# Grand Challenges and Transformative Solutions for Rangeland Social-Ecological Systems – Emphasizing the Human Dimensions

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Forum

# Grand challenges and transformative solutions for rangeland social-ecological systems – emphasizing the human dimensions

By Leslie M. Roche

## On the Ground

- Rangeland food systems around the world are increasingly facing complex and wicked problems with changing climate, environmental, and socio-economic conditions. We must find socially, economically, and environmentally sustainable ways to optimize production of high-quality, accessible food to feed the world's growing population. Further, we need to do this in the face of multiple threats, including climate change, land-use change, and emerging invasive species, pests, and diseases.
- The "human dimensions" are central to solving critical challenges for working rangelands. We must actively build collaborative partnerships that span disciplines, knowledge areas, and backgrounds. Diverse perspectives as well as greater integration of the natural and social sciences will foster critically needed transformative rangeland science, learning, and management.
- A central component of transformative change is training the next generation of scientists, resource users, land managers, and policymakers to work beyond institutional, land ownership, and political boundaries to build broad-scale partnerships and solutions.

**Keywords:** Collaborative adaptive management, participatory research, partnerships, sustainable agriculture, transdisciplinary, translational science.

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Early in my career, I was invited to a meeting focused on defining sustainable rangeland food systems. I was in this grand ballroom with >200 people from academic and research institutions, environmental advocacy organizations, retail associations, food service distributors, and so on. All these great minds, maybe some of the best minds, and then there was me—a new graduate student, largely unknown, and largely unnoticed.

I noticed there was no one in this entire ballroom whose livelihood directly depended on rangeland livestock production. For me, that highlighted a critical gap—and an opportunity. If we as scientists, educators, students, land managers, producers, and conservationists want to build a shared vision of sustainable working rangelands then we need to span the boundaries between policy, research, and management, and engage different voices in the conversation.

Fast-forward to now. I am fortunate to be part of the Cooperative Extension System—a boundary-spanning organization that is partnered with land-grant universities, the United States Department Agriculture, and state and local governments. The Cooperative Extension System has a long-history of research and outreach in agriculture, natural resources, and communities, and has developed and employed models of public engagement for >100 years. I am a rangeland agroecologist. This term is not often used, but for me it makes sense. Agroecology is a multidisciplinary and creative field that focuses on interactions among plants, animals, people, and the environment within agricultural working landscapes. Rangelands are multifunctional landscapes that are not only part of the food and fiber system, but also support biodiversity conservation, water resources, and wildlife habitat as well as other ecosystem services. So, this is my lens. I have the privilege of working with people from a broad range of academic disciplines—from the University campus to counties across California[1]—as well as diverse management, policy, and public stakeholders. For me, the balance is synergistic and natural.

My experience at that rangeland food systems meeting was not unique; it was the first of several experiences I have had just like this over the years. Many of my colleagues have also had similar encounters, in different settings and at dif-

**Figure 1.** As social-ecological systems, the sustainability and resilience of family ranches and rangelands depends on their ability to adapt to changing conditions across social and ecological scales. Photo courtesy of C. Koopmann Rivers.

ferent times. We know rangelands are complex, adaptive systems shaped by interlinked ecological and social components (Fig. 1).[2–4] There exists a long, rich history of rangeland research, extension, and education focused on the important biophysical dimensions of these systems. However, although social science research applications within complex rangeland systems have markedly expanded in the past decades,[5,6] there is still significant work to do to fully integrate and leverage the equally important human dimensions.[7–9] So, how do we disrupt the status quo "build it and they will come" approach and move toward authentic engagement with all stakeholders, emphasizing the human dimensions?

I am not just saying, "we need to collaborate more"; unfortunately, the solution is not that simple. More collaboration is needed—we as scientists, educators, and natural resource professionals need to be collaborating, communicating, and engaging with all stakeholders in rangeland science, ecology, and management—but we also need to transform the way we think about collaboration, the way we communicate, and the way we do science, outreach, and education. We need research and management excellence that brings positive environmental, social, and economic change, which does not happen in a vacuum. The time of silo mentality is gone—and good riddance! We have some grand challenges ahead of us and we need to learn from our past, be in this together, and do better with our inherited legacies in our scientific, education, outreach, and resource management endeavors.[10–12]

## Grand challenges

As I was thinking about themes to discuss in this piece, I kept coming back to "grand challenges." Clearly, human dimensions are central to solving the most critical challenges for rangelands, as well as agriculture and natural resource management issues more broadly. We know that climate, environmental, and socioeconomic conditions are changing. The simple problems have been solved; the problems we are facing are complex and could even be called wicked problems—with no single solution or one "right" answer—and often it is hard to grasp what exactly the problem is.[5] The following is by no means an exhaustive list, but I wanted to highlight some of the grand challenges for rangeland systems.

Global food demand is estimated to rise >70% between 2005 and 2050,[13–15] and demand for animal-based protein is expected to increase substantially around the world as incomes increase.[16,17] So, we need to optimize production of high quality, accessible food to feed the world's growing population, and we need to do this by 1) providing economic opportunities for those whose livelihoods depend on agriculture, and 2) reducing environmental impacts and enhancing environmental benefits associated with food production.[18,19] Additionally, we need to do all of this in the face of multiple threats! Climate change is ushering in more severe and frequent hazards, such as drought and wildfire, with records being set every year. Recent research in California has shown that climate change-induced increases in fall temperatures and decreases in pre-

cipitation have already doubled the frequency of extreme fire weather since the 1980s.[20] Land-use change and fragmentation are also major challenges to conservation of ranches and rangelands with turnover and conversion rates rising each year.[21–23] In California, a majority (73%) of ranching operations have reported <$10,000 annual profit,[24] which is far below more profitable alternative land uses, including residential development and intensive crop production, which have considerably higher per hectare economic outputs.[25] We are also contending with emerging invasive species, pests, and diseases.[26,27] These interacting threats are creating novel ecosystem conditions that are impacting structure and function, including biodiversity, productivity, soil health, and human welfare. And, as we are experiencing now with the global pandemic, unanticipated threat multipliers can exacerbate existing social, economic, and political challenges (e.g., COVID-19 and wildfire[28]). These challenges are multidimensional, wicked problems, but they are not insurmountable.

## Solutions and strategies

### Transforming rangeland science by spanning disciplines

As scientists, educators, and natural resource professionals, we need to actively engage across disciplines to leverage knowledge from diverse perspectives, which can lead to transformative science and learning. Recently, my colleagues and I examined the persistent problem of managing the distribution of cattle on rangelands. Animal behavioral (e.g., cattle preferences), economic (e.g., costs of alternative strategies), and environmental (e.g., spatial and temporal variability of the landscape) barriers all contribute to inefficient use of forage resources on extensively managed rangelands.[29] Subsequently, this problem has been scientifically examined through these separate disciplinary lenses for many years. When we looked at the co-authorship network for this body of research, we found a lack of connectivity across academic disciplines and high within-discipline clustering, resulting in a disjointed network of communities that was not well integrated (Fig. 2). This issue is critical given livestock distribution remains one of the most significant challenges grazing managers face on extensively managed rangelands. The lack of integration among disciplines suggests we have been "stuck" in our individual fields. Such siloed approaches limit opportunities for cross-pollination that can move us forward to novel solutions through, for example, integrating knowledge and methods from disparate fields like comparative psychology, animal production science, ecology, and economics.[29]

If we want to transform the way we do science, then we need to span boundaries and move beyond intradisciplinary modes (i.e., working within our own siloed fields) to interdisciplinary and transdisciplinary modes, which integrate knowledge and methods from multiple disciplines, including the natural and social sciences, to create new ways of working (for an example, see http://makinggood.design/thoughts/tasty). Interdisciplinary and transdisciplinary science can launch our abilities to address complex climate, environmental, and socioeconomic issues. Rangeland science needs experts in the biophysical sciences as well as political science, economics, sociology, political ecology, and psychology. Moreover, to build successful and integrative collaborations, it is important to respect different knowledge systems and engage potential partners, across scientific and management communities, in culturally appropriate ways[30]; this is critical to working effectively to identify, define, and solve collective problems.

I have repeatedly highlighted the social sciences because the focus here is how we can emphasize the "human dimensions," and there has been an imbalance in research funding support. For example, over 30 years of climate change research funding, the natural sciences received ~770% more funding than the social sciences, and only ~0.1% of total funding was spent on the social science of mitigation.[31] This is a critical gap because we know the limited integration of social science has hampered our understanding of conservation decision-making behavior and adoption of sustainable practices in agriculture in general.[2,32,33] Therefore, we need better integration of the natural and social sciences and we need to co-value these approaches.

### Translational rangeland science and management

Rangelands are often described as "social-ecological systems" or "coupled human and natural systems"[34] for obvious reasons—humans are not external to the system, but are interconnected with it and major drivers of change.[5] Therefore, interdisciplinary and even transdisciplinary science with other scientists is not enough; we need to work with stakeholders, including working side-by-side with industry, local communities, and land and resource managers, to develop translational rangeland science from the beginning to better align research with on-the-ground challenges. Many support organizations are using a highly collaborative, co-production approach. In the Cooperative Extension System, for example, some of our most progressive programs have moved from a top-down model of scientists creating, developing, deploying, and disseminating results to stakeholders to a model of multidirectional knowledge exchange and mutual learning through collaboration.[35] These knowledge networks[36] can be tapped through participatory, community science, and public engagement methods to co-produce ideas and integrate both technical and place-based experience and knowledge to ensure the resulting research is relevant to stakeholders and will improve social and ecological outcomes.

To effectively address contemporary rangeland issues, scientists must engage and build multipartner collaborations, beginning with ranchers and land managers. Ranchers and land managers are the individuals on-the-ground who are expected to participate in policy partnerships and comply with regulations,[32,37] so it is crucial to understand their experiences and how they view the landscape. As an example, following the historic, statewide drought that gripped California between

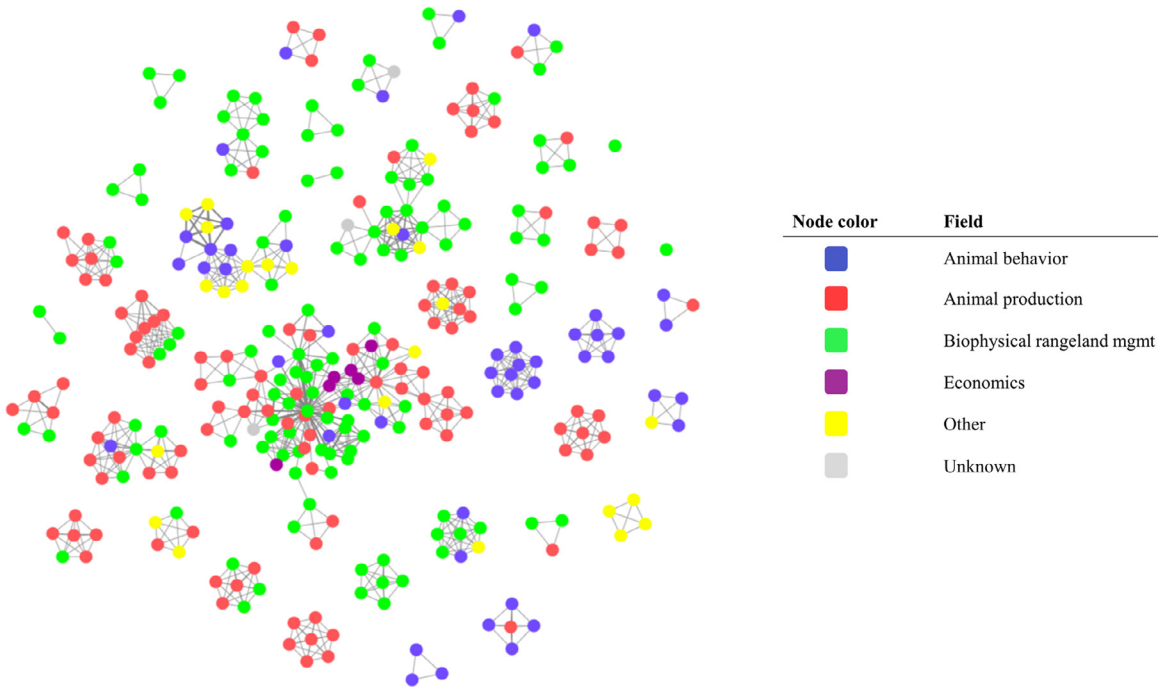


**Figure 2.** Sociogram for the research literature on strategies for optimizing beef cattle grazing distribution. Colored dots, or nodes, represent individual authors, with color denoting author field of expertise. Connecting lines indicate co-authorship between individuals. Co-authorship network analysis revealed very few connections (1.7% edge density) relative to the total number of possible connections in a complete network (100% edge density). We also found high clustering of authors within the same fields of expertise (e.g., high density of interconnected green nodes, which represent authors with biophysical rangeland science expertise), indicating a lack of communication between research disciplines. Figure adapted from Creamer et al.[29]

2012 and 2016, my colleagues and I worked with ranchers to understand how they were coping with the extreme conditions. Given that most ranching operations are multigenerational (i.e., at least third generation in ranching), there is deep experiential knowledge within this community.[32,37] By working within these knowledge networks, my colleagues and I have learned about drivers of impact, social and ecological vulnerability, and adaptive capacity.

Communities reliant on rangelands are vulnerable to climate variability; resilience to drought, for example, is critical to the long-term sustainability of these rain- and snow-fed systems.[38,39] In terms of sustainability and resilience, we learned information sharing, flexibility (e.g., number and type of land resources), and goal setting are key to building adaptive capacity. From efforts after Australia's Millennium Drought,[40] we are seeing how planning horizons and perspectives have been influenced by historic natural disasters. When we interviewed California ranchers about their future outlooks and climate change perceptions, they disagreed with strong negative statements on the impact and importance of climate change, such as "Climate change is NOT an important consideration when developing options for my ranching business, relative to other current issues" (2.54 mean rating; rating scale 1 = "strongly disagree" to 5 = "strongly agree"; n = 48) and "I do NOT believe that the future climate will be any different from my past experience" (2.35 mean rating; n = 48). They were more likely to agree with positive statements about their abilities to adapt and interest in learning, such as "I feel confident that I already have the skills to manage for long-term drought" (3.56 mean rating; n = 48) and "I am interested in learning about climate change and its impacts on the ranching industry" (3.96 mean rating; n = 48).[41] These results on how ranchers view the shifting decision-making landscape are encouraging for collaborative, problem-solving approaches. We know climate, environmental, and socio-economic changes will create conditions that exceed any past or present experiences humans have had on rangelands; therefore, these novel conditions will likely require innovative research, outreach, and management approaches.

Stakeholder engagement is part of transforming the way we do science. To meaningfully engage stakeholders working at the management-scale, we need to develop new ways of thinking, new methods, and new approaches. Grazing systems research, for example, has predominantly focused on comparing biophysical outcomes (e.g., livestock weight gains and annual forage production) between fixed grazing treatments over fine spatial and temporal scales.[7,8,42] This conventional approach relies on command-and-control and top-down communication, with limited partnership with land and resource managers. We know managers make decisions and adapt strategies for multiple social, economic, and ecological outcomes; therefore, if we continue with reductionistic approaches, then we risk missing the broader context and restrict the potential usefulness of our science to managers working in real world conditions (Porensky 2021,[43] this issue). Usable or actionable science at-scale is difficult, but we can advance our progress by working with rangeland communities to co-produce novel approaches, strategies, and tools.

By way of example, intensive rotational grazing has sparked a long debate in academic and management communities

**Figure 3.** Investing in and training future generations of natural resource professionals, land managers, and scientists to address rangeland management and policy issues through holistic and integrated approaches is critical to building resilient rangeland systems. Photo courtesy of T. Schohr.

around the world.[7,44–48] However, once we gain the perspectives of on-the-ground managers (i.e., asking people what they do), we see agreement, not debate, among research and management communities on the success of rotational grazing, particularly for achieving livestock production goals. Across California and Wyoming ranching communities, we found limited (5%) on-ranch adoption of intensive rotational grazing strategies; however, most (62%) ranchers had adopted extensive rotational strategies with moderate grazing periods and livestock densities.[8] Therefore, we can gain valuable, place-based knowledge by directly engaging with stakeholders and potentially avoiding decades of arguing and, instead, immediately focusing on more vital needs, which is more imperative than ever.

Stakeholders need to be engaged and also empowered to take ownership in research-management partnerships, which means scientists need to cede some decision-making power to their management partners. To this end, my collaborators and I launched the California Collaborative Adaptive Management Project, which combined participatory and collaborative processes with adaptive management. We engaged diverse stakeholders from the start to co-develop and co-design the research approach based on their experiences, knowledge, and needs. During the co-development process, we divided participants into working groups based on their professional and experiential identities as ranchers, rangeland professionals, or conservation professionals. We also created "mixed" groups of individuals with different backgrounds and expertise. We found the different stakeholder groups valued different goals—ranchers and rangeland professionals prioritized livestock and forage production, whereas conservation professionals prioritized native plant recruitment and wildlife habitat (Roche et al., unpublished results). These prioritizations did not change during group discussions, which was not surprising as goals reflected fundamental needs of individuals. However, we found participants did change how they connected management practices to their individual goals. After discussion, all groups increased the number of connections they made between goals and practices, and the biggest changes occurred in the mixed group discussions (Roche et al., unpublished results), demonstrating the value of group diversity and interdisciplinary interactions to group learning.

There is a growing number of individuals and organizations directly engaging ranchers, farmers, and landowners, but we also need to meaningfully engage other stakeholders, resource users, and potential partners who have a stake in sustaining working rangelands.[6] We need to work with a broader diversity of stakeholders including race, class, gender, and ethnicity, as well as the intersections of these and other identities. For those of us who work for, or are at least linked with, public institutions, the question "who is the public?" is particularly important when thinking about sustainable and equitable resource management.

Recently, several colleagues and I have been thinking about needs beyond our traditional partners in California, particularly those new and beginning ranchers who have been potentially underserved by support organizations. These first-generation ranchers are typically younger (average age of 43 for first-generation rancher interviewees ($n = 26$) vs. 60 for principle producers), more often women (41% vs. 17%), and more racially and ethnically diverse (e.g., 20% nonwhite vs. 9% nonwhite) than the general California ranching and farming population (Munden-Dixon and Roche, unpublished results). Until now, there has been limited research (e.g., our most recent search revealed only 2 published studies) with first-generation ranchers; at best, first-generation ranchers have been generalized as beginning farmers under many policy and support programs.[49,50] Based on what we had previously learned about sustainability and resilience of ranching communities,[39] we found first-generation ranchers typically have more limited networks, less access to resources, and fewer adaptation strategies available to them than typical, large, multigenerational counterparts.[50] These differences potentially make first-generation ranchers vulnerable to climate and environmental changes. Given an uncertain future, greater outreach and strong partnerships from

**Figure 4.** Cross-institutional partnerships can provide important opportunities for students, as well as all members of the rangeland research and resource management communities, to build capacity in developing successful, interdisciplinary science-management collaborations to tackle the wicked problems within rangeland social-ecological systems. Photo courtesy of L. Roche.

support organizations will be critical to this next generation's success.

### Training the next generation

Building resilient rangeland systems depends on training future generations of natural resource professionals, land managers, and scientists. There is increasing recognition of the value of investing in holistic student experiences, including balancing educational training between fundamental principles, practical field experience, and developing technical capacity[33,51,52] (Fig. 3). Students additionally need to gain relevant knowledge, training, and skills in integrating human dimensions into rangeland management and policy-making. As scientists, educators, and mentors, we also need to support the next generation in developing transferrable life skills (i.e., "soft-skills"); the current global pandemic underscores the importance of these skills to individual adaptability and resilience to change. We are training the next generation of collaborators, leaders, and problem solvers; therefore, it is critical we invest in their excellence because the challenges we face will require all our resources, talent, and creativity.

We have diverse information needs for rangeland conservation and management. Students need to build their technical capacities, including training in developing and using effective monitoring techniques and translating monitoring results for policy and management decision-making. They also need to build capacity in using new technologies and translating big data from big landscapes into actionable knowledge. Open source approaches for data sharing between scientists and managers provide a whole new world of opportunities, but also have their own challenges to navigate, including turning big data into knowledge, maintaining collaborator confidentiality and trust, and transparency in sharing. We can enhance training through cross-institutional partnerships to build capacity in students as well as land managers, natural resource professionals, and scientists.[33] These partnerships can provide important opportunities in developing interpersonal relationships, building leadership skills, and learning effective communication strategies (including communicating science to diverse audiences) as well as the art of networking and coalition-building (Fig. 4).

## Conclusions

Finding transformative solutions to the grand challenges facing rangeland systems calls for changing the culture of our institutions and disciplines, which is no small task. if we—as scientists, educators, students, land managers, producers, and conservationists—want to have impact beyond the experimental unit (e.g., beyond the pasture) and build broad-scale solutions, then we need to work beyond institutional, land ownership, and political boundaries. The rangeland research community is actively advancing applications, approaches, and integration of social science within rangeland research. To continue to effectively grow these approaches and tackle the wicked problems within our complex social-ecological systems, we need to collectively build and support interdisciplinary science and management frameworks to foster transformative rangeland science, learning, and management. When building dialogues around solving grand challenges such as sustainable rangeland food systems, we need to ask ourselves whether we are hearing all voices and considering the broader range of stakeholder values, goals, perceptions, and experiential knowledge. Are we integrating and emphasizing the vital human dimensions in all of our scientific, education, and outreach efforts in rangeland social-ecological systems?

## Declaration of Competing Interest

L.M. Roche serves on the Steering Committee for Rangelands but had no editorial influence on the review or publication of this paper.


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