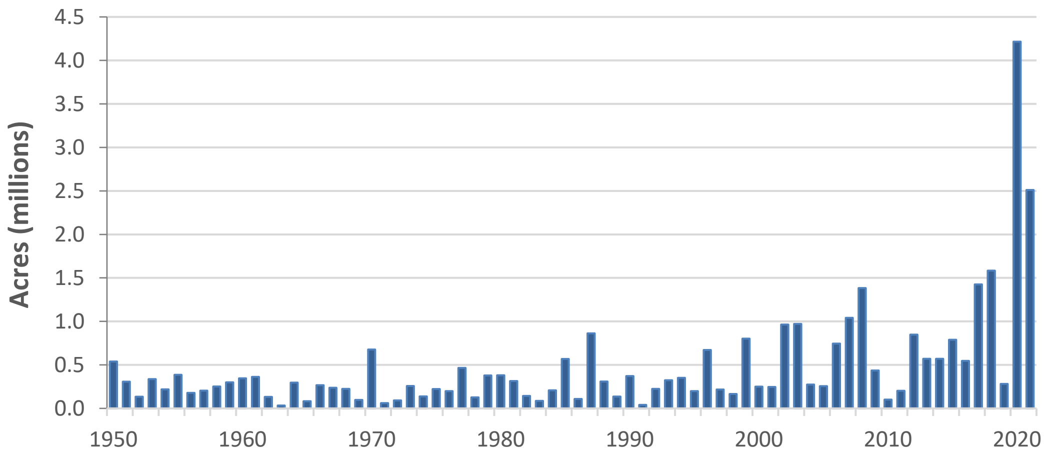
Wildfires

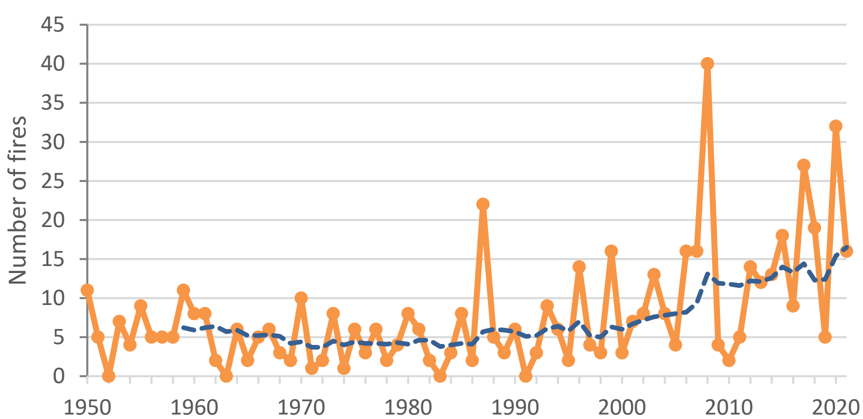
The area burned by wildfires and the number of large fires (10,000 acres or more) across the state have increased markedly in the last 20 years—trends influenced by altered fuel conditions and climate change. Wildfires in 2020 burned an unprecedented 4 million acres across California. In 2021, about 2.6 million acres burned, making it the second highest year, followed by 2018, with 1.5 million acres burned.

Figure 1. Statewide annual acres burned, 1950-2021



Source: CAL FIRE, 2022

Figure 2. Annual number of large wildfires (≥ 10,000 acres), 1950-2021*



Source: CAL FIRE, 2022

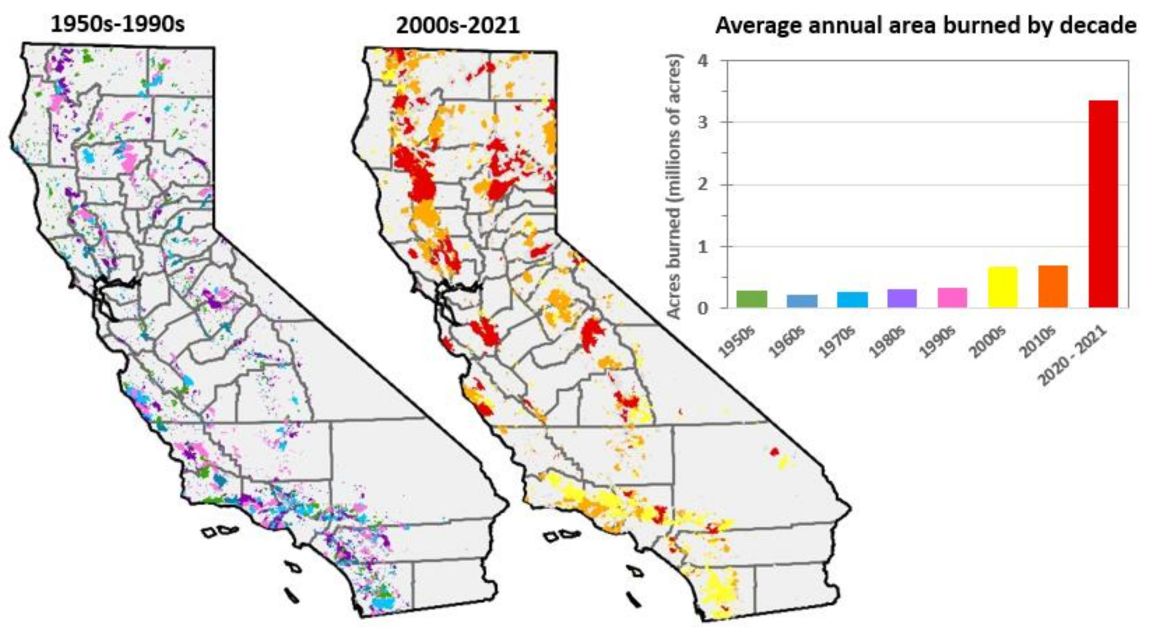
Dotted line is 10-year running average.

What does the indicator show?

The data presented in Figure 1 show the number of acres burned by wildfires statewide each year. The total area burned annually since 1950 ranged from a low in 1963 of 32,000 acres to a record high in 2020 of 4.2 million acres – more than 4 percent of the state's roughly 100 million acres of land. The year 2021 ranks the second highest in acreage burned by a wide margin: wildfires consumed about 2.6 million acres, compared to about 1.6 million in 2018, the third highest year. The number of large fires (10,000 acres or more) has similarly increased in the past two decades (Figure 2).

Figure 3 shows areas of the state burned by wildfires by decade. The average area burned each year in the last two full decades is at least double the acreage in the earlier decades; the annual average in 2020-2021 is about five times higher than in the 2010s. Until the 2010s, the largest fires occurred in Southern California. In the past several years, most of the largest fires have occurred in the north, including the August Complex fires in 2020 (in Mendocino, Humboldt, Trinity Tehama, Glenn, Lake and Colusa Counties) and the Dixie Fire in 2021 (in Butte, Plumas, Lassen, Shasta and Tehama counties), which shattered previous fire size records (see Figure 4).

Figure 3. Fire history, 1950-2021

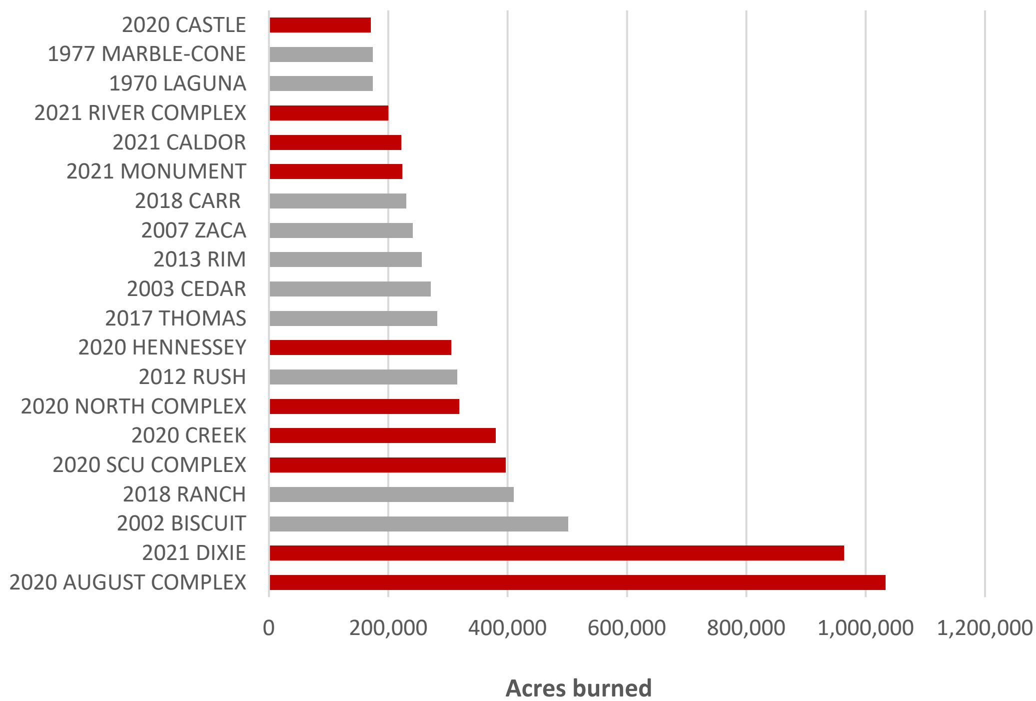


Source: CAL FIRE, 2022

Maps showing areas burned in 1950 to 1999 (left) and in 2000-2021 (right). The colors on the maps correspond to decade burned, as presented on the bar graph showing the average annual acreage burned by decade.

As shown in Figure 4, all but two of the largest wildfires have occurred since 2000, including ten that burned in 2020 and 2021 (CAL FIRE, 2022). The increasing prevalence of very large fires (>10,000 acres) in California and across the West has led many experts to describe the US as having entered into an era of “mega-fires” or, when also considering recent large-scale tree mortality events, an era of “mega-disturbances” (CAL FIRE, 2018).

Figure 4. Top 20 California fires since 1950



Source: CAL FIRE 2022

Red bars denote fires that occurred in 2020 and 2021.

Notable fires in the past five years include:

- The October 2017 wildfires in Sonoma and Napa counties that devastated the affected communities: 44 deaths, more than 100,000 residents evacuated, and over $9 billion in residential and commercial insurance claims (CDI, 2017).

- The Thomas Fire that swept through Ventura and Santa Barbara counties in December 2017 and occurred outside of what has traditionally been considered the state's fire season. Following the Thomas Fire, debris flows in 2018 in Montecito resulted in 23 deaths and nearly 1 billion dollars in damages (Oakley, 2021). Santa Ynez Chumash firefighters helped battle this blaze and additionally worked to protect cultural sites (Shankar, 2017).

- The Mendocino Complex and Carr fires in 2018, which totaled $148.5 billion (roughly 1.5% of California's annual gross domestic product), with $27.7 billion in capital losses, $32.2 billion in health costs, and $88.6 billion in indirect losses (e.g., manufacturing and supply chain impacts) (Wang et al., 2021). Indirect costs often affect industry sectors and locations distant from the fires (for example, 52% of the indirect losses—31% of total losses—were outside of California). During the Lake, Sonoma and Mendocino listening session and in the Big Valley climate change report, Tribes detailed the impacts of this fire on their Tribes (Big Valley and Middeltown, 2021).

- The Camp Fire in 2018, the deadliest and most destructive wildfire in California history: 85 deaths, nearly 19,000 buildings destroyed, and most of the town of Paradise burned down. The fire generated a large plume of heavy smoke that traveled thousands of miles. The smoke caused dangerously high levels of air pollution in the Sacramento Valley and Bay Area in particular, for a period of about two weeks (CARB, 2021).

- The August Complex fire in 2020, described as the state’s first "gigafire," having burned more than one million acres. The fire crossed seven counties comprising an area larger than the state of Rhode Island (CAL FIRE, 2021a).

- The 2020 Creek Fire in Fresno and Madera Counties, fueled by trees stressed from years of exceptional drought in the heart of the tree mortality zone (CAL FIRE, 2021b). The largest single fire as of that date, the fire burned almost 380,000 acres in an area that has no recorded fire history in the Sierra National Forest. Rising warm air from the fast-moving fire carried water vapor up into the atmosphere, creating a “pyrocumulonimbus” cloud—one of the largest ever observed in the United States (NASA, 2020). The Creek Fire had a direct impact on the North Fork Band of Mono Indians of California as it burned historic lands and came within five miles of the reservation (NFRMIC, 2022).

- The CZU Complex fire in 2020, which burned about 86,500 acres in Santa Cruz and San Mateo Counties, destroying about 1,500 structures and damaging 140 others (CAL FIRE, 2021c). The fire burned the majority of the 18,000 acres in the state’s oldest park, Big Basin Redwood State Park (CalOES, 2021). The park is home to the largest continuous stand of ancient coast redwoods south of San Francisco, most of which fortunately survived the fire (CDPR, 2021). The Amah Mutsun Tribal Band suffered direct losses as a result of this fire (Amah Mutsun, 2022).

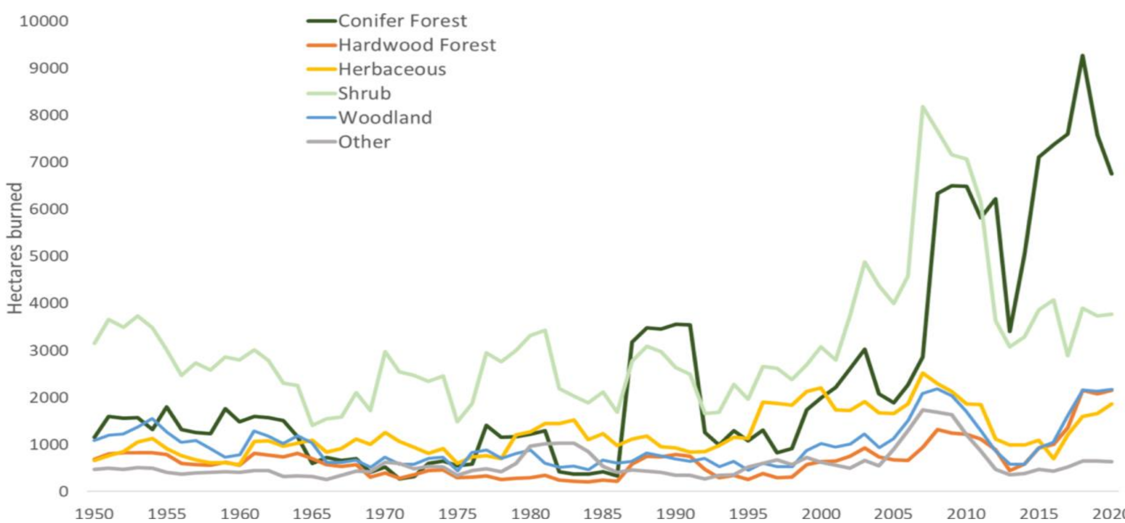
- The Dome Fire in 2020 burned over 43,000 acres in the Mojave National Preserve, through one of the densest and largest Joshua Tree forests in the world. An estimated 1.3 million Joshua trees were killed in the fire (NPS, 2022).

- The Castle Fire in 2020 and the KNP Complex and Windy Fires in 2021 led to the loss of an unprecedented number of giant sequoias: an estimated 9,800 to 14,000 trees that made up about 13 to 19 percent of the large sequoia population in the Sierra Nevada. Giant sequoias are highly valued trees that occur in about 70 distinct groves covering only about 12,000 hectares. An iconic species, giant sequoias are the most massive trees on earth with exceptional longevity, and the center piece of many state and national parks (Shive et al., 2021 and 2022).

- The Dixie Fire started on July 13, 2021 in Butte County. It burned across four other counties –Lassen, Plumas, Shasta and Tehama – and on the Plumas National Forest, Lassen National Forest, and Lassen Volcanic National Park. It is the largest single fire in modern history to date, consuming more than 960,000 acres, and was the first fire known to cross the crest of the Sierra Nevada, followed a month later by the Caldor Fire (Inciweb, 2022a and b).

In addition, changes in the type of vegetation burned have been observed in recent decades. Figure 6 presents the annual area burned by wildfires across the state by five categories of vegetation: herbaceous, shrubland, woodland, hardwood forest, and coniferous forest; the sixth category, “other,” includes partially vegetated areas of lower flammability such as barren, urban, wetland, agriculture and desert (Schwartz and Syphard, 2021). Most vegetation types have seen increases in area burned since 2000, with, conifer forests showing the greatest increase. In most years between 1950 and the mid-2000s, shrubland accounted for the largest area burned in California; cumulatively, fires in shrubland made up more than 50 percent of the area burned since 1950.

Figure 6. Area Burned by Vegetation Type, 1950-2020



Source: Figure 2 from Schwartz and Syphard, 2021

Area burned is smoothed over a five-year window for five vegetation types (coniferous forest, hardwood forest, woodland (consisting of hardwood and coniferous woodland) shrub, herbaceous vegetation, and “other” (lower flammability and partially vegetated areas).

Why is this indicator important?

Wildfires threaten public health and safety, property, and infrastructure, as well as ecosystems and the services they provide. The economic costs associated with fire prevention, mitigation and response, and post-fire rebuilding and restoration have been substantial in recent years (CCST, 2020).

Wildfires severely impact air quality both locally and in areas downwind of the fire (Nolte et al., 2018). Wildfire smoke contains hazardous constituents including fine particulate matter, carbon monoxide, ozone precursor compounds, polycyclic aromatic hydrocarbons, and volatile organic compounds (CDPH, 2019; Black et al., 2017). Exposures to wildfire smoke have been associated with general respiratory illnesses and exacerbations of asthma and chronic obstructive pulmonary disease (Liu et al., 2017; Reid et al., 2016;). As an example of the remote impacts of wildfires, the Camp Fire in 2018 affected air quality 88 miles downwind in Sacramento County, which experienced eleven consecutive days of “unhealthy” air and an increased number of emergency department visits for respiratory-related health conditions (CDC, 2021). (See *Wildfire smoke* indicator)

The rapid growth of wildfire is consistent with predicted increases in property damage that will occur in wildland/urban interfaces proximate to major metropolitan areas in coastal southern California, in the San Francisco Bay Area, and in the Sierra foothills northeast of Sacramento (Westerling and Bryant, 2008). Between 2000 and 2018, the largest number of structures burned in locations classified as “other”—this includes residential areas along the wildland-urban interface (Figure 6; Schwartz and Syphard, 2021). Among lands with natural vegetation types, the largest fraction of destructive fires (those that destroyed structures) occurred in woodlands and hardwood forests; these forests make up only 4 percent of all vegetation types statewide, yet accounted for 16 percent of destructive fires. Only 12 percent of destructive fires occurred in conifer forests.

Wildfires are a serious threat to California’s Tribes. More information specific to each Tribe is presented in the *Impacts on Tribes* section. For example, in the Klamath Basin, the Karuk Tribe has experienced more frequent, large-scale, high-severity intense fires in recent years (Karuk, 2022). Although a historically fire-adapted system, large high-severity wildfires in this region threaten many species, alter the habitat, and disrupt ecosystem dynamics. During the Eastern Sierra listening session Tribes shared that as the Owens Valley is losing native vegetation, invasive plants are less resistant to wildfire. (Bishop Paiute, 2020 and 2022). Wildfire is considered a high-risk exposure for the Pala Tribe also. Nearly a third of Pala’s population lives in a high-risk wildfire area (Pala, 2022).

Less than three months after the Eastern Sierra listening session during which the Tribes discussed the vulnerability of their area to wildfire. The home of the Cultural Monitor for the Coleville Paiute Tribe, Grace Dick, burned to the ground in the Mountain View Fire, which burned over 20,000 acres in the Antelope Valley.

Substantial economic impacts are associated with damage to infrastructure, loss of property, disruption of businesses and jobs, and firefighting and post-fire cleanup. Larger and more extreme wildfires could be especially challenging for rural, low-income households residing in fire prone areas. Property loss is more likely to occur in smaller, more isolated housing clusters that are difficult for firefighters to reach and suppress (Syphard, 2012). Rural, low-income residents often have less capacity to protect themselves and recover from fire impacts than people living in more affluent communities (CAL FIRE, 2018). Wildfires on or near native lands threaten the health, safety, and economy of those Tribes, culturally important species, medicinal plants, traditional foods, and cultural sites (Jantarasami et al., 2018).

As large wildfires increase in size and number and the fire season has grown longer, firefighting has consumed more of the annual resource management budgets for federal and state lands that otherwise could be spent on sustainable programs for fuel management and forest health. The increased threat to losses of property, lives, and natural resources has made fire suppression in California an increasingly higher priority for federal, state, and local land management agencies. In response, the Governor's *California and Forest Resilience Action Plan* provides a strategy to improve wildfire resilience and forest health throughout the state (Governor's Forest Management Task Force, 2021).

Wildfires in forests can lead to long-term changes in forest area, composition, or structure. Forest conversion to shrub or grassland will have adverse impacts on soil productivity, water quality, wildlife habitat, and carbon storage (CAL FIRE, 2018). Recovery of plant communities following a fire determines biodiversity, ecosystem services, future fire activity and other ecosystem conditions. Fires cause injury or death to animals, and lead to immigration or emigration; the habitat changes resulting from a fire (such as altered physical habitats, changes in food availability, and disruptions to landscape processes) can have more profound impacts on animal communities (Smith, 2000). Larger "megafires" kill small mammal, reptile and amphibian species that have evaded or survived smaller, less severe natural historic fires by seeking shelter in burrows (CAL FIRE, 2018). Animals exhibit a wide range of strategies in dealing with fires, and recovery of animal communities is affected by the nature of the fire, the type of vegetation burned, the availability of refugia, and habitat fragmentation outside the burned area (Keeley and Safford, 2016).

Fires affect the physical, chemical and biological properties of soils (Neary et al., 2008). Relatively low temperatures can reduce the organic matter in soils, increasing its bulk density and reducing its porosity. These changes make the soil more vulnerable to post-fire runoff and erosion, leading to damaging floods (Oakley, 2021). Healthy forests play an important role in the hydrologic cycle, promoting infiltration, holding soil on slopes, and maintaining the delivery of high-quality water to streams and downstream uses (CAL FIRE, 2018). Fires affect aquatic habitat and aquatic organisms by altering streamflow, depositing sediment, and introducing fire debris, ash and other water contaminants, including heavy metals from soils and geologic sources and fire retardants into surface waters (Neary et al., 2008). These contaminants have compromised the quality of drinking water sources (Alizadeha et al., 2021). In watersheds, vegetation destroyed by severe wildfire can reduce stream shade and increase water temperatures, threatening species such as Chinook salmon (see *Salmon River water temperature* indicator).

Forests play an important part in regulating levels of atmospheric carbon (Gonzalez et al., 2015; Settele et al, 2014). Trees remove carbon dioxide, a greenhouse gas, from the atmosphere and store it through natural processes. California's forests function as net carbon sinks, sequestering about 25 million metric tons of carbon dioxide equivalent per year (Christensen et al., 2021). However, the long-term sustainability of forests to continue to operate as net sinks is at risk. The increasing frequency of large wildfire events and the increasing loss of conifer and hardwood forests to wildfires, along with pest infestations and associated tree mortality have the potential to drastically impact the quantity, quality and stability of carbon storage in affected areas.

What factors influence this indicator?

A natural element of California's landscape, wildfires play a critical role in shaping the state's wildlands. Prior to Euro-American settlement, an estimated 4.5 to 12 million acres burned annually, ignited naturally by lightning and intentionally by Native Americans to manage the landscape (Stephens et al., 2007). For example, the Karuk Tribe in the mid-Klamath River region of northern California and the Amah Mutsun Band in the central coast have relied on fire to protect ecological and cultural resources and to build wildfire resilience (*Impacts of Climate Change on the Amah Mutsun Tribal Band* and *on the Karuk Tribe* chapters). These patterns of recurring, primarily low and moderate severity fires were disrupted following the depopulation of Native Americans and the implementation of more than a century of fire suppression that led to the accumulation of fuels in California's forests (Taylor et al., 2016).

Changes in population and land use can have immediate and dramatic effects on the number and sources of ignitions and on the availability and flammability of fuels. For example, the escalation of fire losses at the wildland-urban interface is often attributed to new housing development within or adjacent to wildland vegetation (Li et al., 2021; Mass et al., 2019; Syphard et al., 2012). Population growth has brought the suppression of fire and attendant growth in fuel availability, as well as the spread of highly flammable, nonnative plant species. In addition, the expansion of the electrical distribution system, much of it vulnerable to strong winds, provides multiple points of wildfire initiation (Mass et al., 2019).

The size, severity, duration, and frequency of wildfires are greatly influenced by climate. High precipitation years promote the growth of vegetation that then dry up the following spring or summer under warm, low moisture conditions. In largely grass- and shrub-dominated foothills of the Sierra Nevada and across southern California landscapes, the amount of prior-year rainfall has been positively linked to area burned by fire in the following year (Keeley and Syphard, 2017). In western US forests, warmer spring and summer temperatures, reduced snowpack and earlier spring snowmelt have been associated with increased wildfire activity beginning in the mid-1980s: more frequent large wildfires, longer wildfire durations, and longer wildfire seasons (Westerling et al., 2006 and 2016; Williams et al., 2019). Climate change-linked increases in temperature and in vapor pressure deficit (VPD, a measure of dryness, is the difference between the amount of water vapor in air and the maximum amount it can hold) have been shown to significantly enhance fuel aridity over the past several decades, creating a more favorable fire environment (Abatzoglou and Williams, 2016). As summertime temperatures increased by approximately 1.4°C in California since the early 1970s, VPD has likewise increased (Williams et al., 2019). The warming-driven increase in VPD has been found to be the largest wildfire-relevant climate trend in the summer. Warming-driven fuel drying is the strongest link between climate change and increased wildfire activity across the Sierra Nevada (Chen et al., 2021).

In recent years, California has experienced extreme drought intensified by unusually warm temperatures, known as a hotter drought (see *Drought* indicator). With hotter drought come very low precipitation and snowpack, decreased streamflow, dry soils, and large-scale tree deaths. These conditions create increased risk for extreme wildfires that spread rapidly, burn with a severity damaging to the ecosystem, and are costly to suppress (Crockett and Westerling, 2017). A study of wildfires in the western US across ecoregions that represent a wide range of vegetation types, latitudes and precipitation regimes found the largest increases in fire activity in ecoregions where temperatures trended hotter and precipitation trended drier, coinciding with trends toward increased drought severity (Dennison et al., 2014). A disproportionate increase in burned areas in the past two decades have occurred in regions of the western US where vegetation is more sensitive to moisture deficits and prone to drying out (Rao et al, 2022). Tree mortality associated with the severe 2012-2016 drought in California significantly altered forest structure, composition and fuels for wildfire, particularly in the central and southern Sierra Nevada (Stephens et al., 2018). Historical records indicate that in the 1920s, drought also coincided with increased large fires (greater than 10,000 hectares (approximately 25,000 acres) (Keeley and Syphard 2021).

In the fall, warming temperatures and decreasing precipitation statewide over the past four decades have contributed to extreme fire weather (that is, weather conditions conducive to wildfires) across most of the state; the frequency of autumn days with extreme fire weather was estimated to have more than doubled since the early 1980s (Goss et al., 2020). Recent autumn wildfires – notably the Camp Fire in Butte County and the Woolsey Fire in Los Angeles and Ventura Counties, both in 2018 – occurred during periods of extreme fire weather that coincided with strong offshore winds. These fires burned vegetation rendered unusually dry by anomalously warm conditions and late rainfall. As the onset of California's rainy season has become progressively delayed over the past six decades (Luković et al., 2021; Swain, 2021), wildfire risk has increased with the temporal overlap between extremely dry vegetation conditions and fire-promoting winds in late autumn.

Large and damaging wildfires in California are often associated with significant wind events, especially fast-moving downslope winds such as the Santa Ana winds (in Southern California) and Diablo winds (in Northern California). In Southern California, the influence of Santa Ana winds on wildfires is evident; a study found that non-Santa Ana fires, which occur mostly in June through August, affected higher elevation forests, while Santa Ana fires, which occur mostly in September through December, spread three times faster and occurred closer to urban areas (Jin et al., 2015). Recent examples of Santa Ana wind-driven fires include the destructive Thomas Fire in Ventura and Santa Barbara Counties (December 2017 to January 2018) and the Woolsey Fire, mentioned above. Catastrophic wildfires in Northern California, including the series of “Wine Country” fires in Napa and Sonoma Counties in October 2017 and the 2018 Camp Fire, were driven by Diablo winds. These fires burned over non-forested landscapes of shrubs, grasses, and woodlands (Keeley and Syphard, 2019).

Fire severity is affected by climate. The area burned by high severity fires from 1985 to 2017 in western US forests showed an eightfold increase, corresponding with warmer and drier fire seasons (Parks et al., 2020). Among the potential consequences of high severity fires is the growth of vegetation types other than those originally in the burned area, potentially altering forest ecosystems.

Higher altitude forests are buffered against the effects of warming to some extent by available moisture from colder conditions. Snowpack and abundant spring runoff provide moisture to soil and vegetation, reducing the flammability of these forests. However, a study of a 105-year data set (1908 to 2012) found that fire frequency in the Sierra Nevada has been increasing since the late 20th century, as has the upper elevational extent of those fires (Schwartz et al., 2015). Prior to 1950, 7 of 1531 recorded fires burned at elevations above 3000 meters; since 1989, 30 of 1534 fires burned above this elevation. Changes in fire management (such as reduced fire suppression at high elevations), climate (warming temperatures, especially at night, and earlier snowpack melt), fuels (from increasing tree densities) and ignitions (both lightning and human-caused) are recognized as factors influencing the trend. These factors are not mutually exclusive and may have synergistic effects.

The upslope advance of Sierra Nevada wildfires in recent years was corroborated by a study which found that fire is increasing disproportionally at high-elevation compared to low-elevation forests in the western United States (Alizadeh et al., 2021). The largest increased rates in burned area during 1984 to 2017 occurred above 2500 meters. High-elevation fires advance upslope with a cumulative change of 252 meters; the greatest advances were observed in the Southern Rockies, Middle Rockies and Sierra Nevada ecoregions at 550, 506 and 444 meters, respectively. The upslope advancement was consistent with the increase in VPD. The upward migration of wildfire may play a role in fundamentally changing the landscape at higher elevations, and make these areas even more prone to burning in the future.

Technical considerations

Data characteristics

Data on statewide annual acres burned (Figure 1) were downloaded from a fire perimeter database made publicly available online through CAL FIRE. CAL FIRE works with the USDA Forest Service (USFS) Region 5 Remote Sensing Lab, the Bureau of Land Management (BLM), and the National Park Service (NPS) to track fires on public and private lands throughout California. The data for the period 1950 to 2001 include USFS wildland fires 10 acres and greater, and CAL FIRE fires 300 acres and greater. In 2002, BLM and NPS fires of 10 acres and greater were added, as were CAL FIRE timber fires of 10 acres and greater, brush fires of 50 acres and greater, grass fires of 300 acres and greater, wildland fires destroying three or more structures, and wildland fires causing $300,000 or more in damage. Further details are available at the CAL FIRE fire perimeters webpage.

For the graph in Figure 5, the alarm date of the first large fire, and the containment date of the last large fire of the calendar year in the fire perimeter datafile were plotted as the start and end dates, respectively, for each year.

Strengths and limitations of the data

The CAL FIRE database contains the most complete digital record of fires in California. However, some fires may be missing for a variety of reasons (e.g., lost historical records, inadequate documentation). The containment date for many of the fires is missing, but a large majority of the fires have alarm dates. In addition, although every attempt is made to remove duplicate fires, some duplicates may still exist. Overgeneralization may also be an issue, in which unburned regions within old, large fires may appear as burned.

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