A Workshop on Future Directions of Usable Science for Rangeland Sustainability

By Kristie A. Maczko, Lori A. Hidinger, John A. Tanaka, and Chad R. Ellis

On the Ground

- As funding for rangeland research becomes more difficult to secure, researchers and funding organizations must ensure that the information needs of public and private land managers are met.
- Usable science that involves the intended end users throughout the scientific enterprise and gives rise to improved outcomes and informed management on the ground should be emphasized.
- The SRR workshop on Future Directions of Usable Science for Rangeland Sustainability brought together university and agency researchers, public and private land managers and producers, non-governmental organizations, and representatives of funding agencies and organizations to initiate the process of charting a research agenda for future directions of usable science for rangeland sustainability.
- Workshop outcomes address issues and research questions for soil health, water, vegetation (plants), animals, and socio-economic aspects of rangeland sustainability.

Keywords: usable science, sustainable rangelands, soil health, water, socio-economic aspects, plants and animals.

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As funding for rangeland research becomes more difficult to secure, researchers and funding organizations must ensure that the information needs of public and private land managers are met. Coupled with rangeland research funding constraints are ever-expanding environmental, financial, and societal pressures on landowners and managers, as well as competing land uses and opportunities. Given these challenges, great value can be gained by more closely aligning on-the-ground scientific information needs with topics being considered by university and agency rangeland researchers, and major research funding organizations. In an emerging era of budget constraints, usable science that involves the intended end users throughout the scientific enterprise and gives rise to improved outcomes on the ground should be highlighted. With this tenet in mind, the Sustainable Rangelands Roundtable (SRR), Consortium for Science, Policy and Outcomes at the Arizona State University, and the Samuel Roberts Noble Foundation partnered to convene a workshop of university and agency researchers, public and private land managers and producers, non-governmental organizations, and representatives of funding agencies and organizations in June 2014 to initiate the process of charting a research agenda for future directions of usable science for rangeland sustainability.

In the United States, rangelands cover over 300 million hectares, or one third of the country, mainly west of the 95th meridian. These lands provide commodity, amenity, and spiritual values[1] that are vital to the well-being of our Nation and must be managed for sustainability. Since its inception in 2001, SRR, a partnership of rangeland scientists and ecologists, policy and legal experts, sociologists, economists, environmental advocates, and industry supporters, has distilled five criteria and 64 indicators for assessing rangeland sustainability and evaluating emergent rangeland management issues and tradeoffs.[2] The criteria embody social, economic, and ecological factors:

I: Conservation & Maintenance of Soil & Water Resources on Rangelands
II: Conservation & Maintenance of Plant & Animal Resources on Rangelands
III: Maintenance of Productive Capacity on Rangelands
IV: Maintenance & Enhancement of Multiple Economic & Social Benefits for Current & Future Generations
V: Legal, Institutional & Economic Framework for Rangeland Conservation & Sustainable Management

Table 1. Issues of importance to sustainable rangelands identified and ranked by the participants in the Workshop on Future Directions of Usable Science for Sustainable Rangelands.

Issues identified and ranked (highest priority to lowest)	Working group
Understanding and managing for variability (climate, drought, fire)	Socio Econ
Transfer of knowledge to land manager	Water
Proactive drought planning	Animals
Forward-looking drought predictors	Water
Increase support of rangeland programs and extension	Water
Proactive watershed management	Water
Understanding plant community adaptability/ plasticity in the face of change	Vegetation
Core data sets that are shared	Vegetation
Understanding the importance of diversity	Vegetation
Understand and create incentives for improving land stewardship across bounding	Socio Econ
How to get "right" kinds of information to knowledge users in a form they can use	General
Improve mechanisms for communication/ cooperation among diverse stakeholder groups	Vegetation
Landscape change in the face of increasing urban population	Vegetation
Understand role of fragmentation on important ecological processes	Vegetation
Match production system to resource	Animals
Protecting high-quality rangeland watershed (in contrast to mitigation/ storage)	Water
Invasive species	Animals
Empower landowners with knowledge	Animals
Improve desirability and opportunity for new generations to make a living on the land	Socio Econ
Drought indicators that are more sensitive on a regional level	Water
Define and implement drought preparedness	Water
Better coordination among research projects	Water
Focus on multiple objective management	Vegetation
Consider full range of invasive species issues	Vegetation
Education/experience of next generation	Animals

Table 1 (*continued*)

Issues identified and ranked (highest priority to lowest)	Working group
Aligning incentives and outcomes	Animals
Multi-disciplinary, multi-focus research	Socio Econ
Ecological site description states/soil health states	Soil
Understand tradeoffs in forage quantity and quality and fuel load	Vegetation
Understand fire effects	Vegetation
Understand land managers' motivations (profit vs. lifestyle)	Socio Econ
Technological innovations in water management	Water
Tolls to encourage critical thinking about vegetation dynamics across scale	Vegetation
Learning from drought	Vegetation
Matching animals to the resource	Animals
Maintaining affordable water supplies from aquifers in the face of climate change	Socio Econ
Multiple stressors of water (climate change as additional stressor)	Water
Water and increased woody biomass issue (soil resources, wildlife habitat, production ag, watershed)	Water
Better adoption of water conservation policy (e.g., irrigation technology)	Water
Consider multiple scales	Vegetation
Building social capital to enhance adaptive management (trust, reciprocity, and networks)	Socio Econ
Encourage and promote the involvement of younger generations in agriculture	Socio Econ
Building management structure to encourage positive outcomes (incentives not regulations)	Water
Stocking rate flexibility	Animals
Education of non-ag community	Animals
Metrics of sustainability	Animals
Optimize resources: land/water/animals	Animals
Increase improved outreach education and advocacy	Socio Econ
Identify factors driving the motivations of extraordinary producers from a conservation perspective (above-average vs. average producer)	Socio Econ
Relevance of soil survey ESD	Soil

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Table 1 (*continued*)

Issues identified and ranked (highest priority to lowest)	**Working group**
Soil mitigation Rx fire vs. wild	Soil
Targeted conservation programs/ practices for soil resources on landscape and post fire	Soil
Vegetation more than just forage (e.g., habitat)	Vegetation
Using terminology that is understood by all	Vegetation
Effects of livestock on rangeland	Animals
Collaborative range monitoring	Animals
Protection of property rights	Animals
Need better measures of social indicators of sustainability	Socio Econ
Identify and measure broad costs and benefits of renewable energy production	Socio Econ
Who gets the water	Water
What are the economic implications to drought after the drought has left	Water
Soil carbon Rx fire vs. wildfire vs. mob grazing	Soil
Integration of soil data and interpretation (Tying data together)	Soil
Soil erosion (wind/water, climate change predictability) (predictive models regional)	Soil
Focus on magnitude and risk of change	Vegetation
Consider extreme events	Vegetation
Impacts of special status species upon livestock producers	Animals
Enterprise/profitability	Animals
Information for decision support	Animals
Develop management and policy for anthropogenic ecosystems to maintain ecosystem services	Socio Econ
Harmony: community-based conservation vs. commodity-based conservation	Water
Optimal timing for riparian area grazing	Water
Rangeland resiliency in the context of evolving demand and supply	Water
Understanding water price as a driver for conservation (beyond basic needs)	Water
Optimize microbial activity (litter cover, infiltration)	Soil
Understand other sources of income from range	Vegetation

Table 1 (*continued*)

Issues identified and ranked (highest priority to lowest)	**Working group**
Effects of wildlife/livestock interaction	Animals
Communication between neighbors	Animals
Helping communities better adapt to social, economic, environmental, or political change	Socio Econ
Complete water budget	Water
How to productively move cropland to rangeland	Water
Soil/plant interaction	Soil
Understand role of heterogeneity	Vegetation
Importance of stocking rates/density	Vegetation
Reducing the role of implicit, untested assumptions in decision making	Socio Econ
Improve recovery from natural disasters	Socio Econ
Change culture of exploitation to conservation	Water
Embrace climate change science	Vegetation
Consistent and well understood descriptions of current and "desired" conditions	Vegetation
Acknowledge variability in space and time vs. the mean	Vegetation
Understanding impacts of neighbors	Vegetation
Alterations of disturbance regimes	Vegetation
Understand perception of vegetation change	Vegetation
Understanding mental models of woody plants and the role of fire in rangeland ecosystems	Socio Econ
Implement measures of research to facilitate positive ag message to consumers	Socio Econ
Increased creativity of scientists' thought processes on how to fund long-term research	Water
Producer acceptability	Water
Animal impact on rangelands	Animals
Social definitions of sustainability	Socio Econ
Quantitate the value of rangeland and protein production	Socio Econ
How do people react and respond to risk	Socio Econ
How do you incorporate diverse knowledge into decision-making	Socio Econ
Document stated intention to behave vs.	Socio Econ

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Table 1 (*continued*)

Issues identified and ranked (highest priority to lowest)	Working group
actual behavior in terms of land management	
Interrupting plow-out/set aside policy	Water
Feral horses	Animals
Communication of complexity of food system	Animals
Engage woody plant encroachment as dominant	Vegetation
Animal nutrition monitoring	Animals
Scale down vs. scale up	Vegetation
Understanding the role of plants water holding capacity during drought	Vegetation
Restoring and integrating rangeland habitat in tame systems	Socio Econ
Finding common ground for industry groups (i.e., oil and gas)	Socio Econ
Water made available through brush management	Water
Definitions of property rights	Animals
Grazing management not grazed vs. ungrazed	Animals
Efficiency of inputs	Animals
Policy and management decisions should be widely considered fair	Socio Econ
Market-based demographic emphasis to research and demonstration	Socio Econ
Livestock micro activity to soil micro activity	Soil
Recreation impacts on natural resources and agriculture	Animals
Unintended consequences of "sustainable" diets	Animals
Recruitment of producers and expertise	Animals
Good understanding of biophysical systems at various scales (temporal and spatial scale triggers, trade-offs, and certainty)	Socio Econ
Sensitivity of rangeland issues to decision makers	Water
Soil condition rating	Soil
Animal behavior	Animals
Recognize and evaluate rangelands in the eastern states	Socio Econ
Consider industrialization of rangelands	Vegetation
Animal distribution	Animals
Public institutions' organization of knowledge	Water

Table 1 (*continued*)

Issues identified and ranked (highest priority to lowest)	Working group
Soil cryptobiotic crusts	Soil
NEPA	Animals
Breed adaptability to intensive grazing	Animals
Reconcile messages across disciplines	Socio Econ
Stockmanship	Animals
Too focused on livestock	General
Uncertainty and ambiguity about decision-making	Water
Do we need a national water policy	Water
Lack of effects of livestock	Animals
Stockmanship/animal handling	Animals
Soil microbial induced for designer communities	Soil
Dust PM10	Soil

Workshop objectives, structure, and process

These SRR criteria provided a foundation for workshop structure, with work groups focusing on rangeland soil health, water, plants, animals, and socio-economic aspects of rangeland sustainability to capture research needs associated with rangelands' contributions to a broad spectrum of ecosystem goods and services. Work groups had four main objectives[3]:

1. Define and discuss the concept of usable science (science developed with the end-user in mind) as it pertains to rangeland sustainability, with consideration of perspectives of agencies, funding organizations, land managers, producers, non-government organizations, and academics.
2. Develop a portfolio of recommendations for future directions of usable science for rangeland sustainability, incorporating stakeholder input to address soil health, water, plants, animals, and socio-economic aspects of sustainable rangelands and the varied ecosystem goods and services that intact, functioning rangeland systems provide.
3. Consider current and emerging issues in sustainable rangeland management and potential geographic (regional) variations throughout development of the research portfolio for usable science for sustainable rangelands.
4. Identify timeline, tasks, and responsibilities for dissemination of information generated during the workshop through conference workshop proceedings, peer-reviewed journal articles, general interest articles, executive summaries, and briefing activities for thought leaders and decision makers.

The workshop process began with facilitators describing work group expectations and tasks, to address soil health, water, plants, animals, and socio-economic aspects. Each group was assigned a discussion leader from among the participants and a student note-taker from the University of Wyoming or the Samuel Roberts Noble Foundation internship program.

The first step for groups was brainstorming ideas, issues, and challenges confronting sustainable rangelands. These ideas were recorded for discussion in the working groups. Some of the ideas were specific to the resource working groups (soil health, water, plants, animals, and socio-economic aspects), while other ideas were based on rangelands as a whole. After this step was complete, the entire group reconvened and all of the identified topics were listed on flip charts around the room and numbered.

Overall, the five groups identified 142 priorities to be addressed to ensure progress toward rangeland sustainability (see Table 1). Participants individually went through all the items and rated them using a scale developed by the facilitators. Participant worksheets were collected and the facilitators collated responses to create a comprehensive, prioritized ranking of issues for the entire group, incorporating the individual rankings of each workshop attendee.

With lists of ranked issues in hand, the resource working groups met to further develop prioritized issues and determine which ones they felt should be addressed in the near term. A worksheet was filled out for each priority issue that the group selected. Worksheets asked specific questions to provide a complete representation of each issue. Once this was completed, a set of research questions was developed for each of the issues, and a separate worksheet was filled out for each research question.

After issues and research questions were developed, the full workshop reconvened and each resource working group gave a report on their issues and research questions. The floor was then open for discussion to ensure that nothing was excluded. The resource working groups recorded comments from the audience and incorporated them into their ideas. Their priority issues and research questions form the foundation for each of the papers that follow in this special issue. Additional details on the issues, questions, and ranking process are available online in the full workshop proceedings,[3] http://sustainablerangelands.org/projects_usable_science.shtml.

What is usable science?

So how do we know we are doing "the right science" to address the challenges facing policy makers, land managers, practitioners, and the public working to ensure the future sustainability of rangelands? And how do we make that science "usable" to those addressing these problems? Usable science is science that meets the changing needs of decision makers and includes those decision makers throughout the scientific process.[4] The US Geological Survey Advisory Committee on Climate Change and Natural Resources Science has developed a working definition of "actionable science" for their use to cover science that "provides data, analyses, projections, or tools that can support decisions regarding the management of the risks and impacts of climate change. It is ideally co-produced by scientists and decision makers and creates rigorous and accessible products to meet the needs of stakeholders."[5] Whether called usable or actionable, there is pressure on science funders and scientists to create science that can be used in decision-making. It is not new science, but rather a particular approach to science that informs decision-making and responds to societal capabilities and goals.

When we think of the links between science and its use, traditionally we have thought of it as a linear process in which scientists do their research, publish their results, and those outputs go into the "vat o' knowledge" from which we expect potential users to draw to from to answer the questions they face. But science best meets the needs of users when those needs are considered throughout the institutions, policies, and processes of decisions about science.[4] Science is more likely to be usable if

Natural Resources Conservation Service (NRCS) Science and Technology leadership listens and learns about ranch management priorities, practices, and challenges from the National **Cattlemen's** Beef Association then-President Philip Ellis near Chugwater, WY during a June 2015 soil health tour hosted by the Sustainable Rangelands Roundtable. Photo credit to K. Maczko.

DEMAND: Do users have specific information needs?

SUPPLY: Is scientific information produced?	**YES**	**NO**
YES	*SUPPLY & DEMAND RECONCILED:* Users' information needs reconciled with the production of scientific information.	*MISSED OPPORTUNITY:* Research priorities misaligned or users are unaware of possible utility of information produced.
NO	*MISSED OPPORTUNITY:* Research priorities need modification in order to respond to users' information needs.	*SUPPLY & DEMAND RECONCILED:* Information not produced nor needed by users.

Figure 1. Matrix of missed opportunities from Sarewitz and Pielke.[7]

knowledge producers (researchers) are informed by the needs and practices of science consumers (policy makers, land managers, and practitioners) and consider the intended USE of the science as it is being developed. Its usability is a function of the context of its potential use and of the process of how the scientific knowledge was produced.[6] The process of identifying usable science should start with a decision that needs to be made, rather than a research question. Then, repeated conversations between the producers and users of scientific knowledge are critical to developing the sets of questions and approaches that result in usable science.[6] These successful iterations are the result of scientists and decision makers taking ownership of the task of building relationships and mechanisms that foster the co-production of knowledge.[6]

There are four common but misleading assumptions about science-policy decision-making that get in the way of usable science[4]:

1) **Usable science equals applied research**. However, dealing with real world problems often requires advances in fundamental knowledge or basic research.
2) **We can't know the future benefits of research**. But thoughtful planning of research toward explicit societal goals is more likely to get us where we want to go.

Activity	Attribute	Spectra of Research Criteria: Science Values	User Values
Knowledge Production	Expertise	Epistemic	Experiential
	Relevance	General	Contextual
	Disciplinary Focus	Singular, Narrow	Transdisciplinary, Diverse
	Uncertainty	Reduce Uncertainty	Manage Uncertainty
	Goals for Research	Exploratory	Outcome Oriented
Learning & Engagement	Learning	Theoretical	Social, Practical
	Knowledge Exchange	Restricted, Linear	Iterative, Influential
	Network Participation	Homogeneous	Heterogeneous
	Social Capital	Negligible	Significant
Organizational & Institutional Processes	Accessibility	Constrained	High
	Outputs	Narrow	Diverse
	Evaluation & Effectiveness	Science-Centric	Public-Value Oriented
	Flexibility	Constrained	Responsive
	Human Capital	Narrow	Broad
	Boundary Management	Limited	Broad

Figure 2. Typology of research from McNie, Parris, and Sarewitz.[8]

3) **Users benefit from science at the end of the research process**, when the science is "settled". But decision makers benefit from science when they are involved in the research process early and often.
4) **Solving a difficult problem requires more research**, but not all knowledge is equally useful. We reach a point when adequate information exists to make a decision.

We can think of this in terms of the supply of science and the demand for usable information (Fig. 1).[7] Ensuring that the supply of scientific information aligns with the needs of users requires ongoing processes to engage with users.

To produce usable science for decision-making, we need to recognize the differences between research to advance a discipline vs. research to solve a problem. McNie, Parris, and Sarewitz[8] developed a typology to assess the potential of research projects, programs, and institutions to achieve particular goals. The typology divides research into three activities each subdivided into attributes:

1) **Knowledge production** – expertise, relevance to the specific problem, disciplinary focus, uncertainty, and the goals for the research;
2) **Learning and engagement** – learning, knowledge exchange, network participation, and the role of social capital;
3) **Organizational and institutional processes** – accessibility of researchers to uses, variety of research outputs, evaluation and effectiveness, flexibility to respond to changing user needs, human capital, and boundary management.

Projects can then be evaluated in each attribute by where they fall along a spectrum ranging from a focus on achieving ends internal to science (science values) to a focus on achieving ends external to the research itself (user values; Fig. 2).[8] As an example, looking closer at the attributes in the knowledge exchange we can see that a project can be anywhere on the spectrum from the linear model to a more iterative, influential one.

In co-producing usable science, researchers and users together need to define the societal problem for research to address, define the users to be involved, and identify the outcomes that would represent progress to both researchers and users. These processes are all linked so this must be an iterative process of continual adjustment as knowledge advances, user needs change, and understanding of the problem evolves.[4]

At the June 2014 workshop on Future Directions of Usable Science for Rangeland Sustainability, we sought to develop a preliminary set of research questions for sustainable rangelands, implementing this usable science approach to integrate user needs. The ultimate goals of the workshop were to identify issues facing rangelands and to produce a set of recommendations for future research on rangelands that incorporated user needs from the start. Participants included ranchers, producer and environmental advocates, academic researchers, and government land managers, researchers, and funders. The participants focused on 5 topic areas (soil health, water, vegetation, animals, and socio-economics), brainstormed to identify challenges facing rangelands, ranked the importance of each challenge independently, collated them into a prioritized list, and fleshed out those priorities into research focus areas, identifying stakeholders for each.

Workshop outcomes

Results from this interdisciplinary workshop reflect 20 hours of dialogue among the contributors. Participants also considered geographic aspects of usable science for sustainable rangelands to ensure that place-based attributes associated with issues and research questions were included in their evaluations. Usable science considers the needs of its users throughout the basic to applied scientific enterprise, in this case to ensure that rangelands continue to provide a desired mix of economic, ecological, and social benefits to current and future generations. Ecological drivers identified as influencing socio-economic aspects included climate change, drought, flooding, fire, and invasive species. Workshop outcomes are categorized according to the five aforementioned resource groups: soil health, water, vegetation (plants), animals, and socio-economic aspects.

Soil Health

Participants in the Soil Health group quickly coalesced around the idea that healthy soils are fundamental for sustainable rangelands, underlying vegetation communities, animals that forage on this resource base, quality of surrounding waters, and socioeconomic systems and successes of resource dependent communities (see Derner et al. this issue). However, this group also noted that soils' critical contributions to rangeland sustainability are often overlooked until radical events capture the attention

NRCS staff evaluating soil condition. Soil health refers to a soils capacity to function as a vital living ecosystem that sustains plants, animals, and humans. Ecological and economic function go hand in hand, and soil health supports both aspects of a ranching operation. Photo credit to NRCS.

of policy makers and the public. Benefits of soil health identified by the work group include enhanced infiltration and soil water holding capacity, reduced erosion, and increased nutrient cycling, which increases resilience of rangelands to weather variability and predicted climate change. Future directions of usable science for soil health prioritized by the workgroup are as follows.

Relevance of soil survey and ecological site descriptions
- Spatial analysis and soil sampling for soil health to identify indicators.
- Characterization of soil health indicators; what are the sensitivity levels that affect thresholds and what management practices influence the indicators in a cost effective, positive, or negative way?
- Completion and updates of soil surveys.
- Synthesis of current research identifying soil responses to range management practices and effects on climate change.

Soil mitigation: prescribed fire vs. wildfire
- What are soil responses to vegetation treatment? Effects of various ignition methods on soils.
- What are the soil nutrient responses to prescribed fire as compared to non-fire or wildfire?

Water

Participants in the Water Work Group linked water to livelihood, and considered it in the context of agricultural irrigation, energy development, and food security. Effects of land-use change, climate change, increasing demand for water resources, and socially acceptable answers to competing water allocation needs were discussed. Given that water is essential for all life—plants, animals, and humans—the future looks busy and bright for rangeland professionals and research scientists who possess the knowledge and skills to address these issues (see Dobrowolski and Engle this issue). Included in the list of issues and resource questions prioritized by this working group were the following points.

Productively transition cropland to rangeland
- Restoration of abandoned cropland
- Cost/benefit analysis – what are the costs to society of restoring a forage crop? Or not?

Drought
- Better monitoring tools, better prediction tools, and better technology.
- Building adaptive capacity and resilience; how to build adaptability to long-term drought.

Proactive watershed management; protection of high quality rangeland watersheds
- Understand rangeland water budgets.

Vegetation

The Vegetation Work Group identified their subject matter as the foundation of rangeland ecology, noting development of rangeland management as a profession in response to overgrazing and misuse of vegetation resources. Their discussions focused on facilitating development and adoption of a landscape perspective for rangeland conservation and management, given that addressing vegetation management questions requires integration with questions about soil:vegetation relationships or animal:vegetation relationships (see Fuhlendorf and Brown this issue). Within this framework, key questions to characterize future directions of usable science for sustainable rangeland vegetation should build on the following points identified by the work group. Applicability of traditional and alternative approaches to appropriate and informative experimental designs to address such questions were also discussed.

- Determine resilience of rangeland landscapes to extreme events.
- Understand motivations of different user groups for landscape level planning.
- Assess effects of spatial pattern of plants and soils on livestock production, wildlife habitat, and water quality.

Clean water benefits livestock and wildlife communities, and is critical for productive rangeland systems. Photo credit to K. Maczko.

Ranchers inspecting vegetation that provides forage for livestock and wildlife. Photo credit to NRCS.

- Understand the role of variability of space and time to better develop rangeland-monitoring systems.
- Determine effects of invading native and exotic species on rangeland ecosystem goods and services.

Animals

Participants in the Animal Work Group considered rangelands and the animals that they support as a primary source of food and fiber for cultures worldwide. Their focus emphasized domestic livestock, rather than wildlife populations, though wildlife was recognized as a key component of sustainable rangelands. Wildlife-related questions likely require additional evaluation in the future to ensure incorporation into research agendas for sustainable rangelands. Representatives from the livestock industry, conservation community, and academia identified pressing challenges that rangeland management must seek to address through integrated research (see Meiman et al. this issue). Other elements of their discussions included funding sources for new research, compilation of current literature reviews, and distribution of information addressing research priorities to benefit rangelands and the human communities that depend upon them. Priority research issues and associated questions identified by this work group are as follows.

Proactive drought planning

- What are appropriate land management decisions to improve drought resistance?
- What are drought and weather indicators to optimize management of working lands?

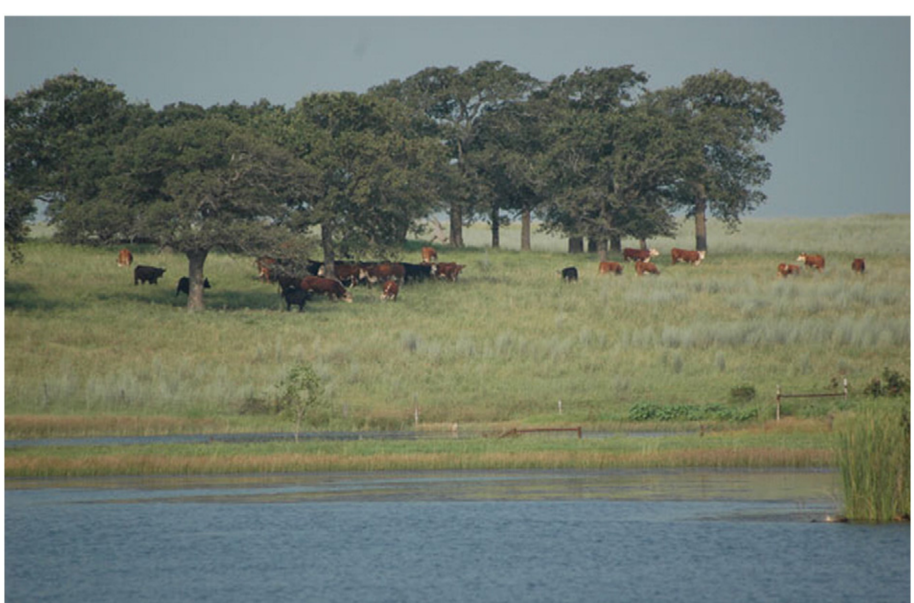
Production/management systems & resources

- What are major resource characteristics that drive production systems?
- How do we properly match animals to resources?
- How do we demonstrate benefits of stocking rate flexibility?
- How do we exploit knowledge of animal behavior and stockmanship to achieve land management goals?

Socio-Economic Aspects

Participants in the Socio-economic Work Group identified decision-makers at various spatial scales as the interested end-user for their research agenda (see Brunson et al. this issue). They noted that consulting with decision-makers is critical to development of research priorities in the social and economic sciences. Their outputs not only identified social and economic research questions, but also addressed why participants felt it was important, who would benefit from the research, and potential funding sources to support the projects. The key issues and questions identified by this work group encompass the following points.

Ranching operations contribute to the social and economic structure of local communities. Photo credit to NRCS.



Cattle grazing on the award-winning JA Ranch near Bowie, TX. Photo credit to K. Maczko.

Get the right kinds of information to knowledge users in a form they can use

- Who needs what information and what are the barriers and opportunities for information transfer?

Improve desirability and profitability for new generations to make a living in rangeland agriculture and environmental benefits

- What are the barriers/opportunities for new people to enter and persist in rangeland occupations and how can we use that information to increase numbers of adults who choose such careers?

Understand and manage for variability (climate, drought, fire), adaptation, and recovery

- How do rural communities best prepare for, adapt to, and/or recover from increased variability?

Understand and create incentives for improving land stewardship

- What motivates landowners to cooperate for environmental stewardship and how do we use that information to create and/or improve incentives and reduce disincentives?

Participant Perspectives

As workshop outcomes evolved, participants were asked to provide their perspectives on perceived challenges and opportunities. Academics, agencies, producers, and funding bodies shared varied viewpoints and valuable insights.

Academic participants wondered aloud, "how did we arrive at a situation where we are rewarded for doing research that pays little attention to whether it is usable?" The response acknowledged dynamics of the social system in which researchers work; there is prestige in journal publications and doing science valued by other scientists. Perhaps the biggest challenge is trying to step out of this box. Training the next generation of researchers to think about usable science is another challenge. Scientists must be able to translate their science into terms that are understandable to intended users, as well as involving users throughout the overall scientific process.

Agencies have self-identified as large producers and consumers of data. They need usable science to guide their management decisions and measure effects of management practices. Presently, they feel that there is a distance between science and management. It was suggested that cross-disciplinary research conducted at local and regional scales would be helpful, as well as synthesis articles combining ecological, social, and economic research.

Producers also endorsed an interdisciplinary approach and discussed how usable science has helped and/or will help them. People not only need to understand the ecological side of the science but also the social and economic sides to capture overall effects. Science needs to be presented in a way that is understandable, especially to teach producers new to the industry. Behavioral changes are needed from researchers and end-users in order to have research outcomes become usable science practices.

With this in mind, USDA National Institute for Food and Agriculture pointed out that they now require involvement of stakeholders and sociologists in the research process for their successful grants. All agreed this was a good starting point, but more modifications to standard research processes and practices are needed to engage end-users from the outset.

Concluding thoughts

Following the workshop, organizers agreed that applying a usable science framework to rangeland sustainability was an informative endeavor, positively impacting expectations among researchers, ranchers, managers, and funders alike. The subsequent articles summarize overarching issues and more detailed research questions in each area of inquiry addressed by work groups: soil health, water, vegetation (plants), animals, and socio-economic aspects. In all cases, work groups concluded that additional dialogue and discussion would have been fruitful. Their desire to continue working after 2.5 days of effort illustrates the value perceived by those who pursue a usable science approach to research. We hope readers react similarly to the work groups' writings, and we look forward to collaborative ideas and innovations stimulated by these outcomes of the workshop on future directions of usable science for rangeland sustainability.

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Authors are [1]Executive Director, Sustainable Rangelands Roundtable and Research Scientist, Department of Ecosystem Science and Management, University of Wyoming, Fort Collins, CO 80526 (kmaczko@uwyo.edu); [2]Director, Fiscal and Business Operations, School for the Future of Innovation in Society, and Managing Director, Consortium for Science, Policy and Outcomes, Arizona State University, Tempe, AZ 85287; [3]Associate Director, Wyoming Agricultural Experiment Station, Director, James C. Hageman Sustainable Agriculture Research and Extension Center, Director, Powell Research and Extension Center, University of Wyoming, Laramie, WY 82071; [4]Center Manager, Center for Land Stewardship, Noble Foundation, Ardmore, OK 73401.