A New Approach to Monitoring Rangelands

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Rangelands are among the most important agricultural ecosystems in the United States and the world. The rangelands of the western United States are fundamental to the rural economy. In order to maintain the quality of these rangelands, they must be monitored over time and space. The ecological condition of rangelands is a major factor in their environmental quality, in their overall performance as watersheds, and in wildlife and livestock production. The monitoring system must be science-based and take into account topography, climate, soils, plant communities, and animal populations that go to make up the western range. An information storage, processing, interpretation, and retrieval system must be included if the monitoring data are to be assessed in a timely manner. This report outlines a research program for the development of a new approach to monitoring rangelands. It includes the principle variables (climate, soils, plants, and grazing animals) involved in determining rangeland condition and trend as an indication of rangeland health.

Keywords climate, soils, plants, livestock grazing, rangelands, monitor, forage, watershed, ranch, wildlife, watershed, sustainable

Rangelands are grasslands, shrublands, and open woodlands managed as natural ecosystems that are traditionally used by grazing animals. These lands occupy about 40% of the land area of the United States. They include Great Plains grasslands, savannas of Texas and Florida, shrublands of the Great Basin, Arctic tundra in Alaska, alpine meadows, wetlands, and southwestern deserts.

Rangelands comprise 80% of the land area in the 17 Western states where more than one million people derive some portion of their income from grazing activities on more than 400,000 farms and ranches with revenues exceeding $13 billion. These rangelands provide multiple uses for society, including wildlife habitat for a variety of game and nongame animals, high quality water, clean air and open spaces for

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industries, municipalities, agricultural uses, recreational activities (hunting, fishing, hiking, etc.), and the foundation for low impact, renewable food and fiber production systems through the livestock grazing industry. The diversity of goods and services derived from rangelands ties them closely to the economic well-being of the communities in which they are located.

The rangelands of the 17 Western states are located west of the Missouri River or about the 100th meridian W (Figure 1). This land is predominantly arid or semiarid and generally referred to as desert. Deserts have chronic droughts but are interspersed with periods of adequate to excessive rainfall. Droughts are often referred to as disasters, however, they are an integral part of the desert ecology. Droughts are cyclic in nature because the climate is highly variable over time.

Beginning from the eastern end of this region, the elevation increases from sea level to 1500 m (5000 ft) in the driest grasslands of the Great Plains, to mountain valleys of up to 2000 m (7000 ft), and to mountain peaks up to 3700 m (12,000 ft). States west to the Pacific Coast provide a great variety in landscapes, soils, plants, grazing animals, and climates.

The livestock producing community is one of the primary users of Western rangelands. The value and quality of a ranching operation and its economic well-being are directly related to the quality and quantity of the forage produced on these rangelands. Management strategies that enhance and promote rangeland sustainability and well-being are essential. Wildlife interests must be involved in the evaluation of sustainability.

If the nation’s options are to be maintained, the capacity of these lands for self-renewal must be monitored. There are currently no generally accepted methods for summarizing the health of rangelands under all ownerships. Due to the consensus of various interest groups and governmental agencies, livestock production operations are being held to varying and arbitrary standards of environmental stewardship.

FIGURE 1 Research sites representing principal ecosystems of rangeland throughout the western United States. One range scientist would be assigned to two or more sites. Other scientists would be centrally located. All scientists would work on the same research outline. Sites indicated are examples only.
Uniform standards for assessing the health of rangelands do not exist. Ranchers are being held accountable without the means of accounting for the environmental consequences of their actions. A scientifically-based system for monitoring rangeland condition and trend as an indication of rangeland health, a system using a uniform set of standards and procedures to be carried out in a consistent and verifiable manner, is critical for the development of sustainable policies for the management of rangelands for all users. The development of a set of standards that expresses condition and trend over time and space is essential for proper communication between users, administrators, and other interested parties.

Our goal is to develop a research program for the development of an accurate, repeatable, and practical monitoring system for individual ranchers and public land managers to document changes in climate, soils, plants, and grazing animals, and occasional events such as floods, fires, and invasive weeds and insects. The question we seek to answer is: what is the condition and what are the trends in condition of rangeland on a given ranch and/or public grazing allotment? The data collected are vital to: (1) designing management alternatives and evaluating the impacts on the environmental and economic efficacy on rangeland livestock production operations and concurrent wildlife habitats, water, riparian systems, and so forth; (2) provide science-based and practical technology to assess and report the rangeland conditions used in the livestock production operations; and (3) provide a basis on which to develop plans for management that will enhance and ensure sustainability of the rangelands. This will provide a scientific base on which to evaluate rangelands for all uses.

A cattle producer from North Dakota said rangeland monitoring is the Achilles heel of the range livestock industry. A sheep producer from Utah suggested that the survival of the sheep industry depends on the development of a scientifically-based monitoring system. A scientist from Nevada indicated that the survival of the range livestock industry depended on the development and implementation of a scientifically-based rangeland monitoring system (personal communications).

What is Monitoring?

Monitoring, by definition, means: observing, detecting, or recording the operation of a system; watching closely for purposes of control; surveilling; keeping track of; checking continually; detecting change. Monitoring implies change, and change implies time. Monitoring then means measuring those things that change in a system over time and space. Rangeland monitoring would be measuring the major changes, condition and trend, over time and space of the principal parameters affecting rangeland health. Such monitoring also indicates measurements that must be taken, for example, precipitation in mm, temperature in degrees, soil organic matter in mg kg\(^{-1}\) soil, kg (or lbs) grass per animal, and numbers of grazing animals. This kind of information permits the determination of variation, interrelationships, correlations, and so on, within and between various sites and among the principle rangeland variables. This approach changes rangeland monitoring from an art to a science. Once in a scientific arena, the opportunity to develop parameters to express condition and trend using a single set of standards arises.

Principle Parameters or Variables that Need to Be Measured

To Determine Rangeland Health

The purpose of this report is to describe a scientific-based research outline for the development of a new approach to monitoring rangeland.
Representative ranchers, in collaboration with the U.S. Department of Agriculture, Agricultural Research Service, and university scientists, have identified four categories of information which include climate, soil, plants, and grazing animals that are important in determining rangeland condition and trend. This group has also identified methods that are currently available for collecting, analyzing, and summarizing this information (Table 1). Other new but unproven methods were also identified as being possibly easier, more repeatable, and more economical. Thus, this program will include a research program to test existing as well as promising new technologies at the same site and under the same conditions and build crosswalks to the currently used protocols. A system for collecting, storing, analyzing, processing, and interpreting the data collected will be developed.

As previously stated, the four principle parameters (variables) to be monitored to determine condition and trend and as an indication of rangeland health include climate, soils, plants, and grazing animals.

1. **Climate.** Rain, snow (effective moisture), temperature, wind, barometric pressure, lightning—climate is variable over time and space. It is measurable but not manageable. However, the conditions favoring uptake and storage of water by soil can be managed. It is essential to understand climate interaction with the other parameters measured. Knowledge of these interactions promotes a greater understanding of the other parameters and the role they play in a healthy range environment. Understanding climate is key to a good monitoring program. To understand climate at the local level, landscape, or ecological site, it must be understood over time and space, for example, the entire West. Monitoring climate holds promise in the development of management strategies and approaches to take much of the risk out of grazing during periods of drought. It can be measured independently of the other variables, but it cannot be understood independently from these parameters.

2. **Soils.** Soils vary spatially but are fixed in place unless erosion occurs. Soils are not static but can change when affected by things such as plants and fire. Soils have been equated to a living entity because of the organisms which are associated with soil health. Therefore soils should be monitored to ensure favoring those things required for a vigorous soil environment. Soils should be managed to maintain their integrity and character in order to prevent erosion, enhance moisture absorption and water holding capacity, and, through proper grazing and fire control, enhance their organic base. Soil functions in the plant’s reproduction process by storing seed and serving as the womb (Mother Earth) wherein germination and early growth of the plant occurs. It is difficult to discuss plants without considering the role of soil in plant reproduction, and in nutrition for plants and animals. Soil is the source of nutrients for the growing plant, and these nutrients can be optimized by maintaining optimum plant cover and litter based on the potential for a site. The soils must be actively monitored and managed in conjunction with the other parameters.

3. **Plants.** Plants and plant communities vary over time and space depending on climate, elevation, soils, geographical location, and use. Plant communities are not static but dynamic, that is, they change over time. The rate of change is probably due to the nature of the factors causing change (climate, fire, insects, etc.). This being the case, then would not the cause and the nature of the change be more important than the composition of the community at a point in time in developing management plans that will ensure a sustainable and healthy rangeland? Plants supply food and cover for all grazing and browsing animals, including birds. At a minimum, plants must be allowed to produce enough growth each season for reproduction and regrowth. Any excess provides forage for grazing animals. Plants and animals live together in a synergistic environment. If plant material isn’t properly grazed, it can become fuel for fire, burn, damage soils, and permit
<table>
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<td>Pasture journal</td>
<td>Geographic Information Systems (GIS), digital cameras with GPS</td>
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<td>Rare events: fire, insects, drought, flood, hail, frost</td>
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<td>Other uses: off-road vehicles, mountain bikes, camping, hiking, hunting, fishing</td>
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<td>Infrastructure: roads, trails, fences, corrals, salt or mineral licks</td>
<td>Pasture journal</td>
<td>Imagery and digital documentation in combination with GIS</td>
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**Table 1** Minimum Potential Set of Indicators that Can be Used to Determine Current Conditions and Trends of Rangeland Ecosystems with Both Current Methodology and Promising New Techniques.
erosion. Plants supply required nutrients for grazing animals. The most important function of plants, however, is protection of the soils as already indicated.

4. **Grazing Animals.** Livestock, wildlife, wild or free-roaming horses, and upland game rely on the interaction of the previously mentioned variables for the production of forage (food) and cover. In considering the forage requirements of livestock, their size, condition, and function must be considered. Management of animals in time and space to maintain rangeland health is of the greatest importance. This requires an understanding of the interrelationship and interactions of all four parameters. Grazing animals provide an economic and feasible way of controlling fire fuel loads, which is necessary in the prevention, control, and management of wildfires and the use of controlled burns. They also function in the cycling of nutrients. Plants provide organic material for the soil; animals play a major role in transport and moving the seeds into the soil. Animals put carbon dioxide and water into the air and take out oxygen. Plants take in CO₂ and give off oxygen. Thus, there exists a synergistic relationship. The four variables listed above function as an integrated, synergistic system. This being the case, monitoring requires a systems approach. This does not mean to imply that monitoring needs to be a complex operation. It implies that we must monitor systems as they normally function, including all the variables, which gives you information and sets boundaries for development of management objectives.

**Strategic Approach to the Development of a Rangeland Monitoring System**

The U.S. Government, the National Cattlemen’s Beef Association, the American Sheep Industry, and others have expressed a need for the development of a scientifically-based monitoring system for rangelands of the United States, a system that establishes conditions and trends over time and space as an index of rangeland health and sustainability. Such a system would establish a uniform set of standards that expressed conditions and trends, standards by which monitoring can be carried out in a consistent and predictable manner. Such a system must take into account the variation across the rangelands (space) in soils, geographical location, plants, and animals and must account for variation in climate over time. This can be accomplished by establishing research sites at strategic locations (space) that would be representative of major ecosystems throughout the rangeland areas of the nation (Figure 1). Variation in climate can be accounted for by monitoring at these strategic locations over time. Due to the dynamic nature of the four variables, data collection should extend over an annual time series of data. For definitive conclusions, it should span at least one drought cycle, and preferably two, including an above average precipitation sequence.

Various methodologies, currently used in rangeland monitoring and newly developed techniques, can be compared at each research site at the same place and time, and on the same soils. Within site and between sites comparisons would allow a relatively unbiased evaluation of economic factors such as efficacy, simplicity, and cost of the methodologies. Commonality of various features of the methods among sites can also be determined in the search for appropriate methods and standards in the monitoring process. A system for the validation of monitoring rangeland data collected will be developed to ensure the integrity of the data. At present there is considerable room to tweak the data and there is no system for the validation of data collected on rangeland conditions and trends to denote rangeland health.

**Staffing Plan**

One outline will be prepared from which all scientists involved will conduct research. This will support the effort to develop a single vocabulary (definitions) and set of
standards to express condition and trend, and to help in the development of a uniform approach to rangeland monitoring.

The variables that have been identified as essential to a rangeland monitoring system dictate the staff and responsibilities required to do the research to develop a scientifically-based monitoring system. The number with each staff description (except the research leader) is relative; the exact number will need to be determined by budget or need or both. However, the numbers cited would form a functional group. The following staff would be required to accomplish this task.

**Research Leader (one).** Provides leadership; ensures coordination of research among staff scientists; ensures that all scientists follow research protocols; establishes and coordinates research involving university scientists as needed; ensures that data is properly collected by staff scientists and is coordinated, processed, interpreted, and stored for future use.

**Data Processing Specialist (one).** Oversees the collection of all data collected on the four variables at all sites; develops correlation and probabilities that deal with intra- and intersite variations; develops methodology for processing, analyzing, and storing data; develops interaction correlation between variables and sites; cooperates with other scientists on the analysis and interpretation of data; cooperates with scientists in developing parameters to express condition and trend as an indication of rangeland health; develops a data processing system that eventually can be converted to a central data processing center that could process data for a group of ranchers or other users. Cooperates with entire staff to develop a set of standards that will express condition and trend as an expression of rangeland health.

**Climatologist (one).** Oversees the collection of climate data from all sites; correlates interactions and impacts of climate over time and space on the other variables; cooperates with other scientists in developing management strategies; cooperates in the development and testing of existing and new methodologies and parameters to express condition and trend as an index to rangeland health. Helps provide a vision and relationship of climate and other variables, the first dimension of a four-dimensional view of the rangeland.

**Soil Scientist (one).** Evaluates and classifies soils at the different sites; describes the interrelationship between soils and the other variables over time and space; develops a protocol for monitoring rangeland soils; defines parameters that express soil health; develops management strategies for the enhancement and sustainability of rangeland soils. Evaluation of soils is the second dimension of a four-dimensional view of a rangeland ecosystem.

**Remote Sensing Specialist (one).** Conducts and correlates remote sensing studies of all sites; correlates remote sensing with ground truthing and with other variables being measured; participates in the development of management strategies that will enhance rangeland health; provides a landscape or spatial view of the rangelands which will help describe the nature and scope of plant communities. Remote sensing is the third dimension of a four-dimensional view of a rangeland ecosystem, providing another view of the rangeland.

**Wildlife Scientist (one).** Helps develop a monitoring program for all sites; develops and incorporates methods and procedures to monitor wildlife numbers, migrations, habitat, and other factors involving the well-being of wildlife with particular attention to those species that are already compromised; correlates wildlife health and well-being with factors such as climate, habitat, and so on; cooperates with other scientists in testing of existing methods and development of new techniques for monitoring rangeland health and developing parameters to express the condition and trend as an indication of rangeland health; describes interactions and correlations between wildlife and domestic grazing animals.
Range Scientists (eight). Each conducts on-the-ground research at one or more research sites to compare, evaluate, and enhance existing monitoring methodology; cooperates in the development of new monitoring methodologies; assists and supports the correlation of data collected on the four variables both within each site and among the sites; correlates livestock grazing program with resource availability and grazing impact on vegetation; conducts research for the development of management strategies to support proper use and management of the rangelands; conducts ground truthing to complement the remote sensing research; cooperates in developing a set of standards that will express condition and trend of rangeland health. This is the fourth dimension of the four-dimensional view of rangeland ecosystems.

Standards

A uniform set of standards is needed if effective communication regarding condition and trend as an indication of rangeland health is to take place. Many do not believe a common set of core standards can be developed. For the sake of better communication, however, it is worth the effort. Good science and technology can and will prevail. The method being proposed emphasizes that the resource (range) comes first. If this doesn’t happen and the use comes first, we lose both resource and use, and a lose-lose situation results. If the resource comes first, all uses can be accommodated; and a win-win situation results.

Monitoring is not unique to rangeland health. For example, farmers monitor irrigation water, herbicide and fertilizer applications, crop yields, and so on, to make management decisions that ensure good production. Manufacturers monitor products to certain tolerances to ensure quality. Medical doctors monitor patients with cardiac disease, cancer, diabetes, and other diseases for condition and trend which may call for a change in health care; they may be required to communicate with other doctors around the world in spite of differences in languages and cultures. Zoo veterinarians use many of the same methods to measure the health of all animals and to communicate with other veterinarians regarding treatment of various diseases.

Monitoring animal health and highly controlled production systems may be compared with monitoring plants. Genetics, first studied in plants, were later found to be essentially the same as genetics in animals. Reproduction in plants is similar to reproduction in animals. In the plant, fertilization takes place within the body; in the plant, it occurs in the flower. The new animal develops within the body of the mother; the new plant in the soil (womb) under the plant. The Krebs cycle was discovered using plants, but it is the same in animals. DNA resides in plants as in animals. The nutrient requirement of a plant is not much different from that of an animal’s. The statement has been made, Is it not possible that the methods used to monitor illness (condition and trend) in animals could serve as models to develop standards and methods to monitor condition and trend in rangelands? They are all part of the same system.

Bridging Old to New

As earlier stated, all monitoring methods, old and new, will be evaluated and compared on the same site, at the same time, over time, and on similar soils and moisture. Duplicate trials will be run on each approach or method. They will be evaluated and compared for, among other things, efficacy, cost, and simplicity. If the old and new are tested side by side, conversion factors can be developed to change from old to new. In this way, old data will not be lost but will be incorporated into the new.
Criteria for Conducting Research to Develop a Unified Monitoring System

As has been pointed out, the four principal variables—climate, soils, plants, and grazing animals—can be highly variable over both time and space. In order to sample these parameters in a scientific way, they must be sampled over the entire space involved. Therefore, the agency doing the research should not be hampered by state or regional political boundaries. Due to the variability of the climate, sampling needs to be done over an extensive period of time. Therefore, the agency doing the research must be budgeted to do long-term research. The research being conducted should not be conducted by any group having a conflict of interest in the management of the land.

Technology Transfer

As indicated earlier, several representative strategic ecological sites (15 or 16) equivalent to a grazing allotment will be selected from the 17 Western states. One range scientist could be assigned to one or more sites. Research will be set up at each site to monitor or measure each of the variables. Visitors will be able to observe the process and duplicate it on their own ranch or land to be monitored. Those interested in implementing the proposed research monitoring program can implement all the data collecting processes and make use of them. Each of the scientists should have some educational responsibility and be responsible for field days and talk at user meetings, and they should publish the results of their research.

Conclusion

The rangelands provide a multitude of functions and uses for society. It is therefore important that this great resource be maintained in a fully functional, sustainable, and healthy condition. The Western ranges are characterized over time by a highly variable climate, ranging from intense drought to more than adequate moisture with a resultant desert environment. They also encompass a vast space, characterized by variable climates, soils, elevations, and geographically different areas. If the nation’s options are to be maintained, the capacity of these lands for self-renewal has to be monitored.

Rangeland monitoring must include all variables—climate, soil, plants, and grazing animals. Monitoring these and calculating correlations among them will provide data not only in the development of grazing plans, and so forth, but will also develop a bridge between drought years and good years, thus providing information on appropriate management strategies and reducing risk.

Historically, the livestock industry has been a principle user of rangeland resources. Various interest groups and governmental agencies have increasingly held the livestock industry to varying and arbitrary standards of environmental stewardship. However, uniform standards to assess the health of rangelands do not exist. Thus, these ranchers are being held accountable without a means of accounting for the environmental consequences of their actions. If these ranchers are to bear the responsibility for the health of the rangelands, they must be provided with science-based technology to assess and report the health of the rangelands they use.

Bedrock Principles Essential to a Universal Rangeland Monitoring System

1. A monitoring system must include all factors affecting rangeland health, such as climate, soil, plants, grazing animals, storms, floods, fire, insects, and invasive plants. Livestock water should be measured as well as streams.
2. Because of the great variation in climate and other variables and the interaction among them, the monitoring system must be developed over an extended period of time, at least one, and preferably two, drought cycles and should include an above-average precipitation sequence for definitive conclusions.

3. In order to account for variation in the Western ranges (space) a network of at least 15 to 16 research locations should be chosen to represent the diversity of the rangelands in the nation.

4. The monitoring system must provide standard terminology that will express conditions and trends as an indication of the health of the rangeland in an understandable and sure way and that will enhance communication among those involved in the use and management of rangelands.

5. The research plan must provide for resources in order that the various approaches now used in monitoring rangeland, as well as new ones to be developed, can be compared in the same place. This plan should cover soils, climate, and grazing pressure over time and space. The comparison must include efficacy of the methods, cost, simplicity, flexibility, and so on.

6. The research plan will provide information obtained in the monitoring process, and will be gathered and processed in an economically feasible manner, and interpreted and stored in a functioning system that can be used in the decision making process. It should correlate interactions among all variables over time and space. The data collection and analysis must undergo quality control, and be transparent and repeatable. In other words, anyone must be able to run the process backwards to the primary data and confirm each step toward the conclusion.

7. The monitoring system developed must be such that users such as range managers and ranchers can implement it on their ranges, public and private, and can account for their stewardship of their rangelands to the appropriate agency.

8. Remote sensing data will be correlated with ground truth data.

9. The monitoring system must be economically available, simple to apply, functionally sound, scientifically based, flexible enough to fit a diverse environment, and it must allow validation and comparison of methods on the same lands at the same time.