General questions:

- How do we manage rangelands to sustainably provide the suite of ecosystem goods and services that we wish to obtain from them?
- How do we identify the ideal suite of services, now and in the future? For "now" we have the status quo, but needs and desires will change in the future (biofuels being a simple example of this kind of change – but will there also be goods or services with which we decide to reduce or dispense?).
- However we optimize choices about suites of EGS production in the present, climate change will force changes in those choices (or in what choices are even possible) in the near term. How will climate change affect the core ecological processes underlying EGS?

Specific questions:

- What are the important spatial scales for measuring the production of EGS? Are they similar or different for different kinds of EGS (e.g., food, fiber, clean water)?
- What are the important temporal scales for measuring the production of EGS?
- How do or should those temporal scales affect management and policy? That is, different temporal scales of measurement affect policy focused on current or year-to-year conditions and the welfare of the current generation vs. the long-term and intergenerational equity. As Vavra and Brown (2006) state, "what is necessary to make rangeland research meet society's needs is a research approach that integrates those ecosystem components into whole-system, landscape scale investigations spanning appropriate time scales."
- What are the needs for tools to help us understand the interactions and tradeoffs among different EGS being produced in the same location? For example, we need water for drinking, irrigation, wildlife and aesthetic purposes. To what extent are those purposes compatible and can we build quantitative models that will help us understand the consequences of different policy choices?

- How will climate change affect the demand for EGS from rangelands? e.g., how will change affect human settlement rates and resource demands in rangelands? How will those changes in turn affect the economy?
- What monitoring tools do we need to help us sustainably manage EGS production? Can we answer that question using the SRR C&I? What tools do we already have that can be adapted for this purpose, essentially modifying them for an explicit EGS focus?

ARS researchers measure soil nutrients, plant productivity, nutritional quality, and grasshopper species composition responses to summer fire and post-fire grazing. Photo courtesy USDA ARS.

Changes to rangeland ecosystems on multiple scales have resulted in new disturbance regimes that cannot continue to deliver the ecosystem services we have come to expect from rangelands (Vavra and Brown 2006). A need to understand these changes and their impacts on rangelands EGS indicates additional requisite research in the following areas identified by Vavra and Brown (2006):

- Develop tools to provide predictions of disturbance–management interactions.
- Develop qualitative and quantitative estimates of plant community resistance and resilience.
- Develop a better understanding of hydrologic processes interacting across greater temporal and spatial scales and a wider variety of rangeland conditions.
- Develop landscape-scale indicators of functional biodiversity.
- Develop risk analysis concepts and tools.

- Develop grazing systems that utilize livestock as an ongoing management process.
- Initiate the use of ecologically based experimental approaches to identify causes of invasion and dominance and options for mitigation management.
- Develop methods for improving success of reintroduced native species.
- Develop landscape-level restoration efforts.
- Identify the impacts of recreation on the range resource and the impacts of other uses on range recreation.
- Define ecological, biological, social, political and economic relationships.

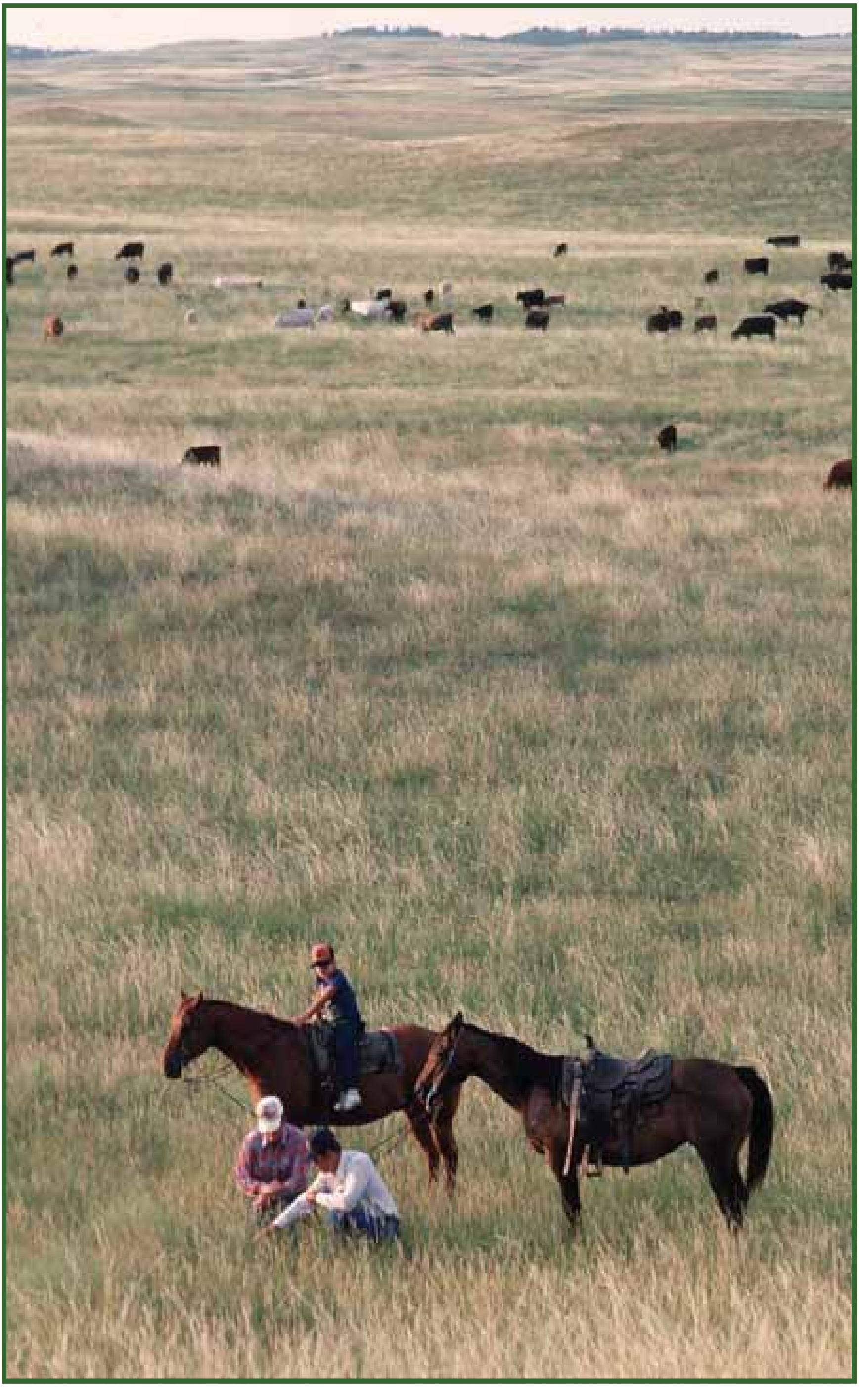


Photo courtesy USDA NRCS.

Concluding Thoughts

This publication clearly establishes the importance of rangeland ecosystem goods and services to society and identifies the challenges associated with quantifying and valuing rangeland commodities and amenities. Previous sections highlight intricacies involved with incorporating standardized ecological, social and economic assessment protocols into agency and organizational policies for conservation and management as well as into private landowners' business plans. Rangeland scientists, managers and administrators acknowledge that much work lies ahead and additional research will be necessary. However, substantial progress has already been made.

As the millennium approached, U.S. rangeland managers and stakeholders recognized an increasingly critical need for comprehensive indicators of ecological, social and economic rangeland sustainability. Consistent inventory and assessment information provided by measurable monitoring indicators will one day enable Congress, agencies and constituents to more accurately assess outcomes of conservation programs and management actions, which will also improve their ability to evaluate impacts of climate change, loss of open space and productivity and wildlife habitat alteration. Agency delivery of efficient land management actions and effective conservation programs, upon which landowners depend for assistance, will be enhanced as well.

An Applied Example of Monitoring for Management of Rangeland Ecosystem Goods & Services: The Oregon Multi-Agency Pilot Project

In 2005, SRR formally asked their participating federal agencies to cooperatively implement a test of indicator-based monitoring to track trends in core rangeland ecosystem processes, goods and services by incorporating all federal, non-forested lands into the two existing large-scale sampling programs – the Forest Service Forest Inventory and Analysis (FIA) program and the Natural Resources Conservation Service National Resources Inventory (NRI) program. To assess the natural resource stocks supplying rangeland ecosystem goods and services, the agencies initiated the Oregon Multi-Agency Pilot Project (MAPP) to:

- develop consistent rangeland monitoring definitions and protocols;
- examine the adequacy of FIA and NRI sampling frames and the adaptability and compatibility of existing survey operations; and
- outline joint budgetary needs for comprehensive rangeland inventory and monitoring.

The MAPP covers 13 counties in Central Oregon (Figure 9) encompassing 30 million acres, including federal, state, private and Tribal lands. This area was selected because of the mix of ownership

Figure 9. The thirteen counties (green) in Central Oregon in which the Multi-Agency Pilot Project is being conducted.

and range types, existence of baseline soils and ecological site information and working relationships across agency boundaries. The original MAPP operating plan outlined four implementation stages spanning four years: (1) Proof of Concept, late 2006; (2) Pilot Project Data Collection, 2007; (3) Process Review and Validation, 2008; and (4) West-wide and/or National Implementation, 2010 (Thompson 2006).

Ecological data collected for MAPP is focused on five SRR indicators addressing the amount of bare ground, vegetation composition, invasive species, rangeland landscape pattern and amount of rangeland by area. Social and economic indicators recommended by SRR participants are being collected and analyzed via an arrangement with a researcher at Oregon State University. These indicators include land tenure, land use and ownership pattern by size classes to deal with social fragmentation of land; population pyramid and population change; employment, unemployment, underemployment and discouraged workers by industrial sector; and sources of income and level of dependence on livestock production for household income.

Data collected and integrated for joint MAPP assessments across agencies in central Oregon will inform management of core ecosystem processes and disturbances impacting soil and vegetation for provision of rangeland ecosystem goods and services including food for human consumption, food for livestock consumption, fiber, biofuels feedstocks and wildlife habitats. Four decades into agency transitions to managing for multiple uses, an integrated approach to monitoring is a belated, but crucial, component of their ability to meet their agency missions and honor obligations to the American public. Such inventory and monitoring is necessary to track trends associated with a variety of rangeland ecosystem goods and services.

Promise for the Future

Fiscal year 2007 saw interagency completion of the first data collection field season and a second field season is planned with sampling conducted by the FIA and NRI programs as part of their on-going work. Following internal agency and external scientific reviews of data collection procedures and potential for integration across the FIA and NRI sampling protocols, preliminary data from the first field season will be available in early 2009. Eventual national expansion of the Oregon Pilot is critical to continued supply of goods and services provided by this Nation's rangeland resources. Anticipated MAPP outcomes include improved coordination and cooperation among agencies and organizations to produce periodic assessments for informed policy decisions, as well as enhanced resource allocations for rangeland management and science throughout the United States.

Recent passage by both Houses of Congress of a new Farm Bill with an expanded Conservation Title illustrates federal government commitment to sustainable management of the nation's natural resources. More specifically, the MAPP and SRR's ongoing work with monitoring frameworks featured prominently in the 2008 USDA Agricultural Outlook presentation given by USDA Deputy Under-secretary Gary Mast as a successful example of cooperative conservation's benefits for natural resource conservation. While progress may not be occurring as rapidly as many would like, rangeland resources' contributions to the sustainability and satisfaction of the nation's needs are gradually becoming more explicitly recognized and incorporated into policy planning and management activities of private and public land managers throughout the United States.

Three generations of ranchers ride out on the McIsaac Ranch. Photo courtesy James Bernard.

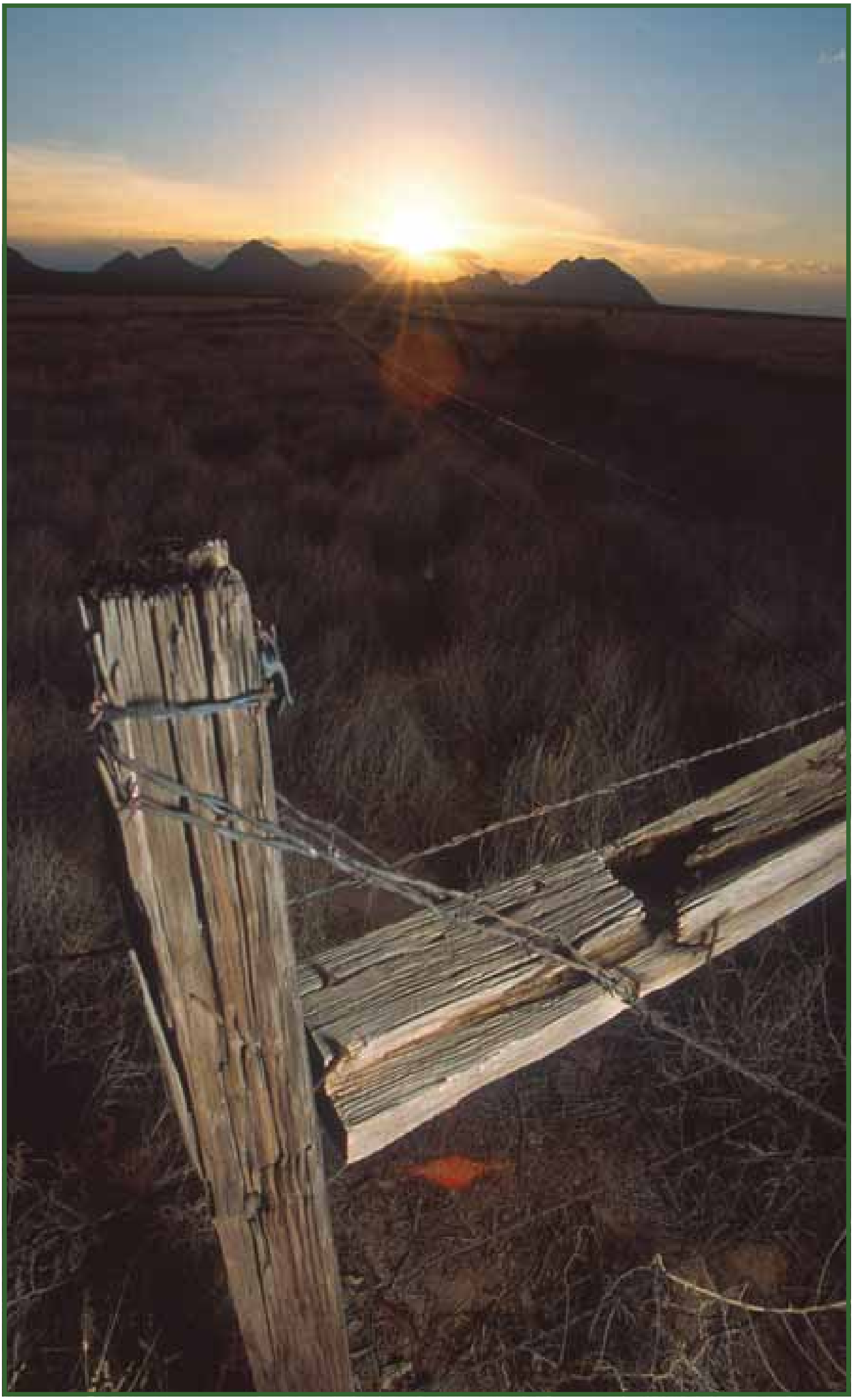


Photo courtesy USDA ARS.

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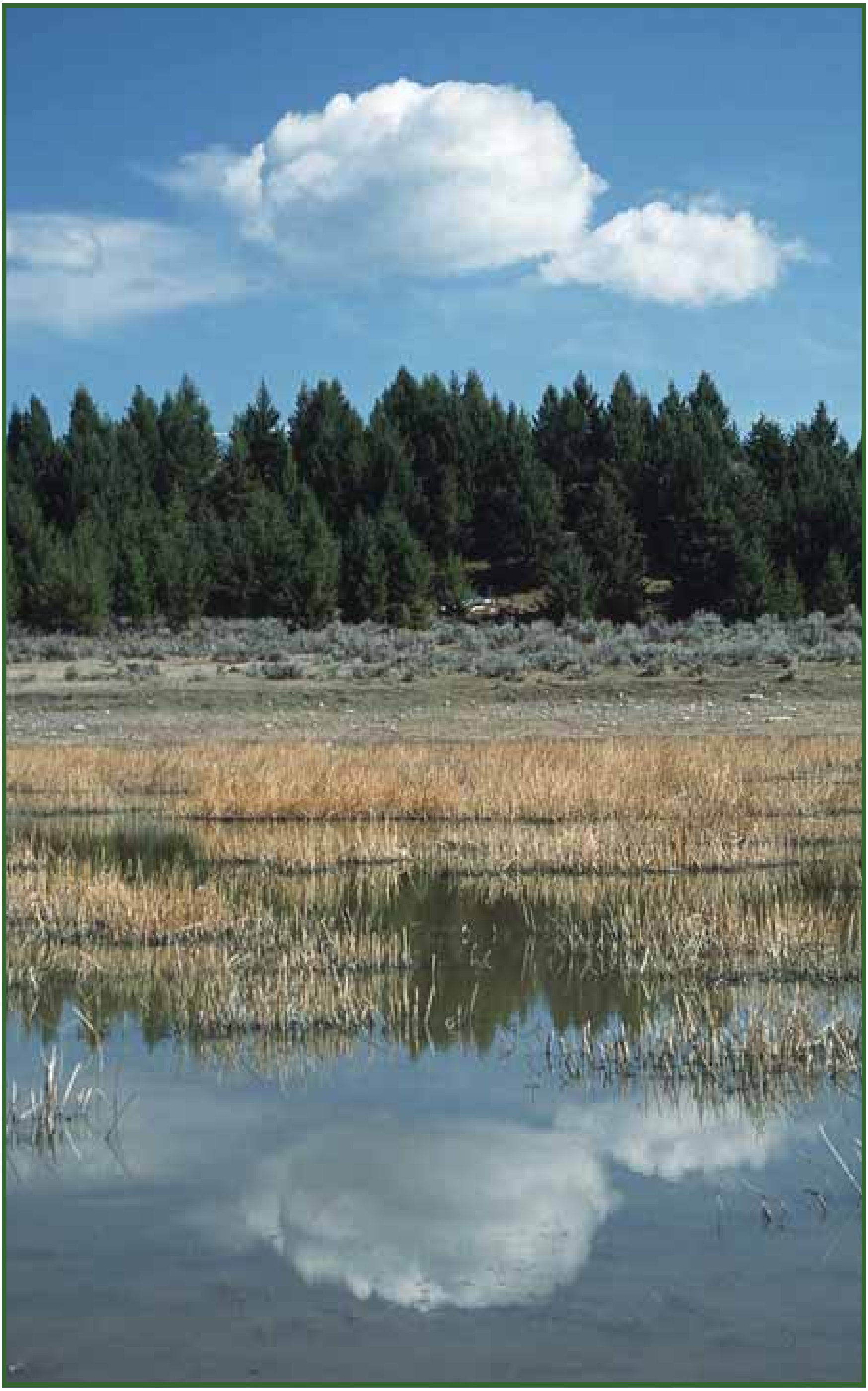


Photo courtesy USDA NRCS.

Appendix A1: Rangeland Biological Ecosystem Goods and Services (EGS)

	Domestic Livestock for Human Consumption	Other Food for Human Consumption	Forage for Livestock	Fiber	Biofuels	Fishing, Hunting and Viewing Wildlife	Biochemicals	Genetic Material	Other
Must Haves (Yes / No)									
Does the EGS exist on or is derived from rangelands?									
Is the EGS important to rangeland ecosystem processes and/or human well-being?									
For each column, both questions must be answered YES to continue.									
Wants (High/ Medium/ Low/ NA)									
High Importance									
Does the EGS provide a basic human need? Is it important to society?									
What is the current level of demand for the EGS?									
How responsive is the EGS to management?									
Moderate Importance									
How easily is the EGS measured?									
How important is the EGS over different spatial scales?									
Local									
Regional									
National									
How important is the EGS over different temporal scales?									
How resilient is the EGS?									
How much does human activity impact the EGS?									
How important are rangelands to this EGS?									
How unique is the EGS to rangelands?									
Low Importance									
For this good, are there no potential substitutes?									
Consequences									
Is the EGS impacted by local, state or federal regulations?									

Appendix A2: Rangeland Hydrologic and Atmospheric Ecosystem Goods and Services (EGS)

	Drinking Water	Water for Economic Benefit	Floods for Channel and Riparian Area Rejuvenation	Flood Mitigation	Water bodies for recreation / tourism	Minimizes Contributions of Chemicals and Particulates	Contributes to Clean, Fresh Air	Hydrologic Energy Potential	Solar Energy Potential	Wind Energy Potential	Other
Must Haves (Yes / No)											
Does the EGS exist on or is derived from rangelands?											
Is the EGS important to rangeland ecosystem processes and/or human well-being?											
For each column, both questions must be answered YES to continue.											
Wants (High/ Medium/ Low/ NA)											
High Importance											
Does the EGS provide a basic human need? Is it Important to society?											
What is the current level of demand for the EGS?											
How responsive is the EGS to management?											
Moderate Importance											
How easily is the EGS measured?											
How important is the EGS over different spatial scales?											
Local											
Regional											
National											
How important is the EGS over different temporal scales?											
How resilient is the EGS?											
How much does human activity impact the EGS?											
How important are rangelands to this EGS?											
How unique is the EGS to rangelands?											
Low Importance											
For this good, are there no potential substitutes?											
Consequences											
Is the EGS impacted by local, state or federal regulations?											

Appendix A3: Miscellaneous Rangeland Ecosystem Goods and Services (EGS)

	Views and Scenes	Cultural or Spiritual	Historic/ Archeological	Scientifically Significant Sites	Recreation and Tourism Sites	Ornamental Resources	Ceremonial Resources	Other
Must Haves (Yes / No)								
Does the EGS exist on or is derived from rangelands?								
Is the EGS important to rangeland ecosystem processes and/ or human well-being?								
For each column, both questions must be answered YES to continue.								
Wants (High/ Medium/ Low/ NA)								
High Importance								
Does the EGS provide a basic human need? Is it important to society?								
What is the current level of demand for the EGS?								
How responsive is the EGS to management?								
Moderate Importance								
How easily is the EGS measured?								
How important is the EGS over different spatial scales?								
Local								
Regional								
National								
How important is the EGS over different temporal scales?								
How resilient is the EGS?								
How much does human activity impact the EGS?								
How important are rangelands to this EGS?								
How unique is the EGS to rangelands?								
Low Importance								
For this good, are there no potential substitutes?								
Consequences								
Is the EGS impacted by local, state or federal regulations?								

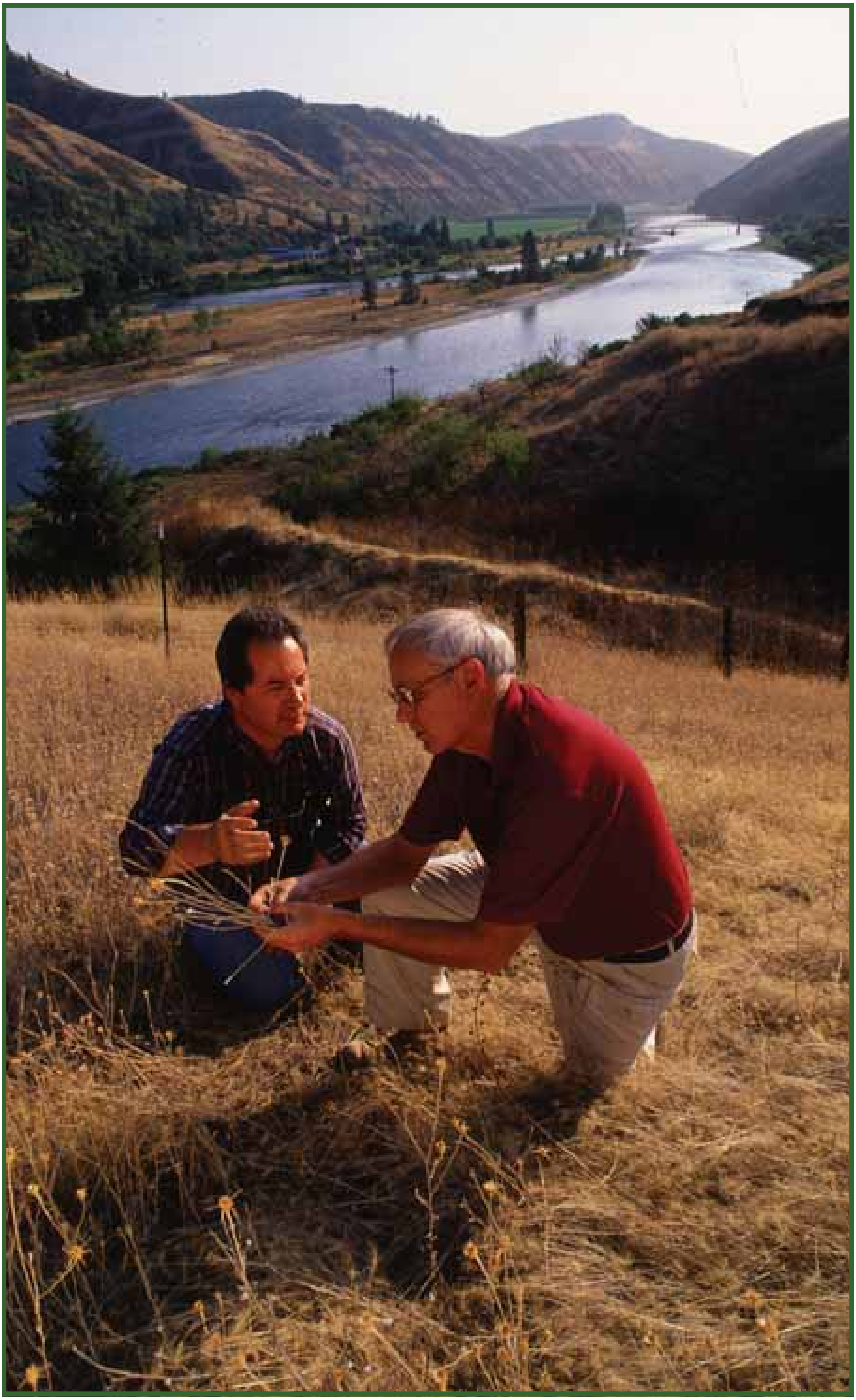


Photo courtesy USDA ARS.

Appendix B: Sustainable Rangelands Roundtable Indicators

Indicators in orange have been identified as core indicators by the SRR

I. Conservation and Maintenance of Soil and Water Resources on 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 a 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. Percentage of stream length in rangeland catchments in which stream channel geometry significantly deviates from the natural channel geometry.

II. Conservation and Maintenance of Plant and Animal Resources on Rangelands

11. Extent of land area in rangeland.
12. Rangeland area by vegetation community.
13. Number and extent of wetlands.
14. Fragmentation of rangeland and rangeland plant communities.
15. Density of roads and human structures.
16. Integrity of natural fire regimes on rangeland.
17. Extent and condition of riparian systems.
18. Area of infestation and presence/absence of invasive and non-native plant species of concern.
19. Number and distribution of species and communities of concern.
20. Population status and geographic range of rangeland-dependent species.

III. Maintenance of Productive Capacity on Rangelands

21. Rangeland aboveground phytomass.
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.

IV. 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. Area of rangelands under conservation ownership or control by conservation organizations.
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).
38. Income inequality.
39. Index of social structure quality.
40. Community satisfaction.
41. Federal transfers by categories (individual, infrastructure, agriculture, etc.).
42. Presence and tenure of natural resource non-governmental organizations at the local level.
43. Sources of income and level of dependence on livestock production for household income.
44. Employment diversity.
45. Agriculture (farm/ranch) structure.
46. Years of education.
47. Value produced by agriculture and recreation industries as percent of total.
48. Employment, unemployment, underemployment, and discouraged workers by industrial sector.
49. Land tenure, land use, and ownership patterns by size classes.
50. Population pyramid and population change.
51. Income differentials from migration.
52. Length of residence (native, immigrant > 5 yrs., < 5 yrs.)
53. Income by work location versus residence.
54. Public beliefs, attitudes, and behavioral intentions toward natural resources.

V. Legal, Institutional and Economic Frameworks for Rangeland Conservation and Sustainable Management

55. *Land Law and Property Rights*. Extent to which laws, regulations, and guidelines, clarify property rights, and land tenure arrangements, recognize customary and traditional rights of indigenous people, and provide means of resolving property disputes by due process as they relate to the conservation and sustainable management of rangelands.
56. *Institutions and Organizations*. Extent to which governmental agencies, educational institutions, and other for-profit and not-for-profit organizations affect the conservation and sustainable management of rangelands.
57. *Economic Policies and Practices*. Extent to which economic policies and practices support the conservation and sustainable management of rangelands.
58. *Public Information and Public Participation*. Extent to which laws, regulations, and guidelines, institutions and organizations provide opportunities for: (1) public access to information; and, (2) public participation in the public policy and decision making process relating to rangelands.
59. *Professional Education and Technical Assistance*. Extent to which laws, regulations, and guidelines, institutions, and organizations provide for professional education and the distribution of technical information and financial assistance related to the conservation and sustainable management of rangelands.
60. *Land Management*. Extent to which land management programs and practices support the conservation and sustainable management of rangelands.
61. *Land Planning, Assessment, and Policy Review*. Nature and extent of periodic range-related planning, assessment, and policy review activities, including planning and coordination between institutions and organizations.
62. *Protection of Special Values*. Extent to which laws, regulations, and guidelines, institutions, and organizations provide for the management or rangelands to conserve special environmental, cultural, social and/or scientific values.
63. *Measuring and Monitoring*. Extent to which agencies, institutions and organizations devote human and financial resources to measuring and monitoring changes in the condition of rangelands.
64. *Research and Development*. Nature and extent of research and development programs that affect the conservation and sustainable management of rangelands.

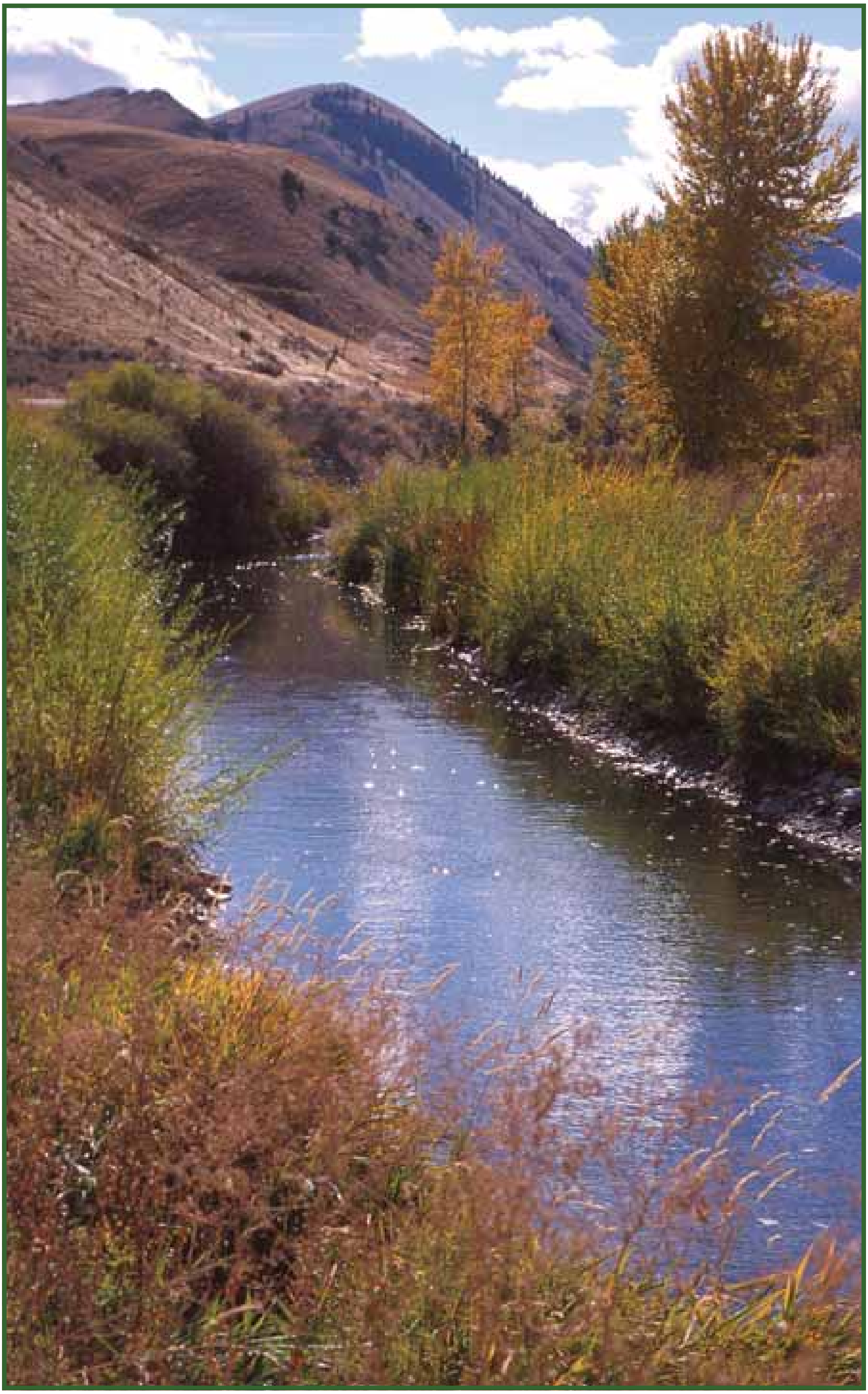


Photo courtesy USDA NRCS.

Appendix C: List of Acronyms and Abbreviations

(R)EGS	Rangeland Ecosystem Goods and Services
AFT	American Farmland Trust
ARS	Agricultural Research Service
ATV	All Terrain Vehicle
BAER	Burned Area Emergency Response
BLM	Bureau of Land Management
C&I	Criteria and Indicators
CCE	Chicago Climate Exchange
CEAP	Conservation Effects Assessment Project
CEQ	Council on Environmental Quality
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CTCA	Central Texas Cattlemen's Association
DOD	Department of Defense
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
ESA	Endangered Species Act
FIA	Forest Inventory and Analysis
FS	Forest Service
GAO	Government Accountability Office
GPRA	Government Performance and Results Act
IAFWA	International Association of Fish & Wildlife Agencies
ISEEC	Integrated Social, Economic and Ecological Concept
LRRP	Leon River Restoration Project
MAPP	Multi-Agency Pilot Project
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NBII	National Biological Information Infrastructure
NFU	National Farmer's Union
NGO	Non-governmental Organization
NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
PORT	Partnership of Rangeland Trusts
R&D	Research and Development
RMRS	Rocky Mountain Research Station
SRM	Society for Range Management
SRR	Sustainable Rangelands Roundtable
TNC	The Nature Conservancy
US	United States
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WSGALT	Wyoming Stockgrowers Agricultural Land Trust
WHIP	Wildlife Habitat Incentive Program
WRP	Wetlands Reserve Program
WWNRT	Wyoming Wildlife and Natural Resource Trust

Getting Paid for Stewardship: An Agricultural Community Water Quality Trading Guide

July 2006

Water quality trading programs that producers might participate in usually start at the local level. Trading programs are developed to address local water quality concerns and the needs of local stakeholders; therefore, each locally developed trading program will be different. However, the following eight key elements are found in most water quality trading approaches:

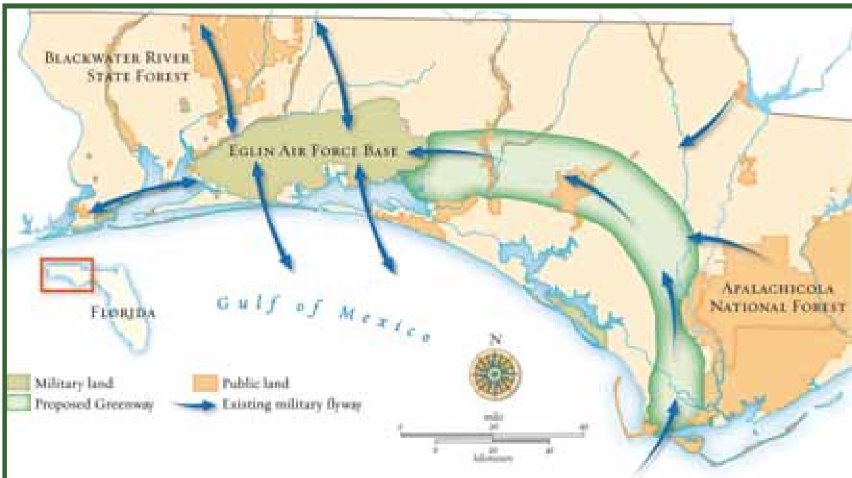
Element 1: Assessing the potential for water quality trading
Element 2: Determining what a producer can trade
Element 3: Determining how much a producer can trade
Element 4: Determining when a producer can trade
Element 5: Finding a trading partner
Element 6: Developing trade agreements and addressing liability
Element 7: Verifying and certifying conservation practice implementation
Element 8: Tracking and reporting pollutant reductions and trades

Increased participation by agricultural producers will further the success of water quality trading as a market-based tool for achieving water quality goals. Getting informed about the opportunities that exist is the first step.

For example, producers in Washington County, Oregon, work with the Tualatin Soil and Water Conservation District to participate in an enhanced Conservation Reserve Enhancement Program (CREP). Participating producers receive an extra $128 per acre per year above the standard $265 per acre per year for tree plantings to cool the excessively warm Tualatin River (Charles Logue, Clean Water Services, Technical Services Department Director, personal communication, May 23, 2006). The additional funds come from Clean Water Services, a wastewater and stormwater public utility that must reduce the amount of heated water entering the Tualatin River from its facilities.

Reproduced from “Getting Paid for Stewardship: An Agricultural Community Water Quality Trading Guide.” (2006) Conservation Technology Information Center (CTIC), 1220 Potter Drive, West Lafayette, IN 47906, 765 494-9555, 765 494-5969 (fax). www.conservationinformation.org

Appendix E: The Northwest Florida Greenway



Military, government and nonprofit organizations have partnered to conserve rangeland ecosystem services. Map courtesy 1,000 Friends of Florida (www.1000friendsofflorida.org).

The Nature Conservancy (TNC) recently identified an area in Northwest Florida as a national "hotspot" due to the intersection of critical habitats, rare wildlife and plant species, and development threats. A pervasive military presence in the region adds additional complications due to National Security issues. To address these issues, the Department of Defense, US Fish and Wildlife Service, US Forest Service, Florida state agencies and TNC have partnered to develop the Northwest Florida Greenway. The greenway collaboration creates a 100-mile long corridor to join tracts of land over 1,000,000 acres in size, generating ecosystem services by satisfying national security needs, protecting biodiversity and water resources, and providing areas for outdoor recreation.

Photo courtesy NPS.

Appendix F: Participants in Sustainable Rangelands Roundtable Activities (2001-present)

Mr. Al Abee, USDA Forest Service
Mr. Marcel Aillery, USDA Economic Research Service
Dr. Jim Alegria, USDI Bureau of Land Management
Mr. Hugh Aljoe, The Samuel Roberts Noble Foundation
Dr. Barbara Allen-Diaz, University of California at Berkeley
Mr. Lee Barber, U.S. National Guard
Mr. Kevin Barnes, USDA National Agricultural Statistics Service
Mr. Hugh Barrett, USDI Bureau of Land Management
Dr. Tom Bartlett, Colorado State University (ret)
Dr. Ann Bartuska, USDA Forest Service
Mr. Dennis T. Becenti, Hopi Tribe
Mr. Robert Belcourt, Chippewa Cree Tribe
Mr. James Bernard, Mendocino Land Trust
Dr. Marty Beutler , South Dakota State University
Ms. Margareta Bishop, USDA Natural Resources Conservation Service
Dr. Ben Bobowski, USDI National Park Service
Mr. Robert Bolton, USDA Bureau of Land Management
Dr. Terry Booth, USDA Agricultural Research Service
Mr. Steven J. Borchard, USDI Bureau of Land Management
Ms. Emily Brott, The Sonoran Institute
Dr. Bob Breckenridge, Department of Energy Idaho National Laboratory
Mr. J.K. “Rooter” Brite, Grazing Lands Conservation Initiative
Dr. Mark Brunson , Utah State University
Dr. Larry Bryant, USDA Forest Service (ret)
Mr. Bob Budd, Wyoming Wildlife and Natural Resources Trust
Dr. John Buckhouse, Oregon State University and Cooperative State Research, Education and Extension Service
Mr. William Burnidge, The Nature Conservancy
Dr. Fee Busby, Utah State University
Dr. Evert Byington, USDA Agricultural Research Service
Mr. Jason Campbell, National Cattlemen’s Beef Association
Dr. Len Carpenter, Wildlife Management Insititute
Mr. Chris Castilian, National Association of Counties
Mr. Mike Cauley, The Samuel Roberts Noble Foundation
Mr. Kevin Chappell, Montana Department of Natural Resources & Conservation
Dr. Dennis Child, Colorado State University
Dr. David Cleaves, USDA Forest Service
Mr. Noel Crase, Western State Land Commissioners Association
Dr. Ralph Crawford, USDA Forest Service
Mr. Bud Cribley, USDI Bureau of Land Management
Dr. Charles Curtin, Gray Ranch and Malpai Borderlands Group
Ms. Elena Daly, USDI Bureau of Land Management
Mr. Tom Davis, USDI Bureau of Indian Affairs
Mr. Robert S. Dayton, USDA Natural Resources Conservation Service
Mr. Pete Deal, USDA Natural Resources Conservation Service
Dr. Justin Derner , USDA Agricultural Research Service
Mr. Virgil Denny
Mr. Jeff Dibenedetto, USDA Forest Service

Participants in Sustainable Rangelands Roundtable Activities
(continued)

Dr. Jim Dobrowolski, USDA Cooperative State Research, Education and Extension Service
Mr. Rob Doudrick, USDA Forest Service
Dr. Janelle Downs, Department of Energy Pacific Northwest National Lab
Mr. Bob Drake, Grazing Lands Conservation Initiative
Dr. Jim Drake, NatureServe
Dr. Mark Drummond, US Geological Survey
Mr. Rich Duesterhaus, National Association of Conservation Districts
Dr. Clifford Duke, Ecological Society of America
Mr. Ron Dunter, USDI Bureau of Land Management
Mr. Jeff Eisenberg, National Cattlemen's Beef Association & Public Lands Council
Mr. Wayne Elmore, USDI Bureau of Land Management
Ms. Jamie Ervin, The Nature Conservancy
Ms. Elizabeth Estill, USDA Forest Service
Dr. Gary R. Evans, se4 consulting, inc
Dr. Jeff Fehmi, University of Arizona
Dr. Maria Fernandez-Gimenez, Colorado State University
Dr. Jim Fogg, USDI Bureau of Land Management
Dr. William Fox, Texas A&M University
Dr. Barbara A. Frase, Bradley University
Dr. Sam Fuhlendorf, Oklahoma State University
Dr. Paul Geissler, US Geological Survery
Dr. Jeff Goebel, USDA Natural Resources Conservation Service
Dr. Robert Goo, US Environmental Protection Agency
Dr. John Gross, USDI National Park Service
Dr. Michelle Haefele, The Wilderness Society
Mr. Robert Hales, Idaho State Department of Agriculture
Mr. Stan Hamilton, National Association of State Foresters (ret)
Mr. Niels Hansen, Wyoming State Grazing Board
Dr. Jon Hanson, Department of Energy Northern Great Plains Research Laboratory
Dr. Linda Hardesty, Washington State University
Dr. Aaron Harp
Mr. H. Theodore Heintz, Jr., Council on Environmental Quality (ret)
Dr. Rod Heitschmidt, USDA Agricultural Research Service (ret)
Ms. Aggie Helle, American Sheep Industry
Mr. Karl Hermann, US Environmental Protection Agency
Mr. Bob Hetzler, USDI Bureau of Indian Affairs
Dr. Calder Hibbard
Ms. Lori Hidinger, Arizona State University, Consortium for Science, Policy and Outcomes
Dr. Alison Hill, USDA Forest Service
Dr. Fen C. Hunt, Natural Resources and Environmental Economics
Mr. Chase M. Huntley, US Government Accountability Office
Dr. Lynn Huntsinger, University of California
Ms. Linda Hutton, USDA National Agricultural Statistics Service
Dr. Eric E. Hyatt, US Environmental Protection Agency
Ms. Myra Hyde, US Fish and Wildlife Service
Mr. Shan Ingram, The Samuel Roberts Noble Foundation

Participants in Sustainable Rangelands Roundtable Activities
(continued)

Dr. Nelroy Jackson, Invasive Species Advisory Committee
Dr. Lynn James, USDA Agricultural Research Service
Mr. Phil Janik, USDA Forest Service (ret)
Dr. Chris Jauhola, The Nature Conservancy
Dr. Mike Jennings, US Geological Survey
Dr. Gary Johnson, USDI National Park Service
Mr. Ken Johnson, Society for Range Management
Dr. Heather Johnson, World Wildlife Fund
Dr. Patricia Johnson, South Dakota State University
Dr. Leonard Jolley, USDA Natural Resources Conservation Service
Dr. Bruce Jones, US Environmental Protection Agency
Dr. Linda Joyce, USDA Forest Service
Ms. Janette Kaiser, USDA Forest Service
Dr. Mike “Sherm” Karl, USDI Bureau of Land Management
Ms. Stacey Katseanes, National Cattlemen’s Beef Association and Public Lands Council
Mr. Mike Kemmerer, Florida Fish & Wildlife Conservation Commission
Ms. Linn Kincannon, Idaho Conservation League
Ms. Corrie Knapp, Colorado State University
Dr. Rick Knight, Colorado State University
Mr. Steve Kouplen, Oklahoma Farm Bureau
Dr. Urs Kreuter, Texas A&M University
Mr. Rick Krause, American Farm Bureau Federation
Mr. Keith Kulman, Western States Land Commissioners Association
Dr. Ron Lacewell, Texas A&M University
Dr. Melinda Laituri, Colorado State University
Mr. C.B. “Doc” Lane, Arizona Beef Council and Arizona Cattle Grower’s Association
Mr. Mark Lawrence
Mr. Richard Lindenmuth, USDA Forest Service
Mr. Matthew R. Loeser, Northern Arizona University
Mr. Dick Loper, Wyoming State Grazing Board and Public Lands Council
Mr. Carl Lucero, USDA Natural Resources Conservation Service
Mr. Daryl Lund, USDA Natural Resources Conservation Service
Mr. Thomas D. Lustig, National Wildlife Federation
Ms. Sarah Lynch, World Wildlife Fund
Dr. Kristie Maczko, Colorado State University
Dr. Mike Manfredo, Colorado State University
Dr. Wayne Maresch, USDA Natural Resources Conservation Service
Dr. Genevieve Maricle, Arizona State University, Consortium for Science, Policy and Outcomes
Dr. Clayton Marlow, Montana State University
Dr. Ken Mathews, USDA Economic Research Service
Mr. Gary Mast, US Department of Agriculture
Mr. Matt Mattox, The Samuel Roberts Noble Foundation
Mr. Dick Mayberry, USDI Bureau of Land Management
Dr. Herman Mayeux, USDA Agricultural Research Service (ret.)
Dr. Dan McCollum, USDA Forest Service
Mr. Tom McDonnel, American Sheep Industry
Dr. Guy McPherson, University of Arizona

Participants in Sustainable Rangelands Roundtable Activities
(continued)

Mr. John "Chip" Merrill, Triple X Ranch
Mr. Keith Miller, Public Lands Foundation
Dr. John Mitchell, USDA Forest Service
Ms. Ann Morgan, University of Colorado
Dr. Jack Morgan, USDA Agricultural Research Service
Ms. Emily Morris, US Department of the Interior
Mr. Kit Muller, USDI Bureau of Land Management
Mr. Bill Mytton, Rocky Mountain Elk Foundation
Dr. Christine Negra, The H. John Heinz III Center for Science, Economics and the Environment
Dr. Kenneth E. Nelson, USDA Economic Research Service
Ms. Renee O'Brien USDA Forest Service
Dr. Robin O'Malley, The H. John Heinz III Center for Science, Economics and the Environment
Ms. Toney Ott, US Environmental Protection Agency
Ms. Hilary Parkinson, Sun Ranch Institute
Dr. Duncan Patten, Montana State University
Dr. Paul Patterson, USDA Forest Service
Dr. Marcia Patton-Mallory, USDA Forest Service
Mr. R. Scott Penfield, Avon Park Air Force Range
Dr. Janet Perry, USDA Economic Research Service
Mr. John W. Peterson, Grazing Lands Conservation Initiative
Ms. Pat Pfeil, Florida Cattlemen's Association
Mr. Doug Powell, USDI Bureau of Land Management
Dr. David Pyke, US Geological Survey
Dr. Carol Raish, USDA Forest Service
Mr. J.O. Ratliff, US Department of the Interior
Dr. Greg Reams, USDA Forest Service
Mr. Floyd Reed, USDA Forest Service
Mr. Tim Reich, National Association of Conservation Districts
Mr. Rich Reiner, The Nature Conservancy
Mr. Tim Reuwsaat, USDI Bureau of Land Management
Ms. Roylene Rides-at-the-door, USDA Natural Resources Conservation Service
Dr. Neil Rimbey, University of Idaho
Mr. Jeremy Roberts, Sun Ranch Institute
Mr. Tom Roberts, USDI Bureau of Land Management (ret)
Mr. Benny Romero
Mr. Lou Romero, GOLD Consulting
Mr. Rob Roudabush, USDI Bureau of Land Management
Ms. Helen Rowe, Colorado State University
Mr. Dan Rutledge, USDA Natural Resources Conservation Service
Ms. Terri Tucker Schulz, The Nature Conservancy
Dr. Jerry Schuman, USDA Agricultural Research Service (ret)
Mr. Ron Shafer, US Environmental Protection Agency
Dr. Bob Shaw, Colorado State University
Mr. Mark Simmons, Lady Bird Johnson Wildflower Center
Dr. Phillip Sims, USDA Agricultural Research Service
Mr. Jason Smith, Confederated Tribes of Warm Springs
Dr. John Spence, USDI National Park Service

Participants in Sustainable Rangelands Roundtable Activities
(continued)

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Dr Kimberli Stine, USDA Natural Resources Conservation Service
Dr. Larry Strong, USGS Northern Prairie Wildlife Research Center
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Dr. Joseph A. Tainter, USDA Forest Service (ret)
Mr. Curtis Talbot, USDA Natural Resources Conservation Service
Dr. John Tanaka, Oregon State University and Society for Range Management
Mr. Arnold Taylor, Hopi Tribe
Mr. Doug Tedrick, USDI Bureau of Indian Affairs
Dr. Dave Theobald, Colorado State University
Dr. Gene Theodori, Texas A&M University
Mr. Dennis Thompson, USDA Natural Resources Conservation Service
Dr. Allen Torrell, New Mexico State University
Mr. Dave Torrell, Rocky Mountain Elk Foundation
Mr. Tim Torma, US Environmental Protection Agency
Dr. Bill Travis, University of Colorado
Dr. Paul Tueller, University of Nevada, Reno
Dr. Bob Unnasch, The Nature Conservancy
Dr. Mark Vinson, Utah State University
Dr. Robert Washington-Allen, Texas A&M University
Mr. Bob Welling, Ridley Block Operations
Mr. Micah Wells, Oregon Cattlemen's Association
Dr. Neil West, Utah State University
Mr. David Wheeler, USDA Forest Service
Dr. Larry D. White, Texas A&M University (ret)
Ms. Jaime Whitlock, Colorado State University
Dr. Michael Wilson, USDA Forest Service
Ms. Liz With, USDA Natural Resources Conservation Service
Mr. P.J. Workman, Tribal Advisory Council
Mr. Tommy Wright, Department of Defense
Dr. JD Wulfhorst, University of Idaho
Mr. Ryan Yates, National Association of Conservation Districts
Mr. Bill Ypsilantis, USDI Bureau of Land Management
Mr. Rob Ziehr, USDA Natural Resources Conservation Service