CIRMOUNT UPDATES

Adapting to Climate Change in Western National Forests: A Decade of Progress

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National forests in the western United States comprise a large proportion of the forested landscape of the Western states, providing many ecosystem services, including timber, water, food, bioenergy, plant and animal habitat, recreation opportunities, and cultural values. Climate change will likely affect the provisioning of these forest ecosystem services, shifting ecosystem productivity, disturbance regimes, and species composition. With increases in temperatures over the last several decades, changes in hydrological processes, including reductions in snowpack, mountain precipitation, and streamflow have already become apparent in some locations. Across the western U.S., there have been increases in area affected by wildfire and insect outbreaks. These trends are likely to continue with increasing temperatures in the coming decades, with disturbance driving forest ecosystem change.

To minimize the negative effects of climate change on forests and the services they provide, natural resource managers need to both understand the potential effects of climate change and have options to address those effects. In recent years, governmental and nongovernmental organizations have been developing climate change vulnerability assessments and exploring adaptation options (Fig. 1). Federal land management agencies in the United States are required to evaluate the potential risks associated with climate change to minimize short- and long-term effects on their operations and mission. As mandated in Executive Orders 13514 and 13653 issued by President Obama, many federal agencies have now developed general climate change vulnerability assessments, adaptation plans, and strategies for addressing climate change. For example, the U.S. Forest Service provided specific direction to the National Forest System in the form of the National Roadmap for Responding to Climate Change and the Performance Scorecard for Implementing the Forest Service Climate Change Strategy. Similarly, the U.S. National Park Service released a Climate Change Response Strategy that provided direction to the agency and employees in addressing climate change, followed by a Climate Change Action Plan, which contained further guidance for national park managers for responding to climate change.

Figure 1. Glacially carved landscapes, dense coniferous forest, and deep lakes are common in the Northern Rockies, where the Northern Rockies Adaptation Partnership was conducted. Photo: National Park Service.

Figure 2. Dry forest dominated by ponderosa pine (shown here in Deschutes National Forest) is common at low to mid elevations in south central Oregon, where the South Central Oregon Adaptation Partnership was conducted. Photo: Miles Hemstrom.

Despite recent progress in climate change assessments and plans, development of local to regional-scale vulnerability assessments and adaptation plans has been slow and uneven across agencies and organizations. Much of the progress to date has been accomplished through science-management partnerships, which have emerged as effective catalysts for developing vulnerability assessments and land management adaptation plans at both strategic (general) and tactical (on-the-ground) levels (Fig. 2). Science-management partnerships typically involve iterative exchange of information on regional climatology and climate change effects from scientists, and of information on local climate (and weather), ecology, and management from managers. This iterative information sharing aids identification of key vulnerabilities to climate change at the local scale, setting the stage for developing place-based adaptation strategies and tactics.

The Process

Our journey started in 2007. Prompted by the Fourth IPCC Assessment released that year, the American public and political leadership became more engaged in the realities of climate change, and federal agencies started to make progress, typically led by scientific efforts within the agencies. The first climate change vulnerability assessments in national forests were initiated in Tahoe and Inyo National Forests (Connie Millar, Toni Lyn Morelli) and in Olympic National Forest (Jessica Halofsky, Dave Peterson). There was no recipe or guidebook, and although assessments for various topics are common in federal agencies, addressing climate change was a new topic, and we made things up as we went along, while building relationships with local resource managers.

These seminal climate-change assessments led to a four-stage process that has now been institutionalized in the Forest Service (Fig. 3). First, education is provided to federal resource managers to ensure a common understanding of basic climate science and how it applies to terrestrial and aquatic ecosystems. Education takes place in workshops or webinars. Second, the assessment is conducted by teams of scientists, resource managers, and often stakeholders to project the effects of climate change on vegetation, water resources, fisheries, etc. Although some new analyses are often conducted (e.g., vegetation modeling), most of

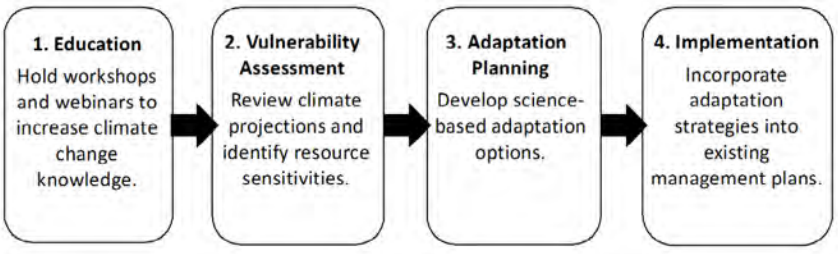

Figure 3. The process used by Adaptation Partners to build organizational capacity for climate change in the U.S. Forest Service and other agencies.

the assessment consists of synthesizing existing information and developing inferences about climate change effects. Third, the assessment is used as the basis for developing adaptation options in response to potential climate change effects. Adaptation options are elicited from resource managers in a workshop setting. Finally, all of the preceding information is (potentially) implemented in national forests operations, including land management plans, NEPA documents, project plans, and monitoring programs. Implementation is at the discretion of national forest leadership, and although it has generally been slow, the pace of implementation is accelerating, motivated by the Forest Service Planning Rule (2012) and recent guidance issued by the Council on Environmental Quality (2016).

Science-management partnerships have been the foundation for all assessments conducted during the past decade. Consisting of a group of researchers and resource managers who work together over a two-year period, the partnership implies both trust and commitment in producing a final product that will be useful to the national forests. That product is typically a published report (a Forest Service General Technical Report), but also includes journal articles that document the science, in addition to face-to-face meetings with national forest leadership and planners responsible for incorporating climate change into operations.

Most climate change assessments in the western U.S. have been conducted by our Adaptation Partners organization (adaptationpartners.org). Although funded mostly by the Forest Service, we work with a wide range of federal, state, university, tribal, and non-governmental partners (the more perspectives the better). And we normally conduct assessments using an all-lands approach that includes lands outside national forest boundaries.

Making Progress

To date, we have established seven climate change partnerships located in Washington, Oregon, Idaho, Montana, North Dakota, Utah, Nevada, and Wyoming, encompassing 38 national forests, 29 national park units, and other lands (Fig. 4). These projects cover about 27 million hectares of forest and rangeland. The partnerships have been small (Olympic Peninsula: 1 national forest, 1 national park), medium-sized (South Central Oregon: 3 national forests, 1 national grassland, 1 national park), and large (Northern Rockies: 15 national forests, 3 national parks) (Fig. 5). Assessments that include larger geographic areas are of course more work and more complex. They also include more partners and stakeholders, which strengthen the project, but also make it more complex in terms of subject matter and communication.

The focus of climate change assessment and adaptation is evolving. In early assessments, the highest priority resource areas were water resources, fisheries, vegetation, and wildlife. The scientific literature contains a large amount of information on the first three of these topics, but not much on wildlife. In addition, existing information on water, fish, and vegetation can often be supplemented by modeling the effects of climate change with respect to hydrology, stream thermal characteristics, and altered plant distribution and abundance, respectively. As a result, we are relatively confident about the projections for these resource areas.

More recently, federal managers have become increasingly interested in recreation, infrastructure, and cultural resources, for which little scientific information is available. We have pioneered assessment approaches to these topics in collaboration with scientists and local resource experts, typically with minimal

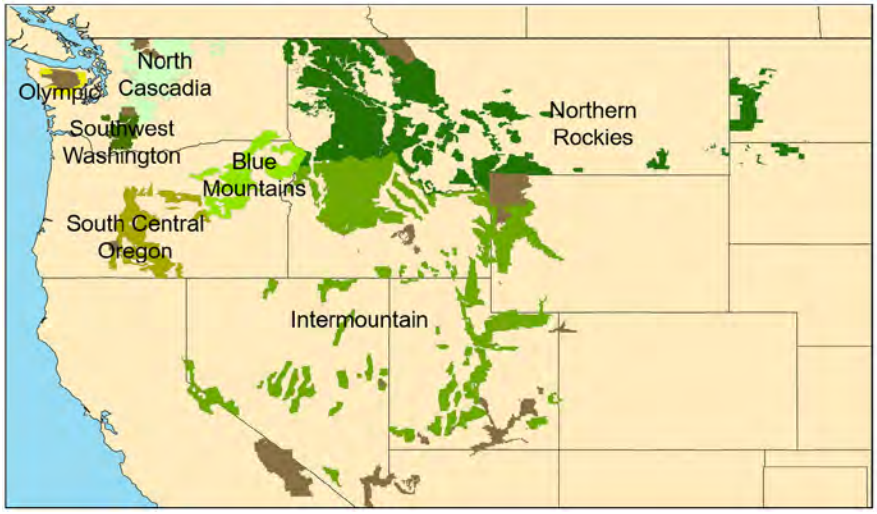

Figure 4. National forests (greens) and national parks (brown) involved in seven adaptation partnerships across the western U.S.

Figure 5. Dry upland herblands dominated by Idaho fescue occur on the Umatilla National Forest in northeastern Oregon, where the Blue Mountains Adaptation Partnership was conducted. Photo: Mark Darrach.

published documentation, although observation and experience provide the basis on which high-quality inferences can be based. In addition, resource managers usually have creative ideas for how to adapt to different climate change scenarios for these resource areas. Ecosystem services are another topic often addressed in recent assessments. This category can cover issues such as water supply, timber production, carbon sequestration, and pollination. Because ecosystem services are so diverse, it is necessary to be specific about priority services for any given location. The amount of scientific information is variable, but as above, resource managers can typically provide feasible adaptation options.

A New Resource for Adaptation

In all of the partnerships, we identified adaptation strategies (general, strategic), and adaptation tactics (specific, on the ground) for each strategy. This information was recently compiled in the Climate Change Adaptation Library for the Western United States (adaptationpartners.org/library.php), to be used as a resource for anyone interested in climate change adaptation in natural resources. The Adaptation Library includes adaptation options for forest vegetation (Table 1), non-forest vegetation, riparian/wetland systems, wildlife, water resources, fisheries, and recreation. Around 150 adaptation strategies and 450 tactics are currently in the Library, and more will be added in the new future. We are currently in the process of converting the Library into a searchable database, and plan to add additional categories for cultural resources and ecosystem services.

The Adaptation Library can be used by the U.S. Forest Service, National Park Service, and other public agencies in many ways, including the following aspects of natural resource management agency operations:

- Planning documents and their components: Provide objectives, standards, and guidelines (e.g., land management plans, general management plans)
- Resource management strategies: Incorporate information into conservation strategies, fire management plans, infrastructure planning, and state wildlife action plans
- Project design/implementation: Provide mitigation and design tactics at specific locations.
- Monitoring evaluations: Provide periodic evaluation of monitoring questions.

In the process of incrementally building the Adaptation Library, we found considerable concurrence in adaptation strategies and tactics among different regions and management units. This suggests that there is a finite set of responses to potential

Table 1. A sample of climate change sensitivities, adaptation strategies, and adaptation tactics associated with forest vegetation, from the Climate Change Adaptation Library.

Sensitivity to climate change	Adaptation strategy	Adaptation tactics
Large disturbances will create the potential for mortality events and regeneration failures	Mitigate consequences of large disturbances by planning ahead	Maintain a tree seed inventory with high-quality seed for a range of species, particularly species that may do well in the future under hotter and drier conditions
		Increase production of native plant materials for post-disturbance plantings
	Use judicious managed relocation of genotypes where appropriate	Relax seed zone guidelines to include genotypes from warmer locations; use a variety of genotypes rather than just one
Increased drought stress will decrease forest productivity at lower elevations	Increase resilience in forests	Increase the amount of thinning and possibly alter thinning prescriptions
		Use girdling, falling and leaving trees, prescribed burns, and wildland fire to reduce stand densities and drought stress
		Maximize early-successional tree species diversity by retaining minor species during pre-commercial thinning activities to promote greater resilience to drier conditions
		Consider including larger openings in thinning prescriptions and planting seedlings in the openings to create seed sources for native drought-tolerant species
Increased warming, drought and wildfire will reduce tree vigor and increase susceptibility to insects and pathogens, with increased potential for large and extensive insect and pathogen outbreaks, particularly of non-native insects and pathogens	Increase resilience of forest stands to disturbance by increasing tree vigor	Thin to decrease stand density, increase tree vigor and accelerate development of late-successional forest conditions
		Harvest to variable densities
		Reduce density of post-disturbance artificial regeneration
		Plant disease-resistant species or genotypes where species-specific insects or pathogens are a concern
		Increase stand-scale biodiversity and minimize monocultures
		Treat existing pathogen outbreaks more aggressively

climate change effects, and that although the Library is intended as a dynamic resource, the accretion of adaptation options in the Library over time will be asymptotic. This concurrence also exists between the Library and a large, independent effort conducted for forest systems in the eastern U.S. thus providing confidence in the universality of at least a core of adaptation options. Finally, a large proportion of adaptation options in the Library is already established as tools and techniques used in sustainable resource management. Rather than revamping existing principles and practices, climate-smart management will often be most effective for establishing priorities for specific resources and locations within management units.

Although climate change adaptation is not a cookbook process, the Adaptation Library provides a science-based foundation for resource managers who want to develop adaptation responses to climate change. Adaptation strategies and tactics in the library can be used “off the shelf” because they have already been thoroughly vetted and peer reviewed. They can also be revised for local conditions, and new options can be added. Resource managers may find comfort in the fact that the Library is based on information elicited from other managers like themselves, and is not developed by scientists without real-world input.

Toward Full Implementation

A relatively new endeavor for public land managers, climate change adaptation is typically complex and filled with uncertainty, and science-based processes and guidelines are still evolving and being tested. Climate change vulnerability assessments are increasingly a component of risk assessment for resource planning and management, and adaptation is increasingly a component of risk management. Including climate change as a component of resource planning and management, which was viewed in the recent past as merely desirable, is now required in the U.S Forest Service and National Park Service, and is becoming a more common element of agency operations.

The biggest challenge for U.S. federal agencies in embracing climate change has been building the organizational capacity to address a complex issue that affects multiple resources. Most resource specialists are already fully committed to ongoing projects and regulatory requirements, and agencies have seen a steady decline in budgets and personnel over the past 20 years, making it difficult to take on new responsibilities. Although education and training on climate change have generally been available, they are only a precursor to aspects of decision making and management that require assessment of climate change effects and responses to them.

Implementing adaptation options in local management units can be challenging. We anticipate that this will gradually occur over time as policies change, as plans and programs are revised, and especially when extreme weather events (e.g., multi-year droughts) and major disturbances (e.g., large wildfires) capture the attention of agencies, local communities, and stakeholders. Adaptation is more likely to be successful when multiple parties collaborate on implementation across large landscapes, rather than acting independently.

We are optimistic that climate change awareness, climate-smart management and planning, and implementation of adaptation in U.S. federal agencies will continue to improve. We anticipate that within the next 10 years:

- Climate change will become an integral component of business operations.
- The effects of climate change will be continually assessed on natural and human systems.
- Monitoring activities will include indicators to detect the effects of climate change on species and ecosystems.
- Agency planning processes will provide opportunities to manage across boundaries.
- Restoration activities will be implemented in the context of the influence of a changing climate.
- Institutional capacity to manage for climate change will increase within federal agencies and local stakeholders.
- Managers will implement climate-informed practices in long-term planning and management.

As adaptation options are implemented, it will be critical to monitor their effectiveness across different landscapes. Monitoring data provide feedback that can be used to validate existing options, inform their modification, or develop new options to be tested. Working across multiple jurisdictions and boundaries and collaborating with the research community will ensure that diverse perspectives are represented and that effectiveness monitoring is robust. This approach requires a multi-decadal commitment to integration of climate-smart thinking in all aspects of resource management.

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