

9. INTEGRATION AND TRADEOFFS

Michele R. Crist, Karen L. Prentice, Jeanne C. Chambers,
Susan L. Phillips, and Lief A. Wiechman

Introduction

Managing for sagebrush ecosystems that are resilient to disturbance and resistant to invasive plants often requires managers to make tough decisions in the face of considerable complexity and uncertainty. The decisionmaking environment is often characterized by multiple management objectives, limited management authority and capabilities, dynamic ecosystems and plant communities, and uncertain responses to management actions. Resource decisionmakers must be able to determine appropriate objectives based on desired management outcomes and sort through the different management considerations involved in obtaining those desired outcomes. Decisionmakers must also be able to evaluate the tradeoffs associated with diverse and often competing management considerations and determine the long-term positive or negative effects of particular management actions on the resource.

Management decisions are most effective when developed and implemented in an adaptive management framework. Adaptive management promotes flexible decisionmaking and allows adjustments in management as part of an iterative learning process (fig. 2.1) (Goldstein et al. 2013; USDOI 2009). This “decisionmaking process” emphasizes: (1) using the best available information to inform decisions, (2) learning from the results of management decisions and actions, and (3) adjusting management as outcomes from management actions and prior uncertainties become better understood. Adaptive management recognizes the importance of changing ecological and socioeconomic conditions in contributing to ecological resilience to disturbance and resistance to nonnative invasive plants. Rigorous monitoring of management outcomes related to clearly defined objectives provides the scientific basis for adjusting policies or management actions in response to dynamic conditions. Adaptive management is a means for making more effective decisions over time that when properly implemented can help to meet ecological, social, and economic goals, increase scientific knowledge, and reduce tensions among stakeholders.

Decisionmaking in an adaptive management context requires a collaborative process where tradeoffs among resources and management objectives are carefully considered. A structured approach to decisionmaking in natural resources can increase both accountability and specificity (Goldstein et al. 2013; USDOI 2009). Greater attention to key elements (text box 9.1) in the decisionmaking process can help decisionmakers focus on what, why, where, and how actions will be taken.

Top left: Sagebrush ecosystem (photo: Tom Koerner, USDOI Fish and Wildlife Service). Top right: Fire suppression in a cheatgrass dominated site (photo: USDOI Bureau of Land Management). 2nd left: Hand removal of piñon pine with a chainsaw (photo: SageSTEP.org). 2nd right: Pinyon jay, a juniper and piñon obligate species (photo: Richard Crossley from Wikimedia Commons). 3rd left: Deep gas drill rig outside of Pinedale, Wyoming (photo: Tomas J. Christensen, retired, Wyoming Game and Fish Department). 3rd right: Conversion of a sagebrush ecosystem in the West-Central Prairies to agricultural land (photo: John Carlson, USDOI, Bureau of Land Management). Bottom left: Greater sage-grouse at a lek site (photo: USDOI Fish and Wildlife Service). Bottom right: Santa Rosa Mountains and cattle (photo by Nolan Preece, used with permission).

Managers need to take into account many different factors when developing management objectives and deciding on alternative actions aimed at maintaining or increasing resilience to disturbance and resistance to nonnative invasive plants.

Spatial and Temporal Scale. In the Science Framework a multi-scale approach is used to inform different aspects of planning and implementation: (1) the sagebrush biome scale, where consistent data for the range of sagebrush and Greater sage-grouse (*Centrocercus urophasianus*; hereafter, GRSG) can inform budget prioritization; (2) the mid-scale (ecoregion or Management Zone), where assessments are typically conducted to inform budget prioritization and develop priority planning areas; and (3) the local scale, where local data and expertise are used to select project sites and determine appropriate management strategies and treatments within priority planning areas (table 1.2, fig. 1.1). In the decisionmaking process it is necessary to ask whether decisions made at one scale will affect the ability to obtain objectives at other scales. For example, will management decisions at the local scale regarding the locations of fuel treatments or restoration activities have net positive, negative, or neutral effects on landscape connectivity, GRSG, and other species at risk at larger scales? It also is important to ask what the effects of decisions made today will be in 10 or 20 years. For example, will seeding an introduced species in an area that may recover on its own or where restoration of native species may eventually be needed have a net positive, negative, or neutral effect on agency budgets and ecological conditions?

Nontarget Resources. Another important question to ask in the decisionmaking process is: How will decisions to either leave current management practices in place or change management practices affect the resource being managed and nontarget resources over time? For example, will maintaining current grazing practices have net positive, negative, or neutral effects on forage production and habitat quality for GRSG and other species at risk? What will be the longer-term consequences on rangeland health of failure to manage wild horses and burros at Appropriate Management Levels (AMLs)?

Data Availability and Quality. Resource management increasingly involves the use of geospatial data, models, and maps to identify optimal management strategies. The quality and availability of data affect the information available

Text Box 9.1—Activities in a Structured Decisionmaking Approach (Based on USDOI 2009)

- Engage the relevant experts and stakeholders in the decision making process;
- Identify the problem to be addressed;
- Specify objectives and tradeoffs that capture the effects on the ecosystem and the values of stakeholders;
- Obtain the best available information on potential management outcomes and identify the range of decision alternatives from which actions are to be selected;
- Specify assumptions about resource structures and functions and the effects of management outcomes;
- Project the consequences of alternative actions;
- Identify key uncertainties;
- Evaluate risk tolerance for potential consequences of decisions;
- Account for future impacts of present decisions; and
- Account for legal guidelines and constraints.

for making decisions, the management actions that are implemented, and the outcomes of those actions. Consequently, it is necessary to stay informed about new data layers and decision-support systems and their relative strengths and weaknesses (text box 9.2). It also is important to consider both the source and quality of the science that is being used and ensure that it has been published in the peer-reviewed literature (text box 9.2).

Text Box 9.2—Data Considerations for the Science Framework

The models, maps, and data layers used throughout the Science Framework (Chambers et al. 2017; Crist et al. this volume) represent the best scientific information available at the time these documents were written. This information is the result of cutting-edge techniques in remote-sensing of plant communities (e.g., Boyte and Wylie 2017; Xian et al. 2013), combination of data from different spatial scales (Maestas et al. 2016), and new analytical techniques for combining complex datasets (Doherty et al. 2016). This information may be updated as we advance our understanding of these complex ecosystems and develop new and improved data layers and decision-support tools. In addition, new data may arise from interpretation of existing information or application of improved techniques for measuring and modeling dynamic and variable systems across space and time. Updates on the models, maps, and data layers used in the Science Framework are intended to be provided as new science information and geospatial data become available.

When selecting information to inform a decision or updating data layers, practitioners need data that are appropriate to the scale of interest. Technological advances in remote sensing and analysis are providing data with increasingly finer temporal, thematic, and spatial resolution. Although this provides tremendous opportunities for understanding and targeting actions, users must ensure that they have selected the best data to meet project objectives or answer the management questions. For example, most of the species distribution modeling literature uses landscape cover metrics derived from remotely sensed land cover maps that characterize ecological communities (i.e., LANDFIRE). Recently, remote-sensing products have been developed that provide continuous vegetation component values that are more equivalent to ground-based vegetation surveys (Xian et al. 2013). These two types of data are not directly interchangeable and it will be necessary to evaluate which data type is better for the intended application.

Users should critically evaluate uncertainty, measurement error, and model assumptions to understand potential limits to application and inference whenever selecting data for analyses. The original scientific publications should be consulted for information on the types of error, degree of uncertainty, and underlying assumptions. This is particularly important for modeling that integrates multiple spatial datasets, because the degree of error and uncertainty can vary across different datasets and can be compounded when data are combined to create new models or decision-support tools. However, integrative models and spatial products still offer very useful ways of understanding and visualizing complex information when the potential errors and uncertainties are understood and specified. These models and spatial products can guide practitioners to places on the landscape that can be verified by field surveys and local knowledge.

Finally, practitioners should consider the source and quality of the science they are using, because new geospatial layers, tools, and applications are being developed rapidly. They should use data that have been published in the peer-reviewed literature. The rigors of the peer review process necessary for publication in respected sources result in quality control and assurance that nonpeer-reviewed literature may or may not have acquired. Although new maps, data, or tools may appear to provide exciting new opportunities for analysis and decisionmaking, caution should be used in applying this information before adequate documentation is available and peer-review of methods and assumptions has been completed.

Dealing with uncertainty is one of the greatest challenges in decisionmaking. Changes in administrative priorities, policies, and economic resources can all cause uncertainty in the types of decisions that should be made as well as the outcomes of those decisions. In addition, there are several well-recognized sources of uncertainty specific to making natural resource decisions (Conroy et al. 2011; USDO1 2009; Williams et al. 2002). **First**, environmental uncertainty, or uncertainty in ecosystem and species responses to factors such as disturbances, weather events, climate change, and management actions, is a well-known source of uncertainty that characterizes all natural systems and requires little explanation. **Second**, partial observability, or the need to estimate and model the relevant “quantities” that characterize natural systems because of our inability to directly observe nature, often limits our ability to accurately determine the resource “quantities” that are the targets of management. For example, the amount of forage production on an allotment is often estimated from sampling a small number of plots and estimating values; the acres of habitat to support a particular species is often estimated from limited research on habitat requirements, often in a different location. **Third**, partial controllability is the frequent inability to apply management actions directly and with high precision. An example is aerial seeding of postfire reclamation species. **Fourth**, structural uncertainty is the uncertainty in the models that predict system responses to specific management actions. Structural uncertainty is often represented by alternative models of system dynamics, each with associated measures of relative credibility. Reducing this type of uncertainty is a key objective of adaptive management (Walters 1986; Williams et al. 2002). Dealing with uncertainty in decisionmaking requires recognizing its existence, establishing rules whereby an optimal decision can be made in the face of uncertainty, and reducing uncertainty where possible (Conroy et al. 2011).

Application to Management

This section is intended to facilitate the decisionmaking process by integrating the management considerations for each of the management topics addressed in this volume and identifying the tradeoffs involved in managing for the different objectives and resources associated with each management topic. On October 17–19, 2017, management and science experts from different agencies and organizations met in Boise, Idaho, to evaluate the management considerations and tradeoffs for the different topics. Specific objectives were to: (1) identify and discuss how to integrate project objectives and evaluate the tradeoffs that need to be considered across scales in decisions about land management activities in sagebrush ecosystems, and (2) develop scenarios that identify and discuss how tradeoffs influence priorities for managing dominant threats in the western and eastern portions of the sagebrush biome. As a result of this meeting and subsequent work by the editorial team, “management scenarios” were developed that focus on the management considerations and tradeoffs involved in managing (1) invasive annual grasses and uncharacteristic wildland fire, (2) juniper (*Juniperus* spp.) and piñon pine (*Pinus* spp.) expansion, and (3) land use and development (e.g., cropland conversion and associated invasion of nonnative species). In addition, an “integration table” was developed that includes all paired combinations of the topics addressed in this volume and identifies the desired outcome, management considerations, and tradeoffs for each paired combination. The integration table also includes any critical information needs and policy needs that were identified at the meeting.

The scenarios and integration table were not developed for a particular management agency and thus do not consider the different policies of individual agencies. Instead, collective management considerations are provided for all managing entities. Managers can incorporate other management considerations and tradeoffs important for their particular agency, geographic region, or program.

Management Scenarios

The management scenarios illustrate how different management considerations and tradeoffs (table 9.1) are taken into account when developing management actions and making management decisions about potential actions. Supporting information is found in Part 1 of the Science Framework (Chambers et al. 2017a; hereafter, Part 1). An overview of persistent ecosystem threats is in Part 1, section 5. These threats include nonnative invasive plant species, altered fire regimes, conifer expansion, and climate change, as well as land use and development threats including cropland conversion, energy development, mining, roads and other infrastructure, urban and exurban development, recreation, wild horse and burro use, and improper livestock grazing. Geospatial analyses with overlays of key data layers can help (1) evaluate the type, presence, and level of threat to ecological types and vegetation communities; (2) target areas for adaptive management; and (3) determine the most appropriate types of management actions. Part 1, section 8 presents data and analytical methods for identifying priority areas for management within ecoregions or Management Zones and evaluating both persistent ecosystem and land use and development threats. The use of higher resolution spatial data, combined with local information and knowledge, helps managers and stakeholders refine project areas and determine the most appropriate management strategies and is detailed in Part 1, section 9. Management strategies for persistent ecosystem threats, climate change, and land use and development threats are identified in table 1.4 (this volume), and recommendations for prioritizing and targeting strategies are in table 1.3 (this volume).

Invasive Annual Grasses and Uncharacteristic Wildfire

This scenario addresses the ongoing spread of invasive annual grasses and resulting uncharacteristic wildfires. The desired outcome is to reduce the occurrence and spread of invasive annual grasses in these landscapes and the loss of sagebrush habitat due to uncharacteristic wildland fire. The emphasis is on landscapes with low to moderate resilience and resistance, where these issues are most problematic and additional management focus is needed. Although the scenario was developed largely for the northern and central Great Basin and Columbia Plateau in the Cold Deserts, it also is applicable to the Western Cordillera (see fig. 1.1), where invasive annual grasses are spreading and uncharacteristic wildfires are occurring.

Three management approaches are provided to help address the threats of invasive annual grasses and wildfire in low to moderate resilience and resistance landscapes. These approaches are intended to work in tandem with the management considerations and tradeoffs described in the integration table (table 9.1) and build on the information provided in tables 5.1 and 5.2. These approaches are: (1) **prevention** of invasion of existing intact sagebrush habitat by nonnative invasive annual grasses, (2) **intervention** to help restore areas at risk

of becoming dominated by invasive annual grasses and higher fire frequencies, and (3) **containment** of invasive annual grasses to decrease the effects and spread of the fire/invasive annual grass cycle in low to moderate resilience and resistance areas.

The use of the different management approaches depends on the extent and relative abundance of invasive annual grasses and associated wildfire occurrences. Multi-scale assessments that include geospatial datasets, monitoring data, and field surveys can help identify the most appropriate scale for applying the management approaches within a region. Geospatial datasets and methods are provided in text box 9.3 to help identify areas on the landscape where these management approaches apply. Areas managed for **prevention** are those where sagebrush communities are ecologically intact and have little to no cover of invasive annual grasses. Areas managed for **intervention** typically have lower cover of sagebrush or shrubs and perennial grasses and forbs, but a relatively low cover of invasive annual grasses. These areas may be at risk of invasive annual grass dominance and intervention may help them return to a more native species-dominated state. Areas managed for **containment** have moderate to high cover of invasive annual grasses and very low cover of shrubs and native grass and forbs. These areas are difficult to restore to a native species-dominated state due to invasive dominance. The three management approaches align with the five invasion states in tables 5.1 and 5.2. **Prevention** areas can be defined as “invasion free” and “trace”; **intervention** areas as “mild” to “moderate”; and **containment** areas as “invasion dominated.”

Text Box 9.3—Mapping Prevention, Intervention, and Containment Areas for Managing Invasive Annual Grasses and Uncharacteristic Wildfire

A multi-scale spatial assessment can be used to identify and delineate where to apply **prevention**, **intervention**, and **containment** management approaches in landscapes with low to moderate resilience and resistance to invasive annual grasses. Geospatial data layers and a mapping framework for prioritizing areas for management at regional scales are in Part 1, section 8 and Appendix 8. The highest resolution data available for the assessment area should be used (text box 9.2). The categorization of an area for **prevention**, **intervention**, or **containment** should include characteristics such as: (1) the cover of native, intact sagebrush ecosystems; (2) the degree of connectivity among sagebrush habitats; and (3) priority resource values such as Greater sage-grouse (GRSG) habitat. Fire risk assessments should be used to identify areas with low to moderate resilience and resistance that have a higher probability of experiencing fire (Part 1, Appendix 10). Relevant data layers include ecological site types or vegetation cover types, resilience and resistance categories, and surface land management. Other information may include the potential of an area to provide native seed sources and reserves.

The proportion of the landscape dominated by sagebrush land cover provides information on the landscape context and potential habitat suitability for GRSG and for other sagebrush dependent species at risk (Chambers et al. 2017a,c; Knick et al. 2013). For example, sagebrush cover categories are based on the proportion of the landscape dominated by sagebrush (5-kilometer [3-mile] rolling window; low = 1–25 percent; moderate = 26–65 percent; high = >65 percent land cover). Data on topography, postfire recovery sites, rare species habitats, migratory pathways, and GRSG lek locations or population indices can refine the identification of these areas.

The use of Assessment, Inventory, and Monitoring (AIM) data, field survey data, and local expertise can be used for refining distinctions between the different areas. Tables 5.1 and 5.2 provide five invasion states that can further refine the delineation of **prevention**, **intervention**, and **containment** areas. **Prevention** areas can be defined as “invasion free” and “trace”; **intervention** areas as “mild” to “moderate”; and **containment** areas as “invasion dominated.”

To implement the approaches, land management objectives of “**prevention**,” “**intervention and restoration**,” and “**containment and long-term rehabilitation**” are developed and assigned based on coordination among the science and resource specialists across a management jurisdiction. Strong partnerships and collaboration between State and Federal invasive programs are needed for targeted prevention, control, and eradication of invasive plants. In **prevention** areas, managers should minimize management activities known to spread invasive plants and implement a strong monitoring and eradication program, such as an Early Detection and Rapid Response program (EDRR) (USDOI 2016). Other prevention measures are in table 5.1. In **intervention** areas (previously burned or unburned), managers should emphasize restoring and maintaining resilience to wildfire and resistance to nonnative annual grass invasions. Primary intervention objectives include increasing the extent, connectivity, and ecological functioning of sagebrush ecosystems. These objectives are requisite to meeting other landscape objectives such as increasing the sustainability and resilience of habitat for different species of wildlife, forage for livestock, and other resources such as native seed reserves. Intervention measures include eradication, suppression, containment, and active restoration. Their use should be aligned with local environmental conditions to optimize success.

In **containment** areas, the management focus is on removal and containment of invasive plants to protect adjacent or nearby areas from invasion and address the higher frequency and larger extent of wildfire in these areas. The effectiveness of different herbicide treatments and seeding strategies can be tested through carefully designed treatments and long-term monitoring. This information can be shared among land management agencies. Monitoring of **containment** areas can provide information on changes in invasive annual grasses and other invasive plants and help identify new invaders. Monitoring along the interfaces of highly invaded sites and intact sagebrush communities can help provide information on where containment strategies have been successful and where adaptive management is needed. Once an area is designated as having a management objective of “containment,” loss of ecological function may occur due to containment strategies. However, there may be opportunities for rehabilitation when methods become available in the future. In addition, surveys of potential **containment** areas for endangered, threatened, or sensitive species, species of concern, and known rare species can be used to determine whether these areas or portions of these areas should be reclassified as **intervention** areas to protect these resources. The development of evaluation criteria for restoration potential, along with an understanding of associated tradeoffs, will help inform the classification of these areas.

Climate Variability and Adaptation

Climate and climate variability have a strong influence on management considerations and tradeoffs and, thus, management approaches for low to moderate resilience and resistance areas. Identification of which invasive plants are likely to spread and of the areas susceptible to invasion coupled with EDRR monitoring can help managers decide where to implement **prevention**, **intervention**, and **containment** strategies to facilitate climate adaptation. Scenario planning also can assist with balancing the tradeoffs of different management approaches (e.g., assisted migration).

To help maintain or enhance the resilience and resistance of areas managed for **prevention** and **intervention**, native plant species distributions should be allowed

to transition and adapt to changing climatic and environmental conditions. In areas managed as **intervention** and **containment**, resilience and resistance may be maintained or facilitated through vegetation treatments that help communities transition to new states or site types where appropriate. The use of carefully designed treatments and monitoring can help identify successful methods for assisted migration of native plant species (Bucharova 2017). Monitoring for appearance of novel invaders, changes in biodiversity and native species populations, and movement of key species can be used to evaluate how changing landscapes are responding to treatments in all three management approaches.

Land Uses, Development, and Rehabilitation

Anthropogenic land uses and developments that are known to serve as invasive and noxious weed vectors, such as roads, pipelines, fuel breaks, utility corridors, juxtaposed agricultural practices, grazing, and mining, should be addressed in all three management approaches. Land uses and developments that serve as vectors for invasive plants should be redirected around **prevention** areas or reduced in number, frequency, and extent to reduce impacts; minimized and monitored in **intervention** areas; and where resource values are not at risk, focused in **containment** areas. Management activities should use defined best management practices (BMPs) for preventing the spread of invasive plants. See tables 5.1 and 5.2 for other “on the ground” **prevention, intervention, and containment** strategies.

Grazing should be minimized in **protection** areas and potentially refocused to other areas that are more resilient to grazing to maintain no to low levels of invasive plants. For **intervention** areas, use of alternative grazing strategies (e.g., shifting the season of use, using outcome-based grazing, creating grass banks) can help contain spread of invasive plants. Where alternative grazing strategies may increase risk to the operator or permittee, outcome-based grazing and evaluating the degree of risk can help provide effective solutions. Identifying **containment** areas that may be used as grass banks or to extend grazing seasons may also address these tradeoffs. Grazing permits should include the season, duration, and amount of grazing that can sustain native grasses and forbs based on state-and-transition models for low and moderate resilience and resistance sites (section 7). They also should include plans for drought conditions and changing weather and climate patterns. Alternative grazing strategies such as changing season of use, targeted grazing, and grass banks could be focused in containment areas to reduce contiguous fuels throughout these areas. Grazing strategies developed for the three approaches will need to be adaptive and responsive to climate and weather patterns that result in changes in forage availability.

Control and removal of invasive plants through the use of adaptive management, EDRR strategies (USDOI 2016), and focused invasive plant removal treatments should become a primary management goal for all Federal and State management agencies. At the field office and district scale, spatial mapping, field surveys, and use of monitoring data can augment geospatial data to refine **prevention, intervention, and containment** areas (text box 9.3). The primary factors to consider are site conditions, relative abundance of residual grasses and forbs, relative abundance of the invader, and proximity and juxtaposition to invasive plant dispersal vectors. See tables 5.1 and 5.2 for “on the ground” **prevention, intervention, and containment** strategies.

In **prevention** areas EDRR is used to quickly remove new invasive plants. In **intervention** and **containment** areas strategies depend on the magnitude of the

invasion, but can include a variety of treatments such as herbicides, seeding, and transplants, to reduce the cover and spread of invasive plants (section 5). In **intervention** areas, invasive plant control treatments should minimize soil surface disturbance and disturbance of biological soil crusts. Restoration should focus on seeding in areas that lack perennial grasses and forbs. Spatial mapping can be used to target restoration efforts between intact sagebrush patches to increase sagebrush habitat connectivity over the long term. Use of herbicides followed by seeding should be prioritized to control spread from **containment** areas, especially those located adjacent to **intervention** or **prevention** areas. Treatment success may be challenging and multiple interventions may be required, especially in **containment** areas. In general, long-term monitoring and adaptive management practices should be used to evaluate treatment successes, test other invasive plant removal strategies, identify challenging areas, and determine when **intervention** areas may need to be considered **containment** areas.

Following wildfire or other disturbances, tradeoffs to consider for invasive plant management in **prevention** areas include the potential negative effects of using herbicides and seeding on native species recovery versus allowing natural recovery. In **intervention** areas, herbicide application, seeding treatments, and other postfire or disturbance recovery efforts should be targeted. Management objectives for seeding in **prevention** and **intervention** areas should focus on reestablishing native species and ecological diversity rather than seeding specifically for livestock grazing benefits. Establishing restoration islands of diverse native forbs, bunchgrasses, and other shrubs can mimic natural recovery and succession after wildfire in sagebrush communities with depleted native herbaceous species.

The use of specific livestock grazing regimes for low to moderate resilience and resistance areas is essential for all restoration and postfire recovery efforts because grazing or use of seeded areas may inhibit recovery. Managers should consider structuring grazing regimes depending on the designated management approach—**prevention**, **intervention**, or **containment**. For example, spring and early summer grazing could be prioritized in **containment** areas before **intervention** and **prevention** areas. Focused monitoring and management of cattle grazing are needed to adapt grazing strategies where recovery goals are not met. Prioritizing management of wild horse and burro populations for population reductions where these populations exceed AML and are affecting ecological conditions will help protect treated and seeded areas (section 8). These types of strategies are applicable to other restoration activities for invasive plant control after disturbance.

Wildland Fire Management

Fire risk assessments are useful in determining priorities for wildfire management objectives for **prevention**, **intervention**, and **containment** areas. **Prevention** and **intervention** areas should receive higher priority for fire suppression efforts, especially if located next to a containment area. This juxtaposition increases the risk of wildfire and conversion to annual invasive grasses in **prevention** and **intervention** areas. Fuel treatments should be focused in **intervention** and **containment** areas. Tables 5.1 and 5.2 offer more specific management strategies. The following approaches, when integrated, can help reduce the occurrence of fire disturbances in lower resilience and resistance areas and mitigate potential natural resource tradeoffs in fuel treatments and wildfire management decisions.

First, a strong emphasis on wildland fire prevention strategies in wildland-human interface areas that focus on common causes of human ignitions such as powerlines, fireworks, campfires, target shooting, and vehicles parking on roadsides is needed to help reduce wildland fires in **prevention**, **intervention**, and **containment** areas. Across the western states, human-caused fires accounted for 31 percent to 97 percent of all wildfires (Balch et al. 2017). Strong partnerships and collaboration are needed between State and Federal wildfire prevention and mitigation programs to help reduce human-caused fires. Industries, land users, and recreationists need to be included in these partnerships.

Second, siting of fire suppression activities (e.g., firelines, burnouts) and equipment in containment areas where they occur adjacent to intervention and prevention areas can be used to minimize disturbance in intervention and prevention areas. Other strategies include training on invasive plant awareness, and incorporating invasive plant information and management into Fire Incident Action Plans.

Third, strategically placed and consistently maintained fuel treatments such as fuel breaks alongside roads within **intervention** and **containment** areas may help reduce substantial losses of sagebrush communities due to wildfire by aiding wildfire suppression efforts and reducing fire spread. The use of fuel breaks should be prioritized for areas of higher fire frequency to help protect wildland-urban interface areas, **prevention** areas, and **intervention** areas. The effectiveness of fuel breaks across large landscapes is unknown, and fuel breaks alone may not reduce the extent of uncharacteristic fire in sagebrush communities (Shinneman et al. 2018). However, different lengths and widths of fuel break networks can be tested using fire simulation modeling to identify strategic placement and design. Design and placement should take into account the fuels in the landscape, fire response, and operational efficiency. Monitoring and adaptive management will further inform their best use and placement over time.

Fuel breaks are for the sole purpose of wildland fire management and should not be used to achieve other management goals. Plant materials used in fuel breaks should have traits such as low stature to reduce flame lengths or resistance to invasive plant species. Native and nonnative species selected for seeding fuel breaks should not be managed as forage for wildlife or have traits that rely on grazing regimes to retain low biomass.

To help avoid unintended management consequences and ecological impacts, the design, placement, and long-term management of fuel breaks should be carefully evaluated before construction. Fuel breaks can become dominated by invasive annual grasses and serve as fire ignition points, especially when located next to wildland-urban interface areas or popular recreation sites. Therefore, consistent fuel break maintenance in perpetuity needs to be a high management priority to maintain their effectiveness for fire suppression efforts over time. To help mitigate unintended ecological impacts, managers should assess effects on wildlife habitat and adjacent ecosystems before deciding to construct a fuel break network (see Shinneman et al. 2018). Tradeoffs, such as habitat loss, fragmentation, and impeding wildlife species movements, may be mitigated by using wildlife habitat fragmentation thresholds and varying fuel break width, length, and placement across the landscape.

Several sections in this volume will be useful in evaluating management considerations and tradeoffs associated with fuel breaks (sections 4 through 6). Also see table 1.4.

In conclusion, this scenario provides a spatially integrated management approach that builds on many of the strategies in tables 5.1 and 5.2. There

are many other factors to consider for applying **prevention, intervention,** and **containment** management approaches in low to moderate resilience and resistance areas, including:

- Special status wildlife and plant species
- Availability of seed
- Land use plan flexibility
- Stakeholders' willingness to engage and collaborate
- Unforeseen or unplanned disturbance
- Staff turnover—key personnel
- Topography and terrain access
- Availability of grass banks and grazing options
- Availability of useful monitoring data in and adjacent to site
- Emerging invasive species that pose a risk to these sites (early watch species)

Juniper and Piñon Pine Expansion

This scenario addresses the expansion of juniper and piñon pine trees into sagebrush ecosystems and the associated decline in sagebrush dependent species and resource values. The desired outcome is to reduce the loss of sagebrush resulting from juniper and piñon expansion, while maintaining a mosaic of sagebrush and juniper and piñon habitats needed for species dependent on these ecosystems. The focus is on moderate to high resilience and resistance areas at mid- to high elevations where juniper and piñon expansion is causing sagebrush habitat loss. This integrated management scenario discusses identifying juniper and piñon areas for targeted removals, addressing the threat of increasing invasive plants during site selection and treatment implementation, and using treatment methods that mimic natural disturbances which may help mitigate the negative effects on the species that depend on these expansion areas.

Identification of areas where juniper and piñon are expanding into currently occupied GRSG habitats or other threatened or at-risk species habitats is needed to locate the highest priority sites for tree removal treatments to maintain or restore sagebrush communities. The framework and geospatial datasets provided in Part 1, section 8 can be used to help select potential treatment sites. After identifying potential treatment sites, managers should coordinate with other science and resource specialists (State and Federal) to evaluate potential conflicts with other species' conservation needs and other resources to determine appropriate treatments. An approach for evaluating a site's relative resilience to disturbance and resistance to nonnative invasive plants and selecting appropriate treatment methods is in Miller et al. (2014).

Management objectives for juniper and piñon removals should incorporate potential changes in native juniper and piñon species distributions, fluctuations in populations, and adaptations to changing climatic and environmental conditions. Considering this information in site and treatment selection can help in managing for longer-term ecosystem resilience and multiple uses. When identifying juniper and piñon removal sites, practitioners should consider the presettlement distribution and history in relation to the number of acres (hectares) of juniper and piñon lost to disturbances, such as wildland fire, insects, and drought (see Board et al. 2018), as well as past removals over a specified period of time (past one to two decades), to help determine the appropriate number of acres for targeted removal. Continued monitoring of juniper and piñon as well as sagebrush habitats that are lost to disturbances such as wildland fire

and drought over time can be used to identify where adjustments are needed in proposed removals and help adapt management strategies for local and regional areas. Recent increases in loss of juniper and piñon woodlands through natural disturbances may be contributing to removal goals, or these goals may have even been met in some areas. This type of information will improve understanding of how much targeted removal should occur across a geographic area and help to plan removals in the context of natural disturbances and climate change.

Areas should be prioritized for treatment where removals will not result in increases or dominance of invasive plants because of the disturbance caused by the removal treatment. Field-based surveys are needed to identify areas for removals that have sufficient cover of sagebrush and native grasses and forbs in the understory for site recovery (Miller et al. 2014). If expansion sites are relatively warm and dry, invasive annual grasses are present, and sagebrush or perennial grasses have low abundance, there is a strong possibility that the site will convert to invasive plant dominance after tree removal. Managers can consider treating the site with pre-emergent herbicides after tree removal and monitoring for recovery of perennial grasses and forbs (but see Pyke et al. 2014). However, seeding perennial native grasses and forbs may be required to facilitate recovery of these types of sites, and investments in tree removal will produce higher returns in areas that have the potential to recover without additional treatments.

Thresholds of native perennial grasses and forbs needed to ensure recovery of sagebrush ecosystems can be found in Davies (2008), Chambers et al. (2014d), and Miller et al. (2014). Recent research related to juniper and piñon treatments is in sections 4 and 5.

Removal of juniper and piñon in expansion areas may have negative consequences for species dependent on the different habitat conditions these areas provide (e.g., seed caching areas for pinyon jay [*Gymnorhinus cyanocephalus*] and winter habitat for mule deer [*Odocoileus hemionus*]). Expansion areas include edge and open transitional habitats important to a variety of species including some that are in sharp decline. Designing removals that mimic the patterns of natural disturbance such as wildland fire and drought will help ensure that the habitat needs of these species are taken into account and that objectives in land management plans for maintaining a mosaic of sagebrush and juniper and piñon habitats are achieved. To meet these needs, removal treatments can be designed to incorporate the following:

- Creation of transitional (feathered) and more convoluted-shaped edge habitats between sagebrush and juniper and piñon to avoid sharply contrasting and straight edges (e.g., dense juniper and piñon woodland adjacent to sagebrush)
- Creation of openings within juniper and piñon stands with high density and cover
- Leaving older piñon pine trees that produce pine nuts

During and after removals and associated treatments, there may be a need to temporarily change grazing management regimes. Shifting seasons of grazing use depending on climate and weather patterns can help encourage recovery of sagebrush habitats and deter invasive plants from spreading into treated sites. However, this can have economic effects on the grazing operator or permittee. Planning for the use of alternative grazing areas for the time needed to allow recovery after removal will help mitigate effects on the grazing operator. Where wild horse and burro management areas overlap or are adjacent to areas for targeted juniper and piñon removal, it may be necessary to reduce wild horse

and burro populations to AML if the juniper and piñon removal treatments are to succeed (section 8).

Land Use and Development Threats

This scenario addresses two closely related issues. The first is type conversions such as those resulting from agricultural uses that degrade habitat quality or remove habitat through conversion to other land uses. The desired outcome is to prevent loss of sagebrush habitats and reduce fragmentation while maintaining or improving connectivity at multiple scales. The second issue is land uses that facilitate increases in invasive annual grasses and forbs. Here the desired outcome is to prevent new invasions and reduce expansion and spread of existing invasive plant threats that may be increased with surface-disturbing activities, such as energy development and conversion of sagebrush communities to cropland. The emphasis is on the eastern portion of the sagebrush biome, including the Northwestern Plains, Wyoming Basin, and Colorado Plateau, and Southern Rockies (see fig. 1.1), but management strategies are broadly applicable.

In the eastern portion of the sagebrush biome, land use impacts often represent a more immediate risk to high quality, intact, and connected GRSG habitat than wildland fire, invasive plant species, or the effects of a changing climate. For example, cropland conversion can pose a more immediate and lasting risk to GRSG habitat quantity or connectivity than is posed by invasive plant species or wildland fire. In the Conservation Objectives Team Report (USDOI FWS 2013), cropland conversion was ranked a widespread and persistent threat on more productive soils for 6 of 15 GRSG populations in the eastern range. The West-Central Semiarid Prairies (Management Zone I) has the highest percentage of private lands and highest amounts of filled cropland of the Management Zones (Doherty et al. 2016; Knick et al. 2011, table 12.1). GRSG extirpations have occurred in areas where cultivated crops exceeded 25 percent of landscape cover (Aldridge et al. 2008) and recent studies show that 96 percent of active leks are surrounded by less than 15 percent cropland in Management Zone I (SGI 2015; Smith et al. 2016). Loss of landscape cover of sagebrush associated with energy development has been well documented in recent analyses, especially for oil and gas. Oil and gas development affects 8 percent of sagebrush habitats, with the highest intensities occurring in Management Zone I and Management Zone II (Part 1, section 5.3.2). Mining is considered a persistent and widespread threat to 8 of 15 GRSG populations in the eastern range (USDOI FWS 2013) (Part 1, section 5.3.2).

Numerous studies have found invasive plant species associated with soils disturbed by development activities and have noted that restoration becomes much more difficult once these species are established (see Part 1, section 5.3.6). The cumulative effects of anthropogenic development and persistent ecosystem threats may be most evident for sites with relatively warm or dry soil temperature and moisture regimes that have relatively low resilience and resistance; these effects may intensify as the climate warms (Part 1, section 5.3.6). The most successful tool for maintaining sagebrush ecosystem resistance to nonnative plant invasions is generally to manage for sufficient density and cover of native perennial grasses and forbs and biological soil crusts to prevent the establishment or population growth of the invader (Chambers et al. 2014b,d).

Best management practices can reduce or prevent introductions of invasive plant species to new areas and can help maintain the resistance of the ecosystem

to invasion. Monitoring (including EDRR) can be used to identify areas where preventive action can decrease the risk of reaching the levels of invasive annual grasses currently found in parts of the Great Basin. Monitoring can also provide the necessary information to quickly respond to reports of new sightings of invasive plant species. Although invasive annual grasses are arguably the most widespread ecosystem disrupters across the sagebrush biome, other plant life forms are also responsible for impacts to the sagebrush uplands and the riparian and wet meadow habitats. These invasive plant species should be included in EDRR efforts as well (see section 5 and Appendix 3). EDRR for these species can be enhanced through the use of standardized vegetation monitoring programs such as the Bureau of Land Management's Assessment Inventory and Monitoring (AIM) and Natural Resources Conservation Service's National Resources Inventory (NRI) efforts which, when combined with enhanced data tracking systems, can be used to locate and treat identified areas in the same year that they are discovered.

In much of the eastern part of the sagebrush biome, the culture, customs, and practices of landscape management have formed within a relatively resilient ecosystem. Failure to consider how land uses and impacts can degrade habitat and increase the likelihood for invasive plants may give a false sense of resilience and resistance. It is important to ask how decisions to either leave current management practices in place or change management practices will affect the resource being managed and nontarget resources over time. To fully address this question, it will be necessary to reexamine current assumptions about the effects of weather and climate on environmental responses and underlying assumptions about the expected results of management actions. Use of appropriate BMPs can help adapt management over time.

Type Conversions

Several management strategies can be used to prevent habitat loss from land uses that degrade habitat and conversion of sagebrush to cropland. These include conservation agreements (easements and Federal and private lands programs, such as the Conservation Reserve Program, Agricultural Conservation Easement Program, Environmental Quality Incentives Program, and Candidate Conservation Agreements with Assurances), land use regulations, and land acquisitions. Factors to consider are:

- Willingness of private landowners to utilize conservation programs
- Wildlife and habitat resource values
- Subsidies for conversion
- Benefits in terms of larger scale connectivity
- International agreements
- Cost of managing the land after acquisition or agreement
- Spatial strategy for acquiring lands or conservation easements (or both) to improve connectivity
- Positioning of existing conservation easements
- Subsurface mineral ownership issues potentially impacting durability and benefit of conservation actions used to address other primary threats
- Existing regulations that may limit the amount of disturbance allowed

There are tradeoffs to consider when easements or land purchases are used to meet conservation objectives. Easements may limit or restrict other land uses and result in a potential long-term economic loss to farmers or to the community. Acquisition of lands results in both short-term and long-term costs associated with managing the land to achieve desired conditions or management goals. Additionally, acquiring easements opportunistically based on the willingness of

landowners may not be the most strategic approach to reaching desired outcomes, such as habitat connectivity, or may not occur in areas with the most important resource conditions (i.e., low versus high resilience and resistance and wildlife habitat values, such as GRSG population densities and seasonal habitats).

Land Uses that Facilitate Increases in Invasive Annual Grasses and Forbs

Preventing new nonnative plant invasions and reducing the expansion or spread of existing invasive plants begins by identifying uninvaded areas and areas at increased risk of invasion and prioritizing management responses. Once the size and impact of an invasion are determined, the recovery potential of the area is evaluated. Uninvaded areas, especially those with lower resilience and resistance, are often at risk and should be identified for prevention strategies to keep “clean areas clean.”

Tables 5.1 and 5.2 provide many management strategies for prevention of invasive grasses and forbs. Integrated pest management techniques are used to prevent introductions and reduce or control invasive plant spread into sagebrush habitat. Increased EDRR monitoring for invasive annual grasses and forbs, such as cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum caput-medusae*), ventenata grass (*Ventenata dubia*), leafy spurge (*Euphorbia esula*), and Russian knapweed (*Acroptilon repens*), is used in high priority areas (i.e., high GRSG population density and GRSG breeding habitat) near areas with development potential (cropland conversion or oil and gas potential). Strong working partnerships with landowners and local governments are developed to treat invasive plant species across ownership boundaries. Where development will occur, Conditions of Approval are employed for regulated activities to reduce the invasion and spread of unwanted nonnative invasive plants. Examples are reducing or controlling invasive plants in an area before disturbance and during active development and production; power-washing construction equipment before transporting to the project area; reclaiming the site to meet objectives for resistance to invasive plants and other objectives, such as value to wildlife; and educating vehicle operators about the dangers of fire ignition resulting from sparks caused by drag chains, cigarettes, and other ignition sources.

Factors to consider are:

- Willingness of private landowners to treat invasive plants
- Adequacy of post-disturbance reclamation requirements, implementation, and outcomes
- Coordination of treatments across ownership boundaries
- Use of methods other than chemical treatment, such as targeted livestock grazing, to control invasive plants
- Durability of treatment efforts to ensure that treatments are maintained long enough to avoid reestablishment of invasive plants and the potential for other land uses (development, infrastructure, grazing [livestock, wild horse and burro, wildlife]) to undo the efforts being implemented

Several tradeoffs need to be considered when implementing these strategies, including: (1) costs of conducting monitoring and potential treatments necessary to control invasive plants versus not having influence on how sagebrush communities are managed, (2) fewer resources for monitoring elsewhere or for other resources, (3) possible increased use of herbicides (which may have unintended impacts to nontarget species), and (4) herbicide application without emphasis on increasing desirable native species (herbicide treatments may create voids in which new invasive plants may occur).

Integration Table

The integration table is a tool that can be used to help develop management objectives and make management decisions regarding potential actions (table 9.1). The table is designed to help identify the relevant management considerations and tradeoffs involved for the different management topics addressed in this volume. It can be used to cross-check the relevant topics for a particular objective or desired outcome to ensure that all of the relevant management considerations and tradeoffs have been taken into account.

Table 9.1—The desired outcomes, management considerations, and tradeoffs, as well as any critical information needs and policy needs, for each combination of the topics included in this volume. The information provided for the integrated topics can be used to help managers determine whether all of the relevant management considerations and tradeoffs have been taken into account when making decisions regarding potential management actions. The length of the table and the inclusion of some repetition reflects the need to ensure that the relevant management considerations and tradeoffs were included for each integrated topic. It is anticipated that only a subset of the integrated topics will need to be reviewed for any particular action.

MONITORING and CLIMATE ADAPTATION

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated by collecting monitoring data that can be used to understand where and how ecosystems are changing and to inform adaptive management.

Management Considerations:

- (1) Identify monitoring questions, ecosystem attributes, and indicators needed to evaluate effects of climate change and incorporate them into monitoring programs.

Tradeoff: Durability of conservation and restoration efforts may be impacted if projects do not incorporate climate change or transition zone information due to changes in resilience and resistance, soils, and other resource conditions.

- (2) Incorporate climate change information into project planning and use it to prioritize monitoring efforts among resources and treatments. Then adapt management based on results.

Tradeoff: Increased monitoring requires greater investment and other areas or resources may be monitored less intensively. If Assessment Inventory and Monitoring (AIM) sampling is increased, it may be difficult to maintain sampling rigor.

- (3) Monitor areas projected to change rapidly and areas with strong environmental gradients (transitions). Focus on resources and species within these areas.

Tradeoff: Additional climate and weather monitoring stations and downscaled climate projections will be needed for areas projected to undergo changes or transitions.

- (4) Use vegetation metrics to evaluate relative changes and impacts on different resources and wildlife species if possible.

Tradeoff: Interactions among climate variables, the metrics for evaluating change, and species will need to be evaluated carefully.

- (5) Use local climate data and climate projections to help indicate possible wildfire activity, potential for reclamation, grazing impacts, limits to recreational activities, and impacts to habitats.

Tradeoffs: (a) Some activities may be limited or prohibited due to climatic conditions for short (summer) or long (years) terms. (b) The current spatial mismatch between the location and coverage of climate monitoring and the location and scales where we are making management decisions makes it difficult to incorporate climate impacts into assessments of other impacts, and to understand the effectiveness of management actions. (c) A temporal mismatch between the climate information collected and weather data, especially drought and seasonal weather which can influence management decisions, limits our ability to predict how seasonal weather has impacted things like wildfire, drought, and seeding effectiveness.

(Continued)

Table 9.1—(Continued).

Critical Information Needs:

- (1) Create a systematic approach to monitoring weather and climate, building on existing monitoring networks that provide compatible data across the environmental gradients in the sagebrush biome. Without an expanded weather network, weather and climate data for mid- and upper elevations will have larger error rates because of spatial mismatches between weather stations and areas where management decisions are being made.
- (2) Assess the relationships among various land changes, management outcomes, and climate to determine potential longer-term effects of climate change and to inform monitoring and adaptive management.

MONITORING and WILDLAND FIRE AND VEGETATION MANAGEMENT

Desired Management Outcome:

The effectiveness of wildfire suppression and vegetation management on current uncharacteristic wildfire regimes in sagebrush systems and the capacity to maintain resilience and resistance are positively related to current policies and practices on the ground across scales and over time.

Management Considerations:

- (1) Identify and refine monitoring metrics for successful wildfire suppression, vegetation management, and invasive plant control with a focus on effectiveness and outcomes (e.g., acres with invasive plants reduced) rather than outputs (e.g., acres treated) to facilitate adaptive management. Utilize project "failure" information from monitoring results and focus on what we can learn from challenging postfire restoration or reclamation projects.
Tradeoff: Reporting to Congress on short-term actions versus long-term outcomes creates too much focus on implementation rather than the effectiveness of treatments and other management actions.
- (2) Change current monitoring (e.g., Fuel Treatment Effectiveness Monitoring) from a binary yes and no response to focus on more meaningful and quantifiable information for adaptive management.
Tradeoff: It may be difficult to obtain the resources needed to monitor adequately.
- (3) Use existing monitoring protocols to track long-term dynamics in grass/fire cycles and grass/shrub ecosystems. Base monitoring on timeframes beyond those specified in current protocols that require short-time measurement intervals at small scales (e.g., seasonal versus annual data over multiple years).
Tradeoff: Results will need to be analyzed in a consistent and timely manner so that the results are meaningful at multiple scales, and land management decisions and actions can be adapted quickly.
- (4) Monitor the spread of annual invasive grasses and their effects on fire processes.
Tradeoff: If annual invasive grasses are shown to have widespread effects on fire spread, changes in firefighting strategies may be needed.
- (5) Monitor the rates of recovery of sagebrush ecosystems in terms of the effects on different wildlife species with varying habitat requirements.
Tradeoff: Failure to consider and plan for a variety of wildlife species and resources in management decisions can have undesired outcomes. For example, postfire recovery efforts may have negative effects on certain wildlife species by changing the composition of plant communities.
- (6) Monitor fuel breaks to determine the effectiveness for wildfire suppression activities and the consequences for ecosystems. Monitoring should include quantifying vegetation loss due to fuel break construction and maintenance.
Tradeoff: Monitoring may show that fuel breaks may be installed and maintained that either do not fully meet project objectives to aid wildfire suppression efforts or provide protection for fire suppression personnel. Monitoring may also show that extensive implementation of fuel breaks may increase both fragmentation and the chance of nonnative plant invasions into sagebrush ecosystems as a result of increased disturbance or intentionally seeding potentially invasive introduced species such as forage kochia (see section 6).
- (7) Allocate both staff time and funding to conduct effectiveness monitoring to increase the return on investment. Embed costs of monitoring within estimated project costs up front and indicate the monetary tradeoff for monitoring to document effectiveness (outcomes) compared to only implementation (outputs).
Tradeoff: Resources are limited for conservation actions. Although funding for this activity will divert resources from action implementation (outputs), it will provide critical information on success of those actions (outcomes).
- (8) Provide the necessary training for conducting monitoring and evaluating the data across scales.
Tradeoff: Without training, the data collected may be less accurate and fail to provide the desired information.
- (9) Monitor current exposure to threats. Use that information to evaluate potential future exposure to the threat and to plan conservation and restoration efforts.

(Continued)

Table 9.1—(Continued).

Tradeoff: It will be necessary to determine whether resources will be used to protect those areas most at risk due to threats such as wildfire and plant invasions, or to protect those areas at least risk to maintain current values.

MONITORING and INVASIVE PLANTS

Desired Management Outcome:

Information on resilience and resistance and the current distribution and abundance, vectors, pathways, and impacts of invasive plants is used to inform prioritization of treatment areas, target monitoring efforts, and evaluate treatment effectiveness across scales.

Management Considerations:

- (1) Monitor for high priority invasive plants with Early Detection and Rapid Response (EDRR) (USDOI 2016) protocols to prevent additional management burden due to new invasions and to detect spread from existing invasions.

Tradeoff: Without adequate monitoring to locate new invasions, invasive plants may spread and increase in abundance, degrading sagebrush habitat and understory and increasing the risk of catastrophic wildfires. Existing invasions may require long-term efforts and monitoring to achieve and identify success. EDRR monitoring can reduce the management burden and costs through eradication of the invasive plant that can be measured with monitoring within a shorter timeframe.

- (2) Link prevention and EDRR strategies to agencies' implementation responses to invasive plant species in the sagebrush biome.

Tradeoff: An agency needs funds and capacity to be able to respond quickly, validate new reports, and have decision rules for level of response.

- (3) Use resilience and resistance classes to stratify areas to monitor for invasive plants, focusing on areas of lower resistance and areas of high resource value.

Tradeoff: Monitoring in low resilience and resistance areas can help prevent spread and reduce current risk. Monitoring in high resilience and resistance areas is necessary to prevent new invasions and reduce future risk.

- (4) Monitor the effectiveness of treatment strategies for invasive plants across ecological site types to provide more local and regional information on treatments or other management actions that have higher likelihoods of controlling invasive plants and thus will save time and resources.

Tradeoff: Monitoring may take resources from short-term actions (outputs), but having longer-term information on success (outcomes) will improve overall cost-effectiveness of future actions.

- (5) Conduct posttreatment effectiveness monitoring following Emergency Stabilization and Rehabilitation (ES&R) to determine invasive plant response and report results to common agency databases.

Tradeoff: ES&R efforts for invasive plant control often have limited monitoring timeframes and can identify short-term reductions in invasive plants. However, additional resources for longer-term monitoring are needed to identify invasive plant treatment needs for effective restoration. Forgoing this monitoring may appease sociopolitical needs or concerns, or partners' concerns if resources are instead used for actions; however, efforts to control or reduce invasive plants in areas that are important for GRSG or other sagebrush dependent species may fail.

- (6) Incorporate data or information on invasive plant presence into project planning to better assess the risk of invasive plant spread from existing invasions and in response to disturbance, development, vectors, and pathways.

Tradeoff: Federal land management agencies have mandates for multiple land use, yet authorized uses may increase the spread of invasive plants. Without incorporating information on the existing distributions and abundances of invasive plants into planning efforts, the risk of invasion from disturbance, development, vectors, and pathways may be underrepresented.

- (7) Use Citizen Science opportunities to assist with EDRR monitoring for presence of new invasive plants.

Tradeoff: Citizen Science may not collect all of the information needed to confirm or evaluate the presence or abundance of an invasive plant and may be opportunistic and inconsistent. However, it is an opportunity to engage the public and can help identify new invasions.

- (8) Identify opportunities to participate in collaborative efforts that are evaluating which tools (e.g., managing for perennial native grasses, selective use of herbicides and targeted grazing) can effectively control annual grasses over large enough areas to reduce risks associated with invasive plant spread and wildfire.

Tradeoff: Unless these efforts are focused and well-conceived, time and resources may be lost for reducing the population while waiting for results.

(Continued)

Table 9.1—(Continued).

Critical Information Needs:

- (1) Develop better spatial information related to presence and cover of invasive plants to better target monitoring.
- (2) Determine the climatic suitability and risk of future invasion for priority invasive plants. Use this information to determine the relationship between invasive plants and the resilience and resistance categories.
- (3) Conduct long-term monitoring across a variety of ecological and geographical areas on native vegetation response to invasive species management tools: cultural (grazing, fire), mechanical (cutting, mowing), pesticides, and biological (pests, pathogens, bacteria, fungi).

MONITORING and SEED STRATEGY

Desired Management Outcome:

Implementation and effectiveness monitoring is used to ensure that projects and seeding strategies increase resilience and resistance by remaining flexible and adaptive and by tracking seed sources, species performance, and the outcomes of different seeding methods.

Management Considerations:

- (1) Use monitoring information to determine whether seeding is necessary based on factors such as disturbance history, relative abundances of native perennial plant species, proximity to intact habitat, potential for invasive plant species competition with seeded species, and likely seed sources. If seeding is necessary, select appropriate species based on management objectives and ecological site characteristics, such as precipitation and soil type.
Tradeoff: Although additional investments are necessary, much of the information required for determining the need to seed and selecting the species to seed could be determined by coupling prior monitoring data with resilience and resistance information and local knowledge about past fires/treatment success (Miller et al. 2015). For example, the response of postfire treatments in loamy, 8- to 12-inch [20–30 centimeter] ecological site types with Wyoming big sagebrush and bluebunch wheatgrass can be determined largely based on vegetation composition and cover prior to the wildfire, intensities of past burns, and past and current site-disturbance legacies, such as spring versus fall livestock grazing, or multiple livestock classes using the same allotment.
- (2) Use effectiveness monitoring to assess the need for follow-up seeding, the addition of other species, and other management actions due to the effects of disturbances such as improper livestock grazing.
Tradeoff: Monitoring the appropriate information for a sufficient period of time to determine the need for follow-up actions requires additional resources, but can help ensure longer-term treatment success.
- (3) Record seed sources, pure live seed (PLS), and seeding methods. Monitor the germination and establishment of the different seed sources in a consistent manner.
Tradeoff: With only anecdotal data, project managers can draw or perpetuate erroneous conclusions about the effectiveness of seeding outcomes. They may not be able to identify the cause of a seeding failure and prevent the failure from being repeated in the future.
- (4) Develop monitoring protocols for managers and practitioners that are simple and infer results quickly in order to adaptively manage seeding strategies (e.g., Wirth and Pyke 2009).
Tradeoff: More simplistic monitoring protocols may not capture long-term successes and failures. Implementation of nonstandardized protocols does not allow for comparisons of results among sites or the ability to analyze data at broad scales to identify trends that may affect seeding strategies across large areas.

Critical Information Needs:

- (1) Better understand environmental cues that trigger germination in species we predominantly use or want to use in restoration, such as forbs, to determine why species perform poorly or seedings fail.
- (2) Further develop climate tools to time seeding treatments to the most appropriate climate window(s). Effective use of these tools would require a new way to get and keep restoration funding to use when those windows are open (Hardegree et al. 2017).
- (3) Develop equipment that ensures that native species seed is placed at the right depth in the seedbed.

(Continued)

Table 9.1—(Continued).

MONITORING and LIVESTOCK GRAZING MANAGEMENT

Desired Management Outcome:

Resilience and resistance of lands grazed by livestock are maintained or improved by using monitoring information to evaluate how and to what extent livestock grazing is influencing an area's rangeland health, effects on wildlife habitat, and forage production and to adaptively manage the timing, intensity, and frequency of livestock use.

Management Considerations:

- (1) Collect monitoring data and analyze the results to evaluate the effectiveness of grazing strategies. Revise grazing permits and leases where rangeland health standards are not being achieved because of current livestock grazing management.

Tradeoff: Monitoring of grazing effects is at the local level and is the primary monitoring activity for most field offices. Although data collection is generally occurring, failure to analyze the data and revise permits and leases as needed can result in declines in rangeland health and forage production.

- (2) Identify expectations should monitoring data show that a grazing management change is warranted. Communicate these expectations to grazing permittees and lessees.

Tradeoff: Monitoring data can indicate improper grazing of public lands, which can strain relationships with grazing permittees and lessees. These may be the same grazing permittees and lessees with whom managers would like to work to implement GRSG habitat improvements.

- (3) Assess grazing utilization earlier than at the end of the grazing season to have the opportunity to make management changes (e.g., move livestock) before reaching utilization levels that can cause negative vegetation impacts.

Tradeoff: Without this type of monitoring information and proactive management, rangeland health may decline over time.

- (4) Use monitoring to determine how long to defer the onset of grazing after restoration or postfire rehabilitation to allow seeded species to establish and gain the vigor needed to withstand grazing pressures.

Tradeoffs: Native grass species have not been selected to produce large amounts of aboveground biomass, are more susceptible to spring grazing, and are generally more palatable than nonnative species, leading to preferential grazing by livestock. (a) It may be necessary to defer the onset of grazing longer in areas where local native seed is used for restoration. (b) Producers may need other grazing options during the deferment in order to provide the treated or seeded area with the necessary time for recovery. Expected outcomes and estimated yields or treatment effectiveness may help achieve buy-in on deferments.

MONITORING and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Resilience and resistance are maintained by determining the effects of wild horses and burros (WHBs) on sagebrush ecosystems and whether Appropriate Management Levels (AMLs) for WHBs are appropriately set into the future.

Management Considerations:

- (1) Continue aerial surveys using defensible methods to evaluate WHB distribution and abundance.

Tradeoff: Increased conflict regarding WHB management could arise without rigorous measures of WHB distribution and abundance.

- (2) Conduct utilization monitoring, keeping livestock grazing numbers and WHB abundance measures as covariates in the analyses. An assessment of range condition before livestock grazing and after grazing has ended in a particular year may help identify which impacts are from livestock and which are from WHBs.

Tradeoff: Determining the effects of livestock versus WHB grazing is challenging, and this approach may not accurately portray WHB effects. However, by not monitoring WHB utilization and managing to AML, certain allotments may not be able to withstand the grazing pressure from both livestock and WHBs.

- (3) Implement a monitoring program that includes measures of WHB impacts at or near water sources because WHBs are known to impair soil penetration, water quality, and flow at spring sites, especially when WHBs are at high densities.

Tradeoff: Other areas may need to be less intensively monitored due to budget constraints.

- (4) Include measures of WHB herd size (i.e., densities relative to AML) in the analysis of status and trends monitoring datasets that can be aggregated over the landscape based on data from multiple monitoring sites.

Tradeoff: The spatial scale of project sites and vegetation monitoring may be very small compared to the scale of a local wild horse herd.

(Continued)

Table 9.1—(Continued).

- (5) Consider including specific levels of WHB population, relative to AML as soft or hard triggers requiring a WHB gather in herd management area plans.
Tradeoff: These adaptive management triggers and responses have a high likelihood of ending up in litigation, which is also a management consideration.
- (6) Consider distance to water as an important covariate in monitoring program design (site selection) in areas with high populations of WHBs.
Tradeoff: By not incorporating this information, monitoring could underestimate population densities and ecosystem impacts.
- (7) Use adaptive management with WHBs and vegetation monitoring (validation monitoring) to answer the question: “Will habitats recover if WHBs are kept at AML?”
Tradeoff: If monitoring data show that WHBs are causing damage or negative impacts, policy changes may be needed to address management needs and actions. These adaptive management triggers and responses have a high likelihood of ending up in litigation, which is also a management consideration.

CLIMATE ADAPTATION and WILDLAND FIRE AND VEGETATION MANAGEMENT

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated through effective prioritization and implementation of vegetation management treatments and other wildland fire management activities as wildfire regimes continue to change and additional conservation priorities arise.

Management Considerations:

- (1) Use regional climate information to better predict high fire years.
Tradeoff: This requires additional investment but can assist with fire preparedness.
- (2) Expect that increases in fire potential will lead to increases in fire staff and the need for greater coordination of emergency services at the local level.
Tradeoffs: Project implementation may be postponed until conditions improve, and budget priorities may shift to emergency services. Fire restrictions could impact recreational and other land uses.
- (3) Clearly identify objectives when prioritizing habitats or species for protection and determining vegetation management strategies.
Tradeoff: Managing for connectivity will facilitate dispersal and adaptation of species. However, assisted migration of native plant species may introduce species into new environments where they are not adapted or alter ecosystem processes (Bucharova 2017). Resources may be wasted if low priority habitats are selected for protection and management.
- (4) Consider the climate vulnerability of species when prioritizing habitats or species for protection.
Tradeoff: Protecting habitats or species in their current location that is not expected to support them in the future may preclude protecting another location that may be viable for them in the future.

Critical Information Needs:

- (1) Determine how climate change is likely to alter vegetation across the landscape to guide management decisions.
- (2) Evaluate how climate change will influence wildfire frequency and size across the sagebrush biome to allow for repositioning suppressive resources (e.g., local fire personnel and equipment) and potentially for locating fuel breaks or green strips.
- (3) Research how climate change will affect landscape scale connectivity, species’ vulnerability to climate change, and their projected distributions.

CLIMATE ADAPTATION and INVASIVE PLANTS

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated by identifying new plant invasions; effectively treating, suppressing, containing, and where possible eradicating existing invasions; and identifying die-offs and restoration opportunities.

(Continued)

Table 9.1—(Continued).

Management Considerations:

- (1) Increase EDDR efforts to detect new invasive plants and monitor for die-offs with a focus along climatic transition zones.
Tradeoff: This may result in other areas being monitored less intensively.
- (2) Use permanent monitoring plots in Areas of Critical Environmental Concern and Research Natural Areas that are generally not grazed by livestock and WHBs, or in ungrazed national wildlife refuges, to detect emerging invasive plant species.
Tradeoff: Emerging invasive plants may be detected, but not necessarily in systems where new invasions are most likely.
- (3) Use all permanent plots (e.g., AIM, possibly National Resources Inventory) to track changes in invasive plants over time.
Tradeoff: Taking advantage of existing systems is cost-effective.
- (4) Identify refugia for climate change that include redundancy and a range of values for stepping stones (linkages) for native species movements.
Tradeoff: Identification of refugia that maintain representative native ecosystems and prevent extinctions will require substantial investment. Refugia would need to be intensively monitored for invasive plant species.
- (5) Use resilience and resistance (soil temperature and moisture regimes) to help evaluate potential nonnative plant invasions.
Tradeoff: This provides a good first filter, especially for invasive annual grasses, but additional information and investment are required to relate soil temperature and moisture regimes to the distributions of many other invasive plants. Changes in climate may modify the distribution of soil temperature and moisture regimes on the landscape (i.e., change the distribution of resilience and resistance on the landscape).
- (6) Use information about resilience and resistance to determine the types of actions for addressing plant invasions. In areas with high resilience and resistance, the priority may be to maintain intact, uninvaded ecosystems. In areas with low resilience and resistance, the priority may be to prevent degradation due to soil erosion, protect groundwater, and manage fire risk.
Tradeoff: Caution is needed to prevent areas with low resilience and resistance from being managed solely for livestock forage and wildfire prevention. Intact areas with low resilience and resistance need to be identified and protected.
- (7) Determine whether programmatic environmental assessments or environmental impact statements are needed to address invasive plant impacts that affect all programs.
Tradeoff: Budgets for inventory of invasive plants and control treatments are expensive and long-term costs usually fall to one program (e.g., range in the Bureau of Land Management [BLM]).

Critical Information Needs:

- (1) Improve capacity to map the extent of all major invasive annual grasses, not just cheatgrass.
- (2) Obtain information on the climate suitability of all major invasive plants (including biennial and perennial forbs) that can be used to understand and map the probability of invasion of these species.
- (3) Increase understanding of how changes in climate are likely to influence the resilience and resistance of sagebrush and juniper and piñon ecosystems.

Policy Need:

- (1) State laws for reclamation and restoration standards are needed to address invasive plant species. If no standards are set (or met), then an increase in spread is likely to be followed by a failure to meet habitat needs. Private companies doing business on public land may push back if stricter reclamation standards are applied. However, if the companies are not responsible or not held accountable, then the land management agency must pay for the long-term invasive control or the problem of invasion will continue to spread.

CLIMATE ADAPTATION and SEED STRATEGY

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated by selecting adapted seed sources, using effective restoration methods, monitoring outcomes, and adapting management. Seeding creates plant communities that are adapted to current climate conditions and can adapt to future conditions. Species should be able to move, adapt, and establish in their future climate zones.

(Continued)

Table 9.1—(Continued).

Management Considerations:

- (1) Prioritize where to invest in restoration and seed based on resilience and resistance considerations—what to collect, what to produce, and what to put on the ground.

Tradeoff: It may be necessary to choose between doing nothing, using native species with the best available information and seed sources, and using introduced species (mid- or local scale).

- (2) Use seed sources that are adapted to site conditions and that maintain genetic diversity.

Tradeoff: Broad- and mid-scale shifts in vegetation species will directly impact local seed collections and needs. Areas exhibiting climate change may no longer support certain native species, including sagebrush (see Chambers et al. 2017a, section 5.2). Information to facilitate transitions is just now being developed and assisted migration is controversial.

- (3) Develop maps that pre-specify seed mixes and treatments before wildfires based on ecological types and ecosystem conditions.

Tradeoff: This requires additional upfront resources, but may substantially increase success.

- (4) Use a continuum in restoration—seed sources, implementation, monitoring, and adaptive management—and recognize differences among stabilization, rehabilitation, and restoration. Also consider incorporating concepts and tools from the Society for Ecological Restoration's International Standards for the Practice of Ecological Restoration (McDonald et al. 2016).

Tradeoff: Funding additional education of staff is likely to be well worth the investment.

- (5) Use adaptive management and monitoring to identify changes with climate in considering the best places for assisted migration. Accidental assisted migration is already occurring but may not have the desired outcome where the environmental requirements of the cultivated species used in restoration do not match the environmental conditions in which they are planted (Bucharova 2017).

Tradeoff: Without information on species adaptations to the new site or how the new species will affect the communities where they are introduced, the results may not be as desired.

- (6) Consider species' current and future distributions and seed zone boundaries to select populations for inclusion in restoration projects that will reduce the risk of future maladaptation and to identify potential bottlenecks to species movement.

Tradeoff: Development of climate shift models is time consuming and will require active planning and coordination to target species populations for collection and growth in order to increase availability in the market (5+ years per seed collection). It is difficult to respond quickly to new information on shifting climates.

Critical Information Needs:

- (1) Continue to develop seed zones for more local restoration species—forbs, grasses, and shrubs.
- (2) Set aside areas to be used for common garden studies across Management Zones.
- (3) Develop and evaluate models of how seed zones may shift as climate changes.
- (4) Develop seeding and monitoring strategies that incorporate and test assisted migration.
- (5) Identify genotypes for focal restoration species that are widely adapted and will lend themselves to facilitated migration as the climate changes.
- (6) Ensure that seed zone development captures seed sources across a species range. Evaluate and develop models on how seed zones may shift as climate changes.

CLIMATE ADAPTATION and LIVESTOCK GRAZING MANAGEMENT

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated by adjusting grazing permits and leases as rangeland ecological condition, forage production, and the level of animal stress change.

Management Considerations:

- (1) Revise ecological site descriptions and grazing management to permit adaptation to changing climate conditions.

Tradeoff: This will require information on projected changes in plant species composition and productivity. Changes in long-term habitat objectives, allotment management plans, and grazing permits and leases may be needed.

- (2) Change both the locations and timing of livestock use.

(Continued)

Table 9.1—(Continued).

- Tradeoff:** Analysis of permittee and lessee flexibility will be needed; some will have capacity to move and some will not. Land use plan amendments may be needed.
- (3) Create regional networks of grass banks to increase flexibility.
Tradeoff: This may require adjusting other land uses such as WHB AMLs and may have unintended effects on species at risk.
- (4) Allow managers to manage for performance (i.e., maintaining or improving resilience and resistance).
Tradeoff: This may increase capacity to manage for resilience and resistance, but would require developing the correct metrics for monitoring.
- (5) Develop the capacity to support outcome-based grazing management under a changing climate by adjusting livestock grazing based on current conditions to allow for corrections to occur as climate gradually changes.
Tradeoff: The method for determining animal unit months (AUMs) may need to be modified so that future projections of site productivity and site capacity for livestock grazing take into account the influence of climate change.
- (6) Develop drought plans that identify thresholds and list responses. Ideally such plans would be coordinated with drought planning for the permittee's base property.
Tradeoff: Additional management investment and proactive coordination that considers impacts to economies and way of life as well as ecological damage or desertification will be required.
- (7) Evaluate changes in wildfire risk due to a warming environment and increases in invasive annual grasses in the context of allotments and the potential mitigation of wildfire effects by grazing, including fuels and the probability of ignition.
Tradeoff: Identifying short-term objectives and the correct metrics will be required. Prioritizing protection of habitats over other resources may be a hard sell at local, mid-, and broad scales.
- (8) Evaluate potential changes in native ungulate distributions attributable to changing climate and their interaction with livestock grazing.
Tradeoff: This requires an understanding of potential changes in native ungulate populations and distributions and likely impacts on vegetation communities, soil erosion, and disease transmission.

Critical Information Need:

- (1) Identify how and where vegetation composition and productivity and thus AUMs will change in response to climate change.

Policy Need:

- (1) Evaluate the policy changes needed to allow grazing management to adapt to climate change.

CLIMATE ADAPTATION and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Resilience and resistance are maintained and transitions to desirable new states or site types are facilitated by managing WHB populations at AMLs that will sustain ecosystems in the face of reduced water and forage availability and increased competition for these resources by livestock and native ungulates.

Management Considerations:

- (1) Reevaluate AML to account for warming and drying conditions. This will require reevaluating site productivity and capacity to support WHBs during drought.
Tradeoff: Failure to adjust AML as climate changes will decrease water and forage for livestock and native ungulates, and place other plant and animal species at greater risk. It may also increase stress on individual WHBs in overpopulated areas. Evaluating and monitoring WHB populations and their use of the landscape will require additional resources that could be spent elsewhere.
- (2) Increase understanding of how WHBs use the landscape. This will provide information on how natural water resources may be altered, which in turn can inform management decisions relative to livestock and native ungulate grazing.
Tradeoff: Failure to understand how WHBs use water sources (seeps, springs, riparian systems) will accelerate degradation. Evaluating and monitoring WHB populations and their use of the landscape will require additional resources that could be spent elsewhere.
- (3) Adjust public expectations.
Tradeoff: Failure to effectively educate the public will result in increased conflict when and if AMLs are adjusted and gathers are increased.

(Continued)

Table 9.1—(Continued).

WILDLAND FIRE AND VEGETATION MANAGEMENT and INVASIVE PLANTS

Desired Management Outcome:

Allocations for fuel treatments and postfire rehabilitation in agency budgets are prioritized for invasive plant management to decrease the invasive grass/fire cycle that causes large losses of sagebrush habitats. Agency staffs and the public are knowledgeable about the negative effects of the spread of invasive plants on public lands and are supportive of rapid response and eradication efforts.

Management Considerations:

- (1) Curtail or change management practices (e.g., some grazing practices) that promote spread of annual invasive grasses and in turn increase fire occurrence and spread.
Tradeoff: Such practices require proactive management by local staff and may not always be agreeable to permittees and lessees.
- (2) Change vegetation management priorities and budget allocations to protect postfire recovery efforts and address invasive plants adjacent to postfire recovery areas so that they do not spread into rehabilitated areas.
Tradeoff: Allocation of funds to invasive plant management may decrease funds for other management activities.
- (3) Use integrated modeling of resilience and resistance, fire risk, and resource values to determine configuration and placement of fuel treatments in conjunction with district-wide, programmatic National Environmental Planning Act (NEPA) analyses to address invasive annual grass/wildfire concerns.
Tradeoff: Certain assumptions may be required regarding effects of fuel treatments on fire risk. Additional resources will be required to complete the necessary models and NEPA documents.
- (4) Design and locate fuel treatments and fuel breaks based on ignition sources and accessibility for firefighters and maintenance activities.
Tradeoff: Fuel breaks may increase wildlife habitat fragmentation and loss, and function as a vector for invasive plants into high quality sagebrush habitats.
- (5) Monitor and remove invasive plants in vegetation or fuel treatments and fuel breaks and remove any nonnatives planted in fuel breaks that have spread outside of fuel breaks to ensure that they do not act as a vector for invasion.
Tradeoff: It will be necessary to recognize that although fuel breaks may have a single management objective and result in an ecological type conversion, they should still be managed to prevent plant invasions.
- (6) Consider designing prescribed burns that result in a mosaic of burned and unburned patches to maintain seed sources and habitat connectivity rather than designing larger, more extensive burns.
Tradeoff: Additional planning and careful execution is needed to create mosaics that will enhance connectivity.
- (7) Use resilience and resistance classes to prioritize areas for postwildfire recovery efforts to increase cost:benefit ratios.
Tradeoff: This approach requires additional staff training to implement and monitoring to evaluate effectiveness.
- (8) Continue partnerships, such as the multi-jurisdictional Cooperative Weed Management Area (CWMA) partnership, for invasive plant management.
Tradeoff: Prioritizing for the largest invasion or for protection of more intact uninvaded sagebrush systems, especially at low resilience and resistance, will require partner engagement. Determining which agency programs should cover the cost of treatment is challenging.
- (9) Focus eradications and rapid response efforts on areas that act as invasive plant vectors (e.g., along roadsides).
Tradeoff: This requires proactive collaboration with and education of State or county agencies responsible for road maintenance and of grazing lessees who may not treat invasive plants on private lands because of the cost.
- (10) Keep annual invasive patches small and focus efforts on proactively treating these before they expand.
Tradeoff: Budgets are limited and treating invasive plants, which includes initial and follow-up treatments and monitoring, is expensive.
- (11) Train field specialists, staff, and the public (including permittees) to recognize local weeds and invasive plants and their negative effects on public lands.
Tradeoff: This takes additional resources initially, but can yield large benefits.
- (12) Incorporate monitoring of any new “invasions” into existing vegetation monitoring efforts.
Tradeoff: Funding and staffing will be needed, as will time to develop collaborative partnerships across jurisdictional and private property boundaries.

(Continued)

Table 9.1—(Continued).

Critical Information Needs:

- (1) Determine how to best address invasive plants in low resilience and resistance areas at a large scale.
- (2) Evaluate the use of a variety of plant species, including native species, for fuel breaks.
- (3) Develop an understanding of how many plants per square foot or how much cover of perennial grasses is needed following wildfires and prescribed fires to promote recovery and effectively keep annual grasses under control. (This is likely to vary by ecological site type.)
- (4) Develop better metrics for measuring perennial grass mortality following both wildfires and prescribed burns and for determining the need to seed.

WILDLAND FIRE AND VEGETATION MANAGEMENT and SEED STRATEGY

Desired Management Outcome:

Resilience and resistance of sagebrush ecosystems are maintained and transitions to desirable new states or site types are facilitated through stabilization, rehabilitation, and restoration treatments following wildfire.

Management Considerations:

- (1) Capitalize on natural recovery following wildfires by evaluating the burned areas' environmental conditions and identifying where native plant species will recover on their own and where native plant species should be planted, seeded, or both.

Tradeoff: Additional effort is required to assess postfire areas to determine the ecological site types and their resilience and resistance after wildfire (see Miller et al. 2015). If bunchgrasses are not adequate for natural succession and site recovery, seeding is likely to be necessary.

- (2) Use genetically appropriate seed sources identified by seed transfer zones, rather than nonnative species or native cultivars, to avoid introducing species that are invasive or overly competitive with native species.

Tradeoffs: Seeding with nonnatives represents an ecological tradeoff because they have the potential to invade, compete with native species, or spread beyond a project boundary. Seeding with native cultivars represents a genetic tradeoff because of potential adverse impacts to local population genetics through hybridization that may affect overall species fitness. However, seed choices may be limited until more source-identified germplasm is developed by seed zone for native forbs, grasses, and shrubs.

- (3) Better match local site conditions with seeded species (right seed, right place, right time) to minimize ecological impacts and increase treatment success (e.g., avoid seeding low sagebrush sites with big sagebrush species).

Tradeoff: More effort and resources are needed to adequately assess sites, determine the appropriate species, and obtain the needed seed sources. Many native species are not readily available and require time for cultivation practices to be developed and for larger-scale seed increase to occur.

- (4) Increase sources of sagebrush by developing seed orchards through the private sector for the different ecoregions in the sagebrush biome.

Tradeoff: Seed sources must be carefully chosen and trusted contractors located.

- (5) Evaluate several approaches for seeding on harsh sites, such as encapsulating seed.

Tradeoff: Successfully implementing more effective seeding approaches may increase expense and will necessitate monitoring outcomes.

- (6) Follow seedings over time using effectiveness monitoring to determine whether and when retreatment is needed or whether the treatment was successful.

Tradeoff: Monitoring resources must be allocated to determine treatment effectiveness.

- (7) Carefully evaluate whether and when herbicide application is needed for postfire reclamation of areas with invasive plants.

Tradeoff: Application of pre-emergent herbicides with active ingredients like Imazapic prior to seeding may be appropriate for burned areas with high risk of invasive annual grass or sites where release of native species would be enhanced by reducing annual grass invasion risk. However, depending on application rates, surviving native species and seedbanks may be affected for several years post-application.

- (8) Carefully evaluate the use of drill seeding and aerial seeding treatments.

Tradeoff: Aerial application of seed after wildfires has been shown to be largely ineffective, except on moister sites (Knutson et al. 2014). However, drill seeding may not be possible in some areas due to terrain conditions. Seeded species may interfere with native species recovery (section 6) and before deciding whether a site even requires seeding, it is necessary to first determine whether there are sufficient native species for recovery. On sites where seeding would be beneficial, but aerial seeding is unlikely to be successful and drill access is limited, it may be necessary to allow recovery without seeding and manage some risk of an invasive plant species component.

(Continued)

Table 9.1—(Continued).

- (9) Test species known to be tolerant of fire and to increase resistance to invasion in fuel breaks.

Tradeoff: Seeding of native species that are not preferred by cattle in fuel breaks could help reduce the spread of cheatgrass in fuel breaks. However, managers and practitioners are not always comfortable using species that they are unfamiliar with or have not used previously.

WILDLAND FIRE AND VEGETATION MANAGEMENT and LIVESTOCK GRAZING MANAGEMENT

Desired Management Outcome:

Grazing management is flexible enough to allow livestock to be moved as needed to maintain the resilience and resistance of sagebrush ecosystems and to provide for grazing deferment following postfire restoration.

Management Considerations:

- (1) Train field personnel in how to manage grazing pre-fire to minimize fire risk in fire susceptible areas and post-fire to promote site recovery.

Tradeoff: This type of training needs to balance the needs to reduce fuels, while maintaining or increasing perennial native grasses to promote postfire recovery. If grazing is not carefully managed, it can decrease resistance to invasive annual grasses and increase fire risk.

- (2) Consider all available options for managing grazing (e.g., season of use, number of animals, type of livestock), and determine whether those options are sufficient to achieve objectives or whether new options need to be explored.

Tradeoff: The grazing permit states the number of livestock (AUMs and season of use) and it is legally binding for grazing on public lands. Permits may need to be adjusted to maintain resilience and resistance and provide for grazing deferment following postfire restoration.

- (3) Minimize grazing use, or adjust the timing or levels of grazing use that are currently promoting spread of annual invasive grasses, which in turn increase fire occurrence and spread.

Tradeoff: Permittees or lessees may not have sufficient flexibility or be receptive to these types of changes even though failure to change may increase fire risk.

- (4) Manage for threatened and endangered (T&E) species' habitats, riparian areas, and restoration and postfire rehabilitation areas that may need a reduction in livestock grazing impacts.

Tradeoff: Managers may be pressured to allow livestock grazing to take precedence over other resources.

- (5) Work with permittees or lessees in an adaptive management setting to defer the onset of grazing to allow for successful postfire restoration projects.

Tradeoff: Grazing is addressed at the local level with each ranch being its own unit. Postfire grazing deferments may depend on the size of the fire, the resources at risk, and impacts to the grazing permittee or lessee. Permittee or lessee willingness to move livestock in relation to seeding and grazing tolerance may vary by geographic area.

- (6) Strategically place targeted grazing in areas where it will be the most effective for fuel reduction and managing fuel breaks.

Tradeoffs: Targeted grazing practices may not always work for permittees or lessees because of the time and management practices required to implement it effectively (e.g., it is expensive for permittees or lessees, or permittees or lessees may not want to participate). If not properly executed, targeted grazing may increase invasion by nonnative annual grasses and fire risk.

Critical Information Needs:

- (1) Determine the effectiveness of grazing to maintain fuel breaks along roadsides or other linear features at operational scales.
- (2) Evaluate the effects of targeted grazing to control invasive annual grasses on establishing and maintaining native grasses.

WILDLAND FIRE AND VEGETATION MANAGEMENT and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Wild horses and burros are maintained at AML, which are intended to be population levels that provide for resilience and resistance of rangeland ecosystems and are consistent with other land uses and resources. WHBs are limited to designated management areas: Herd Management Areas (HMAs) and Herd Areas (HAs) on BLM lands; and Wild Horse Territories (WHTs), Wild Burro Territories (WBTs), and Wild Horse and Burro Territories (WHBTs) on Forest Service lands.

(Continued)

Table 9.1—(Continued).

Management Considerations:

- (1) Monitor vegetation and fuel loads to determine the effects of WHBs on wildfire and the fire/invasive annual grass cycle and ecosystem resilience and resistance.

Tradeoff: WHBs may decrease fuel loads and the potential for wildfire, but may also reduce perennial grasses and forbs, decrease forage for livestock, and compete with wildlife.

- (2) When WHB management areas experience large fires and large-scale WHB removals are not possible, plan for lands to be grazed or browsed by WHBs.

Tradeoff: During wildland or prescribed fires, burned fences can lead to WHB movement outside of established pastures. If WHBs are above AML, they may decrease postfire recovery and increase the risk of nonnative invasive plant spread.

- (3) Explore and fund options for effective exclusion of WHBs in areas of postfire vegetation recovery.

Tradeoffs: Given that horses can routinely move 10 miles (16 kilometers) between water and available forage (Hampson et al. 2010), any seeding area, as well as newly revegetated areas after burns, can be attractive forage to WHBs if the areas have palatable forage. WHB presence in postfire recovery areas is likely to decrease seeding success, especially if WHBs are above AML.

- (4) For prescribed fires, consult with the local WHB specialist or other appropriate agency staff about which gates should be left open to allow WHBs to escape burn areas.

Tradeoff: WHBs have the potential to impact adjacent areas.

- (5) Temporarily remove most WHBs from a landscape (with an emergency gather, holding in BLM facility) to facilitate postfire rehabilitation.

Tradeoff: The efficacy of such options should be weighed against expense and effects on livestock grazing movements. Emergency gathers require agency approval, and may require NEPA analysis.

Critical Information Needs:

- (1) Determine the conditions under which WHBs spread invasive annual grasses and affect invasive plant species distributions, which in turn influence fire processes.
- (2) Determine the effects of WHBs on fuels and wildfire probabilities and evaluate the tradeoffs between reducing fuels and ecological resilience and resistance.

INVASIVE PLANTS and SEED STRATEGY

Desired Management Outcome:

Management practices are modified to maintain or increase resilience and resistance by protecting native seed sources, providing sufficient native seed for restoration or rehabilitation projects, and establishing mixes of species that can compete effectively with invasive plant species.

Management Considerations:

- (1) Ensure that permitting for native seed collection is not resulting in overcollection of native populations by not allowing seed collection in the same areas every year.

Tradeoff: Native seed collections may require additional oversight to ensure permit compliance and cost more.

- (2) Diversify seed mixes to include a variety of life forms (shrubs, grasses, and forbs) that increase ecosystem function and provide the range of plant phenologies and rooting depths necessary for long-term resilience to disturbance and resistance to invasive annual grasses.

Tradeoff: Until the availability of genetically appropriate native plant material increases, it may be difficult to develop more diverse seed mixes.

- (3) Use restoration and rehabilitation practices that will help ensure establishment and persistence of diverse mixtures of seeded species.

Tradeoff: Diverse seed mixes may require adjusting seeding methods, such as seeding depth, based on seed size and germination requirements of the individual species.

- (4) Evaluate site conditions on low resilience and resistance areas to determine whether ecological thresholds have been crossed that may influence the choice of seeded species.

Tradeoffs: Use of nonnative species and native cultivars on highly disturbed or invaded sites that have crossed ecological thresholds may meet objectives for site stabilization or fuel breaks. However, it is necessary to acknowledge that these types of seedings are not designed to meet wildlife habitat objectives.

(Continued)

Table 9.1—(Continued).

- (5) Use postfire vegetation monitoring and reporting to evaluate the competitive ability of both native plant species and mixtures, including forbs, with invasive annual grasses.

Tradeoff: Seed mixes need to match site conditions well in order to effectively evaluate their competitive ability.

Policy Need:

- (1) Change current seed laws to increase consistency in not allowing cheatgrass seed in commercial seed sources, because it is difficult and expensive to remove from purchased seed and seeded sites. This requires evaluation. If seed law required cheatgrass-free seed, then there could be economic impacts and less native seed availability if it is cost-prohibitive or operationally impossible to provide cheatgrass-free seed.

INVASIVE PLANTS and LIVESTOCK GRAZING MANAGEMENT

Desired Management Outcome:

Grazing management maintains or increases resilience and resistance by decreasing or minimizing dispersal and growth of invasive plant populations and does not increase invasive plants when used as a tool for reducing fuels.

Management Considerations:

- (1) Evaluate the different vectors (dispersers) of nonnative invasive plants, including livestock grazing, WHBs, and wildlife, to determine the relative effects of the different vectors.

Tradeoff: Vehicle and livestock movement among parcels can transport and assist dispersal of invasive plant seed, increasing invasive plant species spread and necessitating early detection and treatment based on vector management. If movement among parcels is prevented, then additional areas may be needed for grazing. If invasive plant species spread is not addressed through vector management and hence restriction of the invasion to the original location, a much larger invasive plant species management problem may develop.

- (2) Consider both the state of invasion and resilience and resistance when developing or modifying grazing management practices in areas with invasive annual grasses.

Tradeoff: There are general management strategies for cheatgrass and other nonnative invasive annual grasses based on resilience and resistance and the invasion state (tables 5.1, 5.2) that can be used to help evaluate whether grazing management is appropriate for the site conditions and degree of invasion. Monitoring to ensure that grazing management decreases the degree of invasion or at a minimum does not increase it can be used to develop more effective grazing strategies, but may require additional investment.

- (3) Consider the state and condition of the areas being evaluated for targeted grazing, including relative resilience and resistance, the degree of invasion by nonnative annual grasses, and proximity to invaded areas.

Tradeoff: Targeted grazing may help reduce the biomass of nonnative invasive annual grasses and thus fuels once these grasses are dominant, but in uninvaded or low invasion areas improper grazing may increase invasive plant species. Appropriate use will depend on the degree of invasion.

- (4) Conduct coordinated research and management trials to evaluate the effectiveness of targeted grazing for setting up fuel breaks or fuel reduction. This effort should be limited. Managers should evaluate the amount of time and infrastructure required and strategize as to where to try targeted grazing.

Tradeoff: Targeted grazing to establish effective fuel breaks requires intense livestock management during a short time period. It may be difficult or expensive for permittees or lessees to implement and require close monitoring of contractors. Annual maintenance would be required; species other than cattle, such as sheep and goats, may have less impact, but carry disease risk if bighorn sheep (*Ovis canadensis*) are in the area. Targeted grazing may increase invasive annual plants, facilitate new invasions attributable to livestock movement, or reduce vigor of extant native plants.

- (5) Evaluate the need to move livestock grazing operations outside of the allotment or into different pastures within an allotment after a treatment or disturbance until the desired outcomes are obtained.

Tradeoff: The producer has to keep livestock off the allotment or off certain pastures within an allotment for a set number of years depending on resilience and resistance and current level of invasion by nonnative annual grasses. But policy or landowner agreements limit the flexibility to change implementation guidelines. Returning livestock to the allotment earlier than guidelines suggest may decrease overall sustainability of ecological conditions and forage sources.

- (6) Require the use of weed-free hay for supplemental feeding of livestock following wildfire.

Tradeoff: Requiring weed-free hay is expensive in the short term, but can reduce long-term costs of managing invasive plants.

(Continued)

Table 9.1—(Continued).

- (7) Consider creating grass banks where livestock can be moved during the period required for areas to recover after restoration or rehabilitation activities.

Tradeoff: Nonnative plant species could be seeded to provide for grazing in certain areas, such as those with low resilience and resistance, rather than seeding with native plant species, but this may have negative ecological effects in the long term.

- (8) Use a holistic approach when evaluating effects of livestock grazing on invasive plants that considers: (a) the management objectives; (b) current ecological state, resilience and resistance, and geographic area; (c) wildlife resources; (d) distance to water to prevent concentration of impacts from grazers; (e) different management needs for managing different kinds of livestock (cattle, sheep, goat, horse); and (f) control of livestock for utilization and ability for timing and frequency of movement of the herd.

Tradeoff: Clear information on appropriate grazing management (timing of grazing, number of livestock) based on the ecological site type and kind of livestock is needed for this type of approach but is often lacking.

INVASIVE PLANTS and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Wild horses and burros are maintained at AML, which is intended to be population levels that allow for the resilience and resistance of rangeland ecosystems and are consistent with other land uses and resources. WHBs are limited to designated management areas: HMAs on BLM lands; and WHTs, WBTs, and WHBTs on Forest Service lands.

Management Considerations:

- (1) Evaluate the degree to which WHBs versus livestock are acting as vectors (dispersers) of invasive plants.

Tradeoff: If movement of WHBs among parcels is prevented to manage weed invasions, then additional areas for grazing, or gathers, may be needed. If invasive plant species spread is not addressed through this type of vector management and thus restriction of the invasion to the original location, a much larger invasive plant species management problem may develop.

- (2) Consider both the state of invasion of invasive annual grasses and resilience and resistance of the area when evaluating the effects of WHBs and the need for gathers.

Tradeoff: There are general management strategies for cheatgrass and other invasive plants based on resilience and resistance and the invasion state (tables 5.1, 5.2) that can be used to help evaluate site conditions and the degree of invasion within management areas. Monitoring to ensure that WHBs grazing does not increase the state of invasion by nonnative annual grasses can be used to evaluate the need for gathers, but may require additional investment.

- (3) Identify areas without WHBs present that may be higher priority for conservation and restoration. Consult with local WHB specialists or agency staff to identify areas beyond HMA or WHT, WBT, or WHBT boundaries that WHBs occupy.

Tradeoff: Areas with valuable resources that have WHBs above AML may fail to receive restoration or conservation actions.

- (4) Consider how water sources influence WHB movement patterns when developing invasive plant management plans. (WHBs will congregate around water sources and move up to 10 miles each way from forage to water [Hampson et al. 2010], increasing the likelihood of spreading invasive plants.)

Tradeoff: This requires an extra step in developing invasive plant management plans but may have large benefits.

SEED STRATEGY and GRAZING MANAGEMENT

Desired Management Outcome:

Livestock grazing is managed to maintain or increase the resilience and resistance of restored or rehabilitated native plant communities.

Management Considerations:

- (1) Consider creating grass banks where livestock can be moved during the period required for areas to recover after restoration or rehabilitation activities.

Tradeoff: Areas already seeded with nonnative plant species could be used as grass banks. Nonnative plant species could also be seeded to provide for grazing in certain areas, such as those with low resilience and resistance, rather than seeding with native plant species, but this may have negative ecological effects in the long term.

(Continued)

Table 9.1—(Continued).

- (2) Consider using ecological site descriptions and state-and-transition models within the project area to evaluate the relative resilience and resistance of the area to be seeded.
Tradeoff: Ecological types and ecological sites with relatively low resilience and resistance often require more than one intervention for restoration efforts to succeed. Livestock use can have negative effects on project success.
- (3) Evaluate the distance to the nearest drinking water source for livestock during project planning.
Tradeoff: The shorter the distance, the greater the grazing pressure that can be expected, potentially decreasing the likelihood of success.
- (4) Consider installing fencing to prevent use by livestock on certain habitat restoration projects, particularly those associated with riparian areas.
Tradeoff: Temporary fencing for habitat rehabilitation is generally acceptable, but permanent fencing often requires a more in-depth environmental assessment or land use plan revision, and should be designed in a way that allows livestock to reach drinking water and move throughout the rest of the allotment.
- (5) Consider forgoing a habitat restoration project entirely instead of spending time and resources on projects where spring, summer, and fall season of use occurs or where permittees do not have the flexibility or desire to change grazing system or season of use.
Tradeoff: Areas in need of active restoration may not be treated unless grazing permits are revised.

SEED STRATEGY and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Wild horse and burro populations are managed at AML to protect sagebrush ecosystems from overgrazing and maintain resilience and resistance in areas where native seedings have been conducted.

Management Considerations:

- (1) Consider using ecological site descriptions and state-and-transition models within the HMA to evaluate the relative resilience to disturbance and resistance to invasive annual grasses of the area to be seeded.
Tradeoff: Ecological types or ecological sites with relatively low resilience and resistance often require more than one intervention for restoration efforts to succeed. WHBs use can have negative effects on project success.
- (2) Assess the current spatial extent and population size of any nearby WHB population during project planning.
Tradeoff: Effects of WHBs on seedings depend on the number of WHBs that can enter the site, and high numbers can limit project success.
- (3) Evaluate the distance to the nearest drinking water source for wild horses during project planning.
Tradeoff: The shorter the distance, the greater the grazing pressure that can be expected, potentially decreasing the likelihood of success. Horses can travel long distances (10 or more miles per day) from water to forage in arid to semi-arid environments (Hampson et al. 2010).
- (4) Consider installing fencing to discourage use by WHBs on certain habitat restoration projects, particularly those associated with riparian areas.
Tradeoff: Temporary fencing for habitat rehabilitation is generally acceptable, but permanent fencing often requires a more in-depth environmental assessment or land use plan revision. Permanent fencing should be designed in a way that lets WHBs reach drinking water, and allows their movement throughout the rest of the HMA.
- (5) Consider forgoing a habitat restoration project entirely instead of spending time and resources on projects in areas with wild horse populations above AMLs.
Tradeoff: Areas in need of active restoration may not be treated until WHB populations have been reduced.

GRAZING MANAGEMENT and WILD HORSE AND BURRO CONSIDERATIONS

Desired Management Outcome:

Wild horses and burros are maintained at AML, which is intended to be population levels that provide for resilience and resistance and allow for other land uses and resources (including livestock grazing). WHBs are limited to designated management areas: HMAs on BLM lands; and WHTs, WBTs, and WHBTs on Forest Service lands.

Management Considerations:

- (1) Maintain WHBs at AML because overpopulated WHB numbers along with management actions for grazing may have effects that are counter to rangeland health objectives.

(Continued)

Table 9.1—(Continued).

Tradeoff: Local economies may be impacted in the form of reduced grazing opportunities, reduced wildlife populations, and other multiple uses if WHBs are not maintained at AML.

- (2) Reduce WHBs to AML in order to stabilize rangeland conditions.

Tradeoffs: (a) Periodic deferment or movement of domestic livestock and adjustments of livestock allotments do not reduce WHB grazing impacts, especially where WHB densities are well above AML. (b) Livestock producers may not have the flexibility to move and adjust in response to WHBs and their impacts.

- (3) Once WHB populations are maintained at AML, monitor to determine whether land health standards are being achieved.

Tradeoff: If land health standards are not being achieved, and WHBs are causing the non-achievement, it is necessary to consider a reduction in AML in land use plans.

- (4) Where WHB numbers are above AML, consider using other available livestock management tools to minimize overlap with areas that have high WHB densities.

Tradeoff: Use of such tools presents challenges and costs to livestock producers. Livestock numbers may need to be decreased, but livestock grazing must be considered as a legally protected multiple use of the rangeland resource.

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