Conclusions

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Introduction

This report provides a foundation for climate change response on the Arapaho-Roosevelt and Pike-San Isabel National Forests located along the Front Range and mountainous regions of Colorado. The preceding chapters outline the best available scientific information on the impacts of climate change on the Arapaho-Roosevelt and Pike-San Isabel National Forests. This vulnerability assessment supports national forest managers in meeting expectations to consider climate change in their work, including land management planning guided by the 2012 Planning Rule for implementing the National Forest Management Act (36 CFR 219) and environmental analysis and decision making under the National Environmental Policy Act (42 USC § 4321). The importance of considering climate change in national forest management is highlighted in a series of recent Federal government-wide, department, and agency-specific policies, including Executive Order on Tackling the Climate Crisis at Home and Abroad (Executive Order No. 14,008, 2021), updated National Environmental Policy Act guidance from the Council on Environmental Quality, the USDA Secretary's Memorandum on Climate Resilience and Carbon Stewardship of America's National Forests and Grasslands (USDA 2022), and the Forest Service's Climate Adaptation Plan (USDA FS 2022).

Responding to climate change represents a key contemporary challenge for managers. It will require managers to modify existing management activities, explore new practices, and grapple with considerable levels of uncertainty. Climate change exacerbates existing management challenges, including intensifying recreation pressures in a region with a growing population, restoring fire-adapted forests, and restoring landscapes impacted by recent wildfires. This vulnerability assessment offers a starting point for managers and scientists to work together to take on these challenges. These collaborative efforts have begun, including through a science-management workshop that occurred as part of this vulnerability assessment and that is described below; however, tackling climate change will also require additional work building on this vulnerability assessment. This conclusions chapter provides some initial ideas to support future adaptation based on this assessment.

Vulnerability Assessment Workshop and Opportunities for Future Engagements

Vulnerability assessment processes offer opportunities for scientists and managers to learn from one another about impacts of climate change and potential management responses (Peterson et al. 2011; Swanston et al. 2016; Timberlake and Schultz 2019). To address this need, scientists and managers involved in this assessment convened for a 2-day workshop in November 2019 in Fort Collins, Colorado. The 35 attendees included staff from both national forest units, the Rocky Mountain Regional Office, and scientists

affiliated with the USDA Forest Service Rocky Mountain and Pacific Southwest Research Stations, the Northern Institute of Applied Climate Science, Colorado State University, and the United States Geological Survey Climate Adaptation Science Centers. During the workshop, scientists presented on climate change impacts to different resources, and workshop participants worked through a structured scenario planning approach to explore how to achieve management goals under different future climate scenarios (Murphy et al. 2016; Rowland et al. 2014).

For this scenario planning exercise, participants applied a modified version of the Climate Change Response Framework, which provides a step-by-step approach for developing adaptation approaches and tactics based on the strategies of resistance, resilience, and transition. In this context, the framework was modified to apply specifically to scenario planning (Millar et al. 2007; Swanston et al. 2016). Scenarios provided a picture of future conditions, and the Climate Change Response Framework walked participants through a structured process to consider implications for management and adaptation. Topics discussed by breakout groups included managing forests to reduce risks to insects and wildfire, climate-smart watershed restoration, developing climate-adapted winter recreation infrastructure, and managing changing social expectations in light of changing landscapes. These workshop discussions provided an initial opportunity for staff on these national forests to consider adaptation actions to take in response to climate change; however, they did not result in specific lists of adaptation actions. Moving forward, additional organized workshops and informal discussions may be necessary in order to apply the information in this vulnerability assessment to identify specific adaptation actions relevant to specific projects and activities occurring on these national forests.

Key Concepts in Forest Adaptation

A commonly used framework for guiding forest adaptation involves developing a "toolbox" of adaptation strategies based on the concepts of resistance, resilience, and transition (Millar et al. 2007; Peterson et al. 2011; Swanston et al. 2016). During the workshops described above, participants used these concepts to think through adaptation strategies, and this section briefly summarizes the concepts as they may be relevant for future applications of this assessment. Resistance describes the goal of forestalling or resisting change with the intent of maintaining current conditions or features on the landscape. Resilience aims to allow some level of change or disturbance but ensures that the system is able to recover and retain the same general composition, structure, pattern, and ecological processes following disturbance. Transition (or response) describes the goal of facilitating ecosystem transition and moving the system to a new state.

In designing projects and applying this vulnerability assessment, it may be useful to consider how treatment prescriptions may vary if guided by resistance, resilience, or transition, and how they may be affected under different climate scenarios. For

example, restoration of dry mixed-conifer forests under a resistance strategy may involve uniform thinning to reduce stand density coupled with fuel breaks to keep fire out of treated stands, whereas a resilience strategy may involve more substantial density reductions and thinning to create clumps of trees and gaps, leaving a residual structure able to accommodate low-severity surface fire under most conditions. A transition approach might involve treatments that promote a shift in species composition to favor ponderosa pine (*Pinus ponderosa*) with full removal of Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*), and that result in much lower residual densities. Alternatively, a transition treatment may involve allowing a burned area to transition from forest to grassland following a high-severity fire. By comparing potential treatment options across these concepts, managers may develop a better sense of the full range of possibilities. Ultimately, selecting the appropriate treatment will require considering site-specific conditions, management goals, and constraints.

Adapting to Changes

Climate change adaptation will require practitioners to translate information on climate vulnerabilities, including what is included in this assessment, and adaptation concepts like those described above, into feasible management actions. Many of these actions will build on things that managers are already doing, but they may need to modify these activities to address changes in timing, location, and intensity associated with climate change. This section provides some theoretical examples of these types of changes building on information in previous chapters of the vulnerability assessment, though it does not provide a comprehensive summary of the rest of the report.

As the preceding chapters demonstrate, climate change will lead to shifts in seasons and more variable conditions. Notably, the climate change projections considered in this report (Chapter 3) indicate that the study area will undergo changes in seasonal temperatures, duration of fire seasons, and timing of stream runoff, as compared to current conditions. In response, managers may need to shift the timing of when they implement certain management activities, allowed uses, and seasonal restrictions. For example, longer fire seasons may require looking earlier in the spring and later in the fall for appropriate burn windows for prescribed fire. Similarly, winters with lower snowpack may limit opportunities for pile burning and managers may need to concentrate these activities in the years that offer sufficient snowpack. Other examples of changes in timing include the potential for shorter seasons for winter recreation and longer seasons for warm-weather uses, which has implications for opening dates for recreation sites and roads. Preparing for these yearly variations, as well as changes in seasonality within years, will require enhanced flexibility in business practices, staffing, and out-year planning.

In addition to considering timing, managers will also need to consider how climate change will play out in space. Changes in temperature and precipitation patterns will affect the suitability of locations for supporting species, public uses, and management activities. In this landscape in particular, effects of climate change will interact with topography, and features like slope, aspect, and elevation will be important considerations in identifying adaptation actions. For example, in implementing postfire reforestation projects, silviculturists will need to make site-specific determinations of which species and genotypes are likely to survive given projected changes in climate, while considering factors like north-facing slopes that remain comparatively cooler. These types of careful considerations of changes in space are also relevant for managing watersheds, recreation, and other resource areas. Wildfires, flooding, and other disturbances may make the current locations of developed recreational sites less desirable or unsafe for recreational activities. Maps and other information in this vulnerability assessment help inform these considerations.

Climate change will intensify existing stressors to the landscape, and managers will need to modify the intensity of management activities accordingly. For example, climate change projections indicate an increase in days per year with high fire danger. As the chapter on forests indicates, more intensive drought conditions will impact seedling survival and tree mortality. Intensified drought conditions will also increase susceptibility to insect outbreaks. Thinning is already a common activity to build resilience to these stressors, as it reduces stress on individual trees, removes ladder fuels, and helps forests better accommodate surface fires while reducing the risk of crown fires. However, preparing for climate change may necessitate thinning over larger areas or increasing the intensity of the activity by thinning to lower residual densities.

Climate change may also contribute to intensified uses of public lands in the area. For example, disturbance events like fires and flooding may make some recreation areas unavailable or less desirable for recreation leading to intensified use at unaffected sites. More broadly, increased temperatures in communities along the Front Range may drive increased recreational visits as people look for opportunities to escape the heat and travel to higher elevations. Approaches for responding to these effects include permitting and reservation systems to manage crowding, barriers and signage to prevent resource damage from intensified use, and coordinated messaging and public education campaigns to provide recreationists with up-to-date information. Intensified use may also require more frequent and thorough maintenance activities, including cleaning of facilities and trail work.

Managing Under Uncertainty

Climate-informed management requires accepting the inherent uncertainty associated with climate change. While it is certain that changes will occur, there is still uncertainty in anticipating what the future will hold. For example, as Chapter 3 highlights, temperatures are projected to increase and changes in precipitation patterns are projected to occur; however, the specific magnitude of these changes depends on the models used and assumptions driving these models. Similarly, while previous chapters describe probable trends associated with climate change, it is still difficult to identify exactly when and where effects of climate change will show up on the landscape. The scenario planning process used at the vulnerability assessment workshop and described above offered one approach for considering uncertainty. A need for the future will be to develop management approaches that enable effective and intentional adaptation actions while also accepting the high levels of uncertainty associated with climate change.

Monitoring is essential in managing under uncertainty. Monitoring both indicators related to climate, such as snowpack, and those related to ecological, hydrological, and social responses to climate change can help improve understanding of ongoing trends. For example, ongoing monitoring of postfire tree regeneration trends along with climate indicators provides insights on how forests are recovering from fire under increasing temperatures. Monitoring approaches are also a key element of adaptive management, which generally describes structured efforts to learn while managing and adjust in response to this learning. Adaptive management approaches vary in their complexity but may involve asking questions and making hypotheses, designing projects as experiments, and using control sites. Across these efforts, robust monitoring is crucial for answering questions and facilitating learning that can further refine future management activities (Larson et al. 2013).

Applications in Decisionmaking

Vulnerability assessments offer peer-reviewed syntheses of scientific information that can help managers integrate climate change considerations into existing decisionmaking processes (Timberlake and Schultz 2019). Climate change considerations are broadly relevant to many facets of national forest management, including forest plan revision under the 2012 Planning Rule, project-level environmental analysis under the National Environmental Policy Act (NEPA), and other forms of strategic planning and prioritization. Recent policies emphasize the need to intentionally and explicitly consider climate change across these settings (USDA FS 2022).

Forest planning is a particularly appropriate situation for applying vulnerability assessments, given the longer timeframes and landscape scales associated with land management planning. Further, robust considerations of climate change in land

management plans facilitate the development of projects that address climate change (Timberlake and Schultz 2019). The 2012 Planning Rule, which guides land management planning under the National Forest Management Act, requires considerations of climate change throughout the planning process. The rule requires that assessment reports developed to inform plans consider climate change as a system driver and stressor (36 CFR 219.6). Land management plans developed under the rule are expected to consider climate change in providing for ecosystem integrity and multiple uses (36 CFR 219.8 and 219.10). Additionally, the monitoring program must address whether there are measurable changes to the plan area resulting from climate change (36 CFR 219.12). Collectively, the planning framework and its three phases are intended to enable adaptation to changing conditions.

Beyond land management planning, vulnerability assessments are also directly relevant to project-level planning, including NEPA analyses (Timberlake and Schultz 2019). In 2023, the Council on Environmental Quality released updated interim NEPA Guidance on Consideration of Greenhouse Gas Emissions and Climate Change, which guides Federal agencies' consideration of climate change in NEPA. The guidance indicates that NEPA analyses should consider the effects of climate change on proposed actions, the affected environment, and environmental effects, and highlights the value of using available assessments for meeting this expectation (CEQ 2023). The vulnerability assessment provides general context on observed and projected changes in climate, as well as detailed descriptions of climate effects across different resource areas, which can be efficiently incorporated into NEPA analyses. In addition, the vulnerability assessment can support other forms of decisionmaking, including programmatic multi-year planning, project prioritization, and discipline-specific processes like watershed restoration action plans.

Looking Forward

In 2022, the Forest Service released its Climate Adaptation Plan that highlights the importance of adapting to climate change to the agency's ability to achieve its mission and aligns agency efforts with expectations in executive orders and other high-level policies (USDA FS 2022). This national plan highlights high level challenges brought on by climate change, including changing wildfire regimes and intensifying extreme events, and identifies adaptation actions that managers can implement to address these challenges. The Forest Service Climate Adaptation Plan serves as a call to action for all agency staff and their partners to understand and address climate change in the landscapes where they work. In 2023, Region 2 will draft a regional climate action plan tiering to the six climate change vulnerabilities described in the national adaptation plan. The regional action plan will provide specific adaptation actions that tier to this and other vulnerability assessments. This vulnerability assessment provides a useful resource to help managers on the Arapaho-Roosevelt and Pike-San Isabel National Forests take on this national priority and manage their lands and resources under climate change.

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