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Management Opportunities and Research Priorities for Great Plains Grasslands

Outcome of the Working Sessions Held During the Great Plains Grassland Summit: Challenges and Opportunities from North to South Denver, Colorado April 10-11, 2018

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Abstract

The Great Plains Grassland Summit: Challenges and Opportunities from North to South was held April 10–11, 2018 in Denver, Colorado to provide syntheses of information about key grassland topics of interest in the Great Plains; networking and learning channels for managers, researchers, and stakeholders; and working sessions for sharing ideas about challenges and future research and management opportunities. The summit was convened to better understand stressors and resource demands throughout the Great Plains and how to manage them, and to discuss methods for improved collaboration among natural resource managers, scientists, and stakeholders. Over 200 stakeholders, who collectively were affiliated with all of the Great Plains States, attended the summit. Attendees included university researchers, government scientists, and individuals affiliated with Federal and State agencies, tribes, the private sector, and nongovernmental organizations. Plenary speakers provided syntheses of current knowledge on key topics to help stage working sessions on working lands, native wildlife and biological diversity, native plants and pollinators, invasive species, wildland and prescribed fire, energy development, and weather, water, and climate. The summit steering committee designed a suite of questions that were asked of participants in each working session. This report is a digest of the input from those who attended the seven working sessions and responded to the structured questions.

Keywords: *Great Plains, grasslands, working lands, invasive species, native plants, wildlife, fire, energy development, climate*

Cover photos: Working windmill, Pawnee National Grassland, Weld County, Colorado (photo: USDA Forest Service); tallgrass prairie is a complex ecosystem (photo: Dennis Larson, Natural Resources Conservation Service).

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INTRODUCTION

No single habitat in North America has diminished more than the temperate grasslands. It is estimated that Great Plains grasslands once covered more than 500 million ac (200 million ha) stretching from Canada to Mexico and encompassing at least parts of 12 different States (Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming). Multiple stressors threaten all components of this once immense sea of grass, from the carbon stored in the soil to the emblematic bison (*Bison bison*) that once roamed the full extent of the Plains. Land-use change and agricultural pesticide use in both the breeding and wintering grounds of Great Plains grassland birds have led to well-documented, steep declines in many species (Mineau and Whiteside 2013; Sauer et al. 2017; Soykan et al. 2016). For example, the current distribution of the iconic game bird species, Greater Prairie-Chicken (*Tympanuchus cupido*) is now substantially smaller than its historical distribution (Johnson et al. 2011; Svedarsky et al. 2003).

Altered land and water use in the Great Plains threaten major aquifers used for municipal drinking water, energy and industrial development, and agricultural crop irrigation (Braxton 2009; Buchanan et al. 2015; Parker 2016). Loss of native grassland habitat for native pollinators threatens their populations and the pollination services that they provide to agriculture (Koh et al. 2016). Invasive plants cause economic and ecological harm by reducing forage available to both native wildlife and domestic livestock. Altered fire regimes lead to woody encroachment and habitat degradation (Ratajczak et al. 2012). Energy development of all kinds disturbs ground and disrupts wildlife (Post van der Burg et al. 2017; Shaffer and Buhl 2016). Climate change introduces more powerful storms and is likely to bring longer or more severe drought episodes to the Great Plains region, which already has a highly variable climate (Shafer et al. 2014).

Despite the important role that grasslands play in ground water recharge, this immense ecosystem is poorly represented in conservation areas when compared to other ecosystem types in North America. Successful long-term management to sustain economic and ecological communities of Great Plains grasslands requires collaboration across private and public boundaries. To this end, the Rocky Mountain Research Station (RMRS), in partnership with the Agricultural Research Service (ARS), Natural Resources Conservation Service (NRCS), Western Association of Fish and Wildlife Agencies (WAFWA), Great Plains Fire Science Exchange, and many other agencies and organizations convened a summit of existing knowledge about challenges, opportunities, values, methods, and tools for managing Great Plains grasslands. The Great Plains Grassland Summit: Challenges and Opportunities from North to South was held April 10–11, 2018 in Denver, Colorado. The geographical focus for the summit was the entire Great Plains.

The purpose of the summit was to better understand stressors to and resource demands in Great Plains grasslands and how to manage them, and to discuss methods for improved collaboration among natural resource managers, scientists and stakeholders (e.g., Davenport et al. 2007). The summit was designed to provide: 1) syntheses of information on key grassland topics; 2) networking and learning

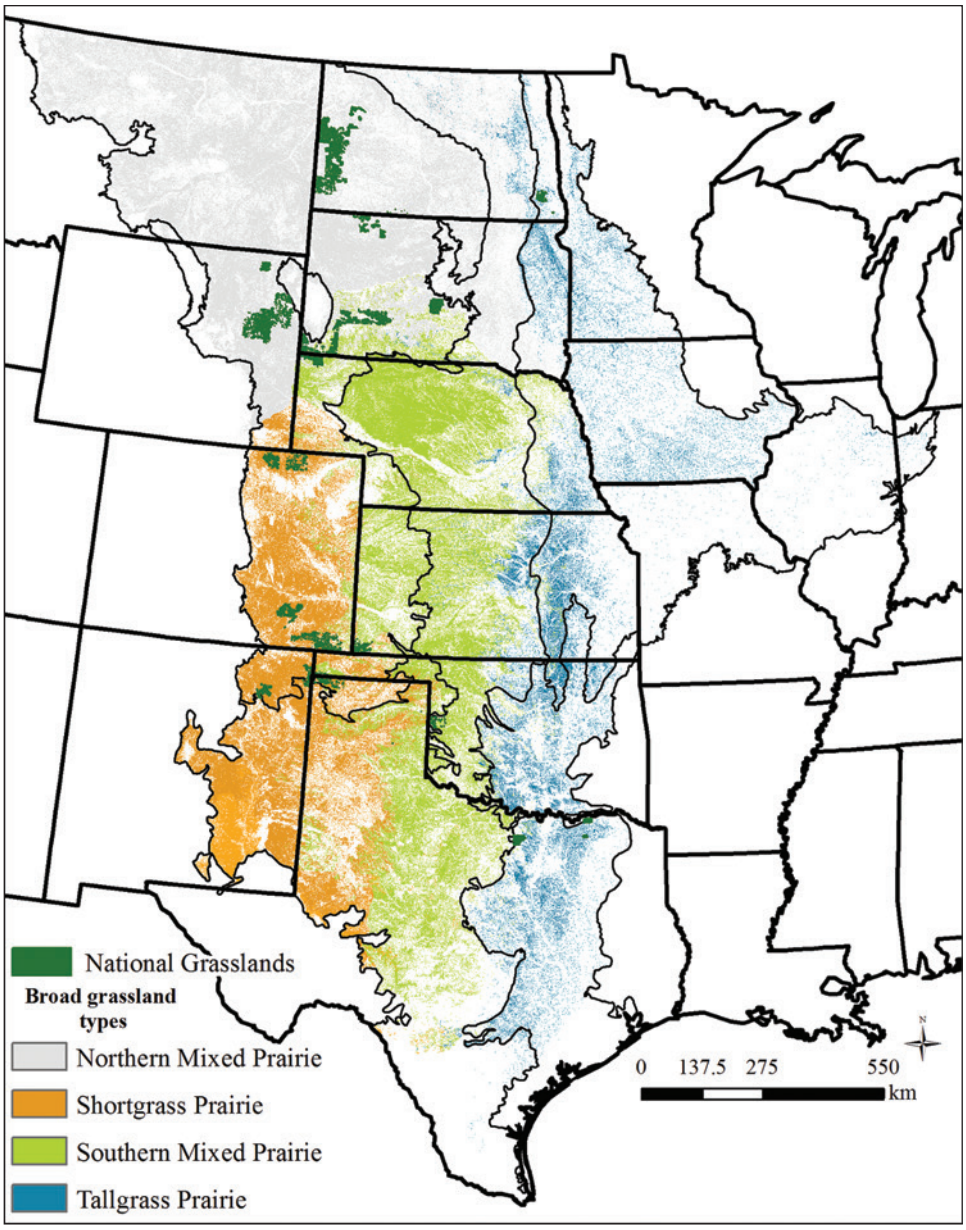

Figure 1—The location of the Great Plains study area, depicting four dominant grassland types. National grassland locations are also noted (adapted from Cleland et al. 2007 by Matt Reeves, USDA Forest Service, Rocky Mountain Research Station).

channels for managers, researchers, and stakeholders; and 3) working sessions on challenges and future research and management opportunities. More knowledge is needed to sustain Federally managed national grasslands, refuges, and parks and State, private, and tribal grasslands under increasingly complex environmental, social, and economic conditions. Highlighted stressors ranged from invasions by nonnative species, natural disturbances, and habitat loss and fragmentation to drought, inclement weather, and climate change. Human uses and demands for water, oil and gas, livestock production, crop cultivation, and recreation were discussed in relation to conservation of native species and management of lands for nonconsumptive purposes. The summit investigated ideas and opportunities for adaptively managing grasslands with diverse tools and in partnerships.

In addition, the summit explored collaborative processes for generating new knowledge and for involving producers, conservationists, scientists, and other stakeholders in management decisions (e.g., Hart et al. 2016; Hoffman and High-Pippert 2010). Methods were discussed for managing challenges, restoring altered environments, and acting on science and management opportunities through cross-boundary collaborations, "co-production," and "structured decisionmaking." Biers et al. (2017) defined co-production as "collaboration among managers, scientists, and other stakeholders, who, after identifying specific decisions to be informed by science, jointly define the scope and context of the problem, research questions, methods, and outputs, make scientific inferences, and develop strategies for the appropriate use of science." Structured decisionmaking is an approach to identify alternatives, evaluate tradeoffs, and make decisions in complicated situations (Gregory et al. 2012; Thompson et al. 2013). The sequential steps of structured decisionmaking are 1) problem framing, 2) elicitation of objectives, 3) development of alternatives, 4) evaluation of consequences and tradeoffs, and 5) deciding on and taking action. Input of knowledge from scientists and clients is typically integrated into the structured decisionmaking process. Risk, uncertainty, and linked decisions are also incorporated as appropriate throughout the process.

On the morning of April 10, plenary speakers set the stage for breakout sessions by delivering syntheses of information. Their Microsoft® PowerPoint presentations are available online at Great Plains Grassland Summit. We hope to publish these syntheses as another product of the summit in a special issue of a peer-reviewed journal. We have solicited additional manuscripts for the special issue on topics not covered by the plenary speakers.

A poster session was held during the evening of April 10. Over 50 posters, many currently available on the summit website, were presented by students, professionals, researchers, and practitioners from diverse States and institutions. Exhibits by companies, professional societies, government agencies, universities, and other organizations also were displayed.

Figure 2—A diverse mixed grass prairie with few invasive plant species (photo: Amy Symstad, U.S. Geological Survey).

STAKEHOLDER PARTICIPATION

Most of the 200 summit registrants participated in working sessions. Participants came from all of the Great Plains States and beyond, representing:

- Federal natural resources management agencies
- State agencies
- Tribes
- Private individuals and businesses
- Nongovernmental organizations (NGOs)
- Research universities
- Government scientists

Summit participants signed up for working sessions by selecting the session they were most interested in during online registration and by selecting an alternate session in case their first choice was full. Working session topics on priority areas were working lands (e.g., ranching and rural futures), native wildlife and biological diversity, native plants and pollinators, invasive species, wildland and prescribed fire, energy development, and weather, water, and climate.

PROCESS FOR WORKING SESSIONS

The summit steering committee designed a suite of questions that were asked of participants in each working session. The questions were the same across each theme so that input could potentially be compared across themes.

Leaders for the working sessions were selected for their expertise and training in the topic area and included scientists, managers, and stakeholders from State and Federal agencies, universities, and NGOs. Session leaders encouraged attendees to express their views, ideas, and priorities in response to the questions and ensured that the questions were answered during the session. Leaders and note-takers assembled session results and delivered them to editors. Trained facilitators were available for larger sessions. Recommendations for conservation of and research on Great Plains grasslands were developed from the notes. The recommendations reflect the input of those in the working sessions and should not be interpreted as the consensus views of the report's editors and authors.

Figure 3—Working windmill, Pawnee National Grassland, Weld County, Colorado (photo: USDA Forest Service).

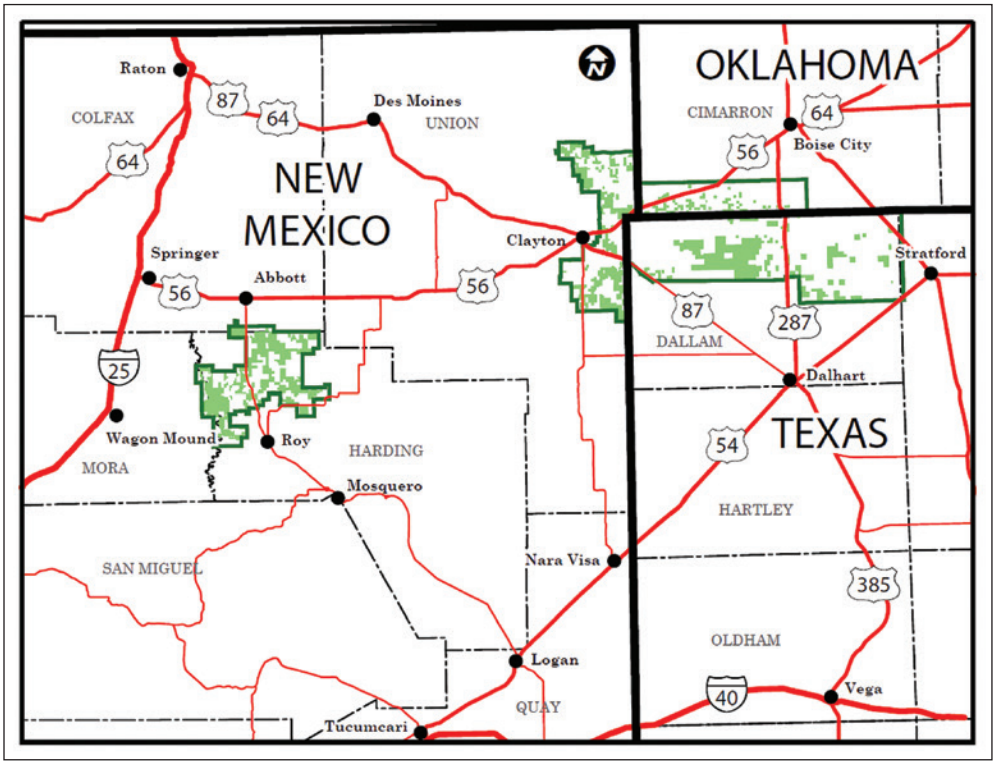

Figure 4—Kiowa and Rita Blanca National Grasslands (green areas) manage a checkerboard of lands across multiple states bordered by private holdings (map: USDA Forest Service).

WORKING SESSION QUESTIONS

1. ***Prior Management Actions (discussed for 60 minutes)***

    a) Give examples of past decisions and actions that have been successful. Define success and how it was measured.

    b) Was monitoring or assessment used to evaluate the effectiveness of an action or plan, and if so, what kind of monitoring was applied? Was it helpful in assessing the action's outcome?

2. ***Current Challenges and Barriers (discussed for 60 minutes)***

    a) Describe multidisciplinary and cross-jurisdictional challenges pertaining to this topic.

    b) What actions, if any, can be taken to overcome barriers?

3. ***Current Opportunities and Future Management Actions (discussed for 60 minutes)***

    a) Describe current opportunities and future actions for making advancements in this focus area.

    b) What players and partnerships are needed to facilitate these actions?

    c) Describe potential sources of funding, levels needed, and necessary steps.

4. ***Research Needs and Actions (discussed for 90 minutes)***

    a) What syntheses, assessments, models, and tools are needed, and is existing information sufficient to develop these?

    b) What new knowledge and/or data are needed by land managers to help solve problems?

    c) Describe potential sources of research funding, levels needed, and steps to obtain funds.

5. ***Bridging Science and Management through Co-Production of Actions and Results (discussed for 60 minutes)***

    a) What steps can managers, scientists, and stakeholders take to work more effectively together?

    b) Making sound management decisions increasingly depends on codevelopment of knowledge, decisions, and actions by managers, scientists, and stakeholders. What can be done to encourage co-production (Nel et al. 2016)?

    c) Give examples of how science and client input were used in adaptive management and structured decisionmaking (Gregory et al. 2012, Thompson et al. 2013).

WORKING LANDS PRIORITY AREA

Prior Management Actions

Definition of Success

The success of management projects was defined in three general ways: implementation, community engagement, and functional grassroots partnerships. The scope of projects or partnerships was not important in defining whether they were successful. Several examples of small projects or collaborative working groups were presented. Community engagement and functional grassroots partnerships were critical to the implementation of nearly every successful project. In several instances the continuity of a functioning group of partners was considered a success in and of itself.

Examples of Success

In many cases, private landowners are open to new ideas if the ideas come from a trusted neighbor or fellow landowner. These relationships have been leveraged by hiring a landowner liaison and building neighbor cooperatives. In one case, the liaison built a network of more than 80 landowners who altered their management practices to protect and monitor nest sites of Mountain Plover (*Charadrius montanus*) while continuing operations. Similarly, expansion of woody plant species into grasslands has been addressed through grassroots organizations of landowners who set up prescribed burn cooperatives that help each other apply fire to their lands. The formation of both of these groups has been driven by landowners. In another example, volunteer fire departments used prescribed burns as fundraisers that benefited the community and the landscape. Certain programs, such as the Beginner Farmer Rancher Program in South Dakota, establish mentoring opportunities among landowners that enable younger generations to learn from others' experience and strengthen relationships within the community.

Some successes came from taking advantage of particularly difficult, controversial, or uncertain situations. In these cases, convening a diverse group for discussion was considered a success. Examples included management of prairie dogs (*Cynomys* spp.), efforts to avoid a listing of the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) under the Endangered Species Act of 1973, preservation of Conservation Reserve Program benefits, and motorized vehicle use. On the Thunder Basin National Grassland in Wyoming, collaborative efforts involving time, work, and trust have resulted in a group of 16 cooperators who map prairie dog colonies and implement restoration and management projects.

In Montana, financial incentives to grow vegetation buffers and the use of conservation credits to encourage easements on private lands have reduced the number of prairie dogs poisoned and their movement to undesired areas. An innovative partnership that used environmental trust dollars to implement cost-share improvement projects in preparation for the termination of the Conservation Reserve Program ultimately resulted in the preservation of more than 10,000 ac (4,000 ha) of grassland. After a controversial court decision upholding limits on use of motorized

Figure 5—The mission of the Natural Resources Conservation Service (NRCS) is to provide resources to farmers and landowners to aid them with conservation. An NRCS range specialist assists a landowner with identifying grasses beneficial to good range management (photo: Natural Resources Conservation Service).

vehicles on a national grassland, managers invited the appellants to join a task force for managing 2,000 ac (809 ha) of a high vehicle-use area. The team relied on open exchange of information and equal ownership of decisions. The task force has received over $100,000 in grants and implemented multiple projects.

Although relationships among researchers, landowners, and managers can be difficult, the Collaborative Adaptive Rangeland Management Experiment is a particularly successful example of an adaptive management team. This effort seeks to understand ways to conduct science at the level of individual ranches with the involvement of managers and landowners (Wilmer et al. 2018). The 11 partners include researchers, ranchers, public land managers, and staff of NGOs and conservation organizations. The partners have prioritized desired outcomes from the experiment, determined criteria or triggers for movement of livestock among pastures, and selected monitoring data to inform adaptive management. The 10-year experiment began in 2012.

Current Challenges and Barriers

Current Challenges

Challenges generally fell into seven categories.

1. *Land-use change*. Several private landowners identified threats to their continued ownership and management of their lands, including regulation, eminent domain, and oil development. They perceived potential conflicts between energy development, including wind turbines and oil wells, and protection of wildlife and grasslands. Others identified the loss of grasslands to development and to growing human communities as a challenge.

2. *Ecological changes.* Managers, researchers, and private landowners recognized climate change as a challenge to the continued use of Great Plains grasslands. Participants expressed concern about the influence of increased atmospheric concentrations of carbon dioxide and warmer and drier conditions on the distribution and phenology of grassland plants. Additionally, drought and its effects on the ecology and economics of the Great Plains were identified as a major challenge.

3. *Economic uncertainty*. Landowners identified economic challenges, including declines in the price of beef and effects of uncertainty in climate and weather projections on their business operations. They mentioned the necessity of planning 13 months in advance and making conservative judgments about stocking rates and other business decisions on the basis of projections that have high uncertainty. Global economies and uncertainty in trade policies can also be a large hurdle for managers of working lands.

4. *Relationships*. Relationships between people and between humans and their environment are challenges. People have different justifications for how they interact with grasslands, and it can be challenging to bring together those with differing viewpoints. Lack of trust can be a major obstacle to sharing information and knowledge. Furthermore, conservation projects have ended early or were never implemented due to lack of support from the community. Participants also identified language and jargon used by different groups as a challenge to building successful relationships.

5. *Funding*. Not only are funds limited, but knowledge of how to obtain funding and the time periods during which funding tends to be available are limited. Several managers acknowledged, and participants agreed, that writing grant proposals is a skill, and insufficient training combined with limited time makes funding from many sources seem unattainable. The process of building trust may take longer than the period during which funding is available. Funding and staffing levels, particularly in public land management agencies, can be so low that simple actions take years to implement, thereby occasionally causing entire projects to fail.

6. *Spatial and temporal extents*. The necessity of working with spatial and temporal extents at a large scale creates major challenges. For example, a manager or landowner may invest funds and effort into the management of a small area, but neighbors may not manage their lands responsibly. Policy and limited funding can inhibit systems-based approaches that are long-term and extensive. Additionally, there can be long periods of time without any accomplishments. It is difficult to sustain trust without frequent successes.

7. *Policy*. Agency offices in small and rural communities often facilitate community engagement, and landowners value their services and offices. Closing or consolidation of these offices can sever agency relationships and hurt local economies. Participants agreed that in some cases Federal agencies support poor managers, which can have negative consequences for grassland condition. Management policies that aim to improve grassland condition but take years to implement are also problematic.

Figure 6—Repairing a fence together on the Arapaho and Roosevelt National Forest and Grassland, Colorado (photo: USDA Forest Service)

Current Opportunities and Future Management Actions

Opportunities were grouped into five themes: 1) partnerships and collaboration; 2) empowerment, education, and building capacity; 3) land uses and other environmental changes; 4) resilient and adaptive solutions; and 5) "contagious conservation."

1. *Partnerships and collaboration*. These opportunities involve creative and transparent community engagement including working groups, public forums, school visits, interagency partnerships, field trips, one-on-one partnerships, and volunteer groups. Partnerships can take advantage of established groups, such as conservation districts that already are trusted within communities, or they can be new groups such as burn cooperatives. Participants emphasized open and inclusive workshops and presentations to ensure that all stakeholders have the same information at the same time. Ideas included hosting fitness classes for ranchers to build community or having regular meetings in casual settings such as breweries or coffee shops.

2. *Empowerment, education, and building capacity*. These opportunities and future actions involve three main groups: producers, community liaisons (staff of NGOs, university extension, NRCS, and so forth), and the research community. An opportunity exists for bidirectional exchange of knowledge between scientists and landowners. Landowners have multidisciplinary knowledge of soils, vegetation, wildlife, economics, climate, and politics that they apply to management. Many landowners can be sources of data on current and past conditions because they monitor precipitation, phenology, and vegetation annually. These data not only offer opportunities for analyses by researchers, but can empower landowners to use their

existing knowledge. Some managers highlighted their one-on-one relationships with scientists and indicated that opportunities exist to increase the number of such partnerships. Similarly, peer mentoring groups, such as Beginner Farmer and Rancher programs, can pass knowledge among generations.

3. *Land uses and other environmental changes*. Many land uses and other environmental changes, such as exurban development, fragmentation, and climate change, alter grassland ecosystems. However, social, ecological, and economic crises also can create opportunities for conservation. Participants suggested that plans should consider the levels of uncertainty and control over drivers of social, economic, political, and ecological conditions and use these levels to identify actions that may be preventive, restorative, or adaptive. Preventive actions can increase the resiliency of the system and create economic buffers when it is difficult to control the driver. Opportunities for restoration exist when there is capacity to change the driver, and adaptive opportunities can help landowners and managers adapt to changes such as drought or different economic markets.

4. *Resilient and adaptive solutions*. Participants felt that both internal and external barriers to collaborative management should be identified and shared with communities and lawmakers. Searching for comprehensive political solutions allows processes to be streamlined and attitudes that reward poor management to be changed. Outreach to politicians also has the potential to encourage systems-based funding; to allow for management, restoration, and maintenance of whole systems; and to change laws that assign responsibility for ensuring property is protected from fire. On public lands, there are opportunities to involve permittees and the community in deciding where to implement prescribed fire. There also are opportunities to partner with researchers and to use local knowledge to improve monitoring. Efforts should focus on finding willing partners, potentially university field or laboratory classes.

Figure 7—Many private, State, Tribal, and Federal government lands in the Great Plains are used for livestock production (photo: Matt Mortenson, ARS).

5. *Contagious conservation*. Start with small and simple projects that can be accomplished without much planning and analysis. These modest projects can be used to build relationships and obtain buy-in from stakeholders. Such opportunities aim to find a way to move forward rather than focusing on the numerous obstacles to action.

Research Priorities

The research needs identified within the breakout group revolved around systems-based approaches with improved monitoring to evaluate success. Working lands are social and ecological systems that require holistic, interdisciplinary study. Participants identified a need for research in sociology, anthropology, economics, and policy. Additionally, quantifying uncertainty would improve decisionmaking. Some participants suggested that research on why certain practices used by managers and landowners are working is preferable to scientists telling managers what they should be doing.

Participants called for research on, or assessments of, the following:

- How humans view themselves as part of their environment and what factors affect that view.
- The culture of rural agricultural communities.
- The economics of working lands and quantification of ecosystem services in systems that are considered to be properly managed versus those that are degraded.
- Methods for simplifying regulation and streamlining the process of implementing simple management actions on public lands.

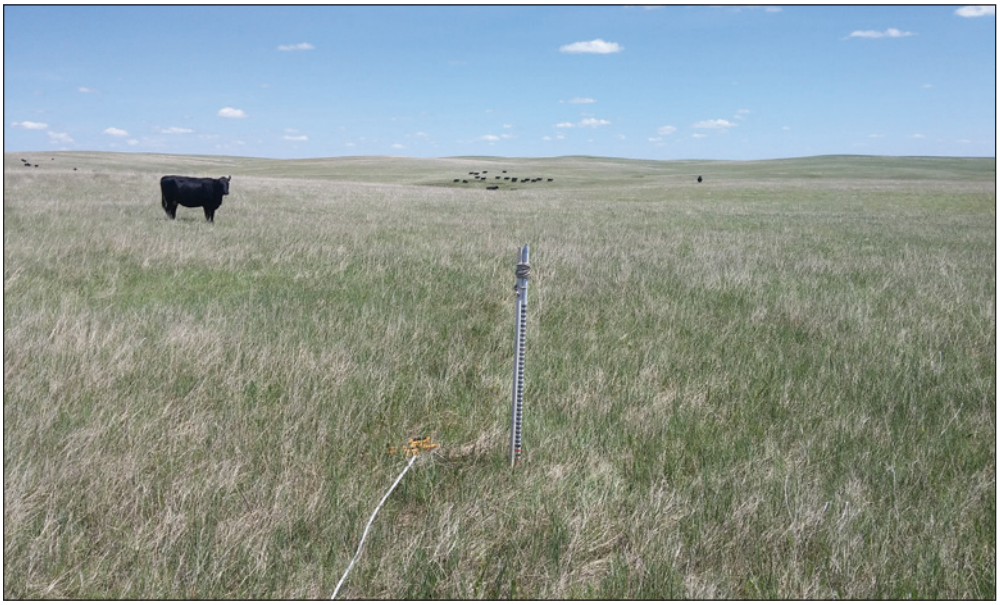

Figure 8—Equipment for forage and plant phenology measurements to relate timing of grazing to vegetation greenness via satellite data (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

- Methods for engaging and improving partnerships among managers, landowners, and researchers. Development of a desk guide that includes facilitator and mediator resources, how to identify who should be at the table, what types of groups are needed for different projects, and identification of triggers for engaging mediators.

- Assessment of conflicting agency policies which produce incentives that can result in poor management, such as assistance programs that provide a financial incentive to not reduce stocking levels during drought.

- Assessment of management practices that facilitate systems-based projects

- Methods for marketing use of fire to managers and landowners.

- Assessment of levels of uncertainty and determination of ways to control social, economic, political, climatic, and ecological drivers of rangeland condition.

- A guide to searching for funding.

- Assessments of how to make case studies more convincing to researchers and to document perceived successes in a more quantitative or statistically rigorous manner.

Bridging Science and Management

Several steps for bridging science and management and encouraging co-production were identified. First, begin the process by asking landowners and managers to identify their goals. Next, create a project plan with priorities, timelines, milestones, and partners that include researchers. Coordinate similar projects or actions across large areas and incorporate experimentation to ensure that research results are included in the adaptive management cycle. Whether actions are effective should be monitored, and monitoring can be improved via landowner observations. Track and store landowners' data to facilitate data sharing; such information can empower landowners in their decisionmaking. A critical step in bridging science and management is learning from successes and failures and communicating this knowledge to others. To this end, studies demonstrating both successes and failures should be published. Likewise, trust and ownership through open sharing of information increase the likelihood of success.

Communication, trust, and outreach among scientists, managers, and landowners can be improved by increasing the representation of social scientists. More outreach to landowners and increasing their access to meetings such as the Great Plains Grassland Summit will increase their representation. Participants recommended identification of settings and situations where opportunities for success appear to exist, such as locations with influential, willing, and geographically well-positioned landowners who can function as messengers to a broader community. Partnership programs that pair one scientist with one landowner or manager would improve relationships and give both parties a resource for co-production.

NATIVE WILDLIFE AND BIOLOGICAL DIVERSITY PRIORITY AREA

Conservation and management of grassland species and their habitats have been addressed in a fragmented manner through various recovery plans, conservation agreements, State management plans, and other planning documents. Actions associated with grassland conservation are often costly or inadequately funded. This section is intended to to apply context for applying a multistate, partnership approach to develop a comprehensive, grassland-conservation strategy that includes actions to help stabilize and expand grasslands while halting and reversing declines of wildlife species dependent on them.

Prior Management Actions

Successful past management actions involve Mountain Plover in Colorado; prairie dogs in the Conata Basin, South Dakota; Farm Bill programs such as the Conservation Reserve Program (CRP) and State Acres for Wildlife Enhancement (SAFE); grazing management prescriptions; and management approaches supported by university extension outreach.

Mountain Plover researchers worked with local landowners to negotiate a 3-year research window and avoid a listing of the species under the Endangered Species Act. Mountain Plover monitoring continues with landowner involvement. Prairie dog management in the Conata Basin resulted in an increase in the area of prairie dog habitat and population health through consolidation of land ownership, plague management, prairie dog-free buffers around private property, and shooting restrictions. These actions helped to restore prairie dog populations after the plague cycle subsided in the area.

Figure 9—Black-footed ferrets, an endangered species of the Great Plains, use prairie dog burrows as dens to raise their young (photo: Kimberly Fraser, U.S. Fish and Wildlife Service).

CRP and SAFE resulted in research on prescriptive grazing to benefit wildlife and led to adaptive management at a landscape scale. Such species as Greater Sage-Grouse (*Centrocercus urophasianus*), Lesser Prairie-Chicken, and black-footed ferret (*Mustela nigripes*) have been included in the Working Lands program administered by NRCS. Subsequent monitoring of conservation actions under this Federal program have revealed population increases, which have led to further funding by NRCS and continued Congressional support for this program.

Monitoring metrics ranged from presence and absence of wildlife species and number of acres of grazing or habitat to more complex measures of effectiveness and validation. Flexibility in monitoring goals and implementation may be needed in the presence of changing conditions. Accounting for socioeconomic conditions was identified as vital to program success but is currently not adequately considered or monitored during implementation.

Current Challenges and Barriers

Barriers and challenges included conflicting management goals across jurisdictions and land ownership, mismatch of scale between collecting data and applying the results of data analyses, discrepancies between funding allocation and management priorities, and balancing wildlife needs with energy development and other socioeconomic needs.

Suggestions for overcoming barriers included:

- Standardizing mapping of protection efforts across a landscape
- Recognizing that building relationships and sharing values at a local level is a vital component of successful programs
- Improving spatial targeting tools like WAFWA's Crucial Habitat Assessment Tool to ensure that important habitats are located next or close to each other versus a scattered and isolated approach across the landscape
- Reducing barriers to collecting and analyzing data
- Encouraging interstate working groups to standardize data collection methods, data storage, and program implementation
- Determining acceptable levels of uncertainty in data collection and analysis
- Ensuring that monitoring produces useful information
- Exploring nontraditional sources of funding such as nonconsumptive wildlife viewing, energy development, and outdoor recreation sources
- Communicating stories that appeal to diverse populations, such as stories concerning stewardship and a sense of place

Figure 10—Long-billed Curlew (*Numenius americanus*) chick found during surveys on Buffalo Gap National Grassland, Wyoming (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

Current Opportunities and Future Management Actions

The discussion on current opportunities focused on the use of existing structures and programs coupled with the creation of local and regional partnerships. Current opportunities include the following:

- Improve the effect of Farm Bill conservation programs on animal species and enhance the capacity of Farm Bill public-private partnerships (e.g., the U.S. North American Bird Conservation Initiative, U.S. Committee 2017)
- Work with sponsors of the Farm Bill and the NRCS to raise the CRP acres enrollment cap
- Collaborate in partnership projects centering on focal species
- Engage in regional conservation planning and actions for individual species, such as Greater Sage-Grouse or Lesser Prairie-Chicken
- Support the use of science to enhance the effectiveness of Farm Bill conservation programs (e.g., U.S. North American Bird Conservation Initiative)
- Implement State wildlife action plans in cooperation with State wildlife agencies
- Coordinate with tribal wildlife agencies on fundraising
- Incorporate remote sensing in identifying conservation actions and priorities
- Support the black-footed ferret recovery partnership among the U.S. Fish and Wildlife Service, national grasslands and parks, States, landowners, and NGOs

- Where possible, use the results of the North American Breeding Bird Survey and Christmas Bird Counts to set priorities and inform actions related to bird conservation

- Support and collaborate with the Forest Service on national grassland wildlife species recovery efforts and cross-boundary projects

- Engage in the Northern Great Plains Initiative of the National Fish and Wildlife Foundation

- Participate in the NRCS Regional Conservation Partnership Program

- Encourage development of native plant restoration materials through ARS and Forest Service networks

- Engage in WAFWA's Western Grassland Initiative

Opportunities for initiating or expanding partnerships include the following, with emphasis on starting partnerships and gaining acceptance by landowners:

- U.S. North American Bird Conservation Initiative joint ventures

- Farm Bill public-private partnerships

- Collaboration between private landowners and natural resource conservation districts

- Multistate partnerships

- Collaboration with national grasslands

- Participation by private businesses in conservation, such as the Forest Service's partnership with the Coca-Cola Company and the outdoor retail industry

- Crop and grazing groups, such as no-till groups

- Partnerships with tribes

- Agricultural organizations such as the Farm Bureau

- NGOs and Federal-NGO partnerships

- Ecotourism initiatives and local chambers of commerce

- Academia, government research, and other research institutions

- Landowners and groups organized for conservation, such as the Thunder Basin National Grassland Collaborative and the Wyoming Blackfoot Challenge Community engagement for species conservation (e.g., butterfly gardens and citizen science)

Advice for Raising Wildlife Conservation Funds

Potential sources of funding included Federal grants, Federal agency agreements, State wildlife grants, Farm Bill, partnerships and investment collaborations across species, outdoor recreational industry, NGOs, zoos, conservation easements, programs with Federal and State funding, legislatures and general funds, and farming and energy industry partners (e.g., marketing for agricultural products that complements conservation measures). Federal legislation under consideration at the time of this publication, such as the Botany Bill and Recovering America's Wildlife Act, would provide additional funding sources.

Participants also offered advice for writing proposals and applying for grants, or other fund-seeking actions. First, the framing of the proposal for funding is very important. When an applicant is seeking funding for a project that requires public support, telling a story about a single species and how it relates to an entire ecosystem may garner more support than a funding request for a whole ecosystem or a general group of species. Linking conservation to what most people want and expect from natural resources, such as clean air and clean water, will also gain public support. Second, a positive message is more attractive than a negative one. For example, asking for funds that pay landowners for wildlife damage to their crops or livestock is often not successful. Rather, the funding request should be described as an investment in wildlife conservation. Third, a funding request should have a clear target and outcomes that link to the objectives and mission of the funding source. Finally, be careful when choosing a source that requires matching funds, as acquiring those funds can be difficult.

Figure 11—Kulm Wetland Management District, North Dakota, is in the heart of a prairie landscape marked by numerous wetlands called potholes. The area's wetlands and grasslands provide habitat for waterfowl and other wildlife species (photo: Krista Lundgren, U.S. Fish and Wildlife Service).

Figure 12—Once abundant in the Great Plains, the Greater Prairie-Chicken has become rare over much of its range due to habitat loss (photo: U.S. Fish and Wildlife Service).

Research Priorities

Research needs can be divided into three categories: interesting, important to know, and critical. All three categories involve major research areas of importance in wildlife species and habitat conservation including topics about specific taxa, economics and human dimensions, stressors and responses, counting and measuring techniques, ecological scales, management scales, monitoring, and habitat restoration and population recovery.

Needed Syntheses, Assessments, Models, and Tools

1. Development of decision support tools such as WAFWA's Crucial Habitat Assessment Tool for standardization of information reporting

2. Consolidation of existing research information on wildlife populations, habitat extent, population and habitat changes, impacts, and conservation models and designs

3. Creation of models that specify useful land management at local and landscape levels

4. Development of habitat management guidelines based on the best available science for use in management decisions about specific wildlife species

5. Collection of baseline inventory data to determine presence and absence of animal species, population numbers, and habitat availability

6. Implementation and participation in the North American Bat Monitoring Program to monitor multiple bat species over the same time and space (Loeb et al. 2015)

7. Creation and implementation of adaptive management programs that include wildlife components, incorporating the best science available in design of projects and adequate monitoring to determine project effectiveness

8. Development of metrics to identify changes in land cover and populations over time

9. Continuation and expansion of analyses and reviews of Breeding Bird Survey and Christmas Bird count data

10. Development of local and regional measures of stressors

11. Measurement and monitoring of stressors and examination of their effects relative to those of management activities, including restoration

New Knowledge or Data Needed to Help Solve Problems

1. Coordination and implementation of efforts to identify research gaps and priorities

2. Determination of changes in the distributions and populations of species affected by climate change, drought, and other stressors, and design of methods for mitigating stressors

3. Increased spatial mapping across Great Plains grasslands and other vegetation types, and integration of findings into species management

4. Analysis of spatially extensive data on species movements, distributions, and habitats, and creation of spatially extensive methods for conserving populations and their habitats

5. Experimental testing and monitoring of the effectiveness of conservation and restoration treatments for wildlife habitat and populations

6. Increased knowledge that improves animal dispersal and migration, and habitat connectivity, including guidance for incorporating research findings into management decisions in areas with highly heterogeneous ownership or jurisdiction

7. Collection and evaluation of long-term data to identify trends in populations and their habitats, and to forecast and determine scales of change

8. Greater research focus on native fishes and amphibians and their habitats, including identification of responses to stressors, trends, and restoration and conservation methods

Creation and expansion of collaborations and partnerships can improve funding opportunities through leveraging of resources. Potential sources of research funding include ARS funds for public lands conservation, National Institute of Food and Agriculture, National Fish and Wildlife Foundation, National Park Service Foundation, State agency competitive programs, Federal agency programs, and conservation innovation grants through NRCS.

Bridging Science and Management

Steps that managers, scientists, and stakeholders can take to work together more effectively include the following:

- Share the questions that need to be answered and define them consistently.
- Improve utilization of place-based groups and associations for the distribution of information and continuing education.
- Encourage public agencies to use the ARS as a model for identification and coordination of research and implementation.
- Use the Great Basin Consortium as a framework for developing a grassland consortium. This consortium is a group of partnering organizations that convene annual meetings involving managers, researchers, and other stakeholders to share science and management information.

To encourage co-production of knowledge, discussion participants recommended that scientists and managers develop more opportunities for scientists to showcase and communicate research results and discuss with managers how they can be used. Increasing the involvement and engagement of stakeholders at all stages of the project would facilitate greater application of science. In addition, it would be beneficial to combine science-based recommendations with cost-benefit analyses when demonstrating the value of a project or the implementation of research results to producers and other users.

Figure 13—RMRS researchers track movements of Greater Sage-Grouse using satellite Global Positioning System transmitters to understand bird responses to environmental changes (photo: Brian Dickerson, USDA Forest Service).

Science and client input are useful in adaptive management and structured decisionmaking. It is important to define the task or problem statement, develop the process, and rank project goals and objectives in partnership with stakeholders. Implementation of the Northwest Forest Plan (DellaSala et al. 2015; Thomas et al. 2006) may be a good example of the application of structured decisionmaking.

Figure 14—Bitterroot (*Lewisia rediviva*) flowering during a wet year on Thunder Basin National Grassland, Wyoming (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

Figure 15—Tallgrass prairie is a complex ecosystem, having not only grasses but also forbs, some trees, and a wide variety of insect and animal species (photo: Dennis Larson, Natural Resources Conservation Service).

NATIVE PLANTS AND POLLINATORS PRIORITY AREA

Prior Management Actions

Examples of successful management decisions and actions centered on stakeholder engagement and communication, increasing acceptance of innovative ideas and techniques, and improving grassroots efforts. Identifying these actions as critical components in management decisions was key to program success. For example, when researchers shared initial study results and the value of landowner contributions, participants found the results to be credible. Research results were also translated into management recommendations to demonstrate the study benefits, with the objective of increased adoption of innovative techniques.

Another example of successful stakeholder engagement was illustrated through a project involving Denver Botanic Gardens and homeowners with backyards adjoining an urban, 71-mile (114-km) recreation trail. Together, this collaborative partnership created a bike path "ecosystem" of pollinator-friendly plantings.

It was also recommended that projects be explained in a manner that ties to long-term benefits versus short-term negative impacts. For example, treatment of the nonnative water hyacinth (*Eichhornia crassipes*) with herbicides to clear thick growth from a navigable channel resulted in brief water toxicity but ultimately increased water yields for irrigation. For similar projects, the argument can be made that improving long-term service to stakeholders—in this case through ensuring higher and sustained flows to nearby farmers—more than offsets the initial inconvenience.

Suggestions for addressing cultural resistance to change included the following:

- Use language meaningful to the audience or stakeholders. Demonstrate or illustrate effective management approaches rather than just talking about them.
- Host face-to-face meetings at accessible and affordable venues to stakeholders.
- Continually engage youth. To stimulate interest in natural resources, educate students about native plant and pollinator ecology, share innovative ideas about land management, and foster stewardship values in future generations of landowners and managers. Examples of relevant youth programs include Texas Brigades, Future Farmers of America, and youth programs through the Colorado Association of Conservation Districts.
- Organize grassroots groups such as the National Grazing Lands Coalition to support ecologically and economically sound livestock grazing.
- Organize community meetings at which speakers discuss a challenge that they have identified. This theme was highlighted by the National Young Farmers Coalition in the blog http://www.youngfarmers.org/bootstrap.

Current Challenges and Barriers

1. *Program monitoring.* Rarely is program success monitored. Resource professionals lack the time to follow up on results of program actions. In addition, programs are not always science-based and therefore may be challenging to monitor.

2. *Communication.* Communication with the public about native plants and pollinators often is not a high priority. This can lead to erroneous assumptions, minimal community support, and little shared learning.

3. *Seeds and plant materials.* Restoration actions typically use traditional seed mixes and seedlings rather than native forbs that support pollinators. More emphasis and training on plants that support pollinators are needed (Olwell and Riibe 2016).

4. *Nonnative invasive species*. The value and success of planting areas intended to support pollinators are reduced when problems with nonnative invasive plants are not addressed.

5. *Focus*. Emphasizing treatment of symptoms (visible change) rather than problems (causes of change) can lead to shifts in plant community structure and composition that may have negative effects on pollinator populations.

6. *Herbicide applications*. Invasive plants in agricultural systems are traditionally managed by applying herbicides to entire fields. Impacts to native plants and pollinators would be lessened if applications are selective and appropriately timed.

7. *Traditional practices*. Traditions, philosophy, and practices in ranching and farming are passed down over generations. Progressive practices may not be readily adopted owing to long-established cultural practices and family customs.

8. *Urbanization*. The increasing rate of urbanization is eliminating native plant communities and pollinator habitat and fragmenting existing land cover. This loss of native plant communities has cascading effects.

9. *Native seed expense*. Use of native seed is typically expensive, in part because supply is limited (Plant Conservation Alliance 2015). Although there is interest in using native seed, funds to purchase seed are often insufficient.

Current Opportunities and Future Management Actions

Budgeting sufficient time for professionals to engage with stakeholders and make them feel valued and respected can help to overcome barriers and create opportunities. This can lead to their interest in a successful outcome and a shared dialog. Expanding apprenticeships for farming and ranching may increase the number of new or young ranchers who will be more likely to adopt sustainable practices that benefit native plants and pollinators.

Understanding what management actions are most needed across large cross-boundary landscapes and where in that landscape they are needed is a critical step in designing partnerships and management strategies that benefit native plants and pollinators. Use of prescribed fire might be valuable throughout the Great Plains, recognizing that different grasslands may benefit from different frequencies and timing of fire. In areas that have been affected by natural disasters, colonized by nonnative invasive species, fragmented by development, or affected by human activities, identification and implementation of methods for restoring rare and vulnerable plant species are needed.

Managers indicated that they would benefit from greater knowledge of best management practices for grazing rather than relying on perceptions of "range readiness," which is viewed as an obsolete rule-of-thumb approach for ensuring that seasonal grazing does not damage vegetation and soil resources (Perryman et al. 2005). Recommendations from State pollinator programs can advance management actions of benefit to pollinators and may be applicable to other States or Federal agencies.

Research Priorities

To address management and restoration needs, participants called for additional research, syntheses, and monitoring to:

- Evaluate and prioritize locations and methods for restoration with the greatest potential benefits to native plants and pollinators.
- Test the effects of different prescribed fire strategies on native plant species, including rare species and plants that support bees.
- Develop and test methods for improving the resiliency of plant communities in the face of drought, climate change, and other stressors.
- Develop strains of native plants that are adapted to the places where restoration is needed.
- Design and test approaches for restoring rare, vulnerable, and valued plant species and communities.
- Develop guidance for best management practices for livestock grazing in different grassland types and under different environmental conditions.
- Inventory and monitor rare, threatened, and endangered plants, and plants needed for the survival and reproduction of declining bees and other pollinators.
- Assess baseline conditions to support identification of future changes in native plant and pollinator communities.
- Develop standardized inventory and monitoring protocols for native plants, rare plants, bees, monarchs (*Danaus plexippus*), and other pollinators that can be used by multiple agencies and landowners.
- Design temporally and spatially extensive methods for collection of data on native plant and pollinator communities.

Figure 16—A patch of hoary verbena (*Verbena stricta*) is a great place to find pollinators on the Buffalo Gap National Grassland, South Dakota (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

Bridging Science and Management

Information about successful applications of science to management can be obtained through a variety of online professional-society newsletters and other publications, government science publication outlets and websites, and NGOs. Many of these sources include clearinghouses, databases, fact sheets, or centralized depositories about upcoming events, science applications, and research projects. For example, the Forest Service makes General Technical Reports publicly available in TreeSearch (https://www.fs.usda.gov/treesearch). Other government science organizations such as the ARS and U.S. Geological Survey (USGS) have comparable publication outlets.

The Plant Conservation Alliance, which includes over 350 public and private partners, is an excellent resource for information on native plant conservation. The alliance has an email listserve. The alliance published the National Seed Strategy for Rehabilitation and Restoration (2016), which outlines goals and needs for application of science to management and for developing and deploying native seed and seedlings for restoration. Oldfield (2018) published an update on the National Seed Strategy.

The National Seed Strategy has organized several task forces to address its objectives. Specialized projects under the Bureau of Land Management's (BLM's) native plant program (BLM Native Plant Seed and Plant Material Program) (Oldfield and Olwell 2015), Western Center for Native Plant Conservation and Restoration, botanic gardens (Blackmore and Oldfield 2017), and native plant societies are additional sources of co-produced information about native plants and pollinators and science-based restoration practices.

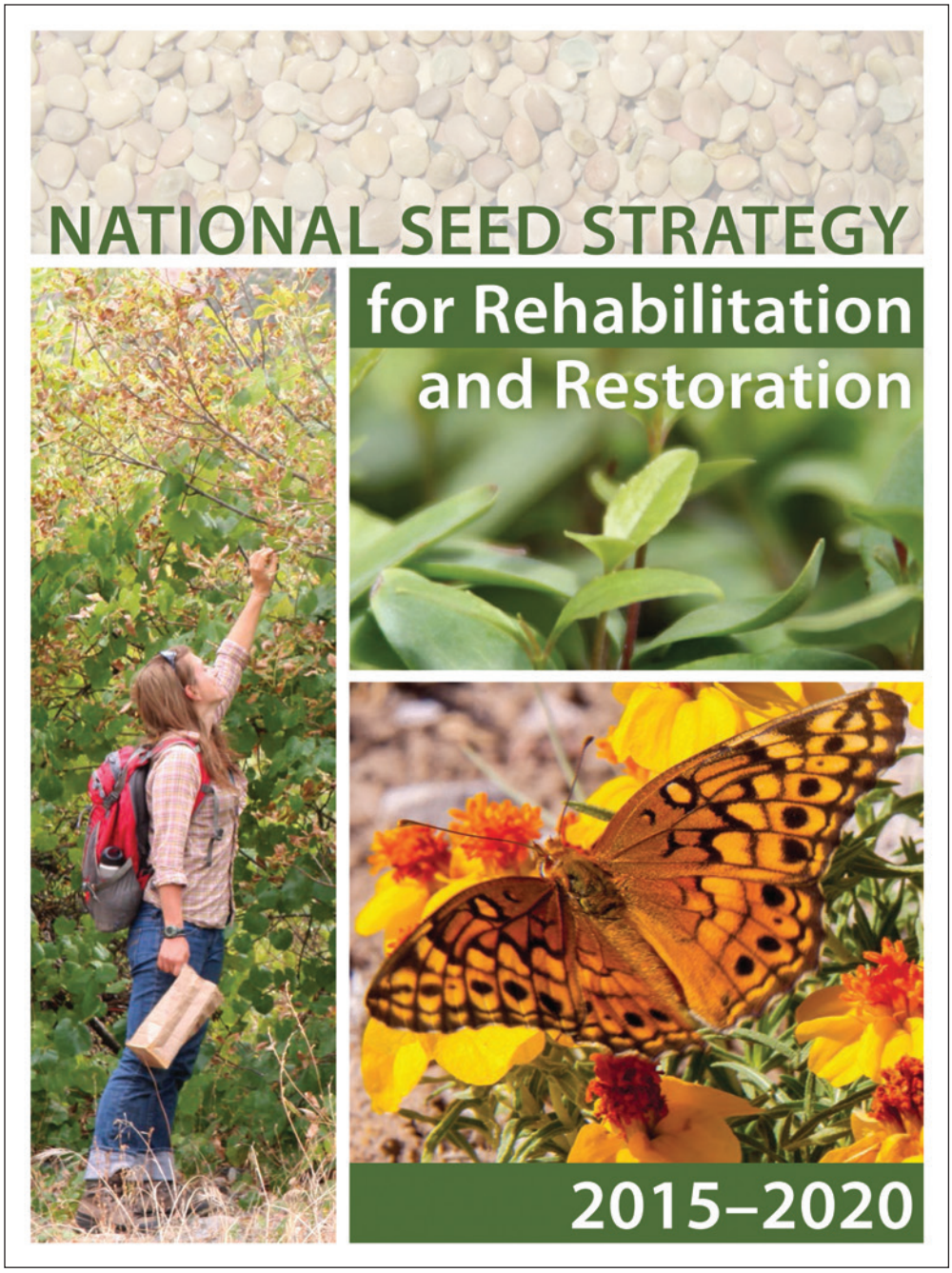

Figure 17—The National Seed Strategy has organized several task forces to address its objectives.

Prior Management Actions

Definition of Success

The definition of successful invasive species management depends on the goals of the agency or the individual. For many in the Great Plains, success is measured as increases in cattle weight. How success is defined also depends on the situation. In some cases in which an invasive species was discovered in a new location, success meant full eradication (at least in the short term and at that location). In other cases, maintaining the distribution or cover of the invasive species was considered a success because full eradication was not feasible.

There was consensus that two common measures currently used in many invasive plant programs—area treated or mortality of target species—are not meaningful measures of success. Suggested alternatives were: 1) area not colonized by invasives, 2) degree of change toward desired plant and animal composition and abundance, and 3) degree of target species control relative to economic and ecological cost (e.g., collateral damage to nontarget species).

Figure 18—Introduced and sometimes invasive yellow sweet clover (*Melilotus indicus*) has use for wildlife, but it can take over native pasture during years of optimal growing conditions (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

Examples of Successes

Examples of successful invasive species control always involved partnerships at a broad landscape scale and typically used integrated pest management. The Wyden Amendment (Public Law 105-277, Section 323 as amended by Public Law 109-54, Section 434) and subsequent Good Neighbor Authority legislation (https://www.law.cornell.edu/uscode/text/16/2113a), which allows Federal agencies to treat invasive species beyond their boundaries, illustrates a policy change that allowed partnerships to develop between Federal and State agencies. The Ecological Area-wide Management (TEAM) Leafy Spurge—an interagency, community effort to control leafy spurge (*Euphorbia esula*) in northern Great Plains States—illustrates a concerted effort to manage an invasive species that was causing ranchers to lose money. Similarly, partnerships have helped to control eastern red cedar (*Juniperus virginiana*) in the southern Great Plains. Historically a minor native species in the Great Plains, eastern red cedar now has an expanded current distribution owing to windbreak plantings, dispersal from plantings, and absence of fire. Efforts to control it have succeeded in some locations because of partnerships between agencies and private landowners, or among private landowners, to apply prescribed fire and mechanical treatments. Federal grants to States, State grants to private entities, and other types of partnerships increase success in part because they leverage or stretch funding, but also because they work across boundaries.

Other examples of successful invasive species management include tools for identification, inventory, and monitoring of invasive species or their biocontrol agents, and strategies for rapidly responding to new colonizations. The online Early Detection and Distribution Mapping System (https://www.eddmaps.org) provides a platform for citizens, managers, and scientists to upload and download

Figure 19—Widely planted in roadsides and pastures, smooth brome (*Bromus inermis*) provides valuable erosion control and forage, but it also invades native prairies, where it forms a monoculture in place of a diverse mix of native grasses and forbs (photo: Amy Symstad, U.S. Geological Survey).

invasive species distribution data. It provides basic information about a wide range of species, and an invasive plant mapping handbook. In Idaho, BLM, Idaho State Department of Agriculture, and other entities are partnering on biological control of at least nine plant species. A critical component of this effort is monitoring the effect of each biological control agent with a standardized protocol. In Wyoming, calls for a statewide early detection and rapid response strategy are being realized through partnerships for species such as rush skeletonweed (*Chondrilla juncea*) and yellow star-thistle (*Centaurea solstitialis*). Other examples of success were simply the increase over time in education of and outreach to the public.

The long-term, consistent monitoring of vegetation in National Park Service units provided by the National Park Service Inventory and Monitoring program illustrates spatially extensive evaluation of the effects of management.

Current Challenges and Barriers

Participants identified seven current challenges.

1. *Money, time, and attention*. The most obvious effects of limited funding are fewer staff and less staff time to learn about how invasive species can be controlled. In many agencies, this work increasingly is allocated to staff who have other higher priority duties. These limitations on staff can result in an inability to develop experience and knowledge of invasive species. Lack of time or agency support for face-to-face meetings between researchers and managers is also a challenge.

2. *Relationships and personalities*. The lack of staff dedicated to invasive species management and staff turnover can challenge the development of communication and trust within the invasive species community—researchers, land managers, and private landowners. However, turnover in research and management staff or landowners sometimes brings in new ideas, reduces resistance to change, and encourages people to try new things.

3. *Conflicting goals*. Conflicting or different goals within and among agencies and regions are a source of concern for many managers. Adjoining counties or states with different noxious weed lists can have different priorities, hampering cross-boundary partnerships. Public and private nurseries continue to develop, market, and sell potentially invasive species without considering whether they could escape cultivation and colonize natural areas. Similarly, some invasive species continue to be promoted or at least not controlled because they are seen as beneficial to some wildlife species. Participants offered an example of one branch of an agency promoting a species for biofuel production, while another branch of the same agency regards that species as invasive and is trying to eradicate it.

4. *Perception.* Some of the preceding challenges result from differences in perception. Limited funds for or attention to invasive species within agencies may stem from the differences in viewpoint between leadership and field-level operations staff. Leadership may include those responsible for noxious weed lists, which often drive policy and funding in different directions from those that field staff perceive as necessary or desirable. Different perceptions about the tools used to manage invasive species also lead to challenges. Fire is seen as effective and efficient by many managers, but risky and, given the smoke, unpleasant or unhealthy by others. Herbicides are seen as effective and efficient by some and poisonous by others, and the herbicide industry must address both of these perspectives when considering whether to spend the time and money needed to seek regulatory approval of a new chemical.

   Similarly, biocontrol agents are seen by some as the only sustainable option for control of some invasive species, but as expensive to develop, ineffective, or ecologically detrimental by others. The latter perception may result from unforeseen consequences from the use of biocontrol agents when the science of biocontrol was in its earlier stages. This perception was furthered by litigation relating to the use of several beetle species (*Diorhabda* spp.) as biocontrol agents. These species effectively control an invasive species (*Tamarix* spp.), which provides habitat for the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*). These conflicting goals and perceptions are seen in part as the reasons behind a substantial decrease in funding for biocontrol development over the recent past.

5. *Procedures*. Procedures required to implement management of an invasive species are often challenging. For example, if prescribed fires are allowed, they often are limited to times with the lowest chance of escape or when the wind is blowing in a certain direction. Such constraints may not be conducive to managing some invasive species adequately. Some agencies' adoption of new or additional herbicides may be delayed because of previous lawsuits related to herbicide use.

6. *Structure*. Invasive species management incentives and tools often are geared toward individual species, whereas a multispecies or ecosystem approach may be desired or necessary to achieve overall goals. A lack of landscape-level cooperative programs also makes invasive species management challenging. Where such programs (e.g., Cooperative Weed Management Areas) exist, their infrastructure may be weak.

7. *Information*. Information on how to most effectively manage some species is still lacking in some areas, as are reliable tools to help decide when and how to treat specific invasives. Transfer of new information from science and knowledge from the field is a continual challenge.

Figure 20—Pale yellow iris (*Iris pseudacorus*) can invade small waterways in the northern Great Plains (photo: Amy Symstad, U.S. Geological Survey).

Current Opportunities and Future Management Actions

Actions to overcome barriers and advance invasive species management fell into four general categories.

1. *Education*. Insufficient attention to invasive species from agency leadership, which can result in insufficient staff and funding, could be countered by conducting economic and ecological analyses of the costs and benefits of invasive species treatment, then presenting them to policymakers. Improving public awareness, from the local to the national level, of the problems caused by invasive species may encourage individuals to ask decisionmakers and policymakers to better address invasive species. Better public awareness may also improve problems that arise from conflicting goals and perceptions. For example, education that provides examples of the value of prescribed fire would be particularly valuable for reducing

negative perceptions of prescribed fire. Public education may come through incorporation of invasive species into school curricula, "Weed of the Week" columns in local newspapers, citizen science opportunities, celebrity spokespeople, or even an icon similar to Smokey Bear or Woodsy Owl.

Dissemination of information about invasive species management requires multiple approaches. Identifying and working with early adopters, both private landowners and public land managers, would provide the personal touch to information transmission that sometimes is required. Others might learn from eye-catching online storybooks or mobile apps, but these need sufficient detail on whom to contact, treatment methods, and what not to do if one encounters an invasive species. Field trips organized in cooperation with trusted, local sources (e.g., extension agents, State weed management associations, or local weed and pest offices) are also useful for educating a range of invasive species managers.

2. *Longer-term, more spatially extensive cooperative approaches.* Although major opportunities identified for spatially extensive, cooperative approaches centered on two species, cheatgrass (*Bromus tectorum*) and ventenata (*Ventenata dubia*), greater emphasis on managing multiple species simultaneously was mentioned repeatedly as a need. Tools that help managers prioritize their objectives, time, and funding among multiple species and in different settings will be helpful. Prioritization needs to be based on objective assessments of both economic and ecological effects of individual invasive species and the methods, including restoration, used to treat them. A shift in focus from control to restoration may possibly be more successful over the long term in controlling a large suite of invasive species, especially when threatened or endangered species are part of the ecosystem.

   Increased cross-disciplinary cooperation in goal-setting and project implementation, such as between fire and invasive species programs within agencies, would help limited resources to be used more effectively and potentially alleviate conflicts among programs. For example, chemically reducing populations of fire-stimulated invasives prior to a prescribed fire, or reducing the likelihood of a severe wildfire, may reduce postfire colonization or expansion of invasive species. Cooperative weed management areas exemplify the focused, comprehensive partnerships that participants viewed as necessary for advancing invasive species management. Cooperative weed management areas would be most effective if they were geographically organized and included all agencies and stakeholders in a watershed. However, participants cautioned against covering extremely wide areas (e.g., the whole Missouri River watershed).

3. *Policies to strengthen prevention*. Participants strongly emphasized the need for better control over the introduction and intentional spread of species that are known to be or may become invasive. The current assumption that species should be allowed into the United States or another jurisdiction unless known to be invasive is ecologically less defensible than assuming that a species is invasive unless proven otherwise (Simberloff et al. 2005).

4. *Data systems, and information synthesis and delivery*. Development of a single national clearinghouse of information on invasive species was suggested as a major opportunity for advancement of invasive species management and research. Such a clearinghouse would aid in standardizing procedures for reporting and verifying invasive species locations and control efforts. The clearinghouse would also provide a consistent location for information on the biology and noxious weed status of, and control methods for, individual species, information that is currently scattered among multiple State extension office websites, for example.

   The Early Detection and Distribution Mapping System platform is a good start to such a clearinghouse, but it is currently split among regions of the United States and is incomplete. Efforts have been made to standardize invasive species databases across agencies, but there is still much work to be done to achieve a national clearinghouse. For example, the National Park Service dropped its Alien Plant Control and Management database and instead built a system compatible with BLM's National Invasive Species Information Management System. All National Park Service units do not yet use this system, however, and other agencies have their own invasive species data management systems (such as the Forest Service's Threatened, Endangered and Sensitive Plants-Invasive Species [TESP-IS] software application). A national clearinghouse ideally would integrate with the USDA PLANTS Database to provide consistent information on species distributions. The creation and maintenance of such a clearinghouse might be facilitated through a nationwide invasive species institute. Such an institute would fund competitive proposals to collate information on, and develop action plans for, individual species or suites of related species.

Potential Participants and Funding Sources

Participants noted that development and deployment of technological solutions such as apps or information clearinghouses may require input from technology companies or experts, scientists, industry, and of course the intended users. Most of the opportunities listed would benefit from the inclusion of local, State, and Federal lawmakers and regulators, and the public and corporations.

Potential funding sources suggested by participants were the Western Governors' Association's Range and Forestry Initiative; programs targeting topics of current interest such as pollinators; targeted taxes or bonds, such as the Montana Noxious Weed Trust Fund, which receives partial funding from a 1-percent tax on herbicides sold in Montana; and large corporations.

Participants called for the following:

- A synthesis on invasive cool-season grasses in the Great Plains, because this suite of species affects nearly the whole region.

Figure 21—Honey locust (*Gleditsia triacanthos*) is a native of the Great Plains that invades tallgrass prairies in which fire has been suppressed (photo: Amy Symstad, Illinois Natural History Survey, used with permission).

- A set of peer-reviewed publications assessing the ecological effects, effectiveness, and economics of various invasive species prevention and management practices. A model for this work is the Conservation Effects Assessment Program, which quantified the environmental effects of conservation practices and government-funded programs. Such an assessment is necessary to prioritize research needs.

- A tool for prioritizing control efforts that includes ecological and economic components.

- A standard, sustainable platform for brief information syntheses on individual invasive species. Participants suggested using a standard format such as that used in the Fire Effects Information System which covers the identification, life history, and distribution of each species, but using a dynamic and sustainable platform such as Wikipedia.

- Development of a national framework for early detection and rapid response such as that described in the report released by the U.S. Department of the Interior (2016).

- A national clearinghouse for information on the distribution of invasive species. High-quality data on distribution are critical for models that effectively project the spread of invasive species.

- Application of drone technology to mapping and treating invasive species.

Research Priorities

Participants suggested that new knowledge and resources are needed with respect to the following:

- Methods to prevent the spread and establishment of invasive species.
- Better information on the basic biology of problematic species and the native species with which they compete. This includes better understanding of the biology of and interactions between soil biota and plants, which could promote the development of such biota for use as bioherbicides on undesired species or soil inocula that favor desired species.
- Improved restoration techniques. Investigation of largely untested techniques, such as selective grazing, could provide new options for restoration. Participants called for improved seed availability, resulting from research on seed collection and propagation of a broad range of species (not just grasses). More reliable methods for restoring native plant communities, especially for semiarid areas with highly variable precipitation, are also needed. Participants would like a better understanding of when restoration achieves specific management goals rather than simple management of invasive species.
- More experiments and models examining the effects of different scenarios of climate change and other environmental changes on the distribution and abundance of individual invasive species.
- Biocontrol agents that may provide long-term, low-cost, and less intensive solutions to some invasive species problems.
- Investigation of the services provided by invaded, novel ecosystems to compare to those provided by uninvaded systems.
- Information on how best to manage novel systems, or areas that cannot be restored, to maximize their ecological and societal benefits.
- Better understanding of how the public and different segments of society view invasive species and the methods used to manage them.

Potential funding sources can be large and small. One suggestion was to create an organization similar to the Great Basin Restoration Initiative to provide a united front for seeking funding on Great Plains topics. Procuring more funds from the Federal government for invasive-species research would require concerted engagement of the public and Congressional representatives. Some invasive-species research could be accomplished through funding sources that target related topics, including fire, wildlife, and pollinators. Some participants stressed the need to move beyond Federal funding for research and seek public-private partnership opportunities, or State and local grants. For example, in Colorado, funds dedicated to open spaces have been used for some research on treatment of invasive species.

Figure 22—Annual brome grasses (*Bromus tectorum* and *Bromus arvensis*; majority of foreground) are invading northern Great Plains grasslands, inhibiting native diversity (photo: Amy Symstad, U.S. Geological Survey).

Bridging Science and Management

Scientists, managers, and stakeholders work effectively together when everyone understands one another's constraints, so making the time to discuss constraints should improve relationships needed for effective partnerships. Although some scientists and managers naturally connect with each other, others need training to effectively communicate and work with each other and lay audiences. A possibility for such scientists or managers is to partner with colleagues who communicate more effectively. Stabilizing agency directions and priorities would improve scientists' ability to address high priority management topics. Managers need to communicate with scientists about what research is most relevant to their work, including the spatial scale at which research will be most applicable. Industries, extension services, and other entities developing control methods must work with managers to understand management objectives, which usually are not limited to mortality of a single species.

Co-production success stories will illustrate the benefits of being involved in co-production efforts to both managers and scientists. Safe Harbor Agreements and Candidate Conservation Agreements with Assurances limit the liabilities of landowners whose actions contribute to conservation of threatened, endangered, or candidate species; however, other types of agreements may be needed for research related to invasive species. Some scientists do not have incentives to participate in co-production because it often is location-specific and may not be valued by tenure review committees at universities or research grade evaluation panels in

Federal agencies. Increasing the value placed on this type of work by the scientific and management communities would encourage more scientists and managers to engage in co-production. A requirement by funding agencies to demonstrate co-production in proposals may encourage more scientists and managers to participate in co-production.

Examples of science input in adaptive management or structured decisionmaking included the Native Prairie Adaptive Management project of the U.S. Fish and Wildlife Service in northern Great Plains wildlife refuges, and the Annual Brome Adaptive Management project of the National Park Service in northern Great Plains parks. Both of these partnerships between the management agency and USGS scientists are targeting invasive cool-season grasses. Collaborative and adaptive rangeland management, which includes the ARS and agricultural, conservation, and public service stakeholders, can address multiple objectives, including grassland vegetation structure and composition. All of these efforts are relatively new compared to the century-old extension program. Created to foster research directly applicable to private landowners' needs, the extension program provided an information outlet primarily aimed at invasive species management in agricultural systems.

WILDLAND FIRE AND PRESCRIBED FIRE PRIORITY AREA

Wildland fire is endemic to grasslands. Grasses burn readily and regrow quickly, and prairie establishment and maintenance are dependent on fire. Both wildfire and anthropogenic fires have shaped the prairies.

Prior Management Actions

Definition of Success

Wildfire success usually centers on suppression, whereas prescribed fire success centers on the accomplishment of management objectives.

Examples of Success

No examples of successful wildfire suppression efforts were discussed, whereas participants provided many examples of the successful use of prescribed fire by Federal and State agencies and individuals. Fire departments have used prescribed burning to decrease fuel loads and maintain natural areas. Habitat for some animals has been improved through the use of prescribed fire. Increasingly, agencies and landowners are working together to implement burns that cross jurisdictional boundaries. Landowners are educating themselves through burn workshops and other programs. These educational opportunities allow landowners to more clearly define their objectives and tailor their burning to achieve those objectives. To more easily achieve management objectives, burn associations have formed to share resources, making burning safer and more likely to occur.

Federal agencies are conducting prefire and postfire monitoring to evaluate whether burn objectives have been met. Participants maintained that livestock gained more weight after grazing in burned versus unburned areas and that species diversity over space and time increased following burning and grazing.

Current Challenges and Barriers

A variety of challenges and barriers were discussed. Burn regulations can seem arbitrary and vary widely across county, State, and Federal jurisdictions. Supervisors' support for prescribed burning varies and without a dominant fire-supportive voice at team meetings, prescribed burning can become a low priority. Research results can be conflicting or may not be applicable directly to management, to large areas, or to particular areas. Agency staffing is often insufficient to train ranchers in use of prescribed burning and to complete required prefire and postfire permitting and reporting tasks (e.g., archaeological surveys). Equipment, funding, and labor can be insufficient for full implementation of prescribed fire projects. Further, agency staff lack liability protection for training landowners in use of prescribed fire.

Figure 23—A fire crew ignites a prescribed fire at dusk for an experimental research study on the Kiowa National Grassland, northeastern New Mexico (photo: Paulette Ford, USDA Forest Service, Rocky Mountain Research Station).

Some actions have proven useful in overcoming or reducing barriers. Burn associations have been effective in using their political clout to shape local public opinion. These associations also increase ranchers' access to equipment and trained crews. Dissemination of successful burn case histories helps educate communities about burn plans and increase acceptance. Successful, existing training programs (e.g., Nebraska Wildland Fire Academy) can be expanded to other States. These collaborations also can make the most of limited training and education resources. For example, memoranda of understanding with The Nature Conservancy have expanded training and operational opportunities.

Current Opportunities and Future Management Actions

Partners such as burn associations, scientists, landowners, conservation districts, and local officials are all needed for effective collaboration. Implementation of common data collection protocols could greatly increase data sharing.

Funding for 10 or more years is needed to adequately monitor long-term effects. Some NGOs provide funding for landowners to conduct prescribed burns. Participants emphasized that funding and field protocols should address multiple objectives and not just fuel-load reduction.

Research Priorities

Needed Syntheses and Assessments

1. Synthesis of social and economic values in relation to grassland fire risk and use.

2. Improved methods for monitoring effects of fire and the efficacy of restoration following prescribed fire. Improved methods for sharing data across projects.

3. Modified national Ecological Site Descriptions maintained by NRCS to include fire and other ecological processes.

4. Expansion of existing monitoring of trends and fire severity to include grasslands, ideally by interagency groups.

5. Synthesis of information on the effects of fire on vegetation, wildlife, and other natural resources in Great Plains sagebrush lands.

6. Collection and synthesis of historical, traditional, and institutional knowledge about past vegetation and fires.

7. Expansion of the soil and moisture monitoring network started by the Forest Service and other agencies by engaging State forestry organizations and additional partners.

8. Improved understanding of spatially extensive fire probability, frequency, and patterns, and timing of fire use. Satellite imagery may provide some of these data.

Figure 24—McClellan Creek National Grassland, Texas, burned in the Interstate-40 Fire, February 2006. This wildfire was about 750,000 ac (304,000 ha) and resulted in loss of most of the grassland's trees (photo: USDA Forest Service).

Needs for New Knowledge and Data

1. Assessment of wildfire risk across the geographical range of the Great Plains using grassland-specific data. Publicly available remote sensing data often are forest-centric and do not focus on grasslands.

2. Determination of the value and risk of using prescribed fire as a restoration tool through use of experimental treatments and modeling under different scenarios of climate and weather.

3. Evaluation of potential scales for managing different species of interest with fire, and clarification of applications of research to local situations.

4. Evaluation of the roles, needs, and values of humans with respect to uses, effects, and risks of fire.

5. Dissemination of soil monitoring probes to landowners to monitor the effects of fire on soil moisture and assist them in analyzing the resulting data.

6. Improved understanding of soil moisture before and after drought and fire.

7. Improved understanding of fire as a restoration tool and its effects during drought and as climate changes.

Potential sources that may fund monitoring or research directly or indirectly through a management project include New Mexico Game and Fish, Nebraska Environment Trust, Great Outdoors Colorado, Audubon Society, USGS, Prairie Wildlife Research, National Wild Turkey Foundation, Rocky Mountain Elk Foundation, Bird Conservancy of the Rockies, Collaborative Forest Landscape Restoration Program, U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program, NRCS, Kansas Grazing Lands Coalition, conservation districts, Sustainable Agriculture Research and Education Program, Playa Lake Joint Venture, Pheasants Forever/Quail Forever, Quail Unlimited, habitat stamp program, Chickadee Checkoff, Mule Deer Foundation, counties, open space programs, Colorado Parks and Wildlife's Habitat Partnership Program, Wyoming Wildlife and Natural Resources Trust, Muley Fanatic Foundation, Wyoming Governor's Big Game License Coalition, New Mexico Big Game Habitat Enhancement Fund, The Nature Conservancy, World Wildlife Fund Northern Great Plains program, Northern Great Plains Joint Venture, and the National Fire Protection Association's Firewise USA® program.

Bridging Science and Management

It is important to involve producers and other stakeholders when determining research needs. All research plans should include a provision for technology transfer. Bringing science into management decisions is difficult when science is developed without manager input and management actions are taken without

consulting scientists. Incentives could be provided to encourage producers to participate in research efforts (e.g., testing whether brush removal creates more forage). Co-production could be enhanced by improving exchanges between agencies and encouraging staff to meet or work with personnel from other agencies or organizations.

The NRCS 9-step planning process and the Wildland Fire Decision Support System are suitable for structured decisionmaking.

Figure 25—Research Ecologist Jackie Ott (USDA Forest Service, Rocky Mountain Research Station) leads demonstration of burn box plots in Thunder Basin National Grassland, Wyoming. This study is being used to determine the effects of fire on invasive annual brome and sagebrush (*Artemisia* spp.) (photo: Brian Dickerson, USDA Forest Service, Rocky Mountain Research Station).

ENERGY DEVELOPMENT PRIORITY AREA

Prior Management Actions

Definition of Success

Management plans that reduce the undesirable effects of energy development are considered successful. Cooperation with energy developers is necessary to achieve compliance with management or participation in voluntary agreements. Stakeholder input, scientific information, and co-production help in development of management frameworks.

Examples of Success

Participants suggested that the Forest Service's management framework, which includes the Forest Plan, analysis under the National Environmental Policy Act of 1976, and approval conditions, may be a good example of a successful management approach. The Forest Service is responsible for surface operations of energy development but has no authority over mineral operations, which are under BLM and State jurisdiction. Activities that create surface disturbance must comply with the Forest Plan. Applications for surface plans are evaluated by the Forest Service and may require National Environmental Policy Act analysis. However, there are categorical exclusions, including applications in which individual surface disturbance is less than 5 ac (2 ha). Currently, all proposed actions require a public comment period; the public is notified, at minimum, through a schedule of proposed actions posted on the Forest Service's website. The Forest Service develops conditions of approval and inspects sites to assess compliance with the permit.

Figure 26—Pumpjack for an oil well, Pawnee National Grassland, Colorado (source: USDA Forest Service, https://www.fs.usda.gov/detailfull/arp/home/?cid=STELPRDB5356427&width=full).

To reduce impacts to Federally listed species from energy production, a candidate conservation agreement (CCA) may be used. A CCA is a formal agreement between the U.S. Fish and Wildlife Service and one or more Federal or non-Federal parties which addresses the needs of species that are candidates for listing under the Endangered Species Act. The CCAs specify actions that if followed by all participants, may reduce the probability of listing. A Candidate Conservation Agreement with Assurances (CCAA) is similar, but applies only to non-Federal landowners. Participants in a CCAA receive assurance from the U.S. Fish and Wildlife Service that if the species subsequently is listed, they will not be required to implement actions not specified in the CCAA.

For example, WAFWA assisted in creation of a CCAA for oil and gas companies to reduce undesirable effects of energy production on Lesser Prairie-Chicken habitat and to pay a mitigation fee for negative effects. As another example, the Thunder Basin Grasslands Prairie Ecosystem Association participates in a CCAA for private property, a CCA for Federal property, and a Conservation Agreement for conservation efforts associated with energy development. Federal agencies such as BLM also have developed CCAs for species including the Lesser Prairie-Chicken and dunes sagebrush lizard (*Sceloprous arenicolus*).

Habitat Conservation Plans allow a non-Federal entity to receive a permit allowing incidental take of specified species that are listed under the Endangered Species Act or that may become listed during the permit period. Landowners work with the U.S. Fish and Wildlife Service to develop a conservation plan. One example is the Great Plains Wind Energy Habitat Conservation Plan for Whooping Cranes (*Grus americana*).

Monitoring is used to evaluate compliance with these conservation agreements. Other Federal management plans are updated through revision of Forest Plans or resource management plans.

Current Challenges and Barriers

Given that time, staff, and information are limited, communication and coordination among agencies, landowners, and industry can be poor. The objectives of multiple stakeholders sometimes conflict owing to different organizational missions and disciplines. Organizations may have competing internal policies or weak connections among staff members and across sections. Staff turnover within agencies, and company sales and mergers, require continual reestablishment of communication and coordination.

Actions to overcome barriers include commitments to communication and coordination within and across boundaries. Face-to-face meetings to share concerns may be the first step. This may be followed by establishment of common and consistent best management practices, perhaps beginning with simple statements such as “We are all trying to manage grasslands sustainably.” Although this process does not require a formal contract, developing a memorandum of understanding, or a nonbinding agreement outlining terms and details, may be helpful to formalize mutual agreement. There is little interaction between the fossil fuel industry and researchers; third parties that have developed relationships can help facilitate contact.

Current Opportunities and Future Management Actions

In addition to developing shared understanding and a common set of best management practices, opportunities to find agreement include in-person visits or engagement in groups such as interdisciplinary teams or grazing associations. Knowledge of decision support tools for identifying project sites and conservation targets would help coordinate and prioritize management actions. Another avenue is expansion of voluntary agreements to generate funding for conservation. The rangewide conservation plan for Lesser Prairie-Chicken led by WAFWA provides tools and incentives to encourage landowners and others to voluntarily partner with agencies in habitat conservation. As another example, Tallgrass Energy and Rockies Express agreed to establish a mitigation fund managed by a third party in exchange for a pipeline construction permit from the Federal Energy Regulatory Commission.

Recovering costs from mineral extractors to use locally for resource management and offsets is not common, and will require staff and time. Restoration and mitigation options need to be prioritized on the basis of strong science. Grants can provide the seed money to fund staff, and energy development industries are a potential source of funding.

Research Priorities

Successful management includes decisions based on the best science available, adaptive management to improve science and management actions, and stakeholder involvement and feedback. Research is needed to provide information on the potential effects of energy development on water use and quality, air quality, soil and vegetation, restoration, invasive species, wildlife mortality and space use, fragmentation and road construction, levels of sound and light, society, economics, and human health. Results may vary as a function of temporal and spatial scale, land ownership, past land use, land cover and ecosystem type, other land uses and environmental changes, species, and type and attributes of energy development.

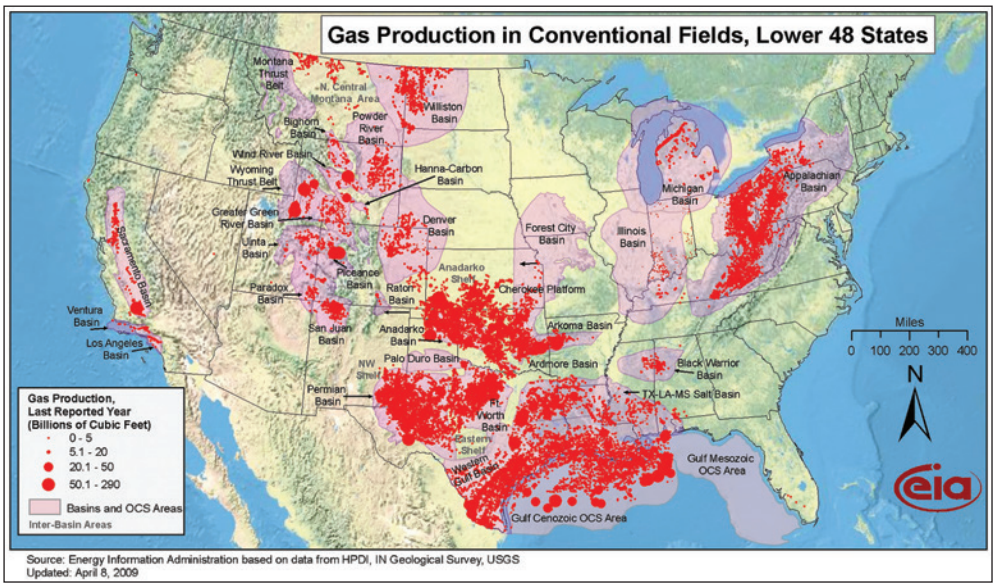

Figure 27—The Great Plains is an important area for gas production (credit: U.S. Energy Administration Information based on data from U.S. Geological Survey).

Limited knowledge of industry practices and lack of access to some sources of data can hinder researchers. For example, industry often does not share or co-produce information, such as curtailed use of wind turbines during bird migration. Third parties can help broker relationships. Funding sources include grants and industry.

Bridging Science and Management

Managers, scientists, and stakeholders can work more effectively together by communicating, pooling information, and developing shared goals. For example, WAFWA coordinated a Grassland Initiative Memorandum of Understanding, which may be a good basis for agreeing on management goals. A committee of decision-makers representing different stakeholders may be helpful. The Thunder Basin Grasslands Prairie Ecosystem Association provides a template for proactive leadership in land conservation and for ensuring that conservation strategies which are investigated, implemented, and promoted are responsible, science-based, long-term, and landscape in scale (https://www.tbgpea.org/conservation/conservation-strategy).

To encourage co-production, relationships can be established through one-on-one meetings and other conversations along with a formal program to match scientists with managers and stakeholders. Identifying partners at different State, county, municipal, and community levels, such as State land boards and conservation districts, may be helpful. Agreement may occur by identifying common management approaches and targets that are flexible enough to tailor to local contexts.

Figure 28—The Northern Great Plains Province and the Powder River Basin are important coal-producing regions in the Great Plains. Thunder Basin Coal Mine on the Thunder Basin National Grassland, Wyoming is one of the largest coal mines in the United States (photo: USDA Forest Service).

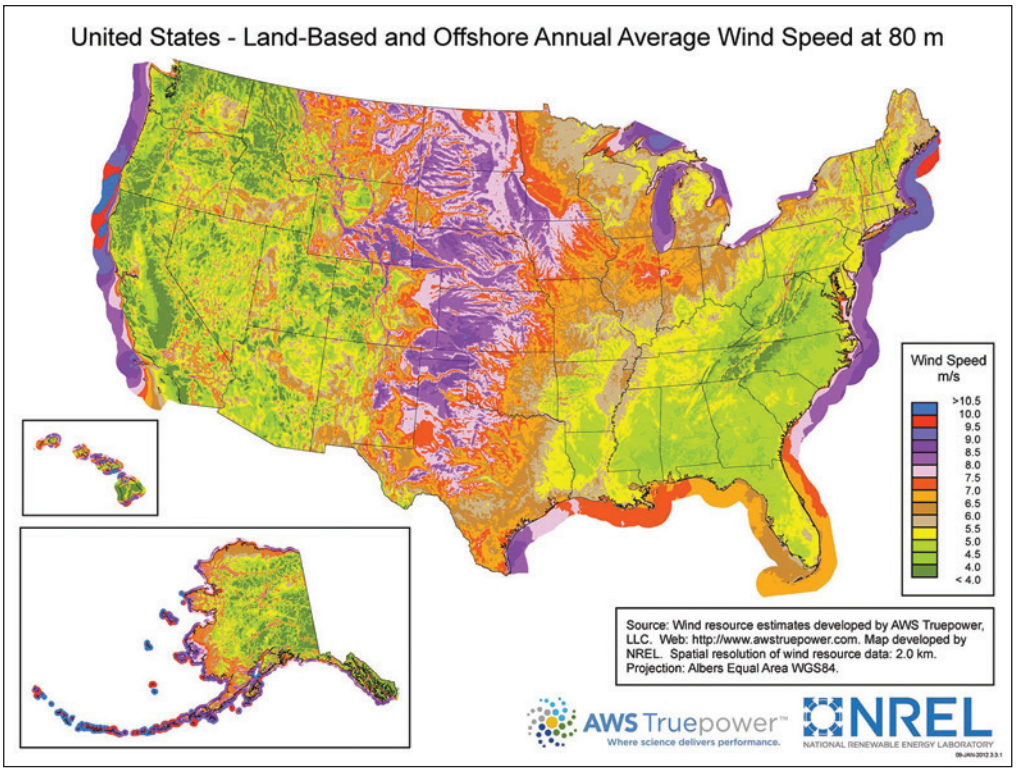

Figure 29—High wind speeds make the Great Plains an important region for wind energy production (credit: National Renewable Energy Laboratory).

WEATHER, WATER, AND CLIMATE PRIORITY AREA

Prior Management Actions

The overriding theme of the Weather, Water and Climate breakout session was that success can be achieved when ranchers and land managers develop common and concrete drought contingency work plans. Such work plans can be used during decadal and persistent drought, enabling ranchers and land managers to manage for climate variability. Success also requires recognizing that grasslands are managed for multiple goals and not just for livestock. Participants suggested addressing how climate affects other resources managed on national grasslands.

Examples of success included the Evaporative Demand Drought Index, an experimental drought monitoring and early warning guidance tool. The index identified a 2015 drought in the Wind River Indian Reservation in Arizona, whereas the U.S. Drought Monitor did not. Success was also achieved when the number of livestock was decreased early in a drought cycle, allowing ranchers to increase the number of livestock more quickly and take advantage of abundant grasses after the drought. Following the 2002 and 2012 droughts in Colorado, the State developed a more formalized plan for emergent drought. An example of successful technology is PhenoCam, which can be used as an automated, near-surface remote sensor to provide continuous, real-time monitoring of vegetation phenology.

Current Challenges and Barriers

Challenges and barriers can be classified into five types: policy, ecological, social, communication, and financial.

Monitoring and assessments are needed to help producers identify and understand threats associated with climate change and early indicators of change in climate, water quantity, and extreme weather events. For example, climate vulnerability for agricultural communities has been assessed for the southern plains (Steiner et al. 2015, 2017). Also needed is a historical context for operations. Timely and readily available remotely sensed data are becoming more accessible, but gaps remain.

Figure 30—National grasslands such as Comanche National Grassland in Colorado are exposed to widely variable weather (photo: USDA Forest Service).

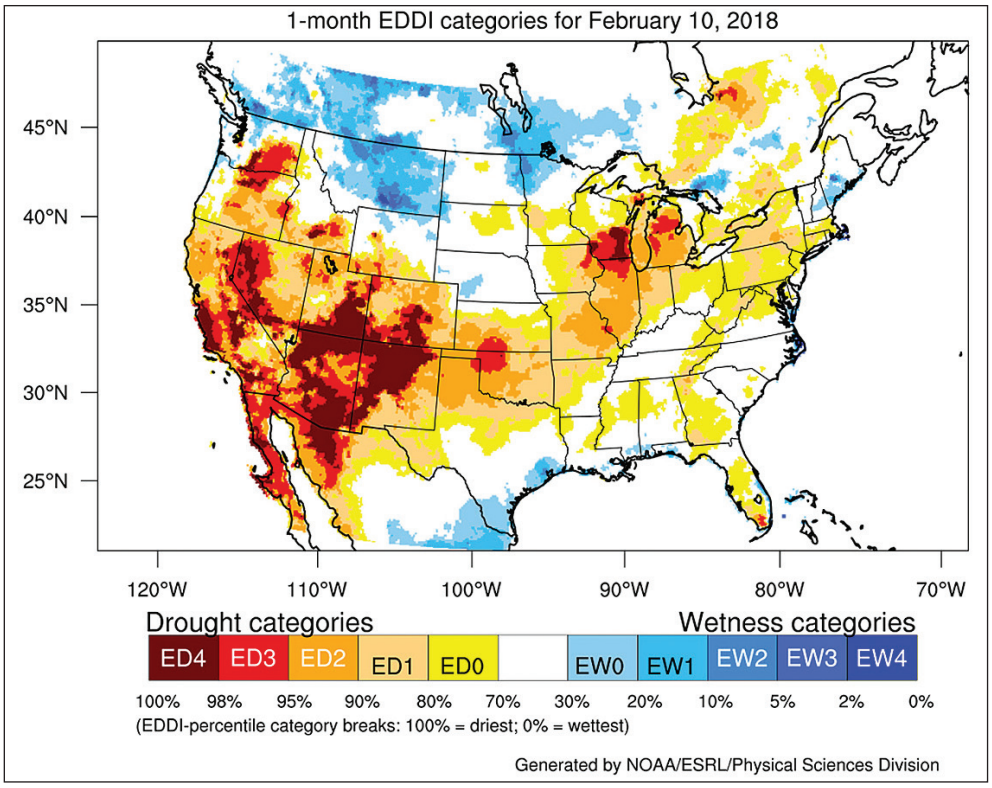

Figure 31—The Evaporative Demand Drought Index (EDDI) is an experimental drought monitoring tool offering early warning of agricultural droughts, hydrologic droughts, and fire-weather risk (credit: National Oceanic and Atmospheric Administration).

Policy challenges revolve around cross-jurisdictional land use. Federal, State, and private lands are managed for multiple goals and objectives at different timescales. Finding the intersection between the objectives of multiple land managers or owners is difficult. Most efforts are focused on the near term, whereas climate change is longer term.

Climate change affects everything, but local producers may focus only on the weather and climate within their area of influence. Climate projections may not be applicable locally, making it difficult to forecast conditions at a plot of land, ranch, or refuge. And all projections have some uncertainty.

It is necessary to understand what people think about climate change, extreme weather events, and water issues linked to weather and climate, and how they communicate about these issues. It is also necessary to provide managers with methods to assess public values and beliefs. Variability associated with climate change can complicate public understanding of how climate change actually works. This complexity can raise questions about the extent to which information can be generalized to match an audience's level of understanding while providing useful products and tools.

The greatest communication challenge is talking about climate change and its connections with extreme events and water availability without losing the trust of producers and landowners. Local experts and community leaders have the greatest effect when communicating local information about management decisions. Agency and extension personnel with local ties also were identified as key communicators.

Figure 32—Wind on the prairie can be stronger than the equipment used to harness it. Kiowa/Rita Blanca National Grassland, New Mexico (photo: Angela Safranak, USDA Forest Service).

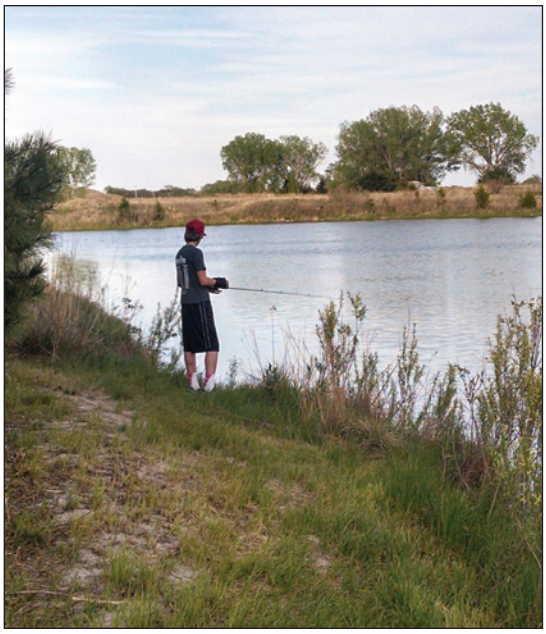

Figure 33—Lakes and streams in grassland landscapes are highly valued for recreational activities such as fishing. However, they are a limited resource, and long-term drought and climate change may impact them (photo: USDA Forest Service, Nebraska National Forest and Grasslands).

Figure 34—Flooding of Lake McClellan on McClellan Creek National Grassland, Texas (photo: USDA Forest Service).

Figure 35—Effects of drought can be visible as dry, cracked mud in a stream bed (photo: U.S. Geological Survey).

Financial challenges centered on the lack of stable funding to test multiyear drought management strategies. In addition, short-term studies may not capture the complexity in climatic, biological, economic, and societal factors that affect ecosystems.

Current Opportunities and Future Management Actions

Participants agreed that management should focus on bringing different stakeholders together to develop shared goals and solutions. Climate change decision-making must be collaborative and participatory. Participants recommended first identifying management issues and then tailoring research to address those needs.

A high degree of cooperation occurs during extreme events such as wildfires. Yet the groundwork for cooperation needs to be established long before the extreme event, and the cooperation should have a local focus. Planning with local neighbors is more productive than planning without them, and neighbor-oriented planning increases the ability to identify management-action needs.

Drought is not atypical of the Great Plains, yet the need is great for robust drought plans, early warning systems, and plans for the worst conditions. The fundamental question always is how to prioritize and make choices. An adaptive management approach can help in assessing and modifying ongoing management activities.

Research Priorities

Needed Syntheses, Tools, and Research

1. Peer-reviewed syntheses of the best science available on the complex problems facing land managers and producers in the Great Plains. A synthesis on drought in forests and rangelands in the United States has been published (Vose et al. 2016), but more focused syntheses are needed for the Great Plains.

2. A peer-reviewed consensus briefing paper on climate change in the Great Plains that communicates benchmarks, indicators, or anthropogenic triggers of climate change in a manner that producers can understand. Such a briefing paper would help producers project, prepare for, and respond to prolonged drought and other manifestations of climate change. A good place to start is the Great Plains chapter of the 2014 National Climate Assessment (Shafer et al. 2014).

3. Drought projection tools for producers and land managers that include estimates of the lead time required for a given response (e.g., 6 months) to help them plan whether to move cattle or plant crops, and to project crop failures.

4. Development of risk scenarios to help managers understand and respond to the uncertainty inherent in climate models.

5. Translations, user guides, and user application websites transferring research data, results, and models into operational management recommendations to bridge communication gaps between managers and researchers on climate, weather, and water topics. The high volume and diversity of data can be daunting for managers, and the relevance and

applicability of research results need to be conveyed through techniques such as face-to-face meetings and demonstrations that go beyond traditional communications such as journal publications.

6. Development of tools and techniques for monitoring and assessing changes in vegetation, and biotic populations and communities in response to climate change.

7. Development of maps showing spatial variation and projections of change over time and across spatial scales.

8. Development of documents, videos, and workshops to help managers better understand, identify, and mitigate social and economic pressures associated with or magnified by climate change.

Bridging Science and Management

Group discussion included the topic of climate change projections for the next 50 years and how scientists can help ranchers relate to these projections and develop adaptation plans. In explaining climate projections, it may be helpful to first connect producers and managers to their recent experiences. For example, one might distribute a survey to managers that asked whether a climate event challenged their management, how they responded, and how they will become more resilient if these events occur more often.

Communication is key. It is important that community members work with scientists to develop common solutions and to achieve engagement without forcing the issue. Managers probably can make better use of existing channels of communication to build relationships.

Extreme events can bring people together, and these situations will build relationships that may persist after the crisis is resolved. A good time to share climate change information is immediately after a crisis. Credible people who experienced the extreme event can share their success stories and experiences.

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