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Drought and Fire in California

Vose, James M.; Clark, James S.; Luce, Charles H.; Patel-Weynard, Toral, 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.
http://www.treesearch.fs.fed.us/pubs/50261

The likely effects of drought associated with climate change in the United States have recently been synthesized by James M. Vose, James S. Clark, Charles H. Luce and Toral Patel-Weynand. Here we summarize their conclusions as they apply to **drought and fire** and provide examples of how these conditions are affecting different ecosystems in California.

For the past five years, California has been in a state of drought, and over this time period the Governor has declared a state of emergency for both drought and forest health.[1] Climate change predictions show that drought impacts are likely to increase in future years throughout parts of the western US including California(Executive Summary & Chapter 2).[2] For an overview of California and drought see the USDA Climate Hub 2-page summary.

Management Implications

- The effects of drought, fire, and climate change may lead to very different ecosystems in the future.
- Current and future droughts will have very different implications for different regions and ecosystems. For many cases, building forest resilience means promoting diversity and drought tolerant species with lower density stands.
- When direct actions to mitigate drought impacts cannot be taken, avoiding actions that worsen drought is advised.
- Droughts may change the current prescribed burn windows and increase wildfire risk to Wildland-Urban Interface areas.

Drought Basics

Drought occurs where water is scarce over a given period of time and spatial area. Another way to think of drought is in terms of water deficit. When water withdrawals (e.g. evaporation, plant use, or irrigation) are greater than water inputs, (e.g. precipitation, snowpack runoff, or the baseline of a reservoir) there is a water deficit. Drought is classified as meteorological, hydrologic, agricultural, or socioeconomic drought based on the cause and implications of the type of water deficit (pg. 15).[2]

Drought Effects

Drought and fire are related; it is necessary to consider the spatial and temporal scale of drought. Droughts can have short-term effects on a given area such as the presence or absence of ephemeral/seasonal streams, or have more long-term impacts such as less groundwater recharge or a decrease in snowpack that can lead to less runoff the following spring/summer.

Changes in the hydrologic cycle, affect individual plants and plant species differentially and can cause larger plant community changes. Higher temperatures, lower humidity, and low soil moisture associated with drought and climate change can further increase the degree of water stress and can lead to changes in plant species abundance, distribution, growth, and mortality (Fig. 1). Prolonged drought can promote drought-tolerant species, including invasives. Additionally, pathogens and insects can either be positively or negatively affected by drought, depending on their life history requirements and the characteristics of the drought. Moderate drought, for example, can reduce bark beetle outbreaks, whereas long-term, severe droughts can weaken trees enough to cause an increase in outbreaks (Chapter 6).[2] The climatic features of drought (e.g. high temperatures, low relative humidity, higher minimum temperatures) can change the fuel characteristics of an area. Examples of these drought-induced changes are increased dead fuels, lower live and dead fuel moisture and lower soil moisture. Additionally, a drought may change the overall vegetation structure and composition that in turn can also translate into changes in fire behavior (see Figure 1 and specific examples for California ecosystems in a later section).

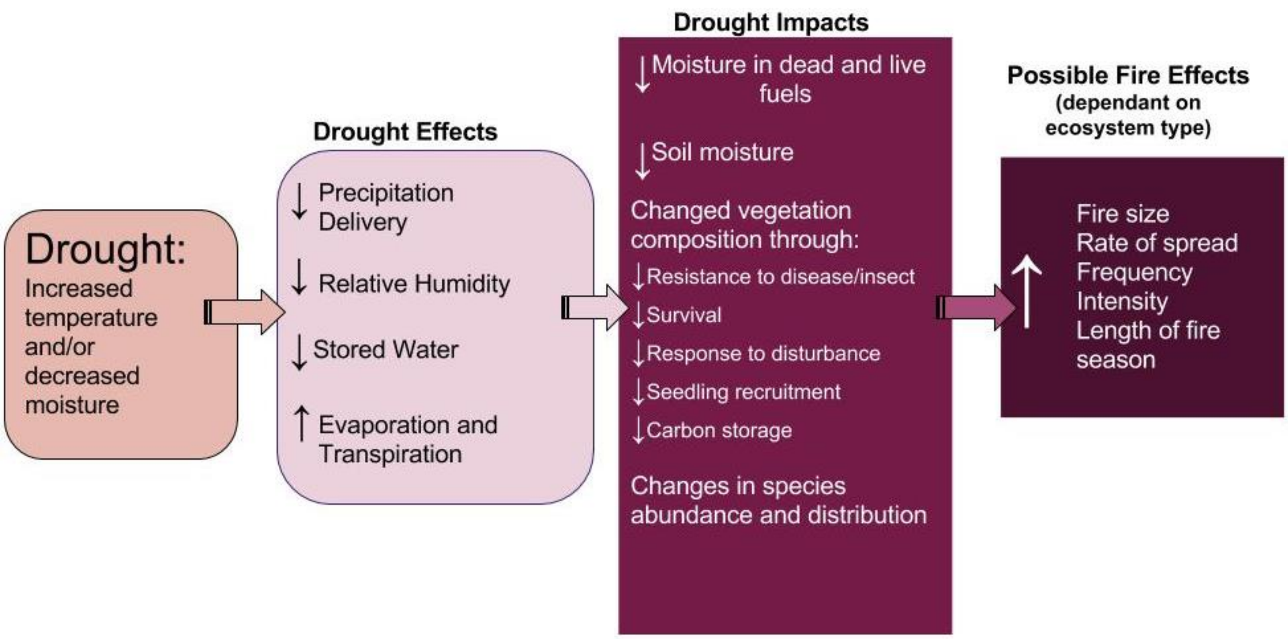

Figure 1. Impacts of drought on ecosystem components that influence wildfire.

Drought and Fire:

Drought is just one of many factors that affect fire, but there are a number of generalizations worth reviewing. Historically, fires have occurred more frequently and burned more area during droughts, especially in the western US (pgs. 5 & 136)[2]. While increased fire size and number of ignitions have been linked to drought, changes in fire severity are still unclear. To quantify the relationship between drought and fire, a number of drought indices have been related to fire regime parameters (pg 138-140).[2] Although the specifics of these findings are different, a general conclusion is that drought is correlated with increased fire occurrence (area burned and fire frequency) in many forested ecosystems.

For many rangeland and desert ecosystems, drought conditions could intensify the current issue of invasive species colonization by increasing the frequency, size, and the duration of fires. In both shrublands and grasslands, dryer and warmer summers could lead to more fire, allowing fire-tolerant invasives to colonize, which in turn can lead to yet more fire in the future. Droughts also have the potential to change one ecosystem type into another such as converting a previously forested area to shrub or grassland or a different type of forest.

Drought is just one of many factors shaping fire regimes. Other factors besides climate and drought that play a role in the occurrence, duration, and size of fires include: ignition sources, land use and land management practices, fire history, type conversion to invasive species, and fuel characteristics related to vegetation structure and composition. Interestingly, wildfires may also have a feedback to drought occurrence through smoke particles and changes in landscape scale vegetation (pg. 148-149).[2] Climate change is expected to cause temperature increases and decreased relative humidity in the Western US, although the effects at specific, regional scales are still unclear based on current predictions.

Whatever uncertainties exist in the geographic location and magnitude of drought impacts throughout the state, we know how drought can change fire behavior by its effects on flammability, fuel continuity, and the probability of ignition. Here are some examples of how drought may change fire behavior and regimes:

<u>Short-term or direct changes</u>

- Longer fire season and changed prescribed burn season windows.
- Less moisture (in air and vegetation) that increases flammability and fire spread.
- Less precipitation events during a fire season.
- Less water available for suppression efforts.

<u>Longer term or indirect changes</u>

- Change fuel structure by affecting plant growth.
  - For example, droughts that decrease spring precipitation may actually lessen wildfire potential by decreasing the growth of herbaceous fuels, decreasing ignition probability (pg 138).[2]
- Increase flammability by increasing dead materials and fine fuels.
  - Increased dead and fine fuels can increase rate of spread, probability of ignition, and fuel continuity.
  - Droughts that last for several consecutive years may lead to more area burned due to faster rate of spread and decreased ability to control spread.[3]
  - Drought-killed trees will have different impacts over time. Freshly killed trees may increase the potential for tree torching and crown fire ignition, especially when they still retain dead leaves/needles. Over the long term, dead trees rot and fall to the ground, posing more of a surface fuels issue.
- Change in the distribution and abundance of plant species

  Examples:
  - Reduced riparian zone coverage from ephemeral streams drying up.
  - Changes in plant species on certain slope aspects.
  - Type converting ecosystems, e.g. from chaparral to grasslands.

Mitigation Measures
As with most natural resource issues, all management actions should carefully consider the local context before taking action. There are some general recommendations that can easily be adapted to the regional needs and restrictions of specific ecosystems and management agencies.

- Consider focusing on other non-drought disturbances (e.g. invasives, pathogen, and insects) that create added stress to desired vegetation.
- Mitigation measures should consider the stage of the ecosystem experiencing drought. This could include actions such as:
  - Facilitating the transition to a new ecosystem.
  - Preventative measures such as aiding in recovery of an ecosystem.
  - Building resilience for future disturbances.

Short term adaptation example: Thinning trees reduces overall water requirements of the forest stand. This also reduces fire risk (if surface fuels are reduced as well) and may yield more pathogen/insect resistant trees. Harvesting may increase water flow to downstream areas but this result is highly dependent on a number of additional factors.	**Long-term adaptation example:** Planting or encouraging more drought tolerant species while still maintaining high biodiversity for the unknown future under climate change.

- Be prepared to deal with both direct and indirect effects of drought. An example of this is to prepare for vegetation mortality and the indirect effect of increased fire risk.
  - Example of mitigation measure: Altering the vegetation structure to increase survivability of remaining vegetation and also changing the fuel structure (e.g. removing competing vegetation, surface, and ladder fuels).

Drought and Fire Impacts on Californian Ecosystems — Examples
The following ecosystems do not cover the entirety of the state but are meant as examples that show the diverse impacts of drought on different ecosystems in regards to fire. One major consideration is whether the ecosystem in question is already adapted to drought. Another consideration is if the drought is mimicking another type of disturbance (such as fire) that has been removed from the ecosystem and may actually assist in ecosystem function restoration.

Northern CA Oak Woodlands [4]
As some of California's most drought-adapted trees, true oaks (*Quercus* species) have a variety of traits and adaptations that help them avoid and/or tolerate water stress. Oaks tend to have thick leaves with relatively small stomata, and an ability to maintain higher rates of photosynthesis during water stress than many co-occurring tree species. They also have deep-penetrating root systems, and some species (like California's native blue oak, *Q. douglasii*) are drought deciduous. These adaptations afford oaks a competitive advantage during times of drought. In northern California, more mesic periods in recent history have posed challenges for some oak species, particularly deciduous oaks that are shade intolerant and adapted to frequent disturbances like fire. In those systems, a combination of fire suppression and mesic conditions have enabled widespread forest densification and establishment of more shade-tolerant tree species, which have

outcompeted and caused mortality in oaks. In some cases, drought can provide reprieve for these oaks by weeding out competing trees that are less tolerant of water stress. Likewise, drought may limit competition from shallow-rooted understory plants (including non-native grasses), which have been shown to compete with and inhibit oak regeneration.

Sierra Nevada Mixed Conifer [5]

Conifer species in the Sierra Nevada have all experienced drought and fire in some combination throughout their evolution and current life cycles but the current drought is pushing the limits of these species to survive. The dominant tree species include ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), Douglas-fir (*Psuedotsuga menziesii*), white fir (*Abies concolor*), and incense cedar (*Calocedrus decurrens*). While each of these species has their own adaptations to fire and drought, it is important to consider how the Sierra Nevada Mixed Conifer (SNMC) system is prepared for, and responding to, the current situation. Our most drought-tolerant species, Ponderosa pine, has been overtaken by an epidemic bark beetle outbreak that is spanning the entire mountain range. Populations of western and mountain pine beetles (*Dendroctonous brevicomis* and *D. ponderosae*) have been able to thrive during recent warm winters, producing multiple broods that have benefited from drought-stressed trees as reliable food sources. Fir trees have also experienced higher levels of insect-driven mortality with fir engraver (*Scolytus spp.*) as the primary agents. While incense cedar is not as heavily impacted by insect activity, drought-induced dieback and diseases has been witnessed throughout the Sierra Nevada. Unfortunately, widespread tree mortality causes concern in terms of fire.

Plant materials, both dead and alive, are already very dry throughout the forests. With the anticipated addition of fuels to both the forest floor and the canopy from bark beetle mortality, this can increase the fire occurrence and severity. Much like drought, the specific location and time frame of impact is important to consider. For example, previous studies from the Rocky Mountains and Pacific Northwest have suggested that beetle-killed trees do not contribute to fire severity in these regions. However, these ecosystems are very different than the SNMC in that high severity fire is the norm. SNMC forests are historically characterized by low severity fires, but with fire suppression and stunted fuels reduction efforts, high severity fires are becoming commonplace (i.e. King, Rim, Rough Fires). Also, it is important to consider both the short and long term impacts of beetle kill mortality. As a tree transitions from living to dead, it goes through many stages of decomposition that all may influence fire behavior differently (think of a standing dead tree with needles compared to a tree on the ground with most of the needles and branches decomposed already). All of these various stages of decomposition can influence fire behavior. Given the extent of tree mortality in the Sierra Nevada, the degree of this influence will need to be researched in the future.

Desert [6]

A major issue facing the management of desert landscapes is the invasion of non-native plants. Because of this, the influence of drought on the conservation of native species can be different than in other regions of California. On the one hand, drought can be beneficial to current desert ecosystems, because lack of precipitation reduces productivity of non-native annual grasses and thus reduces the severe threat of fire facing native desert shrublands. On the other hand, moisture is eventually required for the growth of native plants and sustaining priority wildlife species. The federally listed desert tortoise, for example, depends on precipitation for drinking water and availability of native forage plants. Yet, high-rainfall years that result in copious non-native fuel production can dramatically alter tortoise habitats via fires that change forage and native shrub communities providing protective cover to tortoises.

A recent 10-year Free-Air CO_2 Enrichment (FACE) experiment in the northern Mojave Desert illustrated the complexity of potential future effects of changes in precipitation regimes and other factors in deserts.[6] During the experiment, air CO_2 concentration (simulated to future levels) and rainfall interacted, where CO_2 proportionally increased non-native grasses more than native grasses, but only during years of high rainfall. Years of low rainfall supported few to no annual plants of either native or non-native species, regardless of atmospheric CO_2 concentration. Future changes may be determined by potential shifts in the seasonality and amount of rainfall per event, even if the total yearly rainfall does not change, combined with evolutionary pathways of the species. It should be remembered that annual plants have rapid generations and produce copious seed, creating opportunities for quick changes in species traits.

The most conservative management strategy for drought management in the California desert is likely to implement non-native plant treatments during droughts (if there are plants present aboveground) and also during wet periods following droughts. If there are some non-native plants that germinate during droughts, treating them can prevent seed bank replenishment, while also potentially eliminating the most drought-adapted genotypes if these individuals had some type of adaptation to dry conditions. Treating during wet periods after drought can potentially lengthen the amount of time without inputs to the soil seed bank, and these wet periods are also of primary concern for creating hazardous fuels that can burn during the next dry period. While treatments for non-native desert grasses could benefit from further development, early timed herbicide applications (before most natives have germinated) show some promise.

Chaparral

Chaparral plant communities are drought adapted and are tolerant of the annual summer and fall dry season, typical of California's Mediterranean-type climate. However, high intensity, multi-year drought can lead to differential mortality among the dominant shrub species.[7, 8] The highest mortality occurs in mature, shallow rooted, dehydration-tolerant, obligate seeding species like bigpod ceanothus *(Ceanothus megacarpus*). Lower mortality occurs in large, deep rooted, dehydration-avoiding sprouting species like laurel sumac (*Malosma laurina).*[8] Such species-specific drought mortality reduces stand density and generally shifts species composition from postfire seeders to postfire sprouters [8] (for definitions and more information on physiological differences between seeders and sprouters see here).

With differential species mortality, associated structural and community changes also occur. Canopies become more open, soil temperatures increase, partial heat-stimulated germination of shrub seed banks occurs, and fine surface fuels start to accumulate. The increase in surface fuels that are not a normal feature of closed canopy chaparral makes the vegetation more ignitable. Community composition shifts also occur when drought occurs following a fire. In combination with fire, drought will increase the mortality of the resprouting species, again driving shifts in community composition, but this time favoring postfire seeders over postfire sprouters.[9, 10]

Chaparral can burn most years as intense crown-canopy wildfires as the moisture in live plants declines from mid-summer through fall.[11] Chaparral fires are naturally infrequent with a fire return interval between 30 to 150+ years, but the southern half of California shows a strong departure to higher fire frequencies.[12]

Because the geographic range of chaparral is so large and covers such a wide range of climate zones, the effects of drought and fire must be interpreted within the local climate context. NOAA defines five regional climate zones in California: north coast, north interior, Sierra Nevada, central coast and south coast; of the five zones, southern California has experienced the longest and most intense drought in recent decades. Drought effects on chaparral fire regimes will be manifested in how drought affects seasonal moisture levels in living plants and how these interact with fire weather conditions and ignitions patterns. [13, 14, 15] For example, large wind-driven southern California fires do not normally occur in spring, despite the occurrence of Santa Ana winds at this time of the year. When lack of winter rains leads to early season low live fuel moisture levels, these types of fires can occur, e.g. the May 2009 Jesusita Fire and the 2013 Springs Fire. However, these fire-climate patterns are complex and include feedback cycles on vegetation composition and fuel structure and the increasing influence of human populations in this landscape. The effect of drought on future chaparral fire regimes is therefore hard to predict.

Suggestions for further reading

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Additional reading not cited in chaparral section:

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