Assessing Effects of Climate Change on Rangeland Ecosystem Goods and Services

Introduction

Rangelands constitute approximately 770 million acres in the U.S. and provide commodity, amenity, and spiritual values that are vital to the well-being of our Nation. The Sustainable Rangelands Roundtable (SRR) recognized a critical need to understand rangeland ecosystem goods and services, potential effects of climate change upon rangeland ecosystems, and the importance of standardized assessment to track changes and inform management responses to climate change.

Biological	Hydrological/Atmospheric	Miscellaneous
Domestic Livestock	Drinking Water	Views and Scenes
Other Food for Human Consumption	Water for Economic Benefit	Cultural and 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 (PM 10)	Ornamental Resources
Biochemicals	Contributes to Clean, Fresh Air	Ceremonial Resources
Genetic Material	Hydrologic Energy Potential	
	Solar Energy Potential Wind Energy Potential	

Some experts have proposed management schemes that they expect to be robust to potential climate scenarios, employing adaptive management to adjust and optimize in the face of changing environmental conditions. Key to such an approach is monitoring, so that managers may have necessary feedback to understand how the system is responding. SRR supports standardized ecosystem assessment to optimize natural resource management for the benefit of social and economic systems.

Despite the adage that agriculturalists have always lived with climate variability, the changes predicted for the next 30+ years present an exceptional challenge. Climate change is predicted to manifest in unique ways and there is still considerable uncertainty regarding rates of changes in temperature and precipitation responses in many regions . This uncertainty greatly complicates our ability to develop specific management practices to mitigate and adapt.

Since 2001, SRR, an open partnership involving rangeland scientists and managers, ecologists, sociologists, economists, policy and legal experts, environmental advocates, and industry supporters, representing nearly 50 organizations, has distilled a set of five criteria and 64 indicators embodying social, economic, and ecological factors for assessing sustainable rangeland management. Such an assessment approach also facilitates adaptive management techniques that incorporate change in response to ecosystem condition and available resources. The criteria are:

Criterion 1: Conservation & Maintenance of Soil & Water Resources on Rangelands
Criterion 2: Conservation & Maintenance of Plant & Animal Resources on Rangelands
Criterion 3: Maintenance of Productive Capacity on Rangelands
Criterion 4: Maintenance & Enhancement of Multiple Economic & Social Benefits for Current & Future Generations
Criterion 5: Legal, Institutional & Economic Framework for Rangeland Conservation & Sustainable Management

An important aim of SRR is to employ an integrated social, economic and ecological conceptual (ISEEC) framework to provide an integrated assessment of rangeland condition. The framework has been used in several illustrative examples related to wildland fire, drought, invasive species, and threatened and endangered species. Here we explore the utility of the ISEEC framework for evaluating the responses of diverse rangelands to climate change, an issue more complex than previous applications.

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Risk, Uncertainty and Vulnerability

Uncertainty with regard to climate change has been a topic of much inquiry, with researchers reporting on a wide range of variability regarding responses to climate change in the context of adaptation and mitigation. There is limited consensus about how to characterize uncertainty, or whether the answer is more scientific research or immediate policy action (Congressional Budget Office 2005). Broadening the conversation to include vulnerability, preparation, and adaptation should enhance our ability to deal with the challenges of a changing climate.

Regarding climate change, where probability and consequences are highly uncertain, it may be more useful to consider the vulnerability of rangeland systems to climate change. Understanding and reducing vulnerability relies less on prediction of unfamiliar phenomena, focusing more on what is reasonable; informed by history, general scientific insight, personal experience, and personal priorities (Sarewitz et al 2003). Emphasizing vulnerability management rather than risk management acknowledges the limits of quantitative prediction and presents a decision process that is flexible and reflexive to adapt to uncertainty and experience.

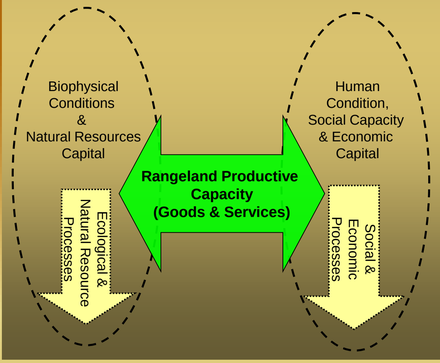
Management can reduce vulnerability of communities, regions, or activities, such as livestock production (IPCC 2001). While climate change is global in scale, these adaptive strategies are local or regional and must consider the ecological, social and economic drivers and responses of rangeland systems. There is always some degree of uncertainty in any natural resource management action. Here we present a framework and indicators that rangeland managers can use to prepare for, adapt to and reduce their vulnerability to climate change even in the face of uncertainty.

Interaction of Socio-Economic and Ecological Systems

The SRR Integrated Social, Economic and Ecological Concept (ISEEC) of ecological, social, and economic indicators connects through rangeland productive capacity. Goods and services are the bridge between the ecological and social/economic sides of SRR's conceptual model (see Tier 0 below).

Interactions occur as extractions of ecosystem goods (timber, forage, etc.) and their uses; tangible and intangible ecosystem services (including core ecosystem processes that purify air and water, generate soils and renew their fertility, detoxify and decompose wastes, among many others); waste discharges (one means by which humans can have deleterious effects on EGS), and alteration of land forms and water flows (including such mechanisms as urbanization, habitat fragmentation, degradation of wetlands, among others).

Ecological systems and processes provide the biological interactions' underlying ecosystem health. Social and economic situations provide context in which rangeland use and management occurs. Systems and processes interact and feedback over time and space. To adequately assess rangeland sustainability a synthesis of ecologic, economic, and social perspectives is needed.



Indicator Selection Considerations

Indicators establish an understanding of how humans and/or environmental systems operate and interact. This is brought out in the conceptual framework developed by members of the Sustainable Rangelands Roundtable.

Indicators, when applied objectively, can provide insight into ways in which human and biophysical sub-systems influence each other and respond to decisions and disturbance. However, the identification, measurement and implementation of appropriate indicators continues to be a significant challenge facing policy- and decision-makers (McCool & Stankey, 2004).

It has been suggested that the selection of ecological indicators to provide information about ecological integrity would be useful to resource managers (Karr, 1991; Dale & Beyeler., 2001). An ecologically ideal suite of indicators would represent pertinent information about ecosystem structure, function, and composition (Dale & Beyeler, 2001).

- Indicators must be easily measured
- Indicators must be sensitive to stresses on ecosystems
- Indicators must respond to stress in a predictable manner
- Indicators must be anticipatory, signifying impending change in the ecosystem
- Indicators must predict changes that can be averted by management
- Indicators must be integrative across ecosystem processes (e.g. soils, water, vegetation, etc.)
- Indicators must illustrate a known response to natural disturbances, anthropogenic stresses and change over time
- Indicators must have low variability

Table 1. Criteria for ecological indicators (Adapted from Dale & Beyeler, 2001)

The SRR provides a systematic approach to identifying processes of interest and associating appropriate indicators to assess identified processes. Use of the ISEEC framework informs indicator development/selection by elucidating responses to two questions:

(1) Are indicators available and defined that will appropriately represent biophysical/socio-economic processes identified as "pertinent" to understanding interactions?
(2) Of the available/identified indicators, which ones provide suitable information to decision-makers at multiple scales, both spatial and temporal?

Monitoring and Managing Rangelands in an Uncertain Climate

Climate change and rangeland disturbances affected by climate change are expected to have increasing impacts on rangeland ecosystems and rangeland-dependent communities throughout the 21st Century. These impacts will affect the ecosystem services that rangelands provide, including forage for wildlife and livestock production, fishing, hunting, and other forms of recreation, clean water and air, and aesthetically-pleasing landscapes. They will do so by directly varying temperature and precipitation patterns and indirectly affecting disturbances such as fire, insects, invasive species, erosion, and drought.

To a greater or lesser extent, ranchers depend upon multiple ecosystem services as sources of income and satisfaction that support their way of life. Consequently, to survive, they must be able to adapt. Adaptation most often takes place as a response to rangelands reacting to environmental changes; however, to be successful in a changing climate, adaptation may have to occur before ecosystem processes reach critical thresholds, much like preventive maintenance is performed on machinery. Two steps are required before any kind of anticipatory adaptation is possible:

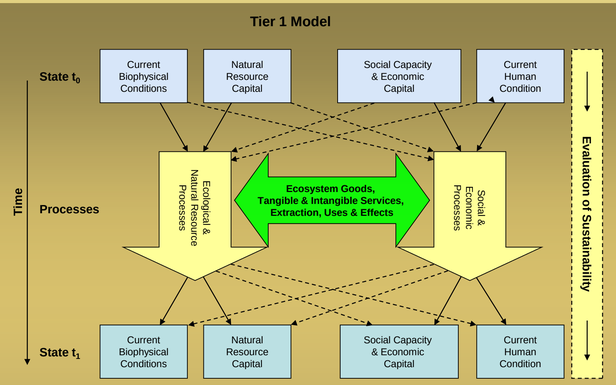
- Accurate monitoring and assessment is necessary, and
- Information must be shared

Regardless of how land managers and ranchers devise mechanisms for adapting to the uncertain future of changing climate, any individual or collective response must include monitoring and assessment of indicators that will provide the best chance of detecting changes in rangeland resources brought about by either climate or management. For example:

- Soil cover
- Erosion
- Water availability
- Abundance and vigor of key forage species (perhaps including phenological stages)
- Extent of invasive plants
- Mapping of prescribed burning and wildfires.

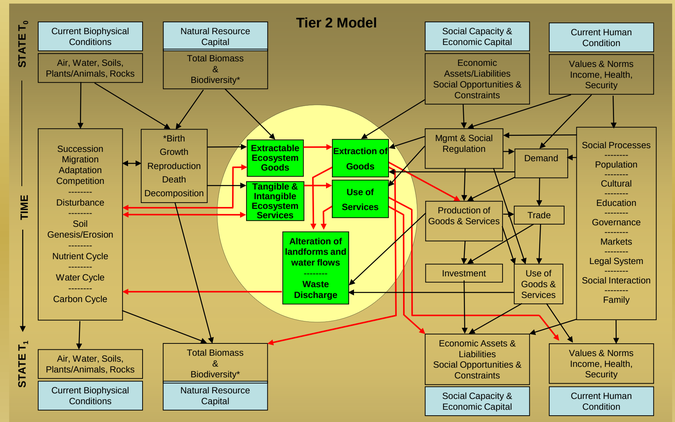
Ranchers should also monitor precipitation and temperature in order to help relate changes in the other indicators to climatic events and trends on their own lands.

Tier 1 Model



The SRR Integrated Social, Economic and Ecological Concept (ISEEC) for Sustainable Rangelands recognizes EGS as the bridge between the ecological and social/economic sides of SRR's conceptual model (Tier 1 is shown above). One response to uncertainty and risk in dealing with climate change is more and better information, contributing to stronger, informed decisions. The ISEEC framework clarifies linkages between system components and social, economic, and ecological states and processes. Thinking within such a framework can help managers identify and assess vulnerabilities. Tier 1 presents a simplified portrayal of the framework. The boxes labeled "Current Biophysical Conditions" and "Natural Resource Capital" represent the current state and condition of the biophysical ecosystem. The "Social Capacity & Economic Capital" and "Current Human Condition" boxes represent the state and condition of the socio-economic system and society. Ecological, social and economic processes act on the states and conditions in time period 1 resulting in the states and conditions present in time period 2.

Tier 2 Model



Tier 2 replaces the broad process arrows shown in Tier 1 with more specific examples of some ecological and socio-economic processes and institutions that might play a role in the interactions of changes and responses to climate change. In the center is a more detailed interface between the two realms, showing the EGS and their uses and how they feedback on ecological and socio-economic processes and institutions. Iterations over time portray the effect and response pattern that is played out as ecological conditions change (resulting from ecological states and conditions acted upon by ecological processes), as changes are perceived by people through changes in EGS and their functions evoking responses by land managers, policy makers, or society in general, as they strive to mitigate deleterious effects and try to shift or adapt human behavior in an attempt to "fix" the changed ecosystem. Those social and economic responses result in further changes in the functioning of EGS which feedback on core ecological processes resulting in changes in ecosystem state and condition.

Conclusions

Ranchers and rangeland managers should consider diversifying their business plans to provide for multiple sources of income and allow the demand for resources to be met by the supply during times of environmental or economic stress. There are a number of resources to help land managers and ranch operators with planning. They include state extension service agents, NRCS conservationists, private consultants, local bankers, nonprofit organizations, and state organizations such as the Wyoming Business Council, http://www.wyomingbusiness.org/.

Land managers and ranchers should make the maintenance of rangeland health and productive capacity a business goal, particularly at the landscape level. Management that reduces risk, both ecological and financial, will be key to any planning framework. Although little research has focused upon the synthesis of ecological and economic sustainability under a varying climate, some work indicates that an optimal stocking rate for economic returns may be less than a stocking rate that maximizes livestock production (Workman 1986). Ecosystems are more susceptible to droughts, invasive species outbreaks, wildfire, and other episodic events when they lack diversity and vitality. Subsequently, they can become more vulnerable to climatic shifts (Joyce et al. 2009).

Lastly, ranchers and all land managers can learn as much as possible about how their ecosystems may respond to climate change:

- Is precipitation expected to increase or decrease?
- Will their key species, being warm-season or cool-season plants, be expected to benefit or suffer from climate change?
- Are grasslands expected to give way to woody plant communities, and where is that most likely to happen?
- What about increasing risks from invasive species, insects and disease, and fire?

The last step in managing for rangeland ecosystem services is to incorporate all of the above information into a business plan that includes a framework for assessing ecosystem processes, goods and services produced, weather, and risks and vulnerabilities associated with climate change.

http://sustainable.rangelands.org