

Executive Summary

This report informs and guides natural resource managers as they evaluate management options to minimize drought impacts, help forest and rangelands recover from drought, and create forests and rangelands better adapted to future drought conditions. An overall conceptual framework and development of organizational structure and chapter content were facilitated by a series of virtual and in-person workshops. Teams of experts used a national-scale drought synthesis (Vose et al. 2016), combined with more recent scientific literature and their best professional judgments, to link scientific evidence with regionally appropriate discussions of risks, vulnerabilities, and management options.

Drought has shaped ecological processes and influenced human and biological communities for millennia and will continue to do so. Climate change will influence future drought characteristics (frequency, severity, timing), and some regions of the United States will experience a higher frequency of severe droughts and longer dry periods. 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.

Droughts can have substantial impacts on the economy at local and regional scales. The timber products industry can be affected by drought-related mortality and reduced productivity, leading to reduced wood supply and an increase in market price. Drought in rangelands reduces forage and water available for livestock grazing and reduces overall vegetative land cover, which can lead to soil loss from wind and water erosion with long-term effects on rangeland productivity. Altered water quantity following drought may have little impact on economics, although degraded water quality after disturbances like fire can substantially disrupt municipal water supply and treatment in ways that may force substantial public investment in water infrastructure to avoid supply interruptions.



This report provides important guidance for evaluating management options to minimize drought impacts, such as reduced forage and water (top) and degraded water quality after disturbances like fire (bottom).

Photos: Lance Cheung, USDA and Chris Stewart, USDA Forest Service



Restoring riparian areas helps to maintain water quality and quantity during drought events (top), as well as critical habitat for culturally and economically valuable species (bottom).

Photos: USDA Forest Service and Don MacDougall, USDA Forest Service

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 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.

Most chapters in this publication 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 is reducing water demand by managing stands at a lower density and favoring species that either require less water or can tolerate drought. 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 for livestock grazing, recreation, agriculture, and drinking water supplies during droughts.

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.

Regionally specific drought issues and management options include the following:

ALASKA AND PACIFIC NORTHWEST

- Water is important for wildlife and people, providing critical habitat for salmon, which are culturally and economically valuable species.
- Across both Alaska and the Pacific Northwest, 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 grazing, fishing, and recreation 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, resilience to drought and fire can be increased by mitigating the effects of past fire exclusion by decreasing stand densities and hazardous fuels.
- Addressing altered fire regimes, overgrazing, and invasive species will help to maintain rangeland productivity and ecosystem resilience under changing conditions.

CALIFORNIA

- 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.
- 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 should be considered during times of drought.
- 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

- Drought increases the risk of wildfire in grasslands and savanna vegetation, which then increases the vulnerability of adjacent forest. The capacity of native 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 by 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.



An entomologist checks dead ponderosa pine trees for pine bark beetle infestations in the Sequoia National Forest, CA.

Photo: Lance Cheung, USDA



Pacific Island communities rely on traditional knowledge and community-based support during water shortages (top). Rangeland management to address ecosystem stressors helps maintain productivity and benefits native ungulates (bottom).

Photos: Forest and Kim Starr, Starr Environmental, Bugwood.org, and USDA

- 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 U.S.-Affiliated Pacific Islands 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 benefit from efforts to engage multiple interacting stressors: invasive species, altered fire regimes, altered climate regimes, insects, and pathogens.

INTERIOR WEST

- The diversity of climate, biogeography, and socioeconomics in the Interior West 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 animal species.

GREAT PLAINS

- 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.
- 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.

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 frequent future drought, seeding and planting genotypes or species considered better adapted to soil moisture deficit is preferred over natural regeneration.
- Although water resources are typically not the primary forest management objective, existing best forest management practices are designed to maintain water supply and quality.

SOUTHEAST

- 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 downed fuels mechanically with mastication treatments, and reducing live fuels with herbicide.
- Thinning or other preventive silvicultural practices that improve pine vigor may help mitigate drought-related impacts by southern pine beetle and other bark beetles.



Forest thinning is an important management strategy to enhance drought resilience (top). Prescribed burning and planting at lower densities are management options that can reduce fuel loads and fire risk (middle and bottom).

Photos: Eli Sagor, University of Minnesota, Bugwood.org, Chris Evans, University of Illinois, Bugwood.org, and Jared M. Dort, USDA Forest Service



- Planting or regenerating more drought-tolerant species (e.g., longleaf pine instead of loblolly pine) could also help reduce drought-related impacts.
- The restoration of longleaf pine and shortleaf pine ecosystems are broad efforts organized across the historic 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.

The following strategic actions will help to institutionalize awareness of drought effects and drought responses in public and private land management:



- Establish and maintain relationships with providers of drought information.
- Include drought in collaborative efforts among agencies and stakeholders.
- Revise best management practices as needed.
- Implement drought in relevant planning processes.
- Establish long-term monitoring of drought effects.
- Share information on effectiveness of drought management practices.

Effective management of drought effects requires that resource managers access information on drought and disturbance, anticipate future conditions, develop robust responses, and implement those responses in a timely way. Being informed enough to take effective action requires a combination of (1) ongoing monitoring of parameters that are critical for making timely decisions, (2) longer term monitoring (e.g., 5–10 years) to determine the success or failure of past management decisions, and (3) active experiments that test the effectiveness of new or revised drought management practices.



Vose, J.; Clark, J.; Luce, C.; Patel-Weynand, T., eds. 2016. Effects of drought on forests and rangelands in the United States: a comprehensive science synthesis. Gen. Tech. Rep. WO-93b. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 289 p.

**Informed management decisions
require active experiments on
drought management practices
(top). Collaborative efforts that
include drought considerations
will help to institutionalize
awareness of drought effects
and management responses
(middle and bottom).**

Photos: Sandy Kase, USDA Forest Service, Jose Witt,
Friends of Nevada Wilderness, and Peter M. Fredin, Vail
Resorts