# 6 Forests

California’s multiyear drought killed millions of trees in low-elevation forests

## Key Message 1

### Ecological Disturbances and Forest Health

It is very likely that more frequent extreme weather events will increase the frequency and magnitude of severe ecological disturbances, driving rapid (months to years) and often persistent changes in forest structure and function across large landscapes. It is also likely that other changes, resulting from gradual climate change and less severe disturbances, will alter forest productivity and health and the distribution and abundance of species at longer timescales (decades to centuries).

## Key Message 2

### Ecosystem Services

It is very likely that climate change will decrease the ability of many forest ecosystems to provide important ecosystem services to society. Tree growth and carbon storage are expected to decrease in most locations as a result of higher temperatures, more frequent drought, and increased disturbances. The onset and magnitude of climate change effects on water resources in forest ecosystems will vary but are already occurring in some regions.

## Key Message 3

### Adaptation

Forest management activities that increase the resilience of U.S. forests to climate change are being implemented, with a broad range of adaptation options for different resources, including applications in planning. The future pace of adaptation will depend on how effectively social, organizational, and economic conditions support implementation.

Forests on public and private lands provide benefits to the natural environment, as well as economic benefits and ecosystem services to people in the United States and globally. The ability of U.S. forests to continue to provide goods and services is threatened by climate change and associated increases in extreme events and disturbances. For example, severe drought and insect outbreaks have killed hundreds of millions of trees across the United States over the past 20 years, and wildfires have burned at least 3.7 million acres annually in all but 3 years from 2000 to 2016. Recent insect-caused mortality appears to be outside the historical context and is likely related to climate change; however, it is unclear if the apparent climate-related increase in fire-caused tree mortality is outside the range of what has been observed over centuries of wildfire occurrence.

A warmer climate will decrease tree growth in most forests that are water limited (for example, low-elevation ponderosa pine forests) but will likely increase growth in forests that are energy limited (for example, subalpine forests, where long-lasting snowpack and cold temperatures limit the growing season). Drought and extreme high temperatures can cause heat-related stress in vegetation and, in turn, reduce forest productivity and increase mortality. The rate of climate warming is likely to influence forest health (that is, the extent to which ecosystem processes are functioning within their range of historic variation)  and competition between trees, which will affect the distributions of some species.

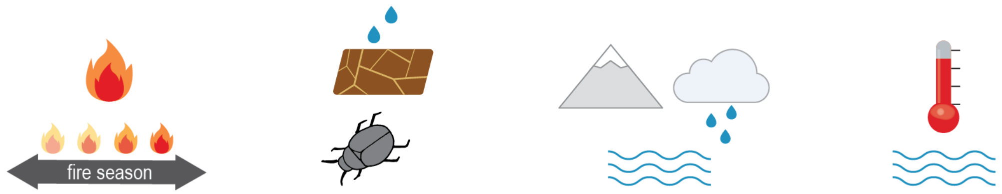
Large-scale disturbances (over thousands to hundreds of thousands of acres) that cause rapid change (over days to years) and more gradual climate change effects (over decades) will alter the ability of forests to provide ecosystem services, although alterations will vary greatly depending on the tree species and local biophysical conditions. For example, whereas crown fires (forest fires that spread from treetop to treetop) will cause extensive areas of tree mortality in dense, dry forests in the western United States that have not experienced wildfire for several decades, increased fire frequency is expected to facilitate the persistence of sprouting hardwood species such as quaking aspen in western mountains and fire tolerant pine and hardwood species in the eastern United States (see regional chapters for more detail on variation across the United States). Drought, heavy rainfall, altered snowpack, and changing forest conditions are increasing the frequency of low summer streamflow, winter and spring flooding, and low water quality in some locations, with potential negative impacts on aquatic resources and on water supplies for human communities.

From 1990 to 2015, U.S. forests sequestered 742 teragrams (Tg) of carbon dioxide ($CO_2$) per year, offsetting approximately 11% of the Nation's $CO_2$ emissions. U.S. forests are projected to continue to store carbon but at declining rates, as affected by both land use and lower $CO_2$ uptake as forests get older. However, carbon accumulation in surface soils (at depths of 0–4 inches) can mitigate the declining carbon sink of U.S. forests if reforestation is routinely implemented at large spatial scales.

Implementation of climate-informed resource planning and management on forestlands has progressed significantly over the past decade. The ability of society and resource management to continue to adapt to climate change will be determined primarily by socioeconomic factors and organizational capacity. A viable forest-based workforce can facilitate timely actions that minimize negative effects of climate change. Ensuring the continuing health of forest ecosystems and, where desired and feasible, keeping forestland in forest cover are key challenges for society.

For full chapter, including references and Traceable Accounts, see https://nca2018.globalchange.gov/chapter/forests.

## Climate Change Vulnerabilities and Adaptation Options

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| **Climate Change Vulnerabilities** | Increasing wildfire area burned and fire season length | Increasing drought severity and incidence of insect outbreaks | Lower snowpack, increasing precipitation intensity, and higher winter peakflows | Lower summer streamflows and increasing stream temperatures |
| **Adaptation Options** | Reduce hazardous fuels with prescribed burning and managed wildfire | Reduce forest stand density to increase tree vigor; plant drought-tolerant species and genotypes | Implement designs for forest road systems that consider increased flooding hazard | Use mapping of projected stream temperatures to set priorities for riparian restoration and coldwater fish conservation |

To increase resilience to future stressors and disturbances, examples of adaptation options (risk management) have been developed in response to climate change vulnerabilities in forest ecosystems (risk assessment) in the Pacific Northwest. Vulnerabilities and adaptation options vary among different forest ecosystems. *From Figure 6.7 (Sources: U.S. Forest Service and University of Washington).*