CLIMATE, FIRE, AND FOREST CHANGE IN CALIFORNIA'S SIERRA NEVADA

PHOTO : JOSHUA VEAL, U.S. FOREST SERVICE

This information brief summarizes and synthesizes adaptation implications from research projects funded by the Southwest Climate Adaptation Science Center (SW CASC). SW CASC works to coordinate and collaborate with users and providers of climate information to ensure that the research pursued by CASC-affiliated scientists results in tools, techniques, and actionable information to inform robust decision-making by resource managers, policy makers, and other stakeholders.

The management and uses of forest ecosystems and resources will be impacted as forests change along with climate and fire regimes. In some areas, forests may be replaced with shrublands, grasslands, or deserts. Climate change effects on forests will be driven by the rate and magnitude of climate change, site-specific conditions, the ability of species to shift distributions through dispersal and recruitment, and the influence of other ecological stressors. While climate-change impacts on structure, composition, and ecosystem function play out over longer time periods, fire can hasten these changes by triggering vegetation type conversions. Adaptation will require a mix of large- and small-scale approaches to challenges.

SW CASC INITIATIVES FOR DECISION-MAKERS

Translational Ecology:
Strong collaborations between scientists and decision-makers during all phases of research.
www.swcasc.arizona.edu/translationalecology

Scenario Planning:
Planning for multiple plausible futures to develop robust strategies for adaptive management
www.swcasc.arizona.edu/strategicscenarioplanning

SUMMARY OF KEY MANAGEMENT ISSUES AND OPTIONS FOR ADAPTATION TO INCREASING TEMPERATURE, DROUGHT, AND CHANGING FIRE REGIMES IN FORESTS OF THE SIERRA NEVADA

1 SW CASC REGION

- **Issues:** Large-scale, regional climate patterns affect climate and fire patterns in the Sierra Nevada.
- **Adaptation:** Stay informed about climate change; collaborate with scientists to improve drought and wildfire predictive capaciity; share lessons learned with other resource managers.

2 SIERRA NEVADA

- **Issues:** Species, forest types, and ecosystem function at risk of declining or disappearing.
- **Adaptation:** Work across jurisdictional boundaries to: identify and protect mesic or less vulnerable areas where species and communities are less affected, to share lessons learned, resources, data, and methods, and to engage in scenario planning to deal with uncertainty.

3 FORESTS

- **Issues:** High tree densities increase vulnerability to heat, drought, fire, pests, and pathogens; large-scale die-off of trees; increased risk of large fires that result in vegetation type conversion.
- **Adaptation:** Thin forests and use prescribed fire; monitor the effects of climate and management practices on forests; use extreme events as learning opportunties to inform actions.

4 TREES

- **Issues:** Species' ability to cope with water stress are overwhelmed by drought conditions, decreasing trees' abilities to resist pests and pathogens; dead trees fuel fires.
- **Adaptation:** Minimize ecological stressors; collaborate with scientists to understand stress thresholds of individual species to inform restoration and post-fire rehabilitation.

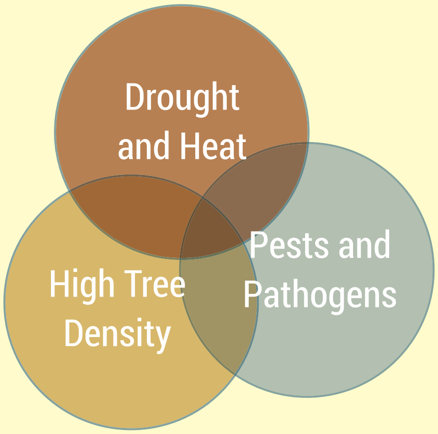
THE SCIENCE

DROUGHT AND CLIMATE CHANGE

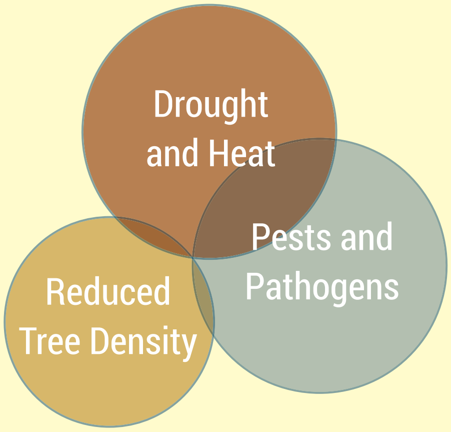
In California's Mediterranean climate, characterized by wet winters and warm, dry summers, winter precipitation is crucial to replenishing soil moisture and supplying water to aquatic and terrestrial ecosystems. Much of this winter moisture is stored as snowpack in mountain watersheds at high elevations, where it is released during spring and summer, helping to maintain stream flow. Increasing temperatures across the southwestern United States, including California, have altered the critical winter snowpack in many ways. These changes, studied in-depth by SW CASC investigators and grant recipients, as well as many climatologists in the region, include trends toward earlier timing of snowmelt runoff, more late-winter and early-spring precipitation falling as rain rather than snow, and reductions in snow-covered area and in the water content of the snowpack. Increased observed temperatures have also contributed to reduced soil moisture. Recent research also suggests an increasing frequency of dry, high-pressure weather systems over the region. These changes amplify the impacts of drought and contribute to aridification of the region. Higher temperatures also contribute to a greater capacity for the Earth's atmosphere to hold moisture. This fuels atmospheric rivers (ARs)—narrow bands of exceptionally warm and moist air—that can contribute to floods that may end droughts but also cause destruction.

SW CASC investigators and grant recipients have devoted much effort to studying the AR phenomenon. Projections of future climate indicate shorter snowfall seasons, less snow and more rain, declining snowpack and earlier snowmelt in California. These factors, along with projected substantial increases in temperatures and decreases in soil moisture, contribute to greater likelihood of severe and sustained drought. Projections of atmospheric dynamics also suggest stronger and more frequent ARs. The combination of these effects leads to "climate whiplash" in which increased multi-year variability of precipitation and drought adds increased erosion to adaptation challenges.

REDUCING TREE DENSITY TO MINIMIZE MORTALITY AND RISK OF CATASTROPHIC FIRE



The circles in this figure represent stressors that threaten forest health. Places where the circles overlap represent areas on the landscape where two or three stressors are present. In places with overlap, compounding stressors increase tree mortality and risk of catastrophic fire dramatically.



Where tree density is reduced through prescribed fire and forest thinning, risk of tree mortality and catastrophic fire are reduced. Fewer trees means less competition for limited soil moisture. This minimizes drought stress, helping trees maintain their natural defenses against pest and pathogens.

TOOLS AND DATA FROM OUR PARTNERS

After Fire: Toolkit for the Southwest
https://postfiresw.info/

Program for Climate, Ecosystem, and Fire Applications
https://cefa.dri.edu/

California Climate Tracker
https://wrcc.dri.edu/Climate/Tracker/CA/

FOREST CHANGE DUE TO DROUGHT AND CLIMATE CHANGE

With increasing drought, warmer temperatures, and declining snowpack in the Southwest, montane forests are expected to shift northward and higher in elevation. The degree to which lower elevation species could displace the species already occurring in cooler and moister areas is uncertain. Areas of high exposure to climate change include southern and western edges of forest community distributions, while areas of lower exposure are in northern and eastern areas, and at upper elevations of community distributions. However, forest communities in locations not highly exposed could still transition rapidly to new vegetation types if disease, pests, fire, or a combination of these, have significant effects on tree health and mortality.

Trees have mechanisms for responding to drought, but these may be overwhelmed during extreme drought, or complicated by other stressors. During an exceptionally hot drought (2012-2016) in California, giant sequoias responded initially with leaf-level adjustments for reducing water stress (stomatal closure, redistribution of leaf water, and building tougher leaves). Some of these responses may be typical during the dry summers in a Mediterranean climate. However,during the most severe year of the drought (2014), foliage on many trees died and was shed in a canopy-level adjustment to further reduce water loss. Some sequoias lost more than 50% of foliage. The extent of dieback exceeded previous records. Few sequoias died (< 1%), but those that did exhibited signs of recent fire damage to the cambium and high abundances of bark beetles, suggesting that these stressors may have made the trees more vulnerable to the drought.

WILDFIRE AND PRESCRIBED FIRE

Fire frequency is increasing at higher elevations in the Sierra Nevada. Between 1908 and 2012, the probability of fires occurring above 3,000 m (9,843 ft) in elevation quadrupled, and the maximum elevation of fire extent increased by over 700 m (2,297 ft). These observations suggest a change in disturbance regime in subalpine forests that may affect forest structure, composition, and ecosystem function. Increasing elevation of fire might be explained by effects of fire management strategies, increasing fuels and connectivity, increasing temperatures, increasing human-caused ignitions, or a combination of these factors.

COMPARISON OF UPPER LEWIS CREEK PREVIOUSLY TREATED WITH PRESCRIBED FIRE. THE TOP PHOTO WAS TAKEN ON JULY 8, 2015 PRIOR TO THE ROUGH FIRE. THE BOTTOM PHOTO WAS TAKEN ON SEP. 29, 2015 AFTER THE ROUGH FIRE CAME THROUGH. NOTICE THE STILL STANDING LIVE TREES. PHOTO: NPS/ K.HOWARD

Prescribed fire in low elevation forests (under 2,100 m/ 6,890 ft) of the Sierra Nevada is associated with reduced stand density, and reduced mortality during drought, suggesting that prescribed fire may help increase forest resistance to drought. In 2014, the third consecutive year of a severe drought, researchers surveyed 9,950 trees in mixed conifer forest plots in Kings Canyon, Sequoia, and Yosemite National Parks. Eighteen plots hadn't burned in over 100 years, and 38 had burned in prescribed fire 6 to 28 years prior to the survey. In the prescribed fire plots, ponderosa pine, sugar pine, incense cedar, and white fir had lower probabilities of mortality compared to unburned plots. Although basal area was not significantly different in burned and unburned plots, reduced stand density and lower mortality in burned plots suggests that reduced competition may play a role in lowering drought mortality in burned plots. The greatest effects were seen in Pinus species. Even burned plots contained much higher stand density and basal areas than were characteristic of the area 100 years earlier.

A remote sensing study incorporating LANDSAT imagery and aerial photo analysis examined the effects of the 1996 Ackerson Fire in sub-alpine meadows in Yosemite National Park. Fire in meadows resulted in a decline in the overall greenness of meadow vegetation that was related to the mortality of evergreen trees along edges of some meadows, highlighting the role of fire in maintaining grassy meadows by limiting the spread of trees.

ADAPTATION IMPLICATIONS

CHANGE

Projections of future fire risks point to increased fire frequency and increased numbers of large fires. As warmer temperatures reduce snow-covered area, induce early snowmelt, and decrease soil moisture, they contribute to longer and warmer fire seasons.

There may be increases in dry and dead fuel load available to burn, which could lead to even larger, more intense fires. Warming temperatures and drought are reducing fuel moistures, increasing tree mortality, and facilitating the spread of pests and pathogens. Increased moisture-holding capacity and frequency of atmospheric rivers may contribute to increased fine fuel loads, which would dry out during summer seasons, especially during drought episodes.

Subalpine tree species may be at risk, along with the wildlife and ecological processes they support. Subalpine forests are adapted to long fire-return intervals. Increasing tree mortality from drought and increasing fire in existing high elevation forests could open up space for other species to migrate upslope from lower elevations, and increase the spread of pests and pathogens.

UNCERTAINTY

Stay informed about climate and vegetation conditions in your region, and collaborate with others. Adaptation will require a mix of large- and small-scale approaches to challenges. Staying updated about the conditions in your region will likely inform projects of all scales, and is important for collaborating with scientists, planners, and others when crafting solutions. When considering adaptation options, don't rely on only one source of information, but review multiple sources. Sharing lessons with others about projects with various levels of success will promote better use of resources and more effective strategies.

Scenario planning can help with decision making that is hindered by uncertainty. Scenario planning explores multiple possible outcomes of climate change, and how human and natural systems may respond, to help guide adaptive management.

Consider multiple stressors and their interactions; forest monitoring plots and research are important for tracking the effects of drought and changing fire regimes on ecosystems, and for evaluating the effectiveness of adaptation actions. Depending on the species, tree mortality in response to drought may be hastened or more likely due to additional stressors (e.g., pests or pathogens, fire, anthropogenic water use), some of which may be addressed through adaptation actions. However, relationships between interacting stressors are complex, which highlights the importance of tracking the effectiveness of actions, and ecological response, so that tactics can be modified as needed.

Extreme climate events are opportunities to learn about the vulnerability of species and different parts of the landscape, and can inform future management decisions.

ACTION

Increase forest heterogeneity to promote resilience; reducing stand density may minimize mortality and reduce excessive fuel loads that contribute to catastrophic fires. High tree density exacerbates impacts from drought, pests, and pathogens. One potential avenue for adapting to increasing temperatures and drought is to increase heterogeneity. In many places, this includes decreasing density, with thought given to forest age, structure, species composition, and site-specific conditions.

Overcoming barriers to the use of prescribed fire may be critical for maintaining the integrity of forests into the future. Prescribed fire may be a tool for adapting to drought, wildfire, and overly dense forests.

Areas that are not experiencing high tree mortality due to drought, fire, pests, or pathogens may be important as refuges to maintain populations, seed sources, and genetic material for species undergoing widespread mortality.

Remote sensing may be a valuable tool for analyzing fire effects across large areas, in areas that are difficult to reach for field-based measurements, or where continuous data are needed to track fire effects over weeks, months, seasons, or years. For example, LANDSAT imagery allows for the analysis of multiple years pre- and post-fire, even for fires that burned several years ago. It is free, and covers the last 40+ years.

Adaptation will require taking the long view on forest health. With so many pressing issues, it may be tempting to focus only on short-term projects with immediate benefits. However, doing so may lead to unexpected consequences and poor outcomes. Working toward long-term goals is important for shaping a more sustainable, climate-adapted future.

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