Chapter 7: Conclusions

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The Sierra Nevada Infrastructure and Recreation Vulnerability Assessment and Adaptation Partnership (hereafter Sierra Nevada Partnership) contributed to our understanding of climate change vulnerabilities and responses to potential climate change effects in national forests in the Sierra Nevada (Modoc National Forest [NF], Lassen NF, Plumas NF, Tahoe NF, Lake Tahoe Basin Management Unit, Eldorado NF, Stanislaus NF, Sierra NF, Inyo NF, Sequoia NF). The effort synthesized the best available scientific information to assess climate change vulnerability for recreation and infrastructure, developed recommendations for adaptation options, and catalyzed a collaboration among land managers, scientists, and stakeholders seeking to address climate change issues. Furthermore, the vulnerability assessment and corresponding adaptation options provided information to support national forests in implementing agency climate change objectives described in the National Roadmap for Responding to Climate Change (USDA FS 2010a).

Relevance to Climate Change Strategies

The Sierra Nevada Partnership process is directly relevant to climate change strategy and accountability in the U.S. Department of Agriculture, Forest Service (USFS) (USDA FS 2010a, 2010b). Information presented in this report is also relevant for other land management entities and stakeholders in the Sierra Nevada Partnership assessment area. This process can be replicated and implemented by any organization, and the adaptation options are applicable beyond USFS lands. As in previous assessment and adaptation efforts (e.g., Halofsky and Peterson 2017; Halofsky et al. 2011, 2018a, 2018b, 2019, in press; Raymond et al. 2014), a science-management partnership was critical to success. Those interested in utilizing this approach are encouraged to pursue a partnership as the foundation for increasing climate change awareness, assessing vulnerability, and developing adaptation plans.

The Sierra Nevada Partnership fills a strategic gap for the USFS Pacific Southwest Region by focusing on recreation and infrastructure, which are critical ecosystem services provided by national forests, as well as major social and economic considerations in California. This assessment of recreation and infrastructure complements climate change assessments for other resources that are focused on Sierra Nevada national forests (Kershner 2014) or encompass national forests within the broader scope of the Sierra Nevada (Dettinger et al. 2018).

The Sierra Nevada Partnership includes strategic priorities and activities that help fulfill the Pacific Southwest Region vision for leadership in restoration

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(USDA FS 2015). The partnership also connects with other assessments and strategies in California that provide a broader context for documenting and responding to the effects of climate change. This broader context includes the "Natural and Working Lands Climate Change Plan" (State of California 2019), the "California forest carbon plan" (Forest Climate Action Team 2018), and "California's forest and rangeland assessment" (Brown et al. 2018). The USFS provides leadership in multiple collaborations of agencies and other institutions focused on natural and human resources in the Sierra Nevada.

Relationships developed through the Sierra Nevada Partnership process were as important as the products that were developed, because these relationships build the partnerships that are the cornerstone for successful agency responses to climate change. The partnership among USFS resource management, USFS research, other agencies, various stakeholders, and the University of Washington will remain relevant for future forest planning and management efforts. By working with stakeholders, the capability to respond effectively to climate change increases, especially in the context of shared stewardship of resources beyond National Forest System lands.

Climate change response is a relatively new and evolving aspect of land management, and the Sierra Nevada Partnership provided an opportunity for participants to effectively communicate their professional experiences with respect to climate change and resource management in a collaborative and supportive environment. The workshops were especially valuable because they covered a broad range of topics, and multidisciplinary group discussions resulted in conceptual breakthroughs across disciplines and land management boundaries.

Communication, Education, and Organizational Capacity

Organizational capacity to address climate change requires building institutional capacity in management units through information exchange and communication. Information sharing and education were built into the Sierra Nevada Partnership process through webinars, face-to-face meetings of the assessment team (resource managers and scientists), and a series of workshops convened at three locations at Sierra Nevada national forests. At the workshops, scientists presented results of the vulnerability assessment, focused on climate change projections and on the effects of climate change on hydrology, recreation, and infrastructure. Resource managers and stakeholders then developed adaptation options in response to climate sensitivities identified in the assessment, including options relevant at the subregional scale and national forest scale. This hands-on approach allowed resource managers to both participate in the process and contribute directly to information and outcomes, thus increasing organizational capacity to address climate change.

Assessing Vulnerability and Adaptation

A science-based climate change vulnerability assessment requires units to identify the most vulnerable resources, assess the expected effects of climate change on vulnerable resources, and identify management strategies to improve the adaptive capacity of national forest lands. The Sierra Nevada Partnership vulnerability assessment described the climate change sensitivity of recreation and infrastructure in national forests located in the Sierra Nevada. Adaptation options developed for each resource area can be incorporated into resource-specific management plans.

Dialogue among groups of resource managers and scientists identified management practices that are useful for increasing resilience and reducing stressors to on-the-ground and organizational components of recreation and infrastructure. Although implementing all adaptation options developed in the Sierra Nevada Partnership process may not be feasible, resource managers can draw from the menu of options (chapter 6) as needed. Some adaptation options can be implemented now, whereas others may require revised management plans or policies, or may become more appropriate as climate change effects become more apparent.

Science and Monitoring

Current monitoring programs that provide information for detecting climate change effects were identified for some components of the vulnerability assessment. Information gaps and uncertainties important to understanding climate change vulnerabilities and management influences on vulnerabilities were also identified. These information gaps can help determine where monitoring and research would reduce uncertainties inherent in management decisions. Working across multiple jurisdictions and boundaries will allow Sierra Nevada Partnership participants to potentially increase collaborative monitoring on climate change effects and effectiveness of adaptation actions. Scientific documentation in the assessment can also be incorporated into large landscape assessments such as national forest land management plans, environmental analysis for National Environmental Policy Act (NEPA) projects, and specific project design criteria and mitigations.

Implementation

Although challenging, implementation of adaptation options will gradually occur with time, often motivated by extreme weather and large disturbance events, and facilitated by changes in policies, programs, and land management plan revisions. It will be especially important for ongoing restoration programs to incorporate considerations for climate change adaptation to ensure effectiveness. A focus on thoroughly vetted strategies may increase ecosystem and organizational function

and resilience while minimizing implementation risk. Land management agencies, American Indian tribes, and private landowners working together will make implementation effective, particularly across boundaries.

Implementation of climate-informed management practices is often motivated by the occurrence of extreme weather events. For example, the storms of 2016–17 in the Sierra Nevada and beyond caused widespread damage to roads and other infrastructure (USDA FS 2017). Extensive drought-related tree mortality in the Sierra Nevada and severe wildfires throughout California over the past decade have captured the attention of federal land managers and the general public. Fortunately, the USFS has access to both internal sources of science-based options that address weather- and climate-related phenomena (e.g., USDA FS 2018) (chapter 3) and external programs focused on adaptation in California (e.g., Cal-Adapt).

Integration Across Resources

This report discusses climate sensitivities in separate chapters for recreation and infrastructure. In practice, overlap exists between these resource areas in terms of biophysical function, socioeconomic implications, and management responses (chapter 6). For example, water, infrastructure, and recreation are all sensitive to winter soil saturation that can lead to erosion and landslides. Higher temperatures, lower snowpack, earlier snowmelt, lower summer streamflow, and increased disturbances are prominent stressors. The compound influence of multiple stressors leading to larger and more frequent disturbances affects recreation, infrastructure, and many other resource areas. Identifying common concerns across resource areas may provide opportunities to coordinate adaptation efforts, thus improving effectiveness and efficiency.

Adaptation options are generally designed to protect individual resources, and reorganizing adaptation strategies and tactics by sensitivity may provide insight on opportunities for coordination. In some cases, adaptation options were identified that are relevant for both recreation and infrastructure, suggesting a need to coordinate and integrate adaptation planning. It is also important to consider adaptation options that are relevant for other resource issues included in previous climate change assessments for the Sierra Nevada (e.g., vegetation, water resources) (Dettinger et al. 2018, Kershner 2014). Adaptation options that yield benefits to more than one resource are likely to have the greatest overall benefit (Halofsky and Peterson 2017; Halofsky et al. 2011, 2018a, 2018b, 2019, in press; Peterson et al. 2011; Raymond et al. 2014). Some adaptation options involve tradeoffs and uncertainties that need further exploration. Assembling an interdisciplinary team to tackle this issue will be critical for assessing risks and developing risk management options.

Information in this assessment can be incorporated into everyday work through climate-informed thinking, assist in planning, and influence management priorities such as public safety. Flooding, wildfires, and insect outbreaks may all be exacerbated by climate change, affecting both recreation and infrastructure, and increasing the frequency and extent of hazards faced by federal employees and the public. Resource management can help minimize these hazards by restoring hydrologic function and reducing fuels. These management activities are commonplace, demonstrating that in many cases, current resource management is already preparing for a warmer climate.

Operations

Implementation of adaptation actions may be limited by insufficient human resources, insufficient funding, and conflicting priorities. However, climate-influenced effects are already apparent for some resource areas, such as altered hydrologic regimes and increased area burned by wildfires. Some adaptation options may be precluded and resources may be compromised if actions are not implemented soon. This creates an imperative for timely inclusion of climate change considerations in resource management and agency operations.

The climate change vulnerability assessment and adaptation approach developed by the Sierra Nevada Partnership can be used by the USFS and other organizations in many ways. From the perspective of federal land management, this information can contribute to the following aspects of agency operations:

- **Landscape and resource assessments:** The vulnerability assessment can be used to inform the assessment phase of planning, providing information on departure from desired conditions and best available science on climate change effects on resources. In addition, adaptation options describe desired conditions and management objectives for inclusion in planning documents.
- **Resource management strategies:** The vulnerability assessment and adaptation options can be used in forest resilience and restoration plans, conservation strategies, fire management plans, infrastructure planning, and State Wildlife Action Plans.
- **Project NEPA analysis:** The vulnerability assessment provides best available science for documentation of resource conditions, climate change effects analysis, and development of alternatives. Adaptation options provide project design recommendations for specific locations.
- **Monitoring plans:** The vulnerability assessment identifies knowledge gaps that can be addressed by monitoring.

- **National forest land management plan revision process:** The vulnerability assessment provides a foundation for understanding key resource vulnerabilities caused by climate change for the assessment phase of forest plan revision. Information from vulnerability assessments can be applied in assessments required under the USFS 2012 Planning Rule, describe potential climatic conditions and effects on key resources, and identify and prioritize resource vulnerabilities to climate change in the future. Climate change vulnerabilities and adaptation strategies can inform forest plan components such as desired conditions, objectives, standards, and guidelines.
- **Project design/implementation:** The vulnerability assessment and adaptation options provide recommendations for mitigation and project design at specific locations. A Story Map tool (https://arcg.is/q8GGf0), typically integrated with geospatial information, can further aid land managers in applying the vulnerability assessment and adaptation options at a local scale.

We are optimistic that climate change awareness, climate-informed management and planning, and implementation of climate change adaptation options in the Sierra Nevada Partnership assessment area will continue to evolve. We anticipate that within a few years:

- Climate change will become an integral component of federal agency operations.
- The effects of climate change on natural and human systems will be continually assessed.
- Monitoring activities will include indicators to detect the effects of climate change on recreation and infrastructure.
- Agency planning processes will provide more opportunities to manage across boundaries.
- Organizational capacity to manage for climate change will increase within federal agencies and with local stakeholders.
- Resource managers will implement climate-informed practices in long-term planning and management.

This assessment provides a foundation for understanding potential climate change effects and implementing adaptation options that help reduce the negative impacts of climate change and transition resources and management organizations to a warmer climate. We hope that by building on existing partnerships, the assessment will foster collaboration in climate change adaptation and resource management planning in the Sierra Nevada and beyond.

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