Rangelands and Global Change

An Issue Paper Created By the Society for Range Management

GLOBAL CHANGE is any change in the global environment that may alter the capacity of the Earth to sustain life. Included are changes in:

- LAND USE and PRODUCTIVITY,
- ATMOSPHERIC CHEMISTRY,
- CLIMATE,
- WATER RESOURCES and
- ECOLOGICAL SYSTEMS

Global change is a natural phenomenon that has been occurring since the beginning of time. We are concerned with changes that can be attributed primarily to the growth in human population (>6 billion in 1999) and their use of natural resources.

RANGELANDS are lands on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs or shrubs and is managed as a natural ecosystem. They include grasslands, savannas, shrublands, deserts, tundras, marshes and meadows. In the United States, over one-third of the land area (770 million acres) is classified as rangeland. Over half of rangelands are privately owned. In general, rangelands west of the Rocky

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Mountains are dominated by federal ownership. The lands east of the Rockies are predominately privately-owned. The significance of ownership is important in the development of the policies and programs of land management that must be crafted and implemented to minimize human impact on global change.

Rangelands provide our society with many products and services that support our standard of living and quality of life. These products can be visualized as ecosystem services.

ECOSYSTEM SERVICES

Ecosystem services include traditional notions of ecosystem goods such as food, forage, timber, pharmaceuticals and fuels. They also include processes vital to human life such as:

- purification of air and water
- flood and drought mitigation
- detoxification and decomposition of wastes
- biodiversity
- soil fertility
- pollination
- pest control
- nutrient cycling
- climate stabilization
- aesthetic beauty and intellectual stimulation

HOW IS GLOBAL CHANGE AFFECTING RANGELANDS?

CHANGES IN LAND USE AND PRODUCTIVITY

Humans use land to produce the products they need and want. This includes changing the land to fit their needs. In a 15 year period from 1982 to 1997, more than 12 million acres of privately held rangeland was shifted to other uses in the United States. During five years, 1992 to 1997, almost as much land was shifted into urban development (5.6 m ac) as was converted to cropland (6.9 m ac).

Rangelands and Global Change: Plant Invasions

Rangeland ecosystems are increasingly under threat from weeds, both exotic and native. The introduction of exotic species into rangelands has had significant consequences for the ability of rangelands to provide goods and services to human populations. There has been a dramatic increase in native shrubs in many rangeland ecosystems in North America. Shrub invasion may occur either as invasion of exotic (non-native) shrubs into native ecosystems or as the increase in native shrub density in ecosystems that they occupied previously, but at low densities.

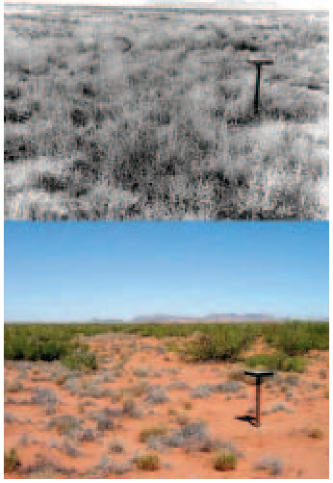
For most of the past century, the effects of shrub increase were thought mainly to be in terms of the reduction of forage for livestock. But as the pressure on rangeland ecosystems has increased for a wider variety of products, that view has changed. Increased shrub dominance changes the hydrologic cycle and the distribution of soil nutrients, releases greenhouse gases into the atmosphere and alters wildlife habitat. In semiarid environments, increased shrub density can change the frequency and intensity of wildfire. In desert ecosystems, increased shrub densities mean more bare soil exposed and increased susceptibility to wind erosion, creating a dust problem.

In the Chihuahuan Desert, the main form of shrub invasion is the increase in a native plant, mesquite *(Prosopis glandulosa)*, in what were formerly desert grasslands. There does not seem to be one single cause. Several factors have been identified:

- Overgrazing of native grasses by domestic livestock reduces their ability to compete with invading shrubs
- Changes in climate (particularly timing of rainfall) favor shrubs over grasses
- Increases in atmospheric CO_2 favor cool season shrubs over warm season grasses
- Domestic livestock are much more effective means of dispersal than native grazers
- Control of fire through grazing and firebreaks have reduced the frequency of burning — burning removes top-growth and grasses recover more quickly than shrubs

Increases in invasive species such as St. Johns wort, cheatgrass, knapweed, yellow starthistle and salt cedar can dramatically reduce the productivity of rangeland by garnering more of the limited resources like water, nutrients and sunlight. Native shrubs such as mesquite and one-seeded juniper have increased and dramatically altered the productive potential of other rangelands.

The changes in land use and productivity frequently represents irreversible change in ecosystem function on human time scales.



The picture on the top is a view of a Chihuahuan desert grassland in southern New Mexico in 1961. The picture on the bottom is the same view in 2002. Livestock had been excluded from the site in the 1950s, but processes resulting in the replacement of grasses with shrubs continued *(Photos – Jornada Experimental Range)*.

CHANGES IN ATMOSPHERIC CHEMISTRY

Human activity has dramatically altered the composition of the atmospheric layer surrounding Earth. The use of fossil fuels and land clearing has increased the level of carbon dioxide (~270 ppm in 1850 vs ~370 ppm currently) in the atmosphere. Methane has increased from 750 to 1700 ppb over the same period due to increases in ruminant livestock, burning natural gas and emissions from landfills. Nitrous oxide, a byproduct of synthetic plastics and fertilizer manufacture and use, has increased from 275 to 312 ppb. All of the gases are known as greenhouse gases because they increase the capacity of the atmosphere to hold heat and amplify the greenhouse effect. The evidence for global climate change in atmospheric chemistry is increasingly strong.

While the vast majority of attention to changes in atmospheric chemistry has been on how greenhouse gases affect climate, there is a more subtle and potentially greater impact on nutrient cycling and effects on soil

Cheatgrass *(Bromus tectorum)* is an exotic annual grass that is increasing rapidly on Great Basin Rangelands. The replacement of sagebrush shrubs with this invasive grass is dramatically changing how water and nutrients are processed *(Photo-Bureau of Land Management)*.

vegetation relationships that regulate ecosystem processes. For instance, increased atmospheric CO_2 has been hypothesized to favor plants with the C_3 photosynthetic pathway over plants that possess the C_4 photosynthetic pathway. The C_3 plants usually do well in cooler conditions. Most invasive plants possess that pathway. Increased atmospheric nitrogen can also act as a fertilizer, the additions of which generally favor annual plants and plants that can adapt to changing conditions quickly.

CHANGES IN THE GLOBAL CLIMATE

The evidence for human-induced climate change at the global level increases every day, yet it remains difficult to credibly predict how climate change will play out for any particular area. However, by examining how rangelands in various regions have responded to climatic events of the past, it is possible to develop a reasonably accurate picture of how different scenarios may play out in the future. In general, it is safe to assume that climatic variability will increase in the future. That is, the frequency and severity of extreme events (droughts, floods, etc.) are likely to increase. It is during those types of extreme events that rangeland degradation is more likely to occur. Thus, it is prudent to assume that increased climatic variability will increase the risk that most rangelands will be affected by conditions that lead to degradation. Decades of research have shown that rangelands can sustainably produce a variety of goods and services even in the face of extreme climatic events, if managers respond quickly and appropriately to changes. However, much of the rangeland degradation observed today can be attributed to a lack of

- Eradication of small grazers such as prairie dogs has allowed shrubs to escape foraging

It is likely that these factors have interacted and the most important ones vary as location and management history change. Research in New Mexico, Nevada, Texas and other locations tries to determine what is causing the invasions. However, just understanding what caused an invasion in the past is certainly no guarantee that the future will be a repeat of the past. The very nature of global change ensures that drivers of change in the future will likely be different than those in the past. A more reasonable approach is to conduct critical experiments to identify important indicators of change, monitor and take rapid action when indicated.

Rangelands and Global Change: Biogeochemical Cycles

One aspect of global change that is well underway is the alteration of biogeochemical cycles. Synthesis of NH_3 from atmospheric N_2 for fertilizer (Haber-Bosch process), formation of oxides of nitrogen via fossil fuel combustion, and increased use of nitrogen fixing crops such as alfalfa has promulgated an increase, relative to pre-industrial time, in nitrogen deposition over the surface of the Earth. Nitrogen deposition on terrestrial ecosystems of the world has approximately doubled in the last 100 years and the rate of increase is accelerating. Nitrogen deposition rates are highest in northern hemisphere temperate ecosystems where rates may exceed, by a factor of 10 or more, that which occurred in pre-industrial time.

Laboratory, glasshouse and field research suggests potential major impacts to rangeland ecosystems. Research at the USDA Agriculture Research Exotic and Invasive Weed Research Unit in Reno, Nevada has studied the effect of inorganic nitrogen addition and nitrogen immobilization on plant dynamics in Great Basin rangelands. Long-term addition of inorganic nitrogen encourages cheatgrass *(Bromus tectorum)* to invade, especially in shrub interspaces. On plots where nitrogen input was controlled, there was virtually no cheatgrass increase. Cheatgrass is an exotic invasive grass that has major impacts on intermountain ecosystems. It can be virtually eliminated by repeated additions of sucrose. Sucrose fuels the growth of soil micro-organisms which then sequesters inorganic nitrogen in biological tissue. Under these conditions the native bunchgrass, Indian ricegrass *(Achnatherum hymenoides)* flourishes. Although illustrative of the role of inorganic nitrogen in invasive species dynamics, the process is impractical because once sucrose addition ceases, nitrogen availability increases through mineralization. Although such processes on rangelands can be altered by manipulating N availability, it is not clear if future atmospheric deposition rates far from industrialized regions will attain deposition rates necessary to elicit similar responses.

The manufacture of N fertilizer will likely increase because it is a relatively inexpensive input that increases production and decreases risk in cropland agriculture. Management of rangelands in an environment of altered biogeochemical cycles must be adaptive and creative to cope with these dramatic changes.

Rangelands and Global Change: Climate Change

To a very large extent, climate is responsible for vegetation. The amount and distribution of precipitation are fundamental "drivers" of rangeland vegetation. As such, impending changes in climate, particularly changes in the precipitation and temperature regimes, are likely to propel changes in vegetation. In short, the structure of rangeland vegetation depends on precipitation, and regional precipitation regimes are undergoing rapid changes as a result of anthropogenic activities.

The response of rangeland vegetation to impending changes in the precipitation regime is likely to be complex and difficult to predict from existing knowledge. Plant response is likely to be highly species-specific, which suggests that current plant communities will not simply move to new landscape positions, but will be replaced by novel plant assemblages. Predicting the "winners" and "losers" in the face of climate change will require innovative experiments. This research will be fundamentally different from past research efforts on rangelands in terms of the types of questions posed and the magnitude of the task.

Field experiments that focus on likely scenarios of climate change will enable managers to predict shifts in species composition and productivity before the

flexibility in adapting management practices or reducing expectations during extraordinary weather and climate conditions.

Changes in dominant plant species in Emory Oak woodlands in Arizona can be attributed to a shift in season of precipitation, an expected result of climate change *(Photo-University of Arizona).*

CHANGES IN WATER RESOURCES

Fresh water supply and demand has changed dramatically as human populations and technologies have changed. The appropriation of surface and subsurface water, particularly for irrigation and industrial purposes, has changed surface flows, altered hydrology and modified landscapes around the world. Currently humans utilize more than 50% of the planet's freshwater resources each year and that is projected to grow to 75% by 2025.

Because of the extensive land area, a significant portion of the world's freshwater supply either falls on rangelands or is processed through rangelands. How rangeland soils and vegetation are managed can have significant short- and long-term effects on the quality and quantity of water. The majority of rangelands are in arid or semi-arid regions and human activities can have a major impact on the water cycle.

HOW CAN RANGELAND MANAGEMENT RESPOND TO GLOBAL CHANGE?

There are two forms of response to global change: mitigation and adaptation. Mitigation are those actions that humans can take to reduce the amount of global change that occurs. Adaptation refers to actions taken to reduce the impact of any change that does occur.

Mitigating global change – Perhaps the most important mitigating action is to reduce the amount of greenhouse gases released as a result of activities that occur on rangelands. For instance, managing livestock for

Improving riparian conditions can increase water quality. In this California Coast Range grassland, riparian conditions are improved by controlling livestock access (*Photo-UC Davis*).

enhanced efficiency and performance can reduce the amount of methane released as a result of enteric fermentation. Methane from grazing livestock represents about 20% of the total U.S. emissions.

Rangeland soils and vegetation are large stores of soil carbon and can be managed to enhance that uptake. In the United States alone it has been estimated that grazinglands can sequester between 29 and 80 m tons of carbon per year, or between 2% and 5% of total U.S. emissions.

Rangelands can also be a source of a substantial amount of biomass for fuel. Many woody plants and some herbaceous species can be harvested and used to generate power, substituting for fossil fuels and reducing the amount of greenhouse gases released into the atmosphere. However, the temptation to over-harvest biomass for fuels will be just as real as the temptation to overgraze has been for the past centuries. Clear guidelines are required on how specific soil/vegetation combinations will respond to woody plant management. Policies need to be developed so that rangelands can be used to help meet national and regional energy needs and still have the ability to sequester carbon in the soil profile.

Adapting to Global Change – The key to managing rangelands successfully in a changing global environment is maintaining and enhancing ecosystem resilience. Resilience is that property of an ecosystem that defines how well it can recover after disturbance or stress has been imposed.

First, rangelands must be managed at the landscape and ecosystem level as well as the individual ranch or allotment level. Many of the impacts of global change will be expressed unevenly across the landscape, but will be the result of processes and changes that accumulate over long time

occurrence of dramatic changes in climate. Experiments should (1) focus on environmental conditions predicted by large-scale modeling approaches, (2) incorporate realistic management strategies, and (3) be conducted at spatial and temporal scales relevant to management. Further, experiments should be conducted across the spectrum of rangeland ecosystems.

One such field experiment manipulated the precipitation regime in the southwestern United States. Contrary to the expected response, summer precipitation controlled recruitment and subsequent abundance and distribution of the dominant woody plant in this system, Emory Oak (*Quercus emoryi*). Winter precipitation had little impact on woody plant recruitment, but did influence grass productivity.

Rangelands and Global Change: Freshwater Resources

A significant portion of the United States' and the world's surface drinking water supplies are derived from watersheds containing grazed rangelands. There is growing concern among public health officials about potential risk to human health via contamination of drinking water sources by fecal borne pathogens from range livestock. Of particular concern is *Cryptosporidium parvum*, a pathogen known to be carried by and transferable between humans, cattle and wildlife. The gastrointestinal illness, cryptosporidiosis, caused by ingestion of *C. parvum* oocysts can be fatal to persons with compromised immune systems.

If rangeland livestock serve to magnify natural levels of *C. parvum* in the environment, is a global change in rangeland microbiological communities occurring? Do rangeland livestock provide a vector to facilitate transport of oocysts into surface drinking water supplies, serving as an agent of global water quality change? If so, can we identify management measures which mitigate these processes, reducing risk to human health while maintaining the benefits of range livestock production on watersheds?

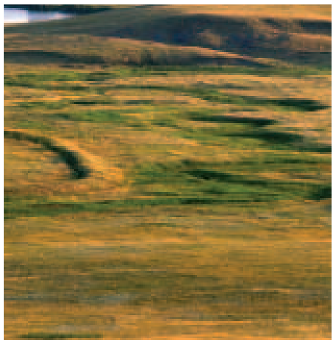
Across the world, a significant amount of research is currently taking place to address these questions. Collectively, we know that the level of *C. parvum* infection in rangeland cattle, and thus risk to water quality, varies by age with the highest infection rates in calves age 1 to 4 months. We know that for bovine-derived *C. parvum* to be a waterborne health risk, the infectious stage of the parasite (oocysts) must reach source water via direct deposition in water or via hydrologic transport from upland and riparian areas. We know that environmental conditions on rangeland, such as heating, freezing or drying, can rapidly inactivate large numbers of oocysts. Applying this knowledge in a systems analysis approach, managers can design grazing and livestock management schemes to reduce the risk of water contamination on a watershed basis. Continuing research will only increase our understanding of the linkages between range livestock, pathogens, water quality and human health, thus improving our ability to mitigate possible human health risks.

periods and over large scales. Making and implementing decisions on rangelands at watershed, landscape and regional scales will be a key factor in determining whether rangelands suffer from global change.

Second, rangelands must be managed to avoid catastrophic changes. History has shown that, for the most part, arid and semi-arid rangelands do not exhibit equilibrium dynamics. That is, they do not have a single condition to which they recover after disturbance. Many, if not all, of the rangelands in the western U.S. exhibit nonequilibrium dynamics and degradation has to be assumed to be permanent, at least on a human time scale.

The number one challenge in managing arid and semi-arid rangelands is to avoid degradation. This requires that planning, decision making and implementation focus on rapid management responses to relatively subtle changes in the environment. Monitoring systems are currently inadequate to identify these ‘thresholds’ as triggers for rapid, decisive actions. Ranch/allotment level monitoring systems that focus on soil/vegetation relationships are incapable of detecting change in time for responses. Monitoring systems must be more interactive with management and focus on detecting the need for action in response to climatic x disturbance combinations before they are expressed as changes in the soil and vegetation.

Regional and national level monitoring systems that sample on an infrequent basis are also incapable of detecting changes in a time frame that allows meaningful management responses, whether the global change issue is change in land use, loss of productivity or alterations to hydrologic function. National monitoring systems should be continuous and focus on detecting pre-defined large-scale indicators of undesirable change and should be linked to policy and program decisions that are triggered by trends in the monitoring data.



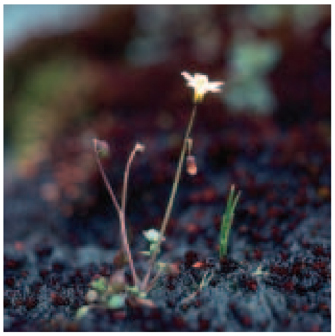
Current rangeland enterprises are poorly suited to counteract the environmental fluctuations that are likely to mark global change in the future. The need to maintain economic performance at the enterprise level too often drives degrading processes during extreme climatic events even though they were appropriate in 'good years'. While overgrazing is merely the most readily visible example of this, any enterprise that extracts a good or service from rangelands can be degrading if it does not reduce pressure on the resource in periods of unusual climatic events. By the same token, opportunities for rangeland improvement are often bypassed because of a lack of economic capacity to marshal resources during periods of favorable environmental conditions. There is a need at a national level to identify rangelands where variable climate and inherent low productivity interact to make the risk of high impact economic enterprises unacceptable.

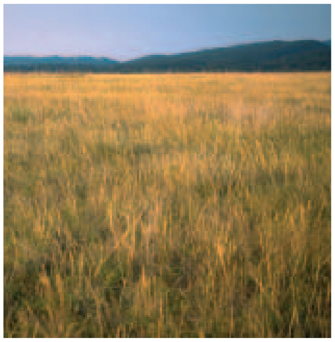
RECOMMENDATIONS

Managing rangelands in the face of global change requires a shift in focus toward the restoration and enhancement of ecosystem resilience.

Evaluating rangeland ecosystem resilience generally involves defining the capability of an ecosystem or community to withstand stress and/or disturbance and recover to its original condition. Some rangelands are quite resilient if current disturbances and stresses mimic those in their evolutionary history. However, different types of disturbances interact differently as soils, vegetation and climate change. It will be impossible to assess the impact of global change on rangeland ecosystems without high quality, consistent, accessible soils and vegetation data and models that describe how changes occur in response to stress and disturbance. The development, validation and implementation of a spatially explicit national soil/vegetation database that describes how climatic change interacts with soils, vegetation and management should be the highest priority for professional rangeland managers and the Society for Range Management.

Management flexibility should be a goal at all levels from individual ranch/allotment to multi-agency. The ability to detect changes and respond quickly offers the most promise for managing rangelands successfully in the face of global change. Decision-making and implementation at all levels should focus on developing a system that identifies the effects of global change in the very early stages and implementing management responses. The Society for Range Management should develop and offer education and training programs for members and nonmembers that communicate what global change is, what it means for rangelands and how responses can be implemented.





Responding to global change will require new concepts of what constitutes spatial units of rangeland management. While individual ranches or allotments remain valid and important levels for setting goals and objectives, public resources must be allocated to achieve goals and objectives at larger scales if the impacts of global change are to be minimized and opportunities for rangelands to improve their service to humans realized. Many of the important products and services that humans extract from rangeland ecosystems are linked to attributes at the watershed and regional scales. Fragmentation of rangeland habitats by changes in land use and management are a threat to many species and ecological processes. Rangeland scientists and managers should collaborate to develop monitoring systems that track and predict how changes in land use and cover affect ecosystem function across spatial scales on rangelands.

Rangelands have been viewed by the public and many professionals in terms of their ability to supply forage for livestock. There should be an increased research and development emphasis on managing rangelands to produce sustainable alternative products and ecosystem services. Sustainability in the face of global change will require quantitative knowledge of ecological thresholds, indicators of change and key decision points in the framework of comprehensive monitoring systems.

Forward-thinking, manipulative field research provides a solid foundation for making predictions about the response of ecosystems to global change within the context of contemporary management. Managers and resource management agencies can support the conduct of field experiments and the development of ecological forecasts in several ways: they can provide advice about relevant management strategies and manipulations, furnish land and infrastructure for field experiments, advocate allocation of funding for relevant research and strive to learn more about global change and rangeland ecosystems. Strong links between researchers and managers will improve science, management and rangeland ecosystems.

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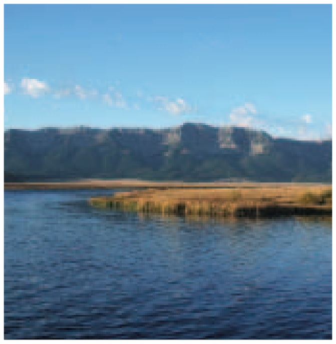

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The Society for Range Management (SRM) is a professional and scientific organization whose members are concerned with studying, conserving, managing and sustaining the varied resources of rangelands. We invite you to contact us at:

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