

Managing Effects of Drought: Key Messages and Conclusions

James M. Vose
David L. Peterson
Charles H. Luce

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J.M. Vose is a Senior Research Ecologist, U.S. Department of Agriculture, Forest Service, Southern Research Station, Center for Integrated Forest Science, Research Triangle Park, NC 27709.

D.L. Peterson is an Emeritus Senior Research Biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Seattle, WA 98103.

C.H. Luce is a Research Hydrologist, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Boise, ID 83702.

Changing drought conditions in the remainder of the 21st century will present significant challenges for natural resource managers as they plan and implement actions to increase the adaptive capacity of the Nation's forests and rangelands to resist and recover from current and future droughts. The combination of warmer temperatures and more variable precipitation regimes across most areas of the United States suggests that although the nature of drought (magnitude, timing, duration) will differ among and within regions, most forests and rangelands will be affected by more frequent and/or intense drought by the end of the 21st century (chapter 2).

In areas where meteorological drought is common, forest and rangeland species have the capacity to survive most droughts through a variety of mechanisms that mitigate drought impacts and facilitate recovery (e.g., deep rooting, leaf shedding, stomatal regulation). However, new drought regimes (e.g., droughts combined with warmer temperatures) may overwhelm this capacity, causing lower vegetation productivity and increasing vegetation mortality, with far-reaching effects on ecosystem conditions and services. Areas where droughts are currently uncommon may be especially vulnerable because species that are not well adapted to drought may be greatly affected by even minor droughts. Secondary impacts of drought, such as more frequent and larger wildfires and large-scale insect outbreaks, may have even greater impacts (magnitude and spatial extent) than direct drought effects. Hydrological drought is a major concern in areas dependent on reliable flows of surface water for aquatic species and habitats, groundwater recharge, and drinking water supply.

Most of the chapters in this General Technical Report discuss management options for minimizing the adverse impacts of drought when they occur, facilitating postdrought recovery, and creating ecosystem conditions that might help minimize impacts of future droughts. For forests, a common theme among regions is reducing water demand by managing stands at a lower density and favoring species that either require less water or can tolerate drought. In many ways, this proactive approach essentially allows active management to guide and facilitate changes in forest conditions that would likely occur without management. For example, wildfires, insect outbreaks, tree mortality, and reduced growth and reproduction of drought-intolerant species are likely to create reduced stand density and favor drought-tolerant species over



Riparian restoration helps to maintain water quality and quantity during drought events. (Photo by Kirsten Severud)

the long term. However, undesirable outcomes such as loss of forest products and carbon storage, risks to humans and property in the wildland-urban interface, and reduced water quality are more likely without management. Responses to hydrological drought include restoring riparian areas and wetlands to improve functionality, ensuring that aquatic habitats for fish and other organisms provide refugia and passage during low streamflow conditions, and carefully managing consumptive uses during droughts for livestock grazing, recreation, agriculture, and drinking water supplies.

For drought management strategies to be most effective, timely implementation is needed across large spatial scales. Optimal responses can be developed by integrating existing policies and practices with new information and by timely reporting of current conditions. Coordination by Federal agencies with other agencies and stakeholders is needed for effective management of drought effects across large landscapes. If drought-informed thinking is institutionalized as part of agency operations, then planning and management will be more effective, and “crisis management” in response to drought can be avoided.

This report provides a range of regionally specific management options that can help natural resource managers anticipate and respond to current and future droughts. Despite large differences in biophysical conditions across regions, many of the concerns and potential management responses are similar. Key messages from the regional chapters are summarized below.



Mountains in Sonoran Desert, California. (Photo by Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org)

ALASKA AND PACIFIC NORTHWEST (Chapter 3)

- Water is important for wildlife and people, providing critical habitat for salmon, which are culturally and economically valuable species.
- Timber production has declined in recent decades, and recreation has emerged as a major revenue source.
- Across both regions, rising temperatures, decreasing snowpack, and less summer water availability will affect both people and ecosystems in the future.
- Restoring riparian areas and wetlands will help to maintain water quality and quantity during drought events and maintain critical habitat for terrestrial and aquatic species.
- Limiting livestock, fishing, and recreational uses in key habitats, and removing physical and biological barriers to fish movement, will help fish survive when streamflow is low.
- In dry forests characterized by historically frequent fire, decreasing stand densities and hazardous fuels can increase resilience to drought and fire by mitigating the effects of past fire exclusion.
- Addressing altered fire regimes, overgrazing, and invasive species will help to maintain rangeland productivity and ecosystem resilience under changing conditions.

CALIFORNIA (Chapter 4)

- Extreme droughts will become the norm by the middle of the 21st century, but even moderate droughts can have significant, long-lasting effects on the structure and function of ecosystems.
- Management options for addressing drought impacts vary by ecosystem, but goals are to (1) shift systems back within the natural range of variation (including disturbance regimes) to the degree possible and (2) facilitate a transition to plant species better adapted to future droughts.
- In forests and woodlands, drought management focused on the use of mechanical thinning and prescribed burning will decrease stand densities and promote the growth and vigor of desirable tree species.
- In chaparral, frequent disturbances are stressors, so soil disturbances need to be limited as much as possible to reduce the spread of invasive, nonnative annual plants that promote wildfires. Invasive plants are also a major problem in grasslands, where they should be removed and replaced with native grasses and forbs, if possible.
- In grasslands, prescribed fire may be useful to manage nonnative species and increase perennial plant cover to make grasslands more drought resilient. In rangelands used for livestock grazing, conservative stocking rates, supplemental feeding, and resting pastures can be considered during times of drought.
- For drought management strategies to be most effective, timely implementation is needed across large spatial scales.
- As the frequency and magnitude of droughts increase, our ability to better quantify and project impacts on ecological and human systems, and to develop and implement appropriate management actions, will become more critical.

HAWAI'I AND U.S.-AFFILIATED PACIFIC ISLANDS (Chapter 5)

- Future temperatures in Hawai'i and U.S.-Affiliated Pacific Islands (USAPI) are expected to increase, and the trade wind inversion is projected to become more frequent, resulting in drying, particularly at high elevations. Even if rainfall does not change, drought severity and frequency will increase because of higher evaporative demand.
- Drought increases the risk of wildfire in grasslands and savanna vegetation, which then increases the vulnerability of adjacent forest. The capacity of native



Continued drought conditions in the Marshall Islands force many to rely on freshwater filling stations. (Photo courtesy of the Marshall Islands Journal)

forests to recover afterward can be reduced by the rapid establishment of nonnative species, many of which increase the probability of future fires.

- Preparing for wildfire before a drought is critical to mitigate drought impacts. Preparation includes (1) building up or maintaining fire suppression and emergency responder capacity and readiness and (2) preparedness at the level of individuals, households, communities, and large landowners and land managers.
- Extreme drought reduces streamflow and groundwater levels. Lower groundwater levels exacerbate the potential for saltwater intrusion and can degrade drinking water wells and nearshore and marine ecosystems that rely on the discharge of fresh groundwater.
- Continued drought conditions force many populations—suppliers of municipal drinking water, domestic users, and agricultural irrigation systems—to rely on more expensive delivery from groundwater sources.
- The most important aquifers in the region consist of freshwater lenses floating on denser seawater, and the groundwater in these aquifers is sustained by deep percolation of rainfall.
- Management options for preparing for water shortages include increasing water capture and storage capacity, improving delivery efficiencies, securing alternative water sources, improving end-user efficiencies, and providing education and outreach.
- Many communities in Hawai'i and the USAPI rely on traditional knowledge developed over thousands of years and on the resulting community-based approaches, practices, tools, and institutions that have supported communities during drought periods from the distant past into the present.
- Management will need to expand efforts to engage multiple interacting stressors: invasive species, altered fire regimes, altered climate regimes, insects, and pathogens.

INTERIOR WEST (Chapter 6)

- High temperatures, low snowpack, and low water availability in summer will affect both people and ecosystems in the Interior West more frequently in the future.
- Planning for and adapting to the likelihood of increasing frequency and duration of droughts are needed to minimize negative effects on species, ecosystems, and ecosystem services, and to facilitate a transition to different climatic conditions in the future.
- The diversity of the Interior West's climate, biogeography, and socioeconomics means that drought occurrence and effects will vary greatly from north to south and from year to year.
- The first, best, and often least costly means of increasing resilience to drought are to reduce existing stressors and improve the current condition ("health") of ecosystems.
- Pre-emptive actions that create benefits for multiple resources are valuable, especially actions that increase the quantity and duration of water availability.
- Reconnecting floodplains with side channels and restoring populations of American beaver contribute to retaining water during the summer, benefit water supply for agriculture and municipal watersheds, maintain productivity of riparian areas, and maintain high-quality fish habitat.
- In dry forests, the effects of past fire exclusion can be addressed by reducing stand densities and hazardous fuels to increase resilience to drought and fire.
- In rangelands, management responses to altered fire regimes, overgrazing, and invasive species will help maintain productivity and benefit livestock grazing, native ungulates, and many other animal species.
- The organizational capacity of Federal agencies to respond effectively and quickly is key to successful management of current and future drought conditions.
- Best management practices for water and climate change vulnerability assessments provide scientific information as the basis for decision making, as well as options that can be implemented to reduce drought impacts.

GREAT PLAINS (CHAPTER 7)

- As the climate continues to warm in the future, weather in the Great Plains is expected to become increasingly variable, and drought is expected to occur more frequently.
- Rangeland management differs based on local conditions, but core principles remain, primarily restoration or maintenance of diverse native species that nurture belowground ecosystem health and facilitate a range of species tolerances to meet changing conditions, including drought.
- Protection of the soil resource will maintain water-holding capacity and support vegetation cover, thus attenuating drought effects.
- Wildfire and variable-intensity grazing are primary disturbances in rangelands and provide mechanisms to increase vegetation heterogeneity.
- Numerous strategies are available for livestock producers to prepare for drought and buffer economic volatility, ranging from conservative stocking to economic diversification.
- Although economic downturns provide disincentives to reducing stocking rates, delayed response to drought may degrade rangelands if high stocking levels are decoupled from forage production, resulting in long-term productivity declines, which makes retention of a core herd more challenging.
- Information about drought scale, severity, and forecasts improves decisions on how to balance short-term gains and losses against risk of damage to future productivity.
- Communication among livestock owners, grazing association boards, governmental agencies, and other stakeholders will help achieve favorable outcomes during drought years, facilitating a return to profitability and sustainability.
- Proactive practices increase management options and flexibility, and collaboration and positive relationships are crucial for planning processes before, during, and after drought.
- Successful practices can inform the next cycle of preparation for drought, a process that needs to become embedded in management of rangelands.

NORTHEAST AND MIDWEST (Chapter 8)

- Climate change projections suggest that the frequency and severity of drought will likely increase in this region in the future, especially under “worst case” climate change scenarios.



Prescribed fire in grasslands makes them more drought-resilient. (Photo by Catherine J. Hibbard, U.S. Fish and Wildlife Service)

- The potential response of different tree species and whole ecosystems to higher moisture stress is unclear, largely because of the historical lack of drought in the Northeast and Midwest.
- Based on climate change projections, future forest responses to drought could include mortality of sensitive species, shifts in forest composition toward more drought-tolerant species (including nonnative species), and potential migration of tree species into more suitable habitats outside of current geographic ranges.
- Such drought-related effects could affect many ecosystem services, including timber and nontimber products, water supply, carbon sequestration, wildlife habitat, and cultural benefits.
- Forest thinning may be an important management strategy to enhance resilience during drought, even in humid parts of the Northeast.
- Using silvicultural systems that promote high species diversity may enhance the sustainability of forest production under changing climate regimes.
- To promote the establishment of individuals that are more likely to survive and adapt to more frequent future drought, seeding and planting genotypes or species considered better adapted to soil moisture deficit is preferred over natural regeneration.
- Although the Northeast is currently relatively wet and not moisture-limited, forest managers are likely to face new challenges related to water availability.
- Although managing water resources is typically not the primary forest management objective, many best management practices for forests are designed to maintain water supply and quality.
- Efforts to prepare forests for uncertain future conditions are needed concurrently with measures to reduce the rate of climate change.

SOUTHEAST (Chapter 9)

- Despite projections that precipitation will increase throughout most of the Southeast, drought frequency and intensity are projected to increase throughout the 21st century
- Severe droughts increase the risk of high-severity wildfires that are costly to suppress; suppression costs are 25-percent higher than average during drought years.
- Projections of increased drought frequency and duration in many areas of the Southeast will present challenges for land managers to reduce the likelihood of wildfire occurrence and area burned.
- Management options to reduce fire risk in the Southeast have mostly focused on reducing fuel loads through frequent prescribed burning. Additional actions include reducing fuel loading through planting at lower densities, thinning natural stands and existing plantations, reducing live and down fuels mechanically with mastication treatments, and reducing live fuels with herbicide.
- Thinning or other silvicultural practices that improve pine vigor may help mitigate drought-related impacts by southern pine beetle and other bark beetles.
- Planting or regenerating more drought-tolerant species (e.g., longleaf pine instead of loblolly pine) could help reduce drought-related impacts.
- Restoration of longleaf pine and shortleaf pine ecosystems is a broad effort organized across the historical range of both ecosystems. Both longleaf pine and shortleaf pine provide numerous benefits for responding to current and future climate change, including resistance to wildfire, higher productivity during drought periods, and higher disease and pest resistance.
- Thinning can increase water availability for tree growth by reducing stand transpiration and canopy interception.
- As climate change intensifies the length and severity of droughts in the Southeast, wildlife managers in this region may need to adopt techniques used in the Western United States to provide water to stressed terrestrial wildlife.



Loblolly pine (*Pinus taeda*) in Alabama. (Photo by David Stephens, Bugwood.org)

NEXT STEPS

Information presented in this report demonstrates that much is known about how forests and rangelands respond to drought and about options available for responding to current and anticipated drought. However, long-term impacts are uncertain, suggesting a need for monitoring and ongoing learning to adjust management actions and goals over time. We contend that effective natural resource managers must be an intelligent component of the ecosystem who are able to learn and use information on trends and responses to disturbance, anticipating future conditions and developing robust management decisions over time. This is challenging because new drought regimes may create conditions that are different than those observed in the past. The ability to anticipate responses to drought, and to change course if anticipated drought effects do not occur, will be critical for effectively sustaining ecosystem services.

The following strategic actions will help to institutionalize awareness of drought effects and drought responses in forest and rangeland management:

Establish and maintain relationships with providers of drought information

Federal agencies such as the National Oceanic and Atmospheric Administration (National Integrated Drought Information System; <https://www.drought.gov>) provide data and maps on current and projected drought in the United States. State agencies, some universities, and other organizations provide data and maps at smaller spatial scales that may be more customized to local interests and needs. Although simply referencing drought data online is useful, establishing working



Sandbar willow (*Salix interior*) in Ohio. (Photo by T. Davis Sydnor, The Ohio State University, Bugwood.org)

relationships with data providers will ensure that the information is clearly understood and used appropriately in planning and management.

Include drought in collaborative efforts among agencies and stakeholders

Drought is generally so pervasive that it will affect multiple ownerships in any given region. Many resources overlap boundaries, including water and wildlife, as do large disturbances such as wildfire. Therefore, stakeholders and organizations engaged in resource management will be more effective in minimizing the impacts of drought if they work together to plan for and implement responses.

Revise best management practices as needed

Best management practices (BMPs) for water resources, vegetation, infrastructure, and other resource areas are part of the standard toolkit used by public land managers. This is particularly true in range management, for which BMPs have been developed by Federal agencies to specifically address drought impacts. Development of drought-informed BMPs across all resource areas will provide science-based options that can be referenced and applied in a timely way when drought occurs. In most cases, this will require fine tuning of existing practices, rather than a major change.

Implement drought in relevant planning processes

Public land management agencies organize their operations around various types of planning documents. For example, each national forest in the Forest Service has a land management plan ("forest plan") that guides the administration of the forest and its management of natural resources; these plans are periodically revised and amended. Agencies also have vegetation management plans, restoration plans, road and infrastructure maintenance plans, and other types of documents that guide specific functions at various spatial and temporal scales. Including drought as a discrete component within these plans will ensure that drought impacts are recognized, response options are available, and response options can be implemented in a timely way.

Establish long-term monitoring of drought effects

Although the general effects of drought on water resources and vegetation are well known, they are not as well known for fisheries, wildlife, recreation, and other ecosystem services. Scientific data on specific conditions in any particular location are needed in order for land managers to document impacts and develop potential management responses. These data are needed over multiple years because some impacts may be cumulative or alternatively may dissipate if moisture availability improves. Long-term monitoring that identifies representative landscapes and employs robust data collection will ensure that drought impacts are accurately quantified. Monitoring drought impacts can generally be integrated within existing monitoring programs.

Share information on effectiveness of drought responses

Monitoring programs as described above need to include an evaluation of the short-term and long-term effectiveness of drought management options that have been implemented. This will guide future application of management responses for any particular location. In addition, sharing information about the effectiveness of drought management within and among agencies, Tribes, the private sector, and stakeholders will help to propagate effective, consistent practices across large landscapes. Shared learning regarding drought can be institutionalized through regional meetings, professional organizations, and online networking.