Future Directions for Usable Rangeland Science: From Plant Communities to Landscapes

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On the Ground

- The profession of rangeland ecology and management has been built, to a large extent, on vegetation ecology.
- Community ecology has been the source of advances in scientific understanding of rangeland behavior and improving management.
- An increased use of the principles of landscape and regional ecology could greatly improve the utility of rangeland science for researchers and managers.

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The profession of rangeland ecology and management has been built, to a large extent, on vegetation ecology. Because the practice of rangeland management started as a response to rampant and destructive overgrazing, much of the early focus in rangeland science was to determine domestic livestock carrying capacity to minimize the negative impacts of heavy grazing on plant community composition and productivity. Early research and development efforts identified consistent relationships between plant productivity and stocking rate and performance, generally with an emphasis on annual monitoring and decision-making.[1]

Much like ecology in general, early rangeland management was fixated on the plant community. Pioneer ecologist Frederic Clements expended considerable intellectual effort establishing the plant community as a distinct and identifiable entity in his hierarchical classification system and, consequently, an important indicator of species interactions and a predictor of landscape scale behavior.[2] The plant community focus gave the nascent profession of rangeland management two very important things: 1) a way to organize field research, and 2) a way to communicate with the emerging institutional (primarily state and federal governments) framework. Experimental units organized around plant community concepts, generally on the order of 1,000 m^2, were sufficiently large enough to allow for the investigation of diverse plant species (and their interactions), allow for multiple experimental grazing animals, and yet small enough to keep land costs under control. Perhaps just as importantly, federal and state agencies with rangeland management responsibilities, following the much more politically powerful forest management profession and their emphasis on timber production, began to adopt the plant community as the finest scale of management decision-making, implementation, and monitoring. The plant community scale gave researchers a manageable experimental size and managers a relevant way to decompose larger management units to a measureable size. It was truly a Goldilocks moment.

Although there were obvious drawbacks to using the plant community scale, the emergence of accessible and translatable concepts and tools to communicate site-scale behaviors in vegetation management helped allay those concerns. Most troubling was the idea that much of the within-community complexity could be homogenized, and scaling community attributes to landscape scales was a linear process.[3] Nowhere was this mistaken assumption more apparent than when we tried to extend the understanding of the effects of grazing across individual, population, community, and landscape scales. At the plant community scale, where most experiments and monitoring took place, dominant interpretations focused on grazing as the primary driver of change (increaser, decreaser, and invader relationships), and reduction of grazing pressure was the only way to improve rangelands by improving species composition and reducing bare ground. While these relationships held up over some communities and were useful in guiding management decisions, many other communities did not follow that model. The effects of important drivers such as animal selectivity, shrub:grass competition and invasive species were often ignored. Beyond the community scale, the spatial distribution of disturbances and their effects on within community dynamics was frequently overlooked in designing experiments and interpreting monitoring results. Over the past 30 years, we have realized that grazing is not the 'cause-all' or the 'cure-all'.

These insights and have prompted rangeland scientists and managers to reexamine the utility of our science for the future. In the workshop on Future Directions for Usable Science for Rangeland Sustainability (see Maczko et al, this issue), the vegetation-working group was a diverse group of professionals that included employees of government agencies and non-government organizations, ranchers, and academics. We started by talking about the limitations of the existing approach, identifying some possible alternatives and finally, made some suggestions about how barriers to adopting new approaches might be overcome. While discussions were broad, several general questions consistently emerged:

- What determines landscape functions, especially resilience?
- How can we motivate diverse groups to plan and manage for a more complex mix of ecosystem services at a landscape scale?
- How can we predict and measure the effects of different kinds of disturbance on landscapes to improve decision-making?

Ultimately, the group settled on one primary theme, expanding vegetation science from a community to a landscape scale, to make our contributions to rangeland science and management more usable.

Traditional Approach

Science on rangelands has followed the same trajectory as most agricultural and ecological sciences. Initially, knowledge grew out of large-scale observations and low-intensity field studies that served to identify some important hypotheses. From there, our discipline was primarily dominated by the process of turning those big questions into growth chamber, greenhouse, common garden, and small plot experiments to test those hypotheses (Table 1). Many of these experiments were elegant and insightful, resulting in the identification of basic principles that transcended locations and seasons. Some, however, were little more than trial-and-error, confounding cause and effect and leading to confusion in both the science and the management.

Experimental units were usually small and homogeneous, designed to limit variation to a single treatment effect rather than include potentially interacting and confounding factors such as variable soil patterns and seasonal variability. Although this approach gives us multiple comparisons of a treatment (e.g., grazing, burning) to a control, they sometimes failed to offer insight or nuance into the processes being investigated. Attempts to integrate process investigation and management decision-making into the same experiment frequently missed the mark for both. While this approach has been instrumental in agronomic applications for comparing yields and for determining the effect of a single or a limiting number of interacting factors (usually tillage, nutrient application, or herbicides), it is often lacking in relation to complex management system decisions. If the objective is to identify a superior crop variety, a superior tillage method, or a superior herbicide for weed control, it works well. But it is poorly suited for combining all these decisions into a usable format, even in croplands. In rangelands, where management systems seldom come with a label and responses require continual adaptation, the approach has not been particularly helpful.[4]

Application of vegetation science to monitoring followed a pathway similar to the experimental challenges. Monitoring subtle change in highly variable processes with a direct link to management action, while a highly desirable goal, has led to the adoption of expedient but frequently misleading methodologies. The dominant approach to vegetation monitoring on rangelands was grounded in Clementsian ecology, and given a quantitative basis by Dyksterhuis[2] and others. The ideal (climax) plant community composition was determined for each soil group (site); each management unit to be evaluated was measured (via species composition) and the difference was referred to as 'condition'. Individual management units were classified into poor (0–25% similar to climax), fair (26–50%), good (51–75%), and excellent (>75%) categories. Livestock grazing impacts (quantified as stocking rate) was implicitly acknowledged as the dominant driver of ecological process (heavier grazing = lower condition and lower productivity); furthermore, stocking rate adjustments necessary to improve condition could be quantified by relatively simple math that transcended the individual site and ecosystem (it could be applied anywhere). Naturally, the simplicity of this system attracted both criticism and advocacy, sometimes from the same source.[5]

Grazing management research has rendered many of the assumptions built into the range condition approach irrelevant and a much broader view of ecosystem services has fueled a debate over whether such a grazing-centric approach is even appropriate. Increasing desire for meeting multiple objectives, that include wildlife, water quality and quantity, and wildfire management, requires embracing complexity at larger spatial scales. Nevertheless, classifying land condition by percent similarity to an undisturbed or lightly disturbed 'reference' community remains a cornerstone in evaluating management, implementing improvements, designing monitoring systems, and assessing impacts.

An Alternative Approach

The challenge to modern rangeland vegetation science is to maintain the scientific rigor possible with an experimental approach and to expand to a broader perspective of both ecosystem services and spatiotemporal scales.[6] Modern society has many demands on rangelands that are difficult to evaluate by a limited approach of treatment averages. These problems require evaluating rangeland ecological processes simultaneously at multiple spatial scales (especially large scales),

Table 1. Characteristics of different experimental approaches in rangeland research and the influence on common performance metrics and land use decisions.				
Common experimental approach	**Greenhouse/ garden**	**Agronomic plot**	**Site scale**	**Large-scale landscape**
Spatial scale	Pot/individual plant	<1 ha	1100 ha	>1000 ha
Experimental control	High	Moderate	Moderate	Low
Possible land use objectives	Single	Single	Several	Multiple
Representation of commercial scale	Low	Fairly Low	Moderate	High
Ease of publication	High	High	High	Low
Statistical requirements	Contingency/ANOVA	ANOVA	ANOVA or multivariate	Multivariate/ modeling
Variance paradigm	Control	Control	Control	Quantify

ANOVA indicates analysis of variance.

consideration of the role of heterogeneity rather than only averages, accounting for an increasingly varied and interrelated set of ecosystem services, and lengthening temporal scales to encompass infrequent, but important, events. As examples, specific questions discussed in our working group and currently under investigation by rangeland scientists include: 1) conservation of multiple species that have distinct, and frequently overlapping, habitat requirements, 2) balancing conflicting livestock management and species conservation goals, 3) managing fuel (for prescribed fire and wildland fuel management) and forage for livestock simultaneously, 4) optimally locating energy development to minimize impacts on conservation and agriculture, and 5) developing management approaches that integrate climate change response. Scale and heterogeneity are critically linked, and understanding their connection is essential for managing to achieve multiple, often competing, objectives on rangelands. Meeting multiple objectives in a limited space over management timeframes requires a much more dynamic perspective of vegetation structure.

The discipline of Landscape Ecology focuses on how human activity affects patterns at multiple scales and how this cross-scale heterogeneity can be used to explain and predict large-scale processes and ultimately, ecosystem services.[i] This approach is much more complex and rarely leads to simple results that are easy to communicate, either as refereed journal publications, extension recommendations, technical advice, or management initiatives but has a much stronger basis in reality. While success in the traditional approach to experimentation hinges on the ability of the experimenter to externalize variability and focus on a limited number of treatments and responses, this new approach requires that hypothesis statements, experimental design, data collection and analysis, and interpretation be built around the quantification and integration of variability at multiple scales. This approach also better integrates the social aspects of rangeland regions so they can be viewed as socio-ecological landscapes. The flow of information among researchers, advisors, and managers becomes more focused on elucidating general principles of how the system works and developing accessible interactive tools that use that knowledge to facilitate communication, rather than an approach that compares a variety, a technique, a system, or even a management philosophy.

Barriers to Usable Science

Adopting a new approach to vegetation science for rangeland management will not necessarily lead to improved outcomes, even if it does more faithfully reflect ecosystem dynamics. One of the primary reasons the plant community (site) scale and range condition (similarity) model is so difficult to displace is that it is relatively simple to communicate. While the direct interactions among scientists, managers, and advisors always reflected the inherent complexity, institutional consumers (agencies) tend to prefer simpler approaches for resource allocation, assessment, and reporting.

Rangeland science and management are inherently a mix of public and private interests. The early history of exploitation in rangeland ecosystems demonstrated that conflict between private and public interests clearly. Even though the principles of sustainable management overwhelmingly influence private sector rangeland management decisions, the strong and explicit links between private-land conservation decisions and the public interests will remain important. This relationship becomes even more complex in regions with intermingled private and public land with very different social structures.

It is impossible to discuss the history or future of rangeland science and management without including government, both

[i] For more information on landscape ecology, visit the International Association for Landscape Ecology at www.landscape-ecology.org.

for good and bad. The goal of transforming government can alter the flow of information through administrative systems and programs. Trying to introduce management objectives that require a better recognition of complexity and the need for greater flexibility into a reorganizing bureaucracy presents major challenges. Overcoming this barrier will require a significant commitment of time and resources among all participants to insure that information moves where it is needed. It also means that a significant effort will likely be required to assist institutional systems in adapting to an approach that better reflects reality. In particular, the need to select indicators for assessment and monitoring may present a difficult challenge. As spatiotemporal scales increase, the variability (rather than a mean) in key indicators may more accurately reflect important attributes and trends. The selection of indicators and inventory/monitoring protocols may very well require significant changes in long-standing programs.

Similarly, organizational and funding challenges are likely to be substantial. Expanding spatiotemporal scales for conservation research may mean an imperfect distribution of treatments, precluding the use of long-accepted and well-understood statistical approaches. Where managers or technical advisors may be much more comfortable with an "A is better than B" outcome, the more nuanced approach using weight of evidence, contingencies, probabilities, and network (system) analyses will create new uncertainties in the decision-making process, uncertainties that could easily result in decision paralysis. To paraphrase General George S. Patton "Is it better to confidently implement a flawed decision, than to wait until later for a perfect plan". The question will be whether an approach that more accurately reflects the dynamics of the ecosystem, but is more difficult to understand and communicate, is more helpful than an overly simplified system that inspires confidence. If the challenge is to get managers to act on the information they have, how important is accuracy when it comes with more uncertainty?

Conclusions

Rangelands are complex landscapes that may best be described by their variability in time and space, and society has greater demands from these resources than at any time in the history of civilization. Science on rangelands has followed similar trends to agriculture and ecology of simplifying and reducing complex systems into homogenous units. The focus has been on controlling variability rather than understanding it and in some cases managing for it. Modern approaches of landscape ecology and adaptive management suggest that embracing this variability is a central critical issue for rangeland management over the next several decades. We have the opportunity to increase both the quality and relevance of rangeland vegetation science by expanding our ideas of what constitutes valid and relevant science. A much broader, integrative view of the space and time relevance of information, a more diverse approach to transdisciplinary interpretations, a greater acceptance of mixed experimental and observational approaches, and a reduced reliance on the belief that there is a simple, best answer are the adjustments that will not only be more likely to solve existing and emerging problems, but will engage a broader audience in rangeland issues. Rangeland scientists, managers, advisors, and policy makers all have to be willing to make these adjustments.

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