Chapter 4: Wildfire



Forested area burning in the 2021 Dixie Fire in the Sierra Cascades ecoregion. Photo: CAL FIRE.

INDICATORS

- ⓘ 4.1 Fire Return Interval Departure
- ⓘ 4.2 Wildfire Hazard Potential
- ⓘ 4.3 Wildfire Activity
- ⓘ 4.4 Fire Severity
- ⓘ 4.5 Vegetation Treatments

INTRODUCTION

Fire is a natural and necessary ecological process in California ecosystems. However, ongoing changes in fire regimes and climate, combined with the vulnerability of people and infrastructure, make it a singular management challenge (Bowman et al. 2020). Due to California's storied history with wildfire, experience with risk, and investment in management response, the state serves as a harbinger to regions newly experiencing wildfire exposure in a rapidly changing environment. This chapter describes current topics and trends relating to the extent, ecological role, and land management concerns from increasingly large and intense wildfires, while direct impacts to people are addressed in Chapter 11 (Wildfire Risk to Communities).

Land and wildfire are inseparable, and over evolutionary time ecosystems have developed the capacity to burn, recover, and burn again. Fire regimes characterize this relationship, representing an ecological process that maintains ecosystem structure and function. Settlement by Euro-Americans over 200 years ago dramatically altered fire regimes by changing ignitions, vegetation, and fuels, and later by initiating 150 years of effective wildfire suppression. This alteration resulted in widespread changes in vegetation structure and pattern across the landscape (Hagmann et al. 2021). More recently, human-caused influences on the climate have exacerbated drought and moisture deficits while also increasing the frequency of weather conditions associated with the most severe and damaging fires, leading to increases in area burned, particularly at high severity (Parks et al. 2025) (see Chapter 7, Climate Change).

While we have known for decades that modern fire regimes are not sustainable in their current and expected future forms, we are capable of moderating this trend. Amid changing fire regimes and contention around appropriate management practices for sustaining fire-dependent ecosystems, we see some burned areas experience beneficial fire effects (Shive et al. 2025), while other areas experience changes in ecosystem type, or "type conversion" (Coop et al. 2020), which may be undesirable. By eliminating fires that burn under mild or moderate conditions, fire suppression has contributed to increases in the overall extent and impacts of wildfire, including the increased costs and damages currently unfolding (Kreider et al. 2024). The challenge faced by the State of California is to have fires provide the greatest benefit while minimizing their negative consequences. While California's fire ecology is well understood, the challenge of balancing competing fire impacts is ultimately reduced to decisions made

by leadership and landowners and is based on values placed on land, people, and infrastructure. As such, wildfire serves as the defining relationship of California to the landscape.

SUMMARY

Challenges related to wildfire constitute some of the most critical land management, development, and policy concerns in California (Ellis et al. 2022). Since the 2017 Assessment, we have seen massive increases in wildfire activity (ⓘ4.3), with direct negative impacts on natural resources, socio-human assets, fatalities, and risks to public health (Dube 2025, Higuera and Abatzoglou 2021). Fires originating from the electrical utility sector's network of overhead infrastructure and associated electrical power systems have been disproportionally responsible for these large and damaging fires. Along with increasing area burned, the proportion of fire burning at high severity has increased (ⓘ4.4), leading to large areas at risk of vegetation type conversion. Significantly, recent high severity wildfires have also caused an estimated loss of nearly 20% of old growth giant sequoia trees, an iconic keystone species.

Wildfire is perhaps the most influential actor on ecosystems throughout the state, and direct action is needed to mitigate impacts on both natural and human systems. Indigenous Californian fire regimes prior to Euro-American settlement (EAS) promoted ecosystem stability and ecological balance and produced needed outputs for livelihoods. Modern landscapes continue to have extensive areas with substantial departure from those pre-colonial regimes (ⓘ4.1). Although wildfire is a statewide issue, wildfire hazard, which reflects a combined metric of burn probability and potential fire behavior, is highest in the Klamath and Interior Coast Ranges, Southern Coast and Mountains, and Sierra/Cascades ecoregions (ⓘ4.2). To address wildfire hazard and the risk of damage to highly valued assets and resources, there have been expanding efforts to increase the pace and scale of fuels reduction treatments (ⓘ4.5), including using cultural burning that incorporates traditional ecological knowledge (TEK). While fuel treatments increase forest resilience to disturbances, there continues to be a significant backlog of areas needing treatment. There also is increasing recognition that many low- to moderate-severity wildfires can contribute substantially to fuel reduction, effectively serving as initial treatments within a long-term resilience strategy.

Fire effects and impacts stemming from changes to historical fire regimes, along with ongoing climate change, have created increasingly clear trends and emergent problems. In addition to loss of life, property, and health impacts from smoke exposure, adverse impacts include loss of timber value, increased insurance costs, and reduced property values. As our forests and other natural ecosystems show greater instability, and their capacity to provide natural resource services is reduced, the evidence is apparent that current fire management strategies must change to meet these challenges. We need a new paradigm for managing our wildlands—one that fosters their health and resilience, while at the same time reduces threats to communities, public health, and safety. The following pages depict the indicators used in this chapter to illustrate the status and trends in wildfire in California. Further narrative is included in the chapter discussion, as well as identification of opportunities for addressing wildfire concerns for forests and rangelands. Topics related to community wildfire protection are addressed in Chapter 11 (Wildfire Risk to Communities).

Indicator 4.1: Fire Return Interval Departure

Which Montreal Process Criterion does the indicator evaluate?

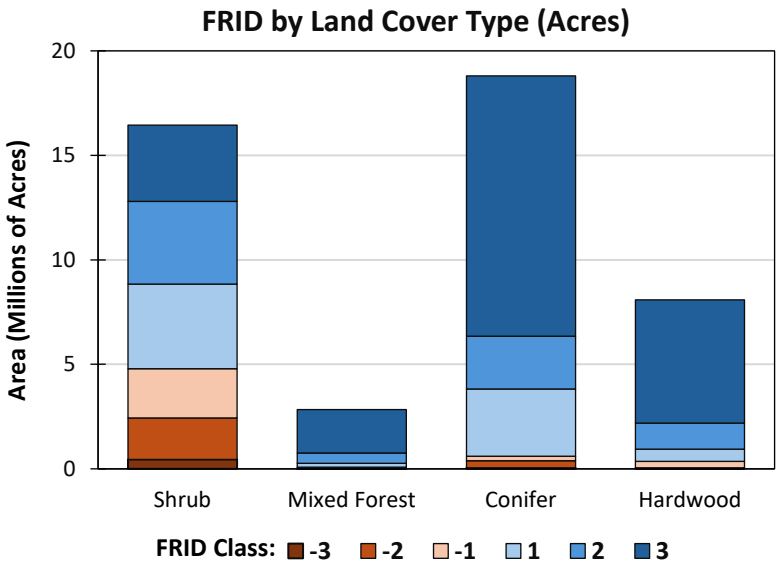
MPC3: Maintenance of forest ecosystem health and vitality

Why is this indicator important?

Most of California's fire-adapted ecosystems are burning either too often or not often enough, and in conjunction with land use practices and development, this has led to ecosystem function and structure changes. These changes cascade down to fuels, vegetation density and composition, hydrology, and wildlife habitat. In turn, altered vegetation can potentially change fire behavior, fire severity, and ecosystem sustainability.

What does the indicator show?

Fire return interval departure (FRID) quantifies the difference between current and reference fire frequencies. Negative values indicate more frequent fire occurrence than reference (fire excess), and positive values indicate less frequent fire occurrence (fire deficit). FRID classes represent low, moderate and high departure classes. Values of -1 and 1 indicate <33.3% departure and can be considered not substantially departed from reference frequencies. FRID was summarized by CA Wildlife Habitat Relationships Lifeforms. Mixed Forest represents Mixed Conifer-Hardwood.



Key Findings:

- Areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are mostly burning less frequently than they did in the pre-settlement era, with 69% of the combined area of these vegetation types in high positive departure (FRID class 3). This condition is most evident in the North Coast, Klamath/Interior Coast, and Sierra/Cascades ecoregions. This percentage represents a slight decrease from 75% in high departure in the 2017 Assessment.

- Shrub-dominated areas are burning both more and less frequently than their reference, with 15% by area in moderate or high negative departure (classes -2 and -3) and 46% in moderate or high positive departure (classes 2 and 3).

- The shrub-dominated area in moderate or high negative departure has declined from 23% statewide during the 2017 Assessment, largely due to sites crossing the threshold from class -2 to -1 due to the increase in time since the last fire. Of the ~44.8 million acres of wildland vegetation with altered fire return interval, 67% have experienced too little fire. The majority of that is in the class of highest departure from historical normal fire return interval.

Data Source

California Fire Return Interval Departure (Safford et al. 2022).

Indicator 4.2: Wildfire Hazard Potential

Which Montreal Process Criteria does the indicator evaluate?

MPC2: Maintenance of productive capacity

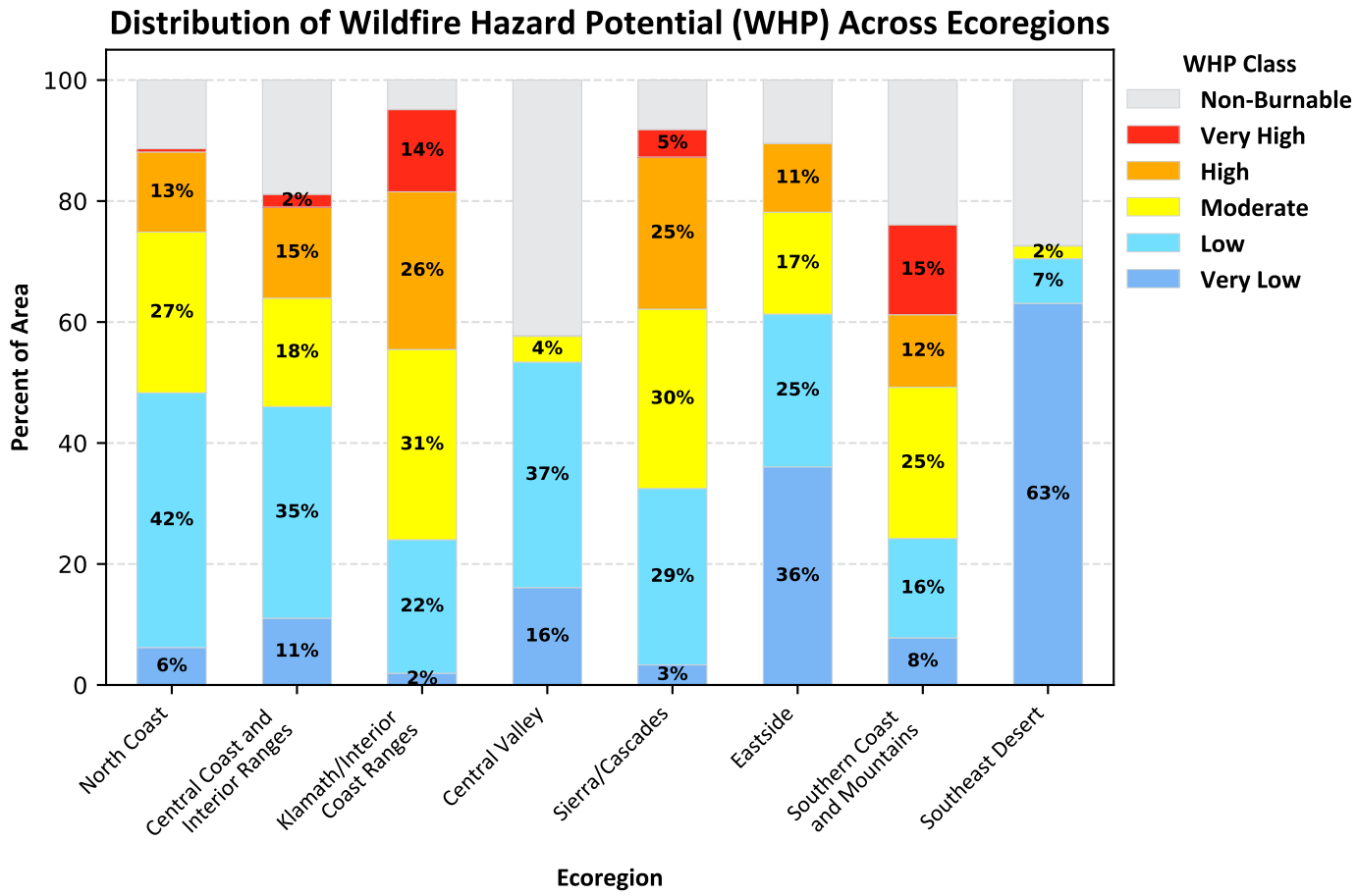
MPC3: Maintenance of forest ecosystem health and vitality

Why is this indicator important?

Wildfire hazard potential (WHP) represents the relative likelihood of damaging or difficult-to-control wildfires, making it a critical factor for proactive fire and land management. WHP is a spatial index that combines estimates of wildfire likelihood and potential intensity to highlight areas most likely to experience extreme wildfire. While WHP is not a complete wildfire risk assessment, it is a useful tool for guiding fuel treatment strategies and identifying areas where communities and resources have elevated wildfire hazard.

What does the indicator show?

WHP is generated from wildfire behavior simulations and incorporates inputs such as fuel conditions and historical fire records. Areas classified as Very High or High WHP are more likely to experience intense fire activity under severe weather conditions.



Key Findings:

- More than 17 million acres of California's total area (around 21% of the state's burnable lands) are classified as having High or Very High WHP. The Southern Coast and Mountains as well as Klamath/Interior Coast Ranges ecoregions have the highest proportion of Very High WHP.
- The Southern Coast and Mountains ecoregion has about 15% classified as Very High and 12% as High WHP, with these areas mainly concentrated in mountainous and mid-to-high elevation zones.
- The Klamath/Interior Coast Ranges ecoregion has around 14% classified as Very High WHP. This region also has the highest combined proportion of High and Very High WHP (~40%), making it the most concentrated region for wildfire hazard potential.
- In the Sierra/Cascades ecoregion, around 5% of the area has Very High WHP and about 55% falls within Moderate or High ranges, primarily distributed across the western side of the mountain ranges.

Data Source

CAL FIRE and Pyrologix, Wildfire Hazard Potential (CAL FIRE and Pyrologix 2025, Dillon et al. 2015).

Indicator 4.3: Wildfire Activity—Trends in Burned Area

Which Montreal Process Criteria does the indicator evaluate?

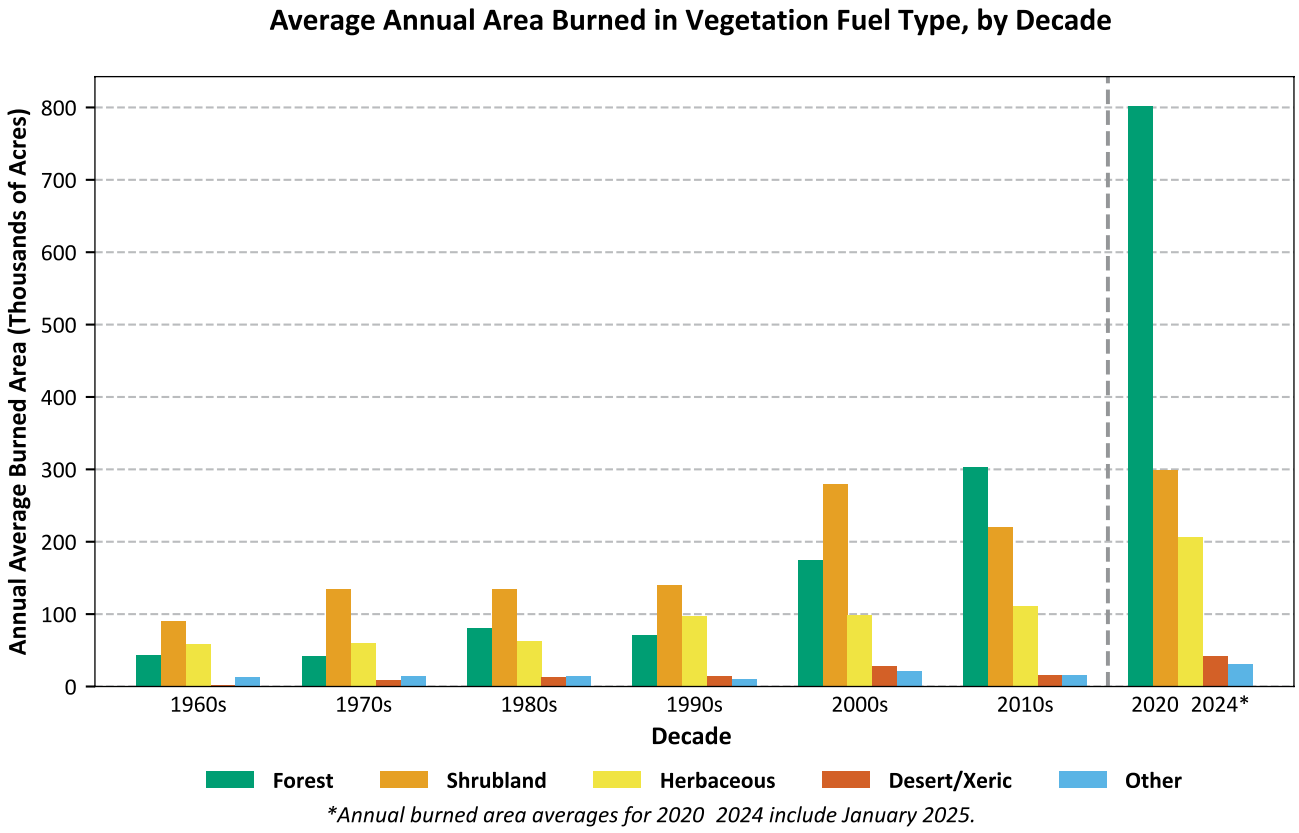
MPC3: Maintenance of forest ecosystem health and vitality
MPC4: Soil and water resources
MPC5: Maintenance of forest contribution to global carbon cycles

Why is this indicator important?

Fire is an important and inevitable ecological process across much of California, and there was significantly more burning across California prior to Euro-American settlement. California's ecosystems have experienced changes from a century of fire exclusion and land management practices, along with population and development increases that have placed people, infrastructure, and ecosystems at significant risk from wildfire. Appropriate fire management planning requires an understanding of how much area is burning relative to ecological need (ⓘ4.1), as well as where and in which vegetation types burning has occurred. Understanding trends in these characteristics over time can provide insight into whether past and current fire and land management policies intended to protect people and promote ecological resilience of natural systems have been effective, and how we may adapt these policies into the future.

What does the indicator show?

Average annual area burned for broad vegetation fuel classes by decade. The 2020s period is an annual average for the years 2020–2024 as indicated by the vertical dashed line, which carries lower reliability due to the shorter time period and potentially greater influence from short-term climate events. However, this period includes years with both very low and very high burned area, and therefore does capture high inter-annual variability.



*Annual burned area averages for 2020 2024 include January 2025.

Key Findings:

- Approximately 1,634,800 acres burned annually in California between 2020–January 2025, on average, up from an annual average of 667,961 acres for the period 2010–2019 and 604,133 acres from 2000–2009.
- Annual rates of burning in forests, and the average size of large fires (>10,000 acres), have increased over the last 13 years.
- Between 1960 and 2009, shrub-dominated vegetation experienced the greatest average annual burned area. Since 2010, forest vegetation has experienced the greatest average annual burned area.
- Nine of the 10 largest wildfires in recorded history (beginning in 1932) have occurred since 2017.

Data Source

CAL FIRE, Historical Fire Perimeters (CAL FIRE 2025b).

Indicator 4.4: Proportion of High Severity Wildfire in Forests

Which Montreal Process Criteria does the indicator evaluate?

MPC1: Conservation of biological diversity
MPC2: Maintenance of productive capacity
MPC3: Maintenance of forest ecosystem health and vitality
MPC4: Soil and water resources
MPC5: Forest contribution to global carbon cycles

Why is this indicator important?

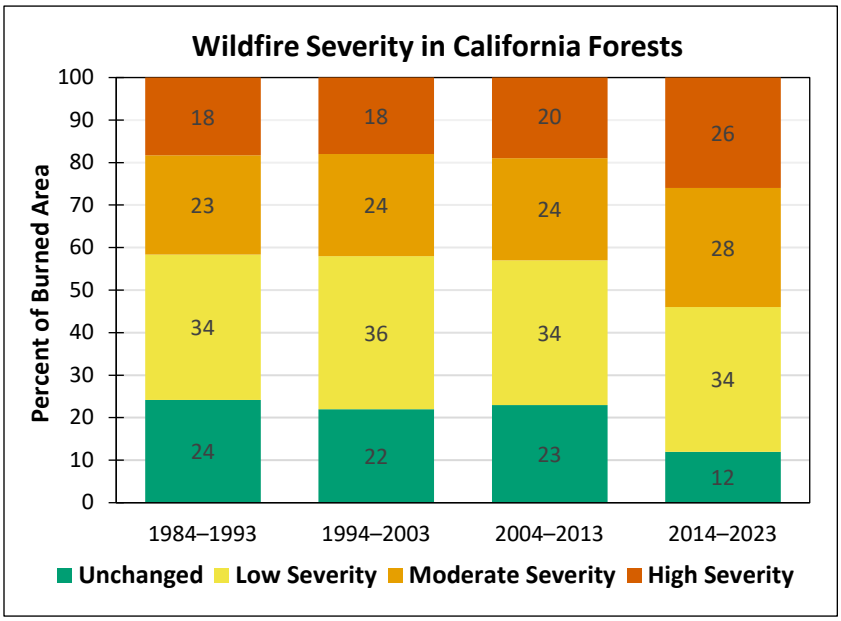
The majority (~80% by area) of California's forests are adapted to frequent, low to moderate severity fire, with high severity patches typically 40 acres or less in size. These patchy high severity mosaics support diverse forest structures across the landscape that are beneficial to forest health. However, large patches of high severity fire greater than 40 acres in size can negatively affect ecosystem services and lead to long-term loss of forest through vegetation type conversion to shrub or grass.

What does the indicator show?

Change in the proportion of fire severity by 10-year intervals for the years 1984–2023.

Key Findings:

- The average annual area burned at high severity within California forests has increased by approximately 99,300 acres per year between 1984 and 2023.
- The proportion of area burned at high severity within California forests increased from 20% during 2004–2013 to 26% during 2014–2023, with the total area burned at high severity rising by 1,486,125 acres over this time period. This far surpasses the historical range for mixed conifer forest (4%–13%), the most abundant forest type in the state.



- The patch size of high severity fire has also increased, which has negative ecological consequences such as a lack of natural tree regeneration in many forest types.

Data Sources

CAL FIRE, Management Landscape Forestland (CAL FIRE 2022).
U.S. Geological Survey and U.S. Department of Agriculture, Forest Service; Monitoring Trends in Burn Severity, Annual Burn Severity Mosaics (USGS et al. 2021).

Indicator 4.5: Vegetation Treatments

Which Montreal Process Criteria does the indicator evaluate?

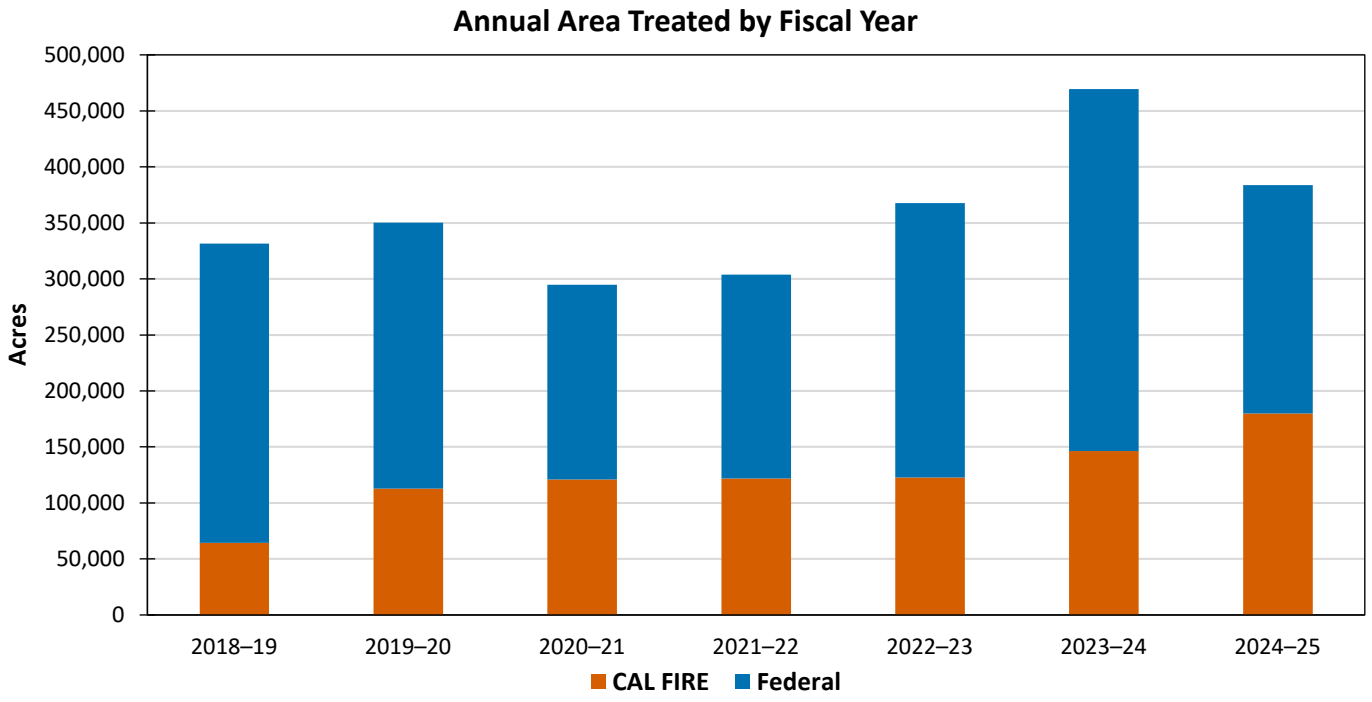
MPC2: Maintenance of productive capacity
MPC3: Maintenance of forest ecosystem health and vitality
MPC4: Soil and water resources
MPC5: Forest contribution to global carbon cycles

Why is this indicator important?

Past land and fire management policy has created a landscape where the natural role of recurrent fire in maintaining ecosystem structure and function is extremely limited (ⓘ4.1). This has increased Wildfire Hazard Potential (ⓘ4.2), endangering important ecological and human assets, including notably over 3 million housing units in the Wildland Urban Interface (WUI) (ⓘ11.3). Fuel treatments are an important tool used to reduce threats to ecosystems and communities.

What does the indicator show?

Annual activity acres of fuel reduction work completed in California by CAL FIRE and federal agencies from fiscal years (FY) 2018–19 through 2024–25. Fuel reduction work includes activities falling under the CalMAPPER Objectives of broadcast burn (which includes pile burning), fuel break, fuel reduction, and right of way clearance. Treatments completed by other state departments are not included due to lack of reliable data prior to 2021. Federal area treated was calculated from the California Wildfire and Forest Resilience Task Force (WFR Task Force) Interagency Treatment Tracking System data (WFR Task Force 2025b), with exclusion of activities not included in CAL FIRE reporting (i.e., pest control, reforestation, and planned treatment burned in wildfire). The federal data include only treatments by the U.S. Department of Agriculture Forest Service (USFS) and the Department of Interior (DOI). The state FY runs from July through June while the federal FY runs October through September.



Key Findings:

- The average annual area treated for fuel reduction by the state's largest fire and land management agencies over the last seven years is about 357,000 acres, an increase of 37% compared to the annual rate reported in the 2017 Assessment.
- Although federal agencies have treated the largest area annually, CAL FIRE has increased the average annual area it treated from ~17,000 acres to ~124,000 acres since the 2017 Assessment, and has treated over 100,000 acres per year every year since state FY 2019–20.
- Forest resilience treatments displayed on the online Wildfire and Forest Resilience Interagency Treatment Dashboard cover a more comprehensive set of land management activities across a greater number of agencies than the fuel treatment data included in this indicator (WFR Task Force 2025c). These activity acres totaled over 1 million across the state in calendar years 2023 and 2024, up from around 800,000 acres in 2021 and 2022. Footprint acres, which account for overlap in areas that receive multiple treatments, ranged from 571,000–767,000 acres for the years 2021–2024, with a generally upward trend.
- Constraints on treatments include risk aversion and public concerns, limited funding and workforce capacity, environmental air quality regulations, and disagreements around priorities between agency leadership and project managers. An additional challenge is in quantifying indirect benefits of treatments (e.g., avoided wildfire emissions, increased baseflow in streams, greater numbers of jobs in rural communities).
- High restoration need, coupled with challenges that can be faced for timely treatment implementation, make it impossible to fully curtail the negative impacts from large, severe wildfires. Taking opportunities offered by ecologically beneficial fire events or treating low-moderate severity areas within wildfires may be significant components of fire restoration and risk management going into the future. The area of federally (USFS and DOI) planned treatments burned in wildfire before treatment implementation occurred and where wildfire impacts aligned with treatment goals ranged from 3,337–91,578 acres/year and averaged 19,433 acres annually between the 2018–19 through 2024–25 fiscal years.

Data Sources

CAL FIRE data from CalMAPPER (CAL FIRE 2025a).

Federal fuel treatment data from the Interagency Treatment Tracking System (WFR Task Force 2025b).

DISCUSSION

Fire Regimes

Baseline versus Current

Fire regimes define the pattern and variability of fire frequency and impacts to ecosystems, and are largely driven by interactions between ignitions, climate, and vegetation fuels (Agee 1993). Climate expressed as weather patterns plays a particularly dominant role in that it can provide ignitions and is a major influence on both growing and burning conditions. Humans in California have coexisted with fire since time immemorial, but many characteristics of fire regimes have changed dramatically since Euro-American settlement (EAS). Prior to EAS, fire was a central tool that humans used across most landscapes for resource management and other cultural purposes (Anderson 2005, Klimaszewski-Patterson et al. 2024).

It is estimated that approximately 4.5 million acres burned annually in California prior to EAS from lightning and human-caused ignitions (Stephens et al. 2007, Van de Water and Safford 2011), although there was significant variability in pre-EAS fire regimes between vegetation types and regions (Noss et al. 2006, Safford and Van de Water 2014). Evidence suggests that fire activity at regional scales was closely connected to climate for millennia (Margolis et al. 2025, Marlon et al. 2012). Indigenous fire management likely buffered climate's influence on fire activity at local to landscape scales and strongly influenced fire regimes prior to widespread EAS (Roos et al. 2022, Taylor et al. 2016).

The long-established relationship between fire, Native Americans, and climate in California began to change with Native American depopulation during the Spanish Mission era. In 1793, the governor of Alta California banned Indigenous burning (Timbrook et al. 1982) and in 1850, the newly constituted State of California did the same. During the gold rush and subsequent EAS period, the forced removal and genocide of Indigenous people from the lands they had previously stewarded resulted in a marked decline in burning. Fire activity was further reduced after implementation of federal fire suppression policy across the West, resulting in a deficit of low and moderate severity fire in many California vegetation types (Mallek et al. 2013, Taylor et al. 2016, Williams et al. 2023). This alteration of fire regimes, in combination with more intensive land use practices and drastic increases in population and development, has resulted in significant vegetation changes in many California ecosystems over the last century.

Pre-EAS fire regimes, or reference fire regimes, were as varied as California's landscapes, but can be generalized by broad vegetation types (Table 4.1). Forest types that are relatively dry and warm, such as lower montane coniferous forest, typically burned at low to moderate severities and on short fire return intervals of approximately 11–16 years on average. Cooler and moister forest types, such as red fir (*Abies magnifica*) and subalpine forests, burned at mixed severity and on longer return intervals of 40 years (red fir) or over 100 years (subalpine) on average. Mixed evergreen forests were intermediate between these two types in terms of severity and frequency. Coast redwood (*Sequoia sempervirens*) forests, although relatively cool and moist, burned with similar frequency and severity as the dry and warm forests, as did oak woodlands (Van de Water and Safford 2011), where grasses and forbs constituted the primary fuels to carry fire. California's grasslands

Table 4.1. Reference fire return intervals (FRI) for selected California vegetation types

Vegetation Type	Mean Min. FRI	Mean FRI	Mean Max. FRI
Chaparral	30	55	90
Coastal Sage Scrub	20	76	120
Mixed Conifer (Dry)	5	11	50
Mixed Conifer (Moist)	5	16	80
Mixed Evergreen	15	29	80
Oak Woodland	5	12	45
Pinyon-Juniper	50	151	250
Red Fir	15	40	130
Coast Redwood	10	23	170
Subalpine Forest	100	133	420
Yellow Pine	5	11	40

Data Source: Van de Water and Safford (2011).

and coastal prairies, which were diverse mixes of forbs and perennial and annual grasses, possibly burned as often as every one to five years, largely due to intentional use of fire by humans to maintain early seral vegetation and inhibit shrub encroachment (Bartolome et al. 2007, Lightfoot and Parrish 2009, Rutherford et al. 2020). Chaparral typically burned at high severity every 30 to 90 years, while most desert systems lacked continuous fuels to carry frequent fire and therefore burned infrequently, along the order of every 65 to 600 years on average, depending on the vegetation type (Bartolome et al. 2007, Lightfoot and Parrish 2009, Rutherford et al. 2020).

It is difficult to determine the spatial extent of individual fires from the distant past, thus fire size is an aspect of historic fire regimes for which there is great uncertainty. More recent records show that the annual frequency of large fires (>24,711 ac or 10,000 ha) in California had several peaks between 1860 and 2020: during the 1920s, in 2007 and 2008, and in 2018 and 2020. Four of the 12 largest fires during this period occurred in the late 19th century, and six were from 2017 to 2020 (Keeley and Syphard 2021). Four additional fires >200,000 acres (~80,950 ha) have occurred since 2021 (Table 4.2). Larger fires recently made up a greater proportion of burned area than in the early suppression period as well. In northern and central California forests, larger fires (>30,011 ac or 12,145 ha) constituted 53–73% of burned area in the contemporary period, but only 0–6% during the period of early fire suppression (1911–1924) (Collins et al. 2019), although the total number of fires in both periods was similar.

Modern fire regimes in forested systems statewide have largely shifted in the direction of lower frequency and higher severity than reference fire regimes (ⓘ4.1,

Table 4.2. Largest California wildfires by size, 1960–2024

Fire Name	Date	County	Area (acres)
August Complex	August 2020	Colusa, Glenn, Lake, Mendocino, Shasta, Tehama, Trinity	1,032,700
Dixie	July 2021	Butte, Lassen, Plumas, Shasta, Tehama	963,405
Mendocino Complex	July 2018	Colusa, Glenn, Lake, Mendocino	459,123
Park	July 2024	Butte, Tehama	429,603
SCU Lightning Complex	August 2020	Alameda, Contra Costa, Merced, San Joaquin, Santa Clara, Stanislaus	396,825
Creek	September 2020	Fresno, Madera	379,842
LNU Lightning Complex	August 2020	Colusa, Lake, Napa, Solano, Sonoma, Yolo	362,921
North Complex	August 2020	Butte, Plumas	318,797
Thomas	December 2017	Santa Barbara, Ventura	281,791
Rush[1]	August 2012	Lassen	271,785
Cedar	October 2003	San Diego	270,686
Rim	August 2013	Mariposa, Tuolumne	256,176
Zaca	July 2007	Santa Barbara, Ventura	240,359
Carr	July 2018	Shasta, Trinity	229,651
Monument	July 2021	Trinity	223,108
Caldor	August 2021	Alpine, Amador, El Dorado	221,786
River Complex	July 2021	Siskiyou, Trinity	199,354
Laguna[2]	September 1970	San Diego	174,162
Marble-Cone[2]	August 1977	Monterey	173,334
SQF Complex	August 2020	Tulare	171,489

Data Notes:
1. California acres only.
2. Data source results in shift in fire size, reordering the list compared to the 2017 Assessment.

Data Source: CAL FIRE (2025b).

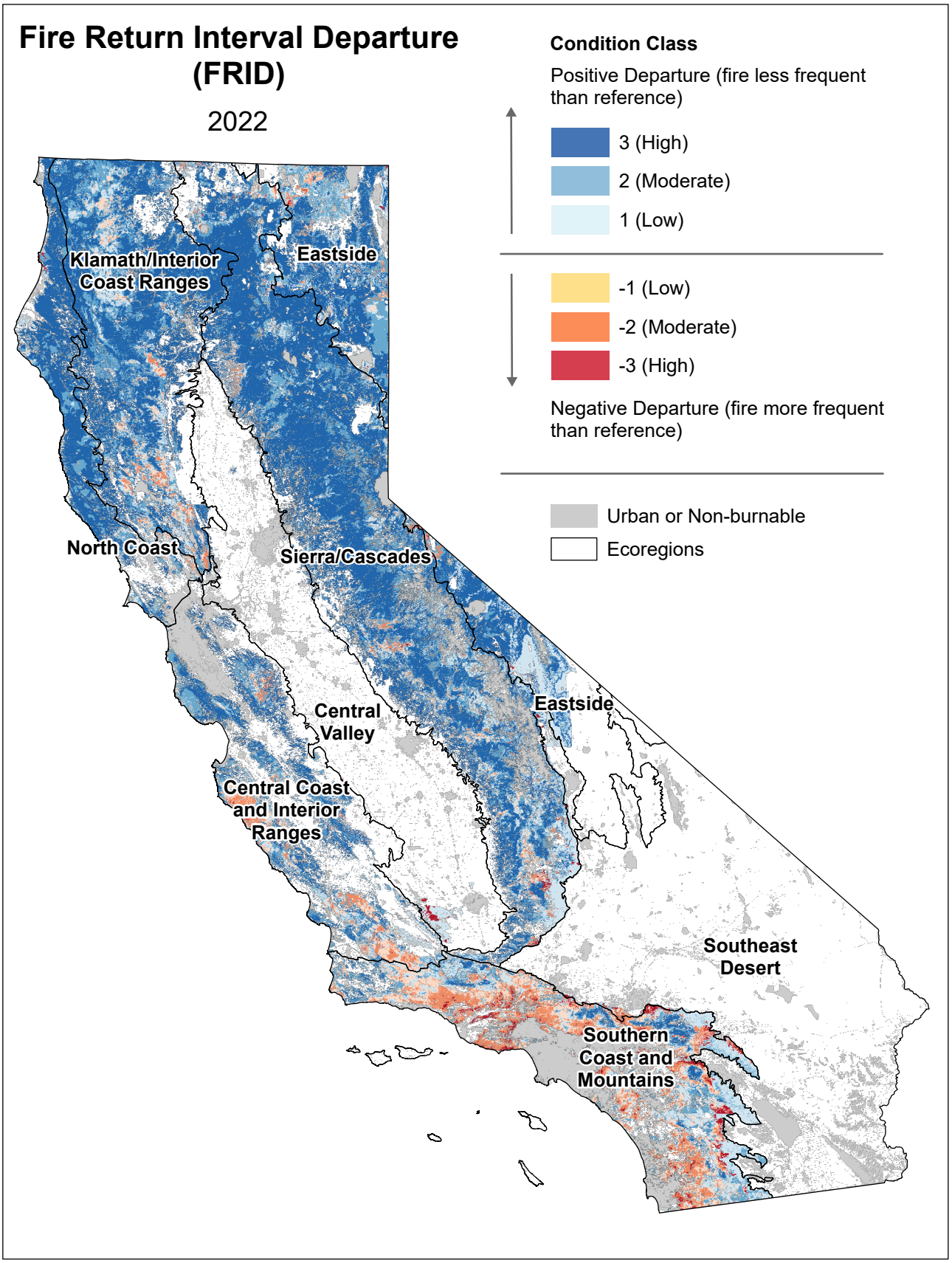


Figure 4.1. Fire return interval departure by ecoregion. Positive departure (blue shading) indicates less frequent fire than pre-settlement fire regimes and negative departure (orange-red shading) indicates more frequent fire than pre-settlement fire regimes. Data Source: Safford et al. (2022).

ⓘ4.4) (Steel et al. 2015, Williams et al. 2023), and while much of the state's shrublands are also experiencing less frequent fire, a notable portion of modern shrublands are experiencing more frequent fire than under reference conditions (ⓘ4.1). Ecosystem changes in forested systems such as increased tree density, structural homogenization, and fuel buildup, especially at low to mid-elevations, represent conditions that more readily support severe fire (Agee and Skinner 2005). These changes also contribute to drought-related mortality (Fettig et al. 2007), which can further promote increased subsequent wildfire severity in dry forest systems (Sieg et al. 2017, Wayman and Safford 2021). In contrast, shrub-dominated systems of the central and southern California coast regions are adapted to periodic high-severity crown fire, and fire in shrublands in these regions has continued at a frequency that is either consistent with or greater than pre-EAS reference fire regimes (ⓘ4.1). As with other parts of the state, humans cause the vast majority of fire ignitions in these systems, especially in the more densely populated areas. In some coastal shrublands, fire is returning at significantly shorter intervals than the systems are adapted to, placing them on a trajectory of type conversion from native woody vegetation to non-native herbaceous vegetation (Keeley and Brennan 2012). Similarly, in desert areas of the state, the interaction between climate change and increased fuel continuity due to invasive grasses has led to an increase in fire size, frequency, and intensity (Syphard et al. 2017, van Etten et al. 2022), putting them at risk for native vegetation loss and conversion to grasslands (see Chapter 2, Sustainable Rangelands).

Fire Return Interval Departure (FRID)

Fire return interval departure (FRID) quantifies the difference between current and reference fire return intervals (the time interval between fire occurrences at a defined location). Historical (pre-EAS) fire frequencies have been developed for most woody vegetation types in California, serving as a reference for comparison to current fire activity. Significant deviation from historical fire return intervals can signal potential ecosystem change, such as the buildup of hazardous fuels, changes to vegetation type, structure, or composition, and unsustainable tree densities.

Areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are burning much less frequently than pre-settlement reference frequencies, with 66–73% of area in these vegetation types in high-positive departure (Condition Class 3; fire return intervals >67% longer than reference) (ⓘ4.1). This is most evident in the Sierra Nevada, Southern Cascades, and North Coast-Interior mountain ranges of northern California, but it is also apparent for many of the hardwood and conifer dominated areas of the Southern Coast and Mountains ecoregion (Figure 4.1).

Shrubs also show predominantly positive FRID departure, but in contrast to forested areas, some shrub-dominated areas are burning more frequently than their reference, with ~15% by area in moderate- or high-negative departure classes across the state. It should be noted, however, that this has decreased from 23% since the 2017 Assessment due to reduced fire frequency in some areas, although it is unknown if this will become an ongoing trend. Overly frequent burning is more acute in the southern portion of the state, where 22% of shrubland vegetation in the Southern Coast and Mountains ecoregion is in moderate- or high-negative departure (shorter fire return intervals). Some shrublands in the interior North Coast Range north of the San Francisco Bay have burned six times in the past 30 years (Grupenhoff and Safford 2024), indicating that too-frequent fire is also a concern for northern California chaparral. Still, ~46% of shrublands statewide are either moderately or highly positively departed, representing a deficit of fire compared to reference fire regimes.

Fire Trends

Burned Area

Wildfire is a natural component of California's forests and rangelands where it catalyzes succession, nutrient cycling, and can reduce the severity of subsequent fires (Pausas and Keeley 2019). However, wildfire can also degrade the health of California's forests and rangelands when it occurs at severities or frequencies greater than its natural range of variation (Ayars et al. 2023). Over the last six decades (1960–2024), wildfires within California have become larger (Figure 4.2) (ⓘ4.3), with nine of the 10 largest wildfires post-1932

occurring since 2017 (Table 4.2). These changes in wildfire have affected both California's forests and rangelands (Figure 4.3), with annual wildfire burned area in California having more than doubled between 2020–2024[1] (1,634,797 acres/year) when compared to 2010–2019 (667,952 acres/year). Annual burning in forests has increased by 165%, while for rangelands it has increased by 35% over the same time period. This dramatic increase in burning has resulted in a greater amount of forested area than rangeland burning each year on average since 2009, a reversal of historical conditions (ⓘ4.3).

Although the area burned has increased, the number of ignitions has been relatively stable in recent years (Figure 4.4). The main drivers of the increases in burned area vary across ecosystem types. Within rangelands, high wildfire years are primarily driven by the co-occurrence of drought and Santa Ana wind events in southern and central California (Keeley et al. 2022), and in many areas can be enhanced when high temperatures or extended dry periods follow wetter than normal years that promote greater growth of fine fuels (Swain et al. 2025). However, increasing burning in forests is driven by a combination of fuels accumulation due to a century of wildfire exclusion (Stephens et al. 2024) and climate change-driven lengthening and intensification of wildfire seasons (Turco et al. 2023). For example, extreme drought and bark beetle activity that created high levels of tree mortality led to extensive burned area in the southern Sierra Nevada in the last decade (Stephens et al. 2022).

Wildfire Severity

As wildfires have grown in size, so have their effects on California's forests. Wildfire severity, the measure of wildfire-caused vegetation mortality, has increased within California's forests over the last four decades (1984–2023) (ⓘ4.4). While forests may be adapted to a low extent of high severity wildfire occurring in small

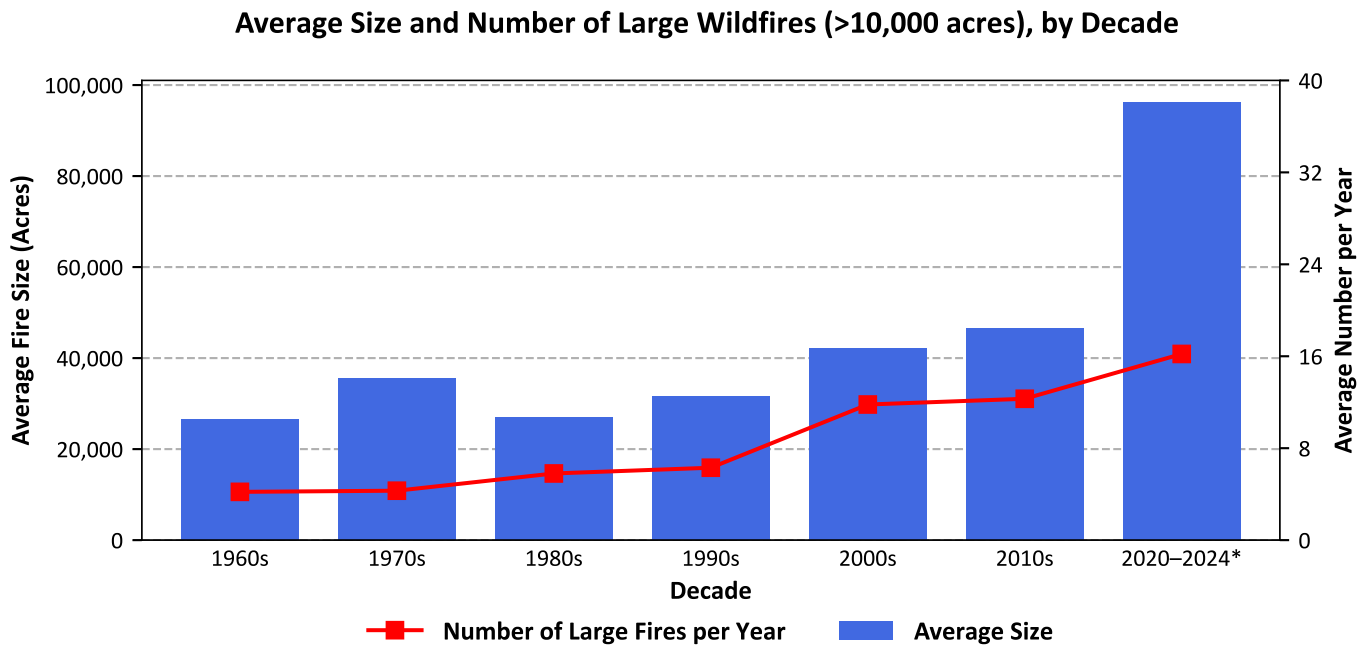


*Figure 4.2. Average size and annual number of large wildfires (>10,000 acres) by decade. *January 2025 fires present in the 2024 perimeter data (CAL FIRE 2025b) were included as a partial year. The 2020–2024 period carries lower reliability due to the shorter time period and potentially greater influence from short-term climate events. Data Source: CAL FIRE (2025b).*

1 *January 2025 fires present in the 2024 perimeter data (CAL FIRE 2025b) were included as a partial year.*

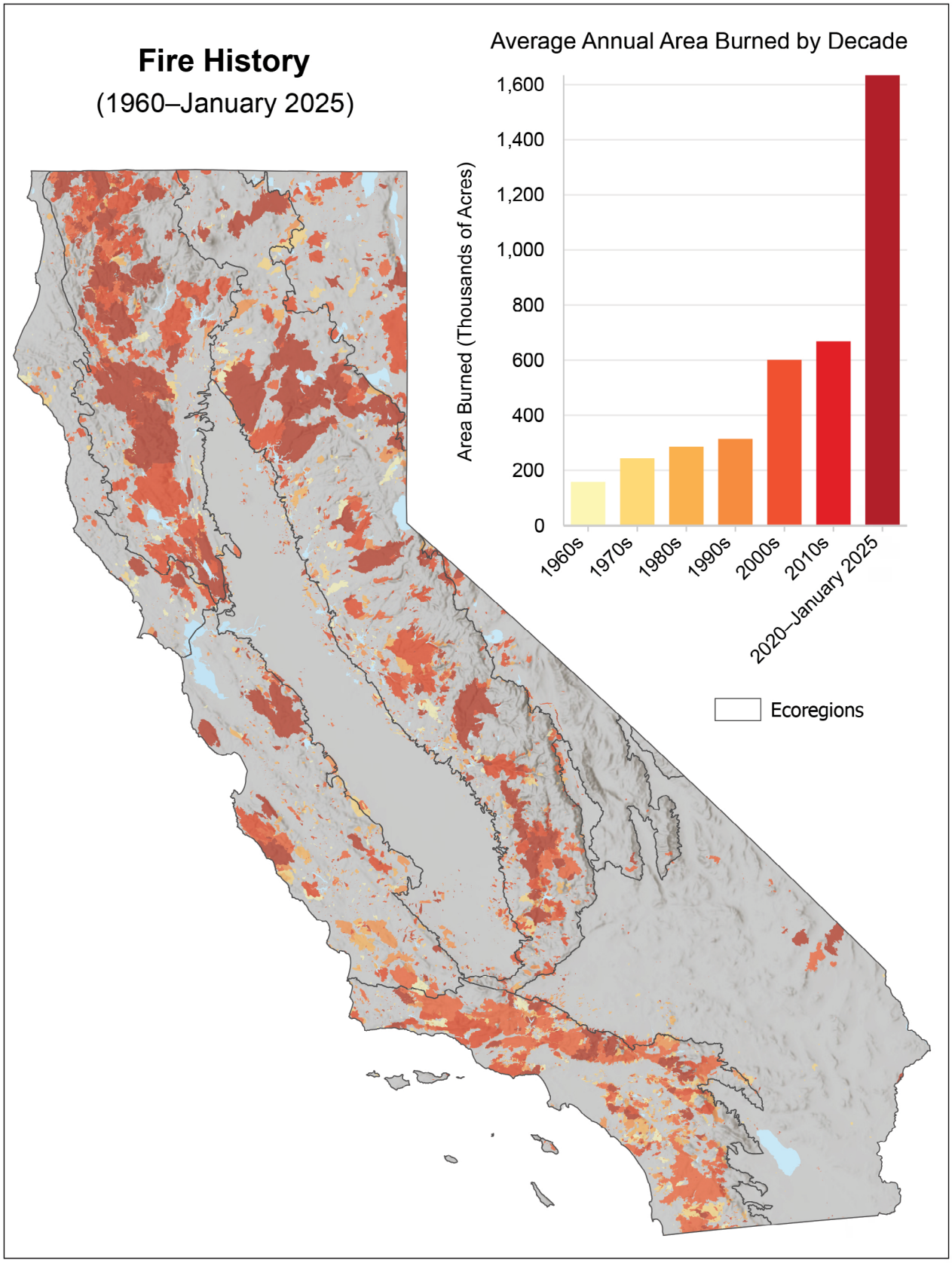


Figure 4.3. Location of wildfires occurring between 1960 and January 2025. More recent fires are shown on top of older fires. Bar chart inset shows average annual area burned by decade. The 2020s period is an annual average for the years 2020–2024, which carries lower reliability due to the shorter time period and thus potentially greater influence from short-term climate events. Data Source: CAL FIRE (2025b).

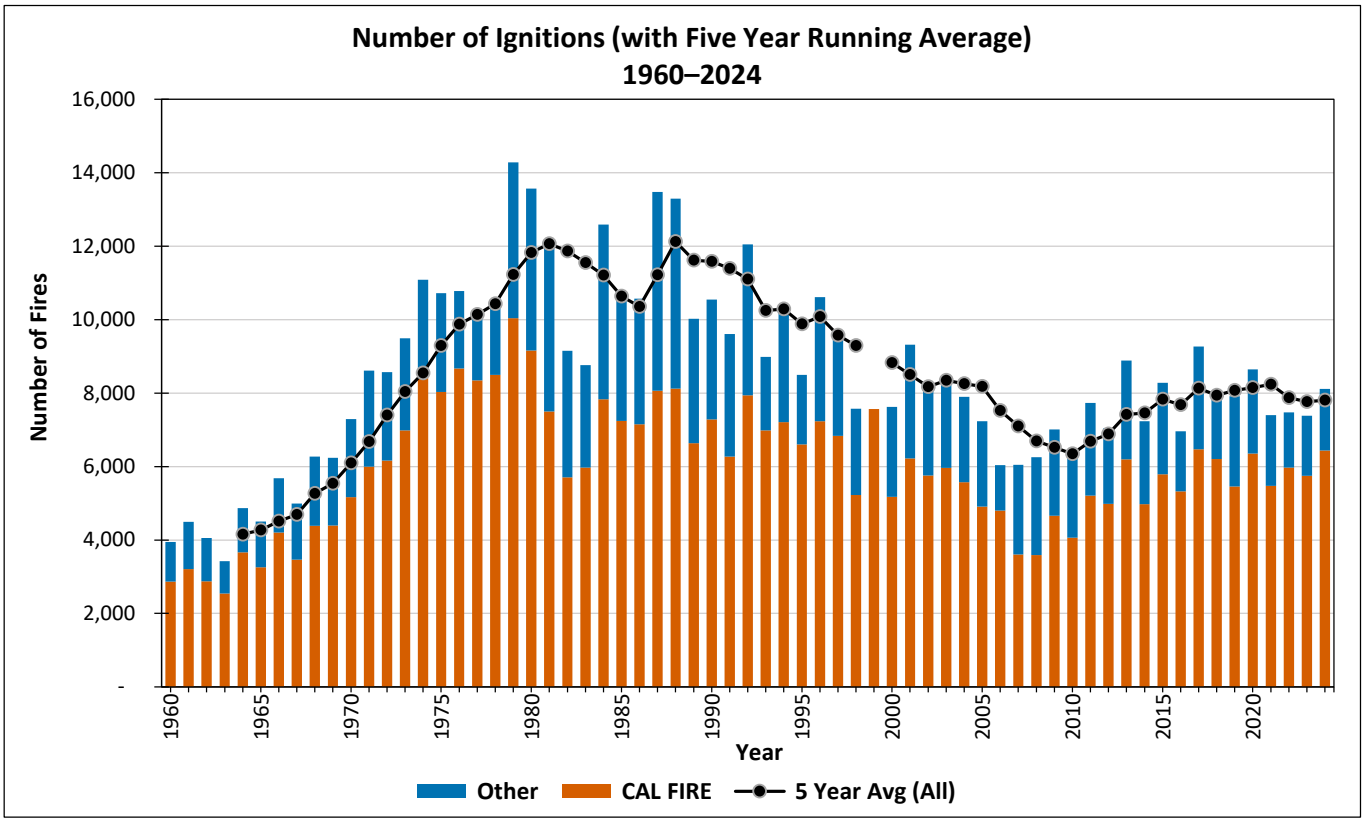


Figure 4.4. Number of ignitions from 1960 through 2024. "CAL FIRE" includes Direct Protection Areas and local government contracts. "Other" includes contract counties, federal agencies, and military. Data Source: CAL FIRE (2025d).

patches, larger patches present a problem for regeneration of species that depend on nearby, live trees to serve as a seed source. For example, historical fire regimes in yellow pine (dominated by *Pinus ponderosa* or *P. jeffreyi*) and mixed conifer forests occasionally included patches of high severity up to 40 acres in size, with rare occurrences of patches up to 250 acres (Meyer 2015, Minnich et al. 2000, Safford and Stevens 2017). Over time, the percentage and amount of area burned at high severity, along with area that is distant from surviving trees, has increased, leading to a heightened need for post-fire reforestation (see Chapter 1, Resilient Forests). The stand-replacing decay coefficient (Stevens et al. 2017) reflects both the size and shape of high severity patches within wildfires to illustrate the amount of area that may lack sufficient natural seed sources for tree reestablishment. Larger patch sizes and less complex shape (e.g., circular as opposed to narrow and branched) result in lower values of the stand-replacing decay coefficient, which has shown a downward trend over time (Figure 4.5).

Wildfire severity is influenced by both forest structure and weather conditions, each of which human activities have altered. A century of fire suppression combined with selective logging has dramatically reshaped forest structure, resulting in many more small trees and fewer large trees than existed historically. These changes have also increased surface fuels and ladder fuels, which facilitate crown fires and create extensive, contiguous regions of forest fuel that enable explosive fire growth. While these structural changes have affected all Californian forests, those managed for private industrial use have had the greatest increase in small tree densities (Easterday et al. 2018). Historically, wildfires have burned a greater proportion of California's publicly owned forests than those on private lands (Table 4.3). However, lengthening and worsening wildfire seasons due to anthropogenic climate change combined with forest structural changes have made contemporary private industrial timberlands especially prone to high-severity wildfires (Levine et al. 2025). Between 1984 and 2023, burned area of publicly owned lands was 23% high severity, while burned area of private

lands was 26% high severity (Table 4.3). An analysis of more recent fires (2018–2021) found an even greater proportion of high severity fire, with 41% high severity on private forest industry lands, 37% high severity on National Forest System (NFS) lands, and 33% high severity on private nonindustrial forestlands (MBG 2023).

These changing wildfire effects are particularly damaging to prevalent forest types such as California mixed-conifer, which rely on nearby surviving seed trees to enable post-fire seedling establishment (Stewart et al. 2021, Welch et al. 2016), and will likely cause large regions of forest loss if replanting and subsequent fuel reduction treatments are not undertaken (see Chapter 1, Resilient Forests) (Stevens-Rumann and Morgan 2019). This increase in the severity of California's wildfires is largely driven by a century of forest fuels accumulation due to a policy of wildfire suppression (Kreider et al. 2024), which now burns during hotter, drier, and longer wildfire seasons due to anthropogenic climate change (Turco et al. 2023).

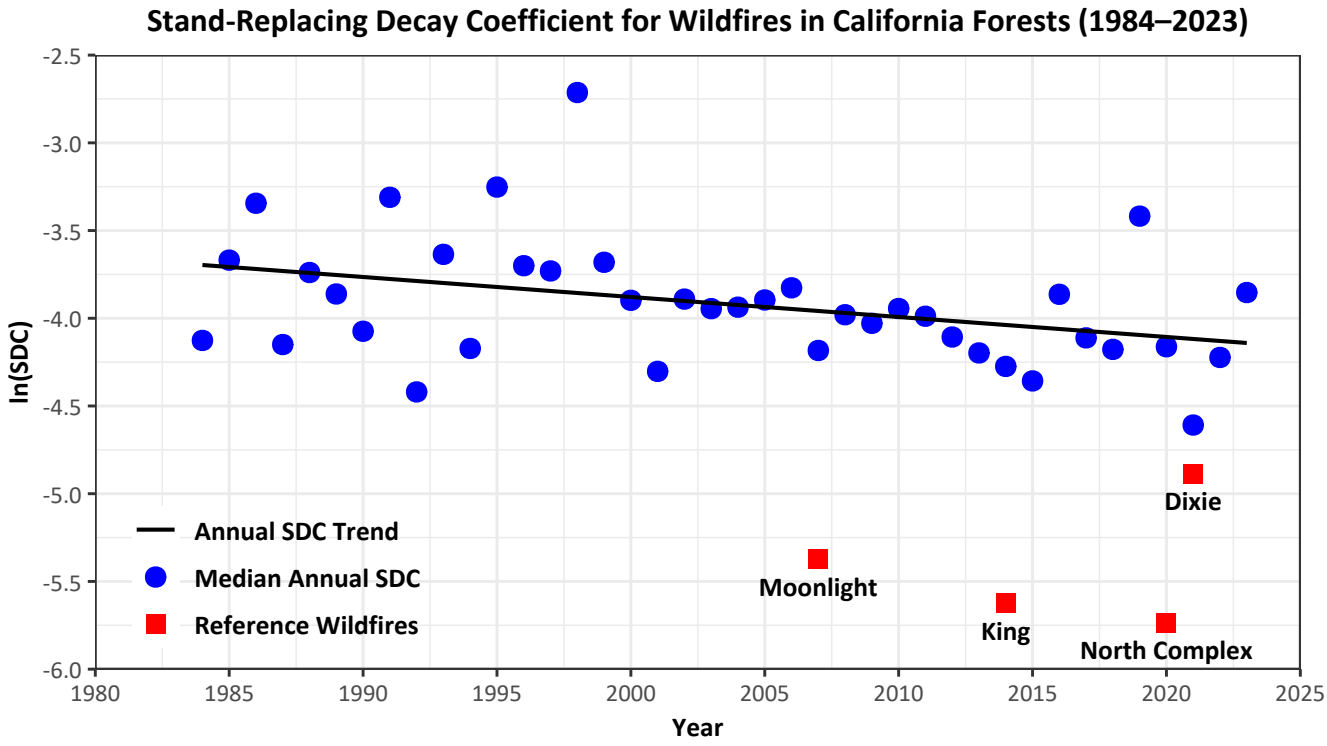


Figure 4.5. The stand-replacing decay coefficient (SDC) integrates the size and shape of high severity (stand-replacing) wildfire patches. Larger high severity patches with a less complex shape have more patch area that is distant from surviving canopy trees and are represented by lower SDC values. Blue dots represent annual median SDC values, and the red squares show examples of individual fires with very low SDC values. Data Sources: CAL FIRE (2022) and USGS et al. (2021).

Table 4.3. Total and proportion of burned area in Californian forests between 1984–2023 by land ownership

Land Ownership Class	Total Forest Area		Unchanged/Low Severity		Moderate Severity		High Severity	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Public	16,207,275	63.3%	5,088,155	83%	2,528,487	79.9%	2,218,132	79.1%
Private	9,385,980	36.7%	1,044,986	17%	637,300	20.1%	586,158	20.9%

Data Sources: CAL FIRE (2022), CAL FIRE (2024), and USGS et al. (2021).

High Severity Fire Impacts on Old-Growth Giant Sequoia

Giant sequoia (*Sequoiadendron giganteum*) is an iconic keystone tree species found naturally only in California. In total there are about 25,450 acres (10,300 ha) of giant sequoia (Stephenson et al. 2024b) in approximately 70 groves in the Sierra Nevada (Shive et al. 2021). They can live to 3,000+ years and are the largest trees in the world, measured by volume. Giant sequoias are well adapted to low and moderately severe fires, which historically burned very frequently through the groves. This type of fire was highly beneficial, decreasing surface fuel loads, reducing the density of fire-intolerant conifer species that result in fuel ladders to tree crowns, promoting seed dispersal from cones opening, and producing canopy gaps that promoted giant sequoia seedling establishment (CSAF 2022, Meyer and Safford 2011, Shive et al. 2022). Additionally, the forest canopy remained mostly intact, and fires severe enough to kill most sequoias over large areas did not occur for at least 1,000 years before 2015 (Stephenson et al. 2024b).

A century of fire exclusion has (1) reduced giant sequoia regeneration, and (2) greatly increased fuel loads in sequoia groves (e.g., Meyer and Safford 2011, Soderberg et al. 2024). Additionally, cedar bark beetle (*Phloeosinus* spp.) activity has increased noticeably since 2018, with some death documented in a small number of large giant sequoia trees (Foote et al. 2024, GSLC 2025). Cedar bark beetle activity has been observed in groves in Sequoia and Kings Canyon National Parks, Yosemite National Park, Mountain Home Demonstration State Forest, Calaveras Big Trees State Park, and on tribal and other federal lands (A. Ambrose, personal communication, February 7, 2024). Research on this beetle and its impacts to giant sequoia is currently ongoing (GSLC 2025; see Chapter 5, Forest Pests). More significantly, increased temperatures, severe drought events from 2012–2016 and 2020–2022, and a subsequent bark beetle (primarily western pine beetle and mountain pine beetle) epidemic that killed pine species surrounding mature giant sequoias and increased dead woody fuel loads, have contributed to multiple large damaging wildfires. Significant amounts of high severity fire occurred within the groves from 2015 through 2021 (Shive et al. 2021, Stephenson and Brigham 2021).

Recent studies have documented the impacts of these catastrophic fires to giant sequoia groves. Fire-caused mortality was previously rare for large sequoia trees, but concerns began to arise following wildfires occurring in 2015–2017 that had substantial areas of high severity in giant sequoia groves, where 84% of large old growth sequoias died (Shive et al. 2022). Subsequently, the 2020 Castle Fire produced losses estimated to be 10–14% of the entire population of the largest trees (over four feet in diameter) (Shive et al. 2021). The 2021 season in the southern Sierra Nevada included the KNP Complex Fire and the Windy Fire, which partially or fully burned 28 groves. It is estimated that these fires produced an additional 3–5% mortality of the total giant sequoia old growth population, which combined with the 2020 fire impacts equates to an estimated loss of ~18% (Shive et al. 2026).

Although giant sequoias are adapted to regenerate after fire, seedling densities tend to be lower with increasing fire severity (Soderberg et al. 2024). Areas burned at high severity and greater than ~330 feet (100 m) from live sequoia trees are likely to experience inadequate natural regeneration. Exceptional summer heat and severe drought are additional factors that have been found to limit adequate post-fire regeneration in recent fires (Stephenson et al. 2024a).

Forest ecologists have documented that active forest management is needed to adequately protect these world-famous trees where high severity fire is likely

(e.g., Shive et al. 2021). Prescribed fire and managed wildfire use have thus far not been adequate in their pace or scale (CSAF 2022). Where prescribed fire use and mechanical thinning treatments have taken place, they appear to have reduced fire severity and allowed fire crews to more effectively control fire in giant sequoia groves (Hankin et al. 2023, Shive et al. 2021, Stephenson et al. 2024b). For example, Mountain Home Demonstration State Forest (MHDSF) has had regularly planned timber harvesting, bark beetle salvage logging operations, and fuel treatments conducted over the past 20+ years (arguably since 1946 with some lapses). The 2020 Castle Fire killed approximately 7% of the old growth giant sequoias present on MHDSF, less than half of that estimated to have occurred in areas with lower levels of treatment (Figure 4.6). Mortality was higher near the grove edges and in areas with drier slopes, where fuel conditions led to a crown fire run (CAL FIRE 2022) (Figure 4.6). Areas that had had some form of timber harvest and/or fuel treatments, such as prescribed fire, had lower fire intensity and greatly reduced mortality. Steep, densely stocked areas with small, sub-merchantable timber adjacent to neighboring land ownerships had very high mortality rates (J. Kral, personal communication, August 30, 2023) (Nagelson et al. 2026).

Prescribed fire use alone has been shown to often be inadequate for long-term giant sequoia stand management (CSAF 2022). Thinning treatments may be necessary in and around giant sequoia groves that have not burned in several decades or where prescribed fire has not reduced tree density significantly. Groves that have not been previously treated with prescribed fire, managed wildfire, or mechanical thinning are the highest priority for treatments (CSAF 2022). Clearly, active management is required to increase resilience of remaining groves so that these large old growth trees will survive or avoid future high severity fires and the trees can successfully regenerate. The Giant Sequoia Lands Coalition (GSLC) was formed in 2021 by all the entities with old-growth groves to promote active forest management, and approximately 17,120 acres had been treated (fuels reduction, broadcast burning, pile burning) by GSLC members by the end of 2024 (GSLC 2025).[2] Additionally, artificial regeneration (planting) was determined to be necessary in six groves with very high fire severity. Planting took place during 2023 in areas with little or no natural reproduction where crown fires occurred in the Board Camp and Redwood Mountain groves in Sequoia and Kings Canyon National Parks (GSLC 2023, Stephenson et al. 2024b). A total of 44 giant sequoia groves have been treated with fuels reduction and/or reforestation (GSLC 2025).



Varied fire severity at Mountain Home Demonstration State Forest resulting from the 2020 Castle Fire. Photo: CAL FIRE.

2 *This total includes acres that have been treated across more than one treatment category from 2022–2024. An additional 1,626 acres have been planted.*

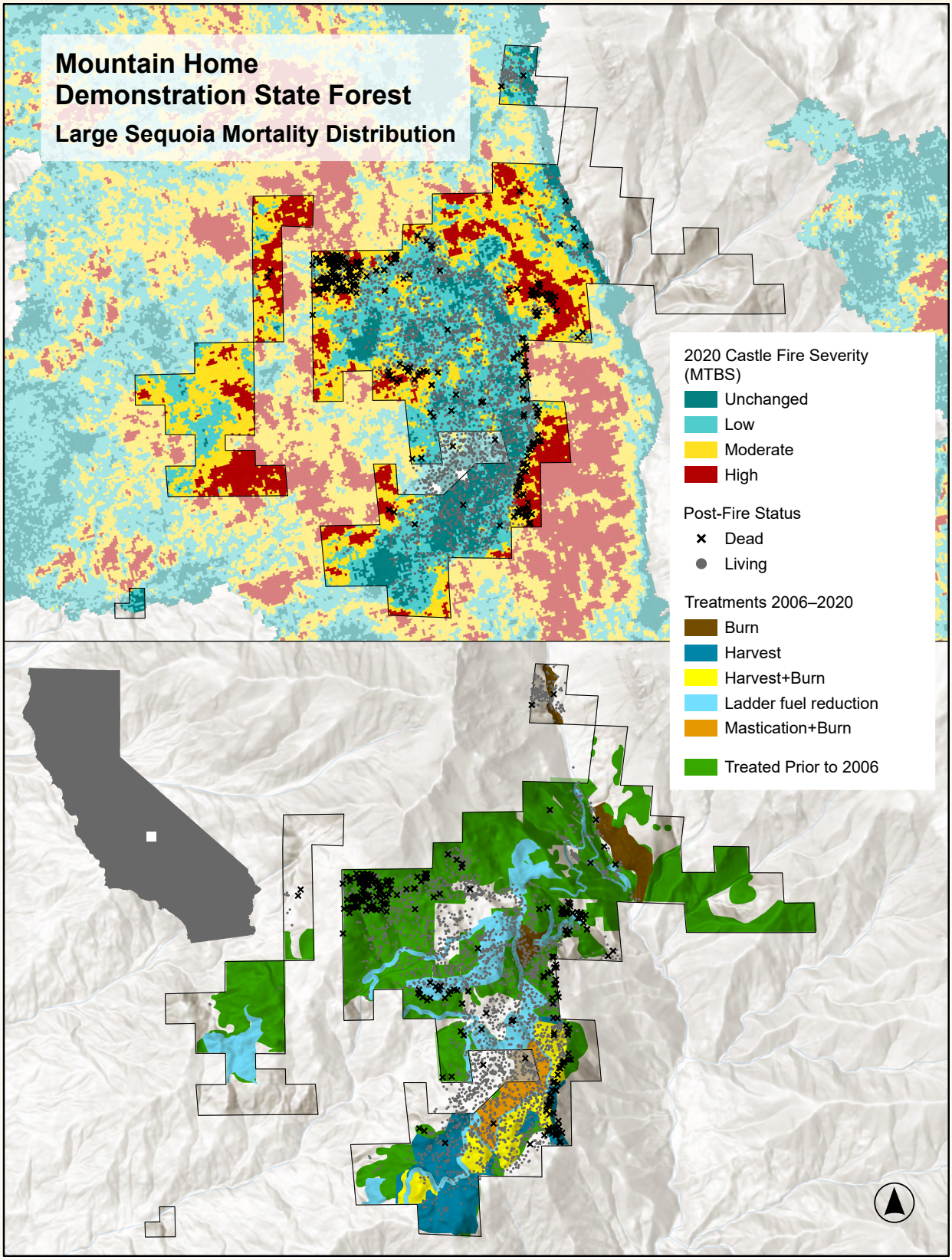


Figure 4.6. Castle Fire severity at Mountain Home Demonstration State Forest (MHDSF). Black x's represent dead large giant sequoia trees (upper figure). Bottom panel shows land management treatments on MHDSF during the 15 years prior to the 2020 Castle Fire. Adapted from Nagelson et al. (2026).

Economic Impacts of Large Wildfires in California

As extreme wildfire activity increases across the state, impacts to society need to be closely monitored in order to set appropriate mitigation and suppression policy. Since the 2017 Assessment, considerable research has focused on quantifying the economic impacts of wildfire in California and the West. This section briefly summarizes this literature, focusing on both the costs of wildfire management and the direct and indirect economic damages.

Various typologies are available for categorizing the economic impacts of wildfires. The cost and net value change (C+NVC) framework is a useful conceptual model that separately quantifies costs of wildfire management and losses from wildfire damage (Donovan and Rideout 2003). Wildfire management costs include spending on wildfire preparedness, mitigation, and suppression, while net value change refers to the net damages (also referred to as losses) from a wildfire event. These could include direct damages such as fatalities, structure loss, adverse health outcomes from smoke exposure, and loss of standing timber, or indirect losses such as supply chain disruptions, impacts to property markets, and general economic impacts (Thomas et al. 2017). By focusing on the net value change, this framework also acknowledges the potential for beneficial ecosystem service outcomes from wildfire (Pausas and Keeley 2019). This accounting framework is useful for separating expenditures associated with wildfire management from the economic impacts of wildfire. When summed up, costs and losses can be interpreted as the economic burden of wildfire. While this analytical framework is very useful, it must be acknowledged that economic analysis cannot account for all wildfire impacts.

Wildfire management costs have increased substantially since the 2017 Assessment. For example, CAL FIRE's total expenditures (adjusted to 2024 dollars) have averaged approximately $3.7 billion per year since the 2017 fiscal year, compared to $1.9 billion per year from 2010–2017, and $1.4 billion per year from 1995–2010.[3] Fire protection expenditures account for the vast majority of the agency budget, although mitigation expenditures have increased substantially as well. Federal spending on wildfire suppression has also increased substantially over the same period (NIFC 2023).

Much of the recent academic research on the economic impacts of wildfires has focused on quantifying economic damage from wildfire and wildfire smoke. While a full review is beyond the scope of this Assessment, we highlight several advances in quantifying the health burden of smoke exposure, the direct and indirect impacts on physical structures and housing markets, timberland value loss, and other general economic impacts.

Smoke emissions from wildfire activity have increased significantly over the past several decades, presenting an increasing risk to public health,[4] with an associated economic burden. The increase in emissions has been large enough to nearly offset the pollution reductions made through policies such as the Clean Air Act. The public health impacts of wildfire smoke exposure are well documented and include increased all-cause mortality and increased incidence of respiratory disease (Heft-Neal et al. 2023). Translating this public health burden in dollar terms shows that mortality and morbidity associated with smoke exposure far outweigh wildfire suppression costs in California (Wang and Lewis 2024). From the perspective of individuals, there is strong evidence that people are willing to pay substantial sums to avoid wildfire smoke exposure, with a recent review suggesting ranges of $100–442 per person per smoke day (Dittrich and McCallum 2020).

Damages to property and other structural assets are another large category of economic loss from wildfire events, and the monetary value of structure loss has increased dramatically in recent decades. The past two

3 *Chapter 13 (Institutional Response) discusses institutional changes in CAL FIRE in detail, including funding and budget breakdowns.*
4 *Chapter 11 (Wildfire Risk to Communities) discusses wildfire smoke impacts to public health in additional detail.*

decades have been especially damaging, with multi-billion-dollar annual losses becoming more common (Buechi et al. 2021). Wildfires can also have broader impacts on housing markets by abruptly changing housing supply, reducing amenity values for homes near burn scars, and affecting the risk perception towards future wildfires (Garnache 2023, McCoy and Walsh 2018). While a number of studies have documented that housing prices temporarily drop in response to larger wildfire events, the size of this effect in California housing markets is relatively small (Dong 2024). There are also nuances, as shown by research following the 2018 Camp Fire that found that home prices in the areas surrounding Paradise increased substantially almost immediately following wildfire due to the surge in demand from displaced residents (Hennighausen and James 2024). Research has also documented how wildfire smoke can negatively affect home prices (Huang and Skidmore 2024). Given the substantial value of California's housing stock located in high-risk areas, more research is needed to better understand the mechanisms driving the relationship between wildfire and property markets.

Wildfire presents a significant financial risk to California's timber industry. A recent report found that from 2018–2021, large fires (>10,000 acres) destroyed over 11 billion board feet of timber in California, valued at approximately $12.6 billion (MBG 2023). Wildfires also affect timber markets by altering the risk perceptions of timberland owners, which are then capitalized into the value of timberland. Wang and Lewis (2024) estimate that wildfires over the past 40 years have decreased the value of California timberland nearly 14%, with over half of this decline attributable to shifts in landowners' expectations of future wildfire risk. This shift lowers land prices by increasing perceived hazard and discounting future timber revenues, rather than through direct physical losses from fire.

Indirect economic damages are less readily observable but have received considerable attention in the academic literature since the 2017 Assessment. A number of recent studies have quantified the indirect economic damages from smoke emissions, which have the potential to affect much larger populations than the fire itself. For example, Borgschulte et al. (2024) estimate that smoke exposure leads to large reductions in labor income, employment, and labor force participation, with total economic impacts being similar in magnitude to the cost of premature mortality due to smoke exposure. Other studies have documented adverse impacts of smoke exposure on learning outcomes (Wen and Burke 2022), recreational activity (Gellman et al. 2022), and supply chains (Wang et al. 2021). An emerging body of literature has also begun documenting the financial distress of wildfires on various consumer groups (Issler et al. 2020, McConnell et al. 2021).

While much of the research on the economic impacts of wildfires has focused on a single dimension of damages, several studies have aggregated various components in an attempt to calculate the total economic damage of wildfire (both for individual fires and entire wildfire seasons) in California and nationally. Table 4.4 highlights several of these studies. Direct comparison is difficult since the studies often evaluate different damage components; however, they give a sense as to the magnitude of the problem, especially regarding suppression and mitigation expenditures (Barrett 2018, Dale and Western Forestry Leadership 2009). These studies highlight two important issues. First, the scale of damages is quite large, with totals of over $100 billion per year from the two California-wide studies. This amounts to 4–7% of state gross domestic product (GDP). This loss represents damages during some of the most destructive wildfire seasons in California's history. Second, the composition of damages shows that indirect economic effects are the largest component of damages. In Paci et al. (2023), lost income accounted for 51% of total damages, while in Wang et al. (2021), indirect economic disruptions accounted for 59% of the damages. Premature mortality and morbidity from smoke exposure was the second largest category of damages, ranging from 22% of total damages (Wang et al. 2021) to 39% (Paci et al. 2023).

Ecosystem Trajectories from Altered Fire Regimes

Forests

Forest recovery from increasing high severity fire faces challenges outlined in greater detail in Chapter

Table 4.4. Studies estimating the total economic damage of wildfire in California and U.S.					
Study	**Unit of Analysis**	**Time Frame**	**Value (billion $2022/year)**	**% of GDP**	**Components**
Paci et al. 2023	California	2017–2021	$117.40	3.60%	Structure loss/damage, fire fatalities, response and clean up, mortality and morbidity from smoke, income loss from smoke
Wang et al. 2021	California	2018	$148–226	4.5%–6.9%	Structure loss/damage, mortality and morbidity from smoke, supply chain disruptions
JEC Democrats, 2023	National	Varies	$394–893	2–4%	Mortality and morbidity from smoke
Thomas et al. 2017	National	Varies	$87.4–427.8		
Data Notes: All estimates have been converted into $2022 using the California Consumer Price Index (for California studies) or the Consumer Price Index (for national studies). Fraction of GDP estimates use either state or national real GDP for the year in which the study reports outcomes.					

Data Source: CAL FIRE.

1 (Resilient Forests). As discussed above, where many of the largest and most destructive California wildfires have recently occurred, natural tree regeneration is unlikely to occur within large high severity patches where the distance to a surviving seed source is greater than 330 feet (100 m) (North et al. 2019, Shive et al. 2024, Welch et al. 2016). Between 2018 and 2021, 668,000 acres of high severity fire in California exceeded these patch size and distance to seed source thresholds (MBG 2023). In a recent analysis applying data from Davis et al. (2023), it is anticipated that up to 82% of future high severity fire areas in California will have natural regeneration failure (under a high global emissions scenario, RCP 8.5; DeLyser et al. 2025). Without adequate reforestation in conifer-dominated forests following large-scale high severity fire, there is a high risk of vegetation type conversion to shrublands or oak woodlands. Thus, active reforestation is needed if such areas are to recover to forested vegetation types on a human generational timescale, and reforestation would need to have a long-term commitment of fuel treatments to be successful.

The obstacles to meeting post-fire reforestation needs in California are substantial, especially on federal lands, yet realistic opportunities for overcoming these obstacles exist. It is estimated that 0.4 million acres of private forests and at least 1.1 million acres of federal forest lands would benefit from reforestation efforts following 2019–2021 wildfires (WFR Task Force 2024), and increasing active post-fire reforestation efforts is one of the state's priority nature-based climate solutions (CNRA 2022). Yet numerous limitations in the reforestation process, also coined the reforestation pipeline, are inhibiting planting efforts on all land ownerships, but particularly on federal lands. Barriers include costly project planning processes, inadequate seed collection and processing, insufficient seedling nursery capacity, inadequate site preparation, and insufficient funding and associated workforce (Dobrowski et al. 2024). The California Reforestation Pipeline Partnership was established in 2022 to address these barriers, and meaningful progress has been made by this and other entities to increase seedling production, workforce development, and funding for implementation. Prioritization of areas for conifer replanting can be informed by recently developed planning tools that predict areas of insufficient natural regeneration and areas where post-fire reforestation outcomes are most likely to be successful (Stewart et al. 2023) (see Chapter 1, Resilient Forests).

With uncertainty in future global climate conditions and ecological response, there is a need for adaptive management to consider different options regarding forest recovery from severe wildfire. Pre- and post-fire management actions across sites should encompass multiple pathways for ecosystem recovery from severe wildfire, with adaptive management strategies falling along a gradient of tolerance for ecosystem change. Resistance actions are aimed at maintaining a relatively unchanged forest; resilience actions allow change from pre-disturbance conditions but encourage an eventual return to

a reference condition; and transition actions are aimed at actively facilitating change to encourage adaptive responses (Meyer et al. 2021, Nagel et al. 2017). For example, facilitating transition from conifer forest to hardwood-dominated forests such as California black oak (*Quercus kelloggii*) may be desirable due to the ecological value and the cultural importance of this species to Native Americans (Stephens et al. 2023).

Shrublands

Many shrubland systems in California currently have substantial areas experiencing too-frequent fire, rather than a fire occurrence deficit. Several chaparral systems are adapted to burning infrequently and at high severity (i.e., shrubs that are top-killed by fire), with the estimated fire return interval and degree of spatial patchiness of fire varying across shrubland types. If insufficient time passes between fires to allow shrubs to mature to reproductive age and replenish the seedbank, or to restore sub-surface carbohydrate stores necessary for vigorous resprouting, the dominance of native shrub species can decline post-fire. This frees up competitive space for non-native annual grass invasion, which creates a more contiguous and highly flammable fuel bed that can foster more frequent fire, perpetuating the decline of native shrubs (D'Antonio and Vitousek 1992). Portions of California's desert shrublands, often dominated by sparse, fire sensitive species, are similarly experiencing too-frequent fire due to increased fuel continuity from non-native grass invasions (Balch et al. 2013, Brooks and Matchett 2006, Syphard et al. 2017).

After wildfire in shrub-dominated systems, management actions can consider similar broad objectives outlined above for forested systems: resistance, resilience, and transition. Adaptive management should evaluate the areas likely to recover to a desired condition naturally, and where this is unlikely to occur, further parse the landscape based on whether restoration to a pre-fire reference condition is feasible. Where conditions related to climate, invasive species, or other factors suggest that the site is unlikely to support native perennial vegetation ill-adapted to frequent fire, management actions could consider actively transitioning the site to an alternative vegetation type that maximizes ecosystem services provisioning (Meyer et al. 2021). For example, where non-native cheatgrass (*Bromus tectorum*) has successfully invaded a formerly sagebrush (*Artemisia* spp.) dominated site and sagebrush is unlikely to persist due to a novel frequent fire regime, post-fire restoration with native perennial grasses and forbs may provide desirable ecosystem services even within a cheatgrass matrix (Meyer et al. 2021).



The 2017 Detwiler Fire burning in Mariposa County. Photo: CAL FIRE.

Carbon, Fire Regimes, and Carrying Capacity

The carbon storage capacity of California's vegetation in a warming climate will depend heavily on the extent and severity of future wildfire. While current carbon stocks in many of California's montane conifer forests are much higher than they were under reference conditions (Collins et al. 2011), these forests are more vulnerable to loss from wildfire since they are denser, with more ladder fuels and a higher proportion of small trees (Lydersen et al. 2013). Forest area loss in California, in the absence of increasing the pace and scale of restoration treatments, could be as much as 48% of current extent by 2070 due to future wildfire and potential post-fire regeneration failure, with a net carbon loss of 24% by 2045 (DeLyser et al. 2025).

Forest Inventory and Analysis (FIA) data indicate California's forests are currently serving as a net carbon sink, but the rate of aboveground live tree carbon gain has declined 76% compared to the 2017 Assessment, driven mainly by decreases on NFS lands (see Chapter

7, Climate Change) (ⓘ7.5). These declines are in agreement with reduced carbon storage predicted by models under climate change (CARB 2022, Liu et al. 2011). These results also generally agree with trends for increased tree mortality associated with wildfires and other forest health issues reported in the California Air Resources Board (CARB) Natural and Working Lands Ecosystem Carbon Inventory (CARB 2025).

California's forest restoration treatments are often designed with a stated goal of stabilizing future carbon stores, via modifying potential fire behavior and ameliorating adverse impacts of drought and insect pests (Sapsis et al. 2016). Thinning and burning treatments cause a decrease in carbon stocks in the short term, but may realize long-term carbon gains compared to a no-treatment scenario (Zhu et al. 2025). These gains can come via growth due to decreased competition (Wiechmann et al. 2015) and/or increased resistance to drought mortality, and increased carbon stability via decreased chance of high severity wildfire (Hurteau et al. 2019, Yackulic et al. 2025). In forests historically adapted to frequent fire, most studies suggest that density reduction treatments, especially those that include a burn treatment, are likely to result in increased future carbon storage as compared to no-treatment scenarios, due to their mitigating effect on wildfire behavior (Hurteau et al. 2016, Krofcheck et al. 2017, Loudermilk et al. 2017, Yackulic et al. 2025). However, the increasingly extreme nature of disturbance in California's forests necessitate elevating the pace, scale, and intensity of fuels treatments above current targets if forests are to become in alignment with the future lowered carbon carrying capacity (Bernal et al. 2022, Hurteau et al. 2024). See Chapter 7 (Climate Change) for greater detail on recent carbon trends and Chapter 1 (Resilient Forests) for statewide initiatives and strategies related to stabilizing carbon stocks.

Fire Hazard and Risk Assessment

Wildfire hazard and risk are terms that are often misunderstood or conflated but collectively refer to the possibility of a wildfire occurring and causing undesirable outcomes and impacts. Establishing clear terminology around hazard and risk has been a major effort over the last two decades, underpinned by standardized lexicon (Bachmann and Allgower 2001) and a quantitative risk modeling framework for use in wildfire management (Finney 2005). In general terms, hazard refers to a physical condition that may lead to damage or loss while risk is an estimate of that damage or loss. In the specific context of wildfire, fire hazard refers to the likelihood of wildfire occurring at a particular location and the fire behavior (e.g., intensity, rate of spread, fire type) that could be expected given the fuel, topography, and weather conditions at that location (Parisien et al. 2019). An area with a high probability of intense wildfire occurring would be considered hazardous. Alternatively, another area may be capable of producing intense wildfire, but the probability of wildfire occurring may be relatively low, resulting in a moderate or low hazard. Wildfire risk expands from hazard to include valuation of things impacted by fires, and how various fire behaviors interact with these elements to produce change. Often, wildfire risk is viewed as the interaction of hazard on assets or resources of value as a function of their vulnerability to damage from a fire. As noted above, the terms hazard and risk are often conflated—when speaking of wildfire risk, it is key to specify "risk to what."

Today, people are inexorably embedded in and adjacent to the wildland, and loss of life and property is obviously the highest and most significant impact from wildfire (see Chapter 11, Wildfire Risk to Communities). But within fire-prone landscapes there also exists a suite of assets, resources, and ecosystem services that people value (valued assets, resources, and services or VARS), including homes and communities, infrastructure, wildlife habitat, slope stability, timber, recreational opportunities, water resources, and many other components and processes of ecosystems. Wildfire can impact these VARS negatively (e.g., a home burning, loss of old growth forest), and in some cases positively (e.g., improving wildlife habitat, increasing drought resistance). The sign (negative or positive) and the magnitude of the impacts depend on the wildfire intensity and the response of the VARS to that wildfire. A home may be damaged by low intensity wildfire or destroyed by high intensity wildfire, both negative outcomes but of

different magnitude. A fire-adapted, dry, pine-dominated forest may respond positively to low intensity fire or sustain long-term undesirable damage, such as type conversion, by an uncharacteristically high intensity fire.

Wildfire risk thus refers to the expected impacts to VARS from wildfire. We can assess wildfire risk by identifying the VARS in a particular area that may be impacted by wildfire, assessing the likelihood of wildfire occurring where they are located, evaluating the wildfire intensity to which those VARS may be exposed, and understanding how those VARS will respond. In short, wildfire hazard is the expected wildfire for a location, and wildfire risk is wildfire hazard plus the expected impact of that fire on the things we care about. An analysis of risk and how it is spatially distributed across the landscape is an important element of both operational wildfire response planning as well as pre-fire risk mitigation efforts such as prescribed fire, mechanical treatments, defensible space, or home hardening. Wildfire risk assessment allows us to distribute limited resources more effectively, from fire engines to investments in fuel reduction, and there are a host of modeling platforms designed to assess wildfire risk explicitly using these components and relationships (Scott et al. 2013). The 1996 California Fire Plan (CA BOF and CAL FIRE 1996) is an early example of an effort to develop and implement such a strategy (see Chapter 13, Institutional Response, for further discussion).



The 2025 Palisades Fire burning in an urban area of Los Angeles County. Photo: CAL FIRE.

In Situ vs. Transmitted (Source) Wildfire Risk

Wildfire risk can be viewed and evaluated from two important lenses. First, in situ risk is the risk posed to VARS from wildfire hazard at the same location. For example, a home or structure within the forest or urban interface may have significant in situ fire risk due to heavy fuels immediately surrounding it and from the topography and expected weather at that location. But wildfire risk can also be transmitted from hazardous conditions in another location (also known as source risk). For example, wildfires that start miles away from an important communications tower may be likely to impact that tower given the particular fuels, weather, and topography between the two locations. Embers generated from a wildfire in a nearby forest may be likely to loft into a community, given prevailing wind patterns in the area. Thus the risk to a particular resource or asset may be posed by the wildfire hazard in its immediate vicinity (in situ), or in a location some distance away (source), and "transmitted" to that asset.

Contemporary Wildfire Hazard

Wildfire hazard is characterized by both the expected fire behavior at a location, and the likelihood of fire of any intensity actually occurring (Figure 4.7). Various methods exist for estimating these elements and mapping them across the contemporary landscape, either separately or as integrative measures. Prior assessments have used an integrative metric called Fire Threat, which combined historical fire rotation (probability) for different vegetation strata with estimates of potential fire behavior under near-worst case weather conditions. Wildfire Hazard Potential (WHP), used in this assessment, utilizes a different approach, simulating thousands of "fire years" on a contemporary landscape (fuels and topography) with stochastic weather and ignition patterns drawn from historical records (Dillon et al. 2015, Finney et al. 2011). Estimates of fire intensity and probability are averaged across the thousands of fire-year simulations and integrated into the single WHP metric (Figure 4.8). WHP evaluated for the year 2022 shows more than 17 million acres in high or very high hazard across all burnable areas in the state (ⓘ4.2). These hazardous areas are distributed unevenly, with the Southern Coast and Mountains,

Klamath/Interior Coast Ranges, and Sierra/Cascades ecoregions having the highest proportions. Areas with recent wildfires tend to be classified as lower hazard initially, primarily due to the reduction in fuel loads and potential fire intensity, especially in areas of high severity. Reduction in hazard from wildfires and from management actions such as fuel treatments (see below) can change the distribution of hazard across the landscape in the near-term but will need maintenance as fuels regrow and change over time. The intersection of WHP and valued resources and assets can give us a picture of where we anticipate the greatest impacts to the things humans care about in the near future. It is important to acknowledge that while prioritizing high values of WHP makes sense for strategic planning, risk is still widespread in lower WHP areas, often due to the influence of relatively low likelihood of fire burning there on potentially vulnerable, high-value assets. All wildland areas of the state exhibit some level of wildfire risk that needs to be understood and managed for.

Electrical Utility Wildfire

Since 2000, fires originating from the electrical utility sector's network of overhead infrastructure and associated electrical power systems have been disproportionally responsible for large and damaging fires. Five of the state's most destructive fires were caused by powerlines (see Chapter 11, Wildfire Risk to Communities). In response to devastating utility-caused fires in 2017 and 2018, Senate Bill (SB) 901 (2018) created new requirements for wildfire risk mitigation planning for electrical utilities, and ultimately led to the creation of a new Office within the California Natural Resources Agency (CNRA), the Office of Energy Infrastructure Safety, which has direct oversight and regulatory review of the mandated Wildfire Mitigation Plans (WMPs) filed by investor-owned utilities. The public service benefit associated with utility companies presents complex challenges for companies and regulators seeking to reduce risk and liability, as well as fire management agencies that are responsible for managing fire control in the context of ongoing climate change (Wara et al. 2024).

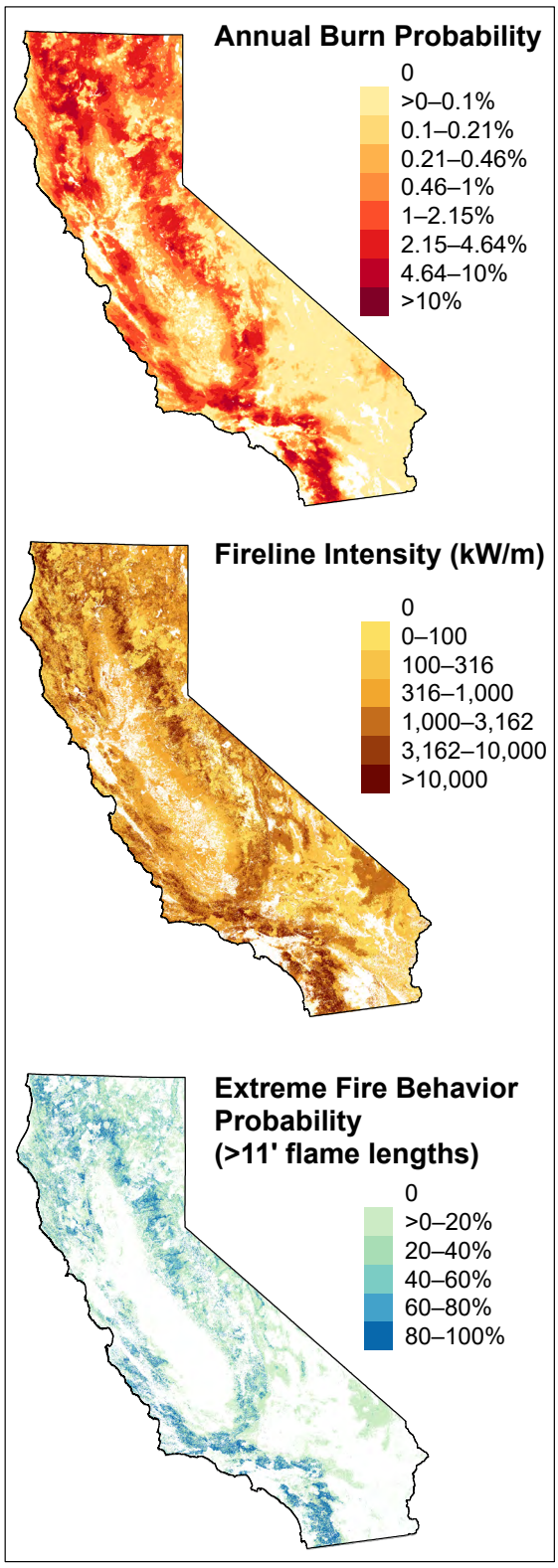


Figure 4.7. Selected wildfire hazard metrics estimated for 2023: annual burn probability, characteristic fireline intensity, and probability of extreme wildfire behavior (flame lengths >11 ft). Data Source: CAL FIRE and Pyrologix (2025).

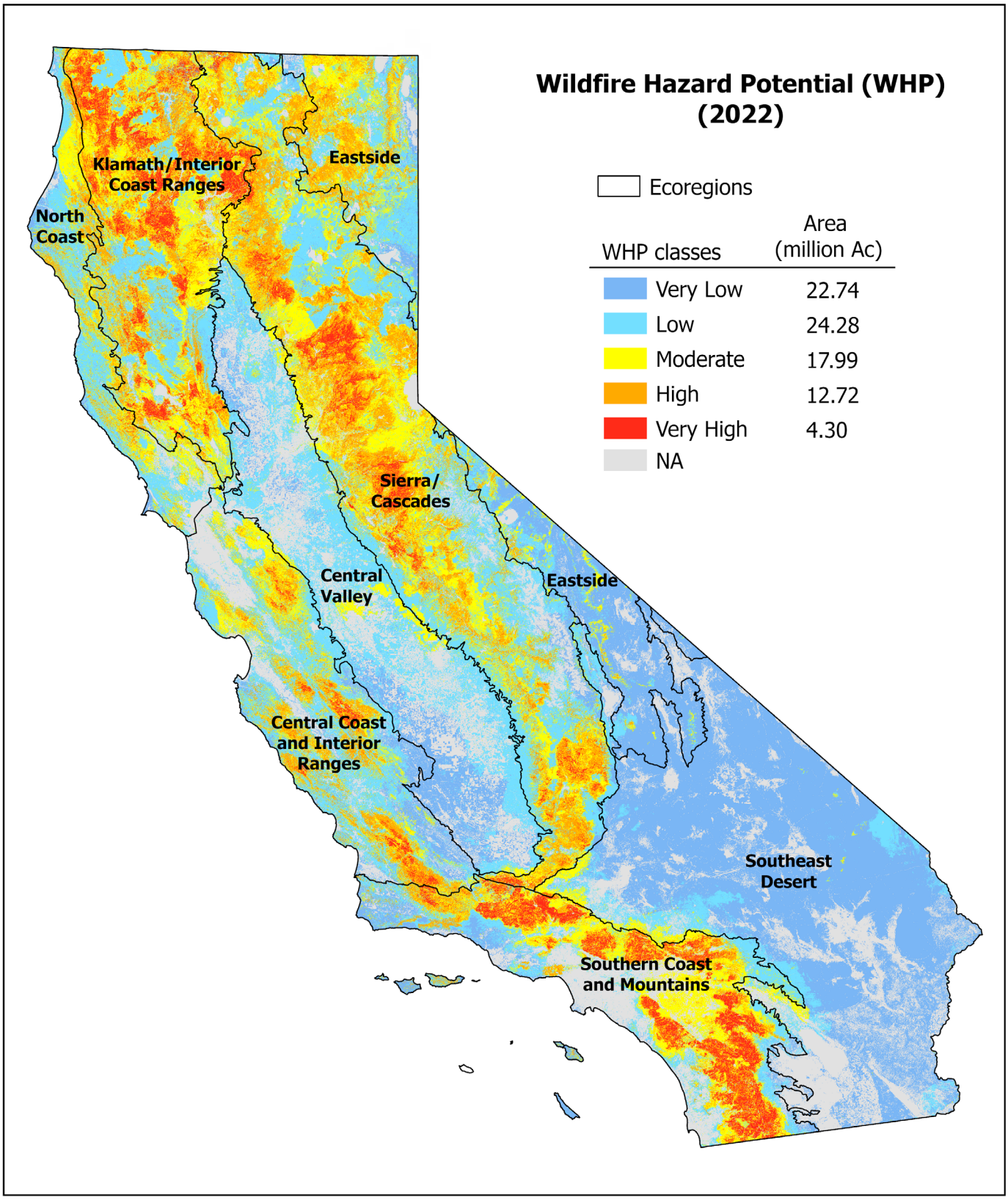


Figure 4.8. Wildfire hazard potential by ecoregion. Data Source: CAL FIRE and Pyrologix (2025).

Risk reduction through enhanced hardening of infrastructure (e.g., covered conductors, undergrounding, improved fault detection systems); preemptive power de-energization (Public Safety Power Shutoff [PSPS]); and targeted vegetation mitigation activities are common features of ignition management developed out of these WMPs. These approaches are currently being improved through risk modeling techniques incorporating weather and fuel condition forecasting, two-dimensional fire spread modeling, and emergent risk assessment techniques to estimate potential impacts of fires from the utility power network (Huang et al. 2023, Luu 2023). However, these modeling efforts have been criticized for bias in both under- and over-estimating risk and the mitigation effectiveness of proposed policies and treatments. Critically, the influence of severe dry wind events presents unique challenges for ignition management and planning, and notably, the risk may be underestimated as the public health impacts for wildfire smoke are largely missing from risk assessments (Mitchell 2023).

Iterative development of WMPs since 2019 has prompted continued evolution of wildfire mitigation strategies. Utilities have increased investments in infrastructure hardening, enhanced vegetation management, improved inspections, weather station networks, automated fire-detecting cameras used by fire management agencies and others, and a variety of other strategies (e.g., OEIS 2026). Utilities are also piloting new risk mitigation strategies and measuring outcomes to inform the most effective uses of limited ratepayer funds.

Fuels Reduction Treatments

Fuels treatments are a standard tool for reducing wildfire hazard and a long-standing element of forest management (Agee and Skinner 2005). Over the last seven years, about 357,000 acres per year of fuel treatments have been completed in the state by CAL FIRE and federal agencies, an increase of 37% since the 2017 Assessment, which found a ten-year average of 261,000 acres treated annually (ⓘ4.5). CAL FIRE has shown a substantial increase in the average annual area treated, from ~17,000 acres/year in the 2005–2015 time frame reported in the 2017 Assessment to ~124,000 acres in fiscal year 2025, while federal area treated has stayed similar over recent years (256,000 acres/year on average).

The California Wildfire and Forest Resilience Task Force (WFR Task Force) has developed a more comprehensive reporting system for tracking fuel and forest resilience treatments, called the Interagency Treatment Tracking System. Modeled after CAL FIRE's CalMAPPER system, this tracking system goes beyond fuel treatments to include other activities that foster landscape resilience (e.g., reforestation, pest management, and beneficial wildfire on federal lands). The Interagency Treatment Tracking System goes back as far as 2021 and also includes a larger number of data providers than CalMAPPER, including representatives in the timber industry and a comprehensive set of state agencies. This system also allows for parsing activity acres versus footprint acres, the latter of which avoids double counting where the same plot of land may be treated by multiple activities. The Interagency Treatment Tracking System (WFR Task Force 2025b) offers a more comprehensive measure of treatment area, and the data displayed on the Interagency Treatment Dashboard (WFR Task Force 2025c) are more consistent with comparisons to the treatment targets in the Million Acre Strategy (WFR Task Force 2021). The comprehensive tracking system data show that for the two most recent years available (2023 and 2024), total activity acres have averaged 1.065 million acres per year, corresponding to an average of 750,000 footprint acres per year (Figure 4.9).

Fuel Treatment Effectiveness

Within forested systems across the Western U.S., there is widespread evidence that fuel reduction treatments are generally effective at reducing subsequent wildfire severity (Baijnath-Rodino et al. 2023, Brodie et al. 2024, Davis et al. 2024, Yackulic et al. 2025), especially in the first 10 or so years following treatment (Prichard et al. 2020), and even under severe fire weather conditions (Lydersen et al. 2017, Prichard et al. 2020). There is also mounting evidence that fuels treatments that include both thinning and burning are the most effective (Yackulic et al. 2025), and thin-only treatments

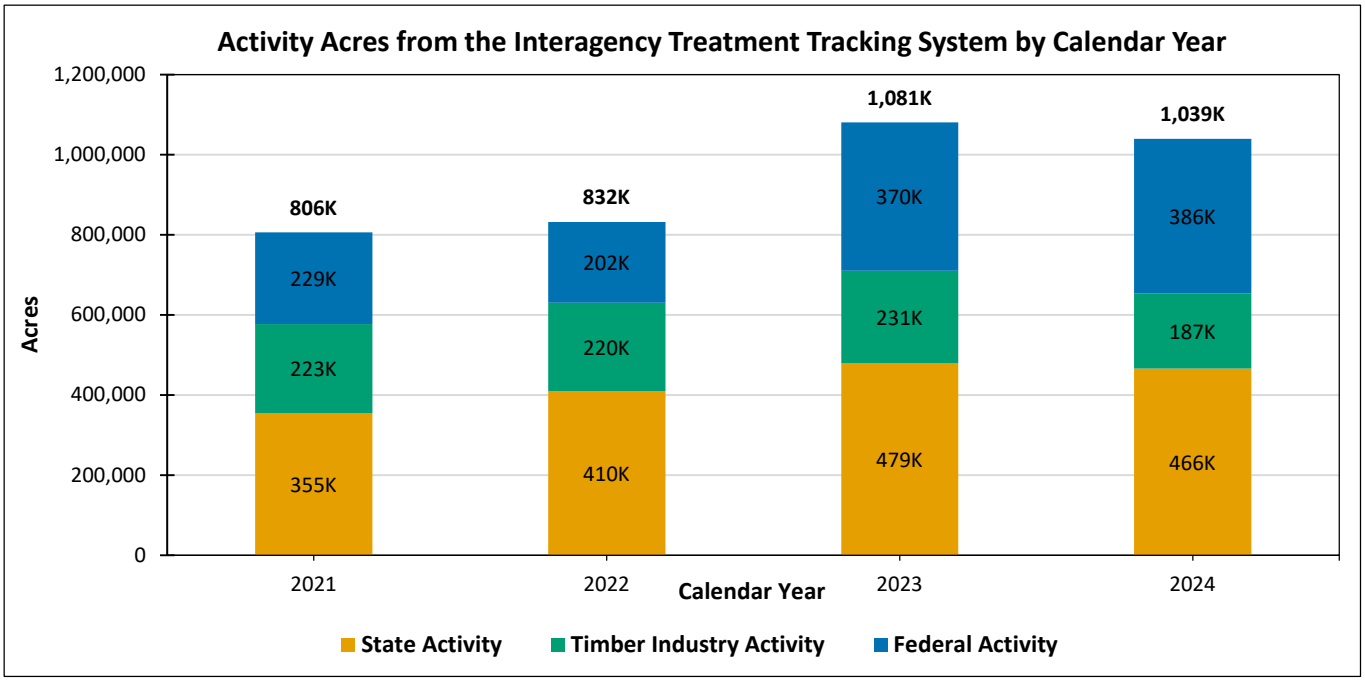


Figure 4.9. Activity acres treated for wildfire and forest resilience in California (2021–2024). Acreages include some treatments and reporting entities not included in ⓘ4.5. Data Source: WFR Task Force (2025b).

that do not remove fine surface and ground fuels are relatively less effective (Brodie et al. 2024, Davis et al. 2024, Lydersen et al. 2017, Shive et al. 2024).

In the montane forested systems of California, there is much alignment between treatments designed for WUI protection and those designed for ecological benefit (Stephens et al. 2020), but this convenient alignment is not generally present for southern California chaparral systems, where ecological and fire behavior mitigation goals are often in conflict (Syphard et al. 2011). Treatments in chaparral systems, which are typically adapted to low-frequency but high-severity fire, have fundamentally different ecosystem effects than in forests adapted to frequent fire. In dense, mature chaparral, fire burns through the crowns of the dominant species, with complete top-kill being a common outcome in both prescribed fire and wildfire, and this is the fire behavior to which this vegetation type is adapted (Rundel 2018). Recovery of native vegetation to a flammable state may be rapid due to resprouting and prolific regeneration from seed. However, chaparral and other shrubland systems are susceptible to negative ecosystem effects from too-frequent burning (Syphard et al. 2019), as described above under Fire Regimes, and in more detail in Chapter 2 (Sustainable Rangelands). Too-frequent burning, in addition to unmaintained mechanical treatments, can introduce highly flammable non-native grasses that can further increase fire hazard and the likelihood of type conversion to non-native species. Therefore, there is tension between the potential beneficial short-term fuels reduction effects and potential negative ecosystem consequences of prescribed fire in chaparral. While this does not preclude prescribed fire treatments in chaparral, the tradeoffs should be acknowledged and carefully considered.

Research on fuel treatment effectiveness in chaparral is limited, but one study in northern California chaparral found that 15-year old fuel treatments (combinations of mastication, burning, and hand thinning) did not have different post-fire vegetation and fuels outcomes from untreated controls after an extreme wildfire, possibly due to treatment age and the severity of burning conditions (Jones et al. 2023). However, in chaparral systems that naturally burn in high severity crown fire, fuels treatments are often designed to create corridors of drastically reduced vegetation and, with the aid

of fire suppression operations, stop fire spread rather than reduce severity where fire does occur. Linear fuel breaks constructed in largely non-forested areas of southern California national forests were found to be effective at holding the fire in many cases, but effectiveness depended on fuel break accessibility, suppression resource availability, and fire weather (Gannon et al. 2023, Syphard et al. 2011).

Constraints on Treatment Implementation

Multiple barriers to fuels treatment implementation continue to constrain the pace and scale of fuels reduction. Risk aversion and public concerns, a need for dedicated, consistent funding and increased workforce capacity, and air quality concerns have been cited as substantial barriers to treatment implementation of both prescribed fire and mechanical fuels treatments in California (Lyman 2024, Miller et al. 2020). The top type of barrier identified in Lyman (2024), mentioned by 86% of interviewees, was environmental constraints, such as the effects of climate change on public perceptions of intentional fire use, increased drought conditions and extreme weather that increase the complexity of fuel management, and limited prescribed fire prescription windows. On federal lands in the Western U.S., lack of capacity and funding were some of the strongest barriers to successful project implementation in the recent past, with air quality concerns generally less restrictive except in certain locations (Schultz et al. 2019). However, increases in federal and state funding for treatment implementation over the past five to 10 years have made funding less of a constraint. Operational constraints such as lack of road access and unsuitable topography also constrain mechanical treatment implementation on public lands (North et al. 2015a). Further constraints exist when attempting to mitigate direct impacts from treatments to other ecocultural features (e.g., wildlife habitat, watercourses, wilderness, archeological resources). These constraints not only limit the areal extent of treatments, but also their intensity and ultimately their effectiveness (Collins et al. 2010, Lydersen et al. 2019). Building trust and relationships through collaborations, education and outreach, transparency, and pilot demonstration projects is perceived by resource managers as crucial for successful treatment implementation (Lyman 2024).

Using Past Wildfire to Reduce Future Wildfire Severity in Forested Systems

While fuel treatments such as prescribed fire and mechanical thinning increase forest resilience to disturbances (e.g., drought and high severity wildfire), there continues to be a significant backlog in work needing to be accomplished in and around communities and in the broader landscape. Challenges with catching up with this backlog, along with increasing annual wildfire extent, have sparked interest in opportunistically considering wildfire as a fuel treatment (Greenler et al. 2023, Larson et al. 2022, North et al. 2021, Tortorelli et al. 2024), since wildfires cover much larger areas than planned fuel treatments (Shive et al. 2025).

Even though high severity fire often garners more attention for post-fire management concerns, the majority of the area burned in wildfires across the Western United States is characterized as low to moderate severity. For example, approximately 64% of the area burned from 2010 to 2020 in California occurred at low to moderate severity (Williams et al. 2023), more than three times the area treated using mechanical thinning or prescribed fire in the same decade (North et al. 2021). This makes harnessing low and moderate severity wildfire as first-entry treatments a practical way to increase rates of fuel treatment implementation (Wu et al. 2023). While the idea is not entirely new, the expansion of very large fires into the Pacific Northwest has prompted states to explore these opportunities directly (WADNR 2025, Williams et al. 2023).

A study from eastern Washington State found that wildfire moved some aspects of forest structure and landscape patterns towards desired conditions based on the natural range of variation (NRV), but increased departure from desired conditions for others (Churchill et al. 2022). The authors characterized wildfire as a “blunt tool” for restoration. In another study in the Sierra Nevada, first-entry wildfire was moderately successful at moving canopy cover and ladder fuel density towards NRV, but was less effective at creating tree clump and

opening patterns. Moderate severity patches had a higher proportion of area within NRV when compared to patches with low or high severity. There was a higher probability of restoration effects within 0.6 miles of previous fires, at higher elevations, and under moderate fire intensities (Chamberlain et al. 2024).

Low to moderate severity fire can reduce the likelihood of damaging, high-severity wildfire by reducing fuel loads, especially in forests that are adapted to a frequent fire regime (Collins et al. 2018, Hessburg et al. 2015, Prichard et al. 2017, Rodman et al. 2023, Tortorelli et al. 2024). In contrast, high severity fire areas often reburn at high severity in subsequent wildfires. Understanding where and when wildfire can be considered as a landscape-scale fuel treatment, and how to take advantage of those benefits, is crucial but understudied. In general, moderating effects of previous low to moderate severity wildfire last longer in the areas burned at moderate severity, although low severity areas tend to have the lowest severity in subsequent wildfires (Tortorelli et al. 2024). The wide range of fire effects in the moderate severity category can contribute to highly variable responses to subsequent wildfire (Collins et al. 2018). However, even experiencing multiple low to moderate severity burns does not ensure resilience to subsequent wildfire given the lasting legacy of fuels accumulated from many decades of fire exclusion (Jasperse et al. 2025).

Recent work has shown that previous low to moderate severity wildfires moderate reburn severity across all forested ecoregions in the Western U.S., with the strongest effects seen along the California Coast Ranges and western mountains, including the Sierra Nevada, Klamath Mountains, and Cascade Range (Tortorelli et al. 2024). These moderating effects have a more extended duration in cooler, wetter forests in the Coast Ranges, lasting more than 36 years. The moderating effects generally last less than two decades in most ecoregions, and less than 12 years in the more interior western mountains. In California closed-cone pine forests, live and dead surface fuels were found to accumulate quickly, reaching levels similar to those capable of supporting severe fire after 10–15 years (Agne et al. 2023).

To take advantage of wildfire-caused fuel reduction, land managers can apply pyrosilviculture, which is the use of fire to achieve silvicultural management objectives (North et al. 2021, York et al. 2021) (see Chapter 1, Resilient Forests). This opportunistic application of pre- and post-fire activities coordinates mechanical thinning, prescribed burning, and managed wildfire to maintain improved forest conditions. Although addressing the acute management needs caused by large, high severity wildfires is necessary, focusing additional resources and attention on management following low to moderate severity fire is an important strategy for fostering forest resilience and increasing the pace and scale of prescribed fire (Chamberlain et al. 2024).

Benefits of Cultural Burning

In recent years, the State of California has been working to more directly address the historical legacy of abhorrent treatment of the Indigenous peoples of this region. Of particular significance for forest and rangelands, this includes recognition of the importance of tribal cultural values and traditional ecological knowledge (TEK) for restoring and maintaining ecosystems. This still nascent shift is in part reflected in Governors' executive orders (e.g., Brown 2011, 2019, Newsom 2019), legislation (Gatto 2014, Ramos 2022, Ting et al. 2022), and specific administrative actions, such as the establishment of the Governor's Office of Tribal Affairs and the creation of high-level tribal liaison positions in many agencies and departments.[5] For example, CAL FIRE established the Tribal Affairs Program in 2024 and appointed its first Deputy Director. In 2024, SB 310 (Dodd 2024) formally recognized tribal authority to regulate cultural burning on state lands, and directed the state to work cooperatively with federally-recognized California Native American tribes to better meet fuel management and wildfire resilience goals and to address the wrongs of criminalizing cultural use of fire.

Numerous articles and published papers in the past five years have described how using traditional tribal cultural burning extensively throughout California's wildlands can benefit ecosystems and the species that depend on them, including humans (Cagle 2019, Elassar 2022, Jordan 2019, Long et al. 2021, Schelenz and Wheelock 2022, Sommer 2020). Through cultural burning, tribes maintained a spiritual connection to the land and a culture of living with fire. This practice promoted and enhanced diverse plant communities and forest structures that supported their livelihoods, while also establishing and maintaining resilient ecosystems. Indigenous peoples used fire extensively until approximately the mid-1800s, when Euro-American settlers decimated native populations and government agencies outlawed the practice of intentional burning with legislation, such as the 1850 Act for the Government and Protection of Indians (Schelenz and Wheelock 2022). Intentional burning by Native communities was banned entirely in 1911 with the passage of the Weeks Act by the U.S. federal government (Elassar 2022). Prior to 1800, an average of approximately 4.5 million acres burned annually in California due to Native American burning practices and uncontrolled lightning-ignited fires (Stephens et al. 2007). By any measure, modern fire rates show large deficits in natural fire frequencies across widely divergent ecosystems throughout the state (see ⓘ4.2, Fire Return Interval Departure).

Restoring opportunities and incorporating TEK is a key goal of this expanding effort (e.g., Hankins 2013). The Karuk and Yurok tribes resumed burning in 2013, leading California in reclaiming the intentional use of fire. To date, Native American cultural burning has been shown to significantly reduce forest biomass and maintain forest biodiversity (Knight et al. 2022), enhance native plant species revitalization (Marks-Block et al. 2019), reduce the threat of catastrophic wildfire for residents, and support traditional hunting and gathering activities (CAL FIRE et al. 2017). Longer term goals include renewing and maintaining cultural resources, enhancing sustainable economic opportunity, helping the land become more resilient to climate change, and addressing historic injustices against Native Americans (Cagle 2019).

A key approach to enabling and scaling cultural burning is to form collaborations that support it.

5 *See Chapter 13 (Institutional Response) for more specific information on executive orders and legislation.*

These partnerships must address the important differences between traditional prescribed burning programs and cultural burning, such as the involvement of multiple generations for knowledge transfer (Williams et al. 2023). Additional keys for the success of this effort include (1) continuing prescribed burning trainings and workshops (e.g., Prescribed Fire Training Exchanges or TREX), (2) providing sufficient state and federal funding, (3) using decentralized prescribed burn associations (e.g., Cultural Fire Management Council, Humboldt County Prescribed Burn Association, Indigenous Peoples Burn Network) (Marks-Block and Tripp 2021), and (4) utilizing the Prescribed Fire Liability Claims Fund for protection of both cultural practitioners and certified burn bosses. Among the outstanding items to resolve are evaluating existing air quality and burn permitting regulations and lack of sufficient funding and federally certified personnel.

The WFR Task Force's 2021 Action Plan called for treating 500,000 acres of non-federal lands annually with prescribed/cultural fire, mechanical treatments, and herbivory (WFR Task Force 2021). It asks Native Americans to revive their cultural burning practices to help meet this goal, working with federal, state, and local partners. Specific goals listed in the Action Plan include 1.20—establish a grant program to support cultural burning, and 1.21—establish a California Prescribed Fire Training Center. Additionally, in March 2022, the WFR Task Force released California's Strategic Plan for Expanding the Use of Beneficial Fire (WFR Task Force 2022). This report establishes the following goal and five supportive actions:

> **Goal #3** The state and its partners will support and enable the expansion of cultural burning and better integrate California Native American tribes, tribal organizations, and cultural fire practitioners into other forms of beneficial fire across California.
>
> **3.1** Respect tribal sovereignty
>
> **3.2** Invest in cultural burning
>
> **3.3** Include tribes in planning
>
> **3.4** Improve co-management
>
> **3.5** Support Indigenous fire workshops

To help achieve these various goals, Native American tribes throughout the state are partnering with CAL FIRE to host cultural burn workshops for firefighters. Firefighters learn directly from tribal leaders about the tradition of fire and its importance to tribal culture (Elassar 2022). Through mid-2024, there have been nine CAL FIRE cultural burn workshops held.

There are natural synergies between the use of prescribed fire and cultural burning to address widespread fire risk across the state. Working partnerships with shared knowledge and mutual objectives may provide a path forward to the vexing problems of people and fire in California and other Western states with similar forest and climate risks (Eisenberg et al. 2024).



Cultural fire practitioner at the 2025 Leok Po cultural burn demonstration at Cache Creek. Photo used with permission and provided by CAL FIRE.

Quantifying Treatment Success

As discussed previously, tracking annual area treated across the state is complex due to numerous reporting entities and land ownership types, overlapping treatments (i.e., multiple treatments in the same location), differences in recording methods (e.g., project planning area vs. implementation area), differences in treatment categories, and data gaps due to lack of reporting. Activity acres capture the sum of multiple treatments completed in succession on the same area, while footprint acres capture the extent of area receiving at least one treatment, without double counting for multiple treatment entries. For the activity acres reported in this Assessment, we have relied on CalMAPPER to track projects on non-federal lands, and filtered data from the WFR Task Force Interagency Treatment Tracking System (WFR Task Force 2025b) for federal lands (ⓘ4.5). The annual treated area calculated from these sources differs from the WFR Task Force Interagency Treatment Dashboard (WFR Task Force 2025c) due to the latter tracking several categories of treatment not counted in our methods (pest control, reforestation, and planned treatments burned in beneficial wildfire) and a greater number of agencies included, which did not have data available for the earlier years portrayed in the indicator. As discussed above, the Interagency Treatment Dashboard provides a more complete view of treatments that aim to improve ecosystem resilience. In addition, there is often a lag time between when acres are treated and when they are reported to the Interagency Tracking System, so the most recent years included in this report may be missing some completed treatments.

Despite the substantial efforts to evaluate progress towards meeting annual fuels reduction targets, there is no comprehensive statewide treatment effectiveness or treatment impact monitoring system. However, the Board of Forestry and Fire Protection, CAL FIRE, the California Department of Fish and Wildlife, the California Geological Survey, and the Regional Water Quality Control Boards have collaborated to do some evaluation of the implementation and effectiveness of certain forest practice Exemption and Emergency operations that address fuels and fire effects (see Chapter 13, Institutional Response, for details). The nascent state and federal collaborative Wildfire, Ecosystem Resilience, and Risk Assessment Initiative (WERK) project seeks to address this shortfall (NASA 2025).

Acres treated is a useful metric describing progress and is critical to ensure progress is traceable and tracked, particularly given the lag time between when a treatment occurs and observations of its impact can be assessed. However, acres alone do not provide information on the quantity of fuel removed or rearranged, the proximity to valuable resources, or whether the site has been successfully restored to a wildfire-resilient state. Furthermore, having a target based on acreage alone can have the unintended effect of causing practitioners to select easier, more feasible acres which may not coincide with the highest strategic priorities. This in turn may promote type-conversion of native shrublands or grasslands to undesirable non-native plants, if treatments are too frequent for native vegetation to recover. Statewide treatment targets would be more meaningful if they included metrics of treatment quality and effectiveness.

Additionally, there is a need to understand the impacts of treatments during wildfire incidents and outside of the treated area itself (sometimes referred to as “shadow effects”). The CAL FIRE Fuels Treatment Effectiveness Reporting Dashboard was launched in 2024 to provide qualitative reporting on observed impacts of vegetation management treatments on wildfire behavior, ingress or egress, and fire suppression (CAL FIRE 2025c). The WERK project aims to assess treatment effectiveness in and around treatments statewide at a watershed level.

Management Response

CAL FIRE and CNRA have taken many steps in recent years to address the increasing negative impacts of wildfire in California. These efforts have included (1) increased funding for staffing and fire-fighting

equipment; (2) increased funding, regulatory efficiencies,[6] and support for fuels reduction and elevated targets for treatment acres; (3) collaborative projects with federal, state, local agencies, and tribal entities; (4) development of new programs and institutions; and (5) improved public awareness. These topics are briefly addressed below and covered in considerably more detail in Chapter 13 (Institutional Response), Chapter 1 (Resilient Forests), and Chapter 11 (Wildfire Risk to Communities).



Firefighter in foreground of 2021 Dixie Fire in northern California. Photo: CAL FIRE.

Increased Funding for Staffing and Fire-Fighting Equipment

CAL FIRE total staffing has increased from approximately 7,000 positions in 2017 to over 12,000 in 2025, mostly for additional fire protection personnel (ⓘ13.2). Similarly, Department expenditures for fire protection have increased from approximately $2.3 billion in 2017 to over $3.8 billion in 2025 (see Chapter 13, Institutional Response). The state has invested heavily in improving its early detection and rapid response capabilities. This includes obtaining new aircraft, using remotely sensed imagery to map wildfire spread, and utilizing advanced fire modeling to predict fire behavior and plan effective responses. CAL FIRE has also invested in Artificial Intelligence (AI)-powered wildfire detection systems to detect fires more rapidly and increased its use of unmanned aerial systems for real-time assessment of wildfires.

Increased Funding for Fuels Reduction and Elevated Targets for Treatment Acres

The primary source of elevated funding for fuels reduction work in California over the past 10 years has come from the California Climate Investments (CCI) Program, which receives money from the Greenhouse Gas (GHG) Reduction Fund. CAL FIRE has received approximately $2.4 billion of the more than $33 billion in CCI expenditures through FY 2023–24. These funds have supported Forest Health and Wildfire Prevention grants to reduce wildfire hazard, as well as urban and community forestry, business and workforce development, forest health research, CAL FIRE-implemented fuels reduction projects, and other programs (see Chapter 13, Institutional Response). A newer funding source comes from Proposition 4, the $10 billion Safe Drinking Water, Wildfire Prevention, Drought Preparedness, and Clean Air Bond Act passed by the voters in November 2024, which includes $1.5 billion for wildfire and forest resilience programs. The WFR Task Force estimates that nearly $6 billion of state and federal funds have been invested for forest health and wildfire resilience projects and programs since 2021 (WFR Task Force 2025a).

Collaborative state-federal efforts initially set an annual treatment goal of one million acres by 2025 to help achieve resilient forest conditions, including 500,000 acres of non-federal lands and 500,000 acres of NFS lands. This work includes increasing the pace and scale of prescribed burns, as well as cultural burns (e.g., SB 310; Dodd 2024). A more ambitious state goal has been established by the Newsom administration following enactment of Assembly Bill (AB) 1757 (Garcia and Rivas 2022), which seeks to bolster natural carbon

6 *Increased regulatory efficiency constitutes another type of management response prioritized by the state. See Chapter 13 (Institutional Response) for important examples under the section "Cutting Green Tape," and the subsection "Los Angeles and Ventura Counties Wildfires" under the section "Governors' Executive Orders and Proclamations as Important Directives for Wildfire and Forest Management," regarding the 2025 Executive Order fast-tracking critical wildfire prevention projects statewide.*

sequestration and nature-based climate solutions that reduce GHG emissions. This strategy set a goal of ramping up to 2.5 million acres per year of wildfire resilience and restoration work in forests, shrublands, and grasslands by 2045 (CNRA 2024). Following an emergency proclamation noting the critical need to expedite project implementation, Executive Order N-25-25 lays out a process to streamline and fast-track environmental review and permitting for critical fuel reduction projects (Newsom 2025).



Prescribed fire in the South Grove of Calaveras Big Trees State Park, September 2024. Photo: CAL FIRE.

Collaborative Projects

Collaborative landscape-level projects designed to improve forest health, reduce fire threat, and contribute to local economic development can facilitate landscape-level and cross-boundary planning and increase stakeholder buy-in for landscapes with a complex matrix of ownerships. Examples of collaborative efforts at the federal level include the Joint Chiefs' Landscape Restoration Partnership, National Cohesive Wildland Fire Management Strategy, Collaborative Forest Landscape Restoration Program, and Wildfire Crisis Strategy. Examples at the state level include the Sierra Nevada Conservancy Watershed Improvement Program and the Department of Conservation Regional Forest and Fire Capacity Program (see Chapter 1, Resilient Forests). A major state collaborative effort is the WFR Task Force. Created in 2021 and building on the preceding Forest Management Task Force, it coordinates and helps catalyze the efforts of federal, state, local, public, private, and tribal entities to reduce high severity wildfires by increasing the pace and scale of forest health treatments.

Additionally, local communities are being encouraged to work together with state and federal partners to develop Community Wildfire Protection Plans (CWPPs) (see Chapter 11, Wildfire Risk to Communities). The North Coast Resource Partnership (NCRP) provides an example of a broader regional wildfire planning effort. NCRP is developing a Regional Priority Plan (RPP) that will outline a region-wide strategy for fuel load reduction and forest health, including a list of priority forest health and fire resiliency projects, strategies, and tools.

Development of New Programs and Institutions

In addition to the WFR Task Force, several other new programs and institutions have been established in the past seven years to address the wildfire crisis in California. For example, the Office of Energy Infrastructure Safety was created in 2019 to reduce the risk of utility-related wildfires by reviewing and approving Wildfire Mitigation Plans developed by the investor-owned electric utilities. Other examples include the Climate & Wildfire Institute, established in 2022 as a nonprofit organization to provide climate and wildfire-related research to public policy decision-makers, and the California Wildfire Mitigation Program, created in 2019 with CAL FIRE and the California Governor's Office of Emergency Services to strengthen community resilience against wildfires.

Improved Public Awareness

Finally, California is addressing its wildfire crisis through increased public awareness about wildfires, using online tools, educational resources, and community engagement. The Office of the State Fire Marshal's Community Wildfire Preparedness and Mitigation Division (CWPM) was established following approval of SB 901 (Dodd 2018). CWPM works with federal, state, and local agencies, Native American tribes, non-profit entities, and other stakeholders to prepare California communities against the devastating effects of wildfire. The various programs within the division allow

CAL FIRE to continue to build local and regional capacity, as well as developing, prioritizing, and implementing strategies and projects that create wildfire prepared communities. The tasks involve working with stakeholders on wildfire planning to reduce or eliminate fire hazards and risks, modifying the environment by removing or reducing receptive fuels, conducting fire hazard compliance inspections, and providing education and grant opportunities for wildfire prevention efforts. As a component of this division, CAL FIRE's Wildfire Public Education Program, established by AB 9 (Wood 2021), conducts outreach to regional and local wildfire mitigation groups, ensuring compliance and informing stakeholders about relevant laws and regulations. University of California Agriculture and Natural Resources (UC ANR) Fire Network Advisers also provide important knowledge to increase treatments on private and state lands.

OPPORTUNITIES

The ecosystems of California evolved over time with fire; our strategies for human habitation in a fire-adapted landscape must evolve as well. Despite having one of the largest and most effective wildland fire workforces in the world, large, deadly, expensive, and ecologically damaging wildfires continue to happen and are increasing in many areas. Fire management priorities and policies that focus primarily on suppression only ensure that more of the same destructive wildfires will occur (Kreider et al. 2024, Moritz et al. 2014, North et al. 2015b, Stephens et al. 2013). For Californians to live sustainably with fire over the long term, agencies, landowners, and the public alike must acknowledge the inevitability and necessity of fire and other fuel treatments in ecosystems and for ecosystem services, and work to enhance the capacity of communities and ecosystems to withstand periodic fire without devastating impacts.

Below is a list of opportunities for improving fire management and resource protection into the future.

Ecosystem Management for Health and Resilience

- Enhance understanding among the public, land managers, and fire agencies that wildfire is endemic to much of California, that it is inevitable, and that adverse impacts can be strategically addressed through a variety of layered programs and activities as described below.

- Continue to strategically and significantly expand the pace and scale of forest health treatments to reduce wildfire hazard, improve forest resilience to disturbance, and encourage long-term stability of ecosystem services, including carbon storage (Jones et al. 2025).

- Make forest resilience a top priority, above individual resource concerns (Jones et al. 2025, Stephens et al. 2016).

- Improve efficiency of vegetation management planning and implementation.

    - Utilize recently mandated streamlined regulations designed to expedite fuels reduction projects and promote forest health and carbon-positive trends (e.g., Newsom 2025, Skinner and Chesbro 2010).

    - In both pre-fire vegetation management and post-fire recovery efforts, evaluate multiple pathways to ecosystem recovery, including returning them to their original conditions, helping them shift to an altered but resilient native vegetation state, or, when those options aren't possible, guiding recovery toward a partially restored state that provides the most ecological benefits.

- Utilize the national fire management policy of fire restoration, including expanded use of prescribed fire and managed wildfire where ecologically appropriate.

    - Support increased use of pyrosilviculture, including managed wildfire on public lands, particularly California's national

forests—when and where appropriate—to improve forest health and reduce wildfire threat.

Strategic Fire and Fuels Management

- Emphasize a landscape-level, all lands approach to planning consistent with the scale of typical modern-era fire events. This requires cross-agency/landowner coordination and consideration of multiple objectives.
    - Fully implement SB 1101 (Limón 2024), which calls for mapping of Potential Operational Delineations (PODs), a proactive approach to wildfire management that helps to identify and map potential control lines and areas for fire suppression and for more beneficial fire outcomes.
    - Take advantage of recently burned areas for their opportunity in long-term ecosystem restoration and hazard mitigation. Past fire severity and current ecological condition can provide a planning, implementation, and monitoring framework within PODs to engage in a landscape-level risk-informed approach for fuel treatments.
    - Maintain a high level of public grant funding and leverage private and philanthropic funding for collaborative landscape-level forest health, resilience, and fire prevention activities.
    - Expand cultural burning and increase implementation of SB 310 (Dodd 2024), which authorizes the state to enter into cultural burn agreements.
    - Support local Prescribed Burn Associations to empower nonindustrial landowners to utilize prescribed fire on private lands; expand partnerships with UC ANR Fire Network Advisers.
    - Include pre-fire hazard mitigation planning for post-fire debris flow and flood risk where appropriate, including expanding the network of permanent Emergency Forest Restoration Teams (EFRTs) that can work across agency jurisdictions on resilience projects.
- Place greater emphasis on pre-fire management, including ignition management, fuel reduction, ecosystem restoration and maintenance, and restoration of natural fire regimes.
    - Expand land management agencies' technical capacity and staffing for pre-fire fuel and vegetation management.
    - Continue to reduce the risk of electric utility-caused wildfires by reviewing and approving Wildfire Mitigation Plans developed by investor-owned electric utilities.
- Develop site-specific plans that recognize key elements of fire regime, plant and ecosystem response, and human safety concerns.
- Strategize fuel reduction treatments to most effectively reduce risk and protect valued assets, rather than focusing on maximizing acres treated.
- Continue to adapt the fire suppression workforce to better respond to changing trends in wildland fire and evolving ecosystem management strategies.
    - Maintain adequate funding for local, state, and federal firefighting equipment, advanced technology, and staff as appropriate.
- Educate the public on the types of risks and tradeoffs inherent in utilizing prescribed, cultural, and managed wildfire and other fuels treatments (e.g., mechanical) with the aim of improving public acceptance of some unintentional negative effects to property and ecosystems in return for decreased risk of large-scale catastrophic wildfire.

Land Use and Community Planning

- Continue state and federal efforts to engage in local land-use planning to ensure that fire risk concerns are understood and mitigated when updating general plans and planning new development

projects. Increase planning efficiency on federal lands where ownership constraints are low (Levine and Stephens 2025).

- Promote sound planning and mitigation in the WUI to make communities more resistant to damage from wildfire, including enhancements to fire-safety regulations designed to reduce community impacts.
    - Update, as needed, Fire Hazard Severity Zone (FHSZ) maps for State Responsibility Area (SRA) and Local Responsibility Area (LRA), and support ordinances to reduce wildfire hazard/risk, including but not limited to home hardening, land-use zoning, and defensible space compliance.
- Incentivize and provide financial and logistical support for individual land and homeowner efforts to mitigate fire risk through fuel management, structural retrofit, and engagement in community wildfire planning efforts.

Research and Monitoring

- Support ongoing research and establishment of new long-term studies examining the management of fire in a variety of fire-adapted ecosystems, particularly with respect to treatment effects, climate change, post-fire and post-drought dynamics of fire hazard, carbon storage, and wildlife habitat.
- Support communication of research findings to broad audiences to build understanding and support among the public.
- Promote research that enhances our ability to forecast wildfire probability, predict outcomes, and develop strategies for a changing climate. Use this understanding to prioritize areas for restoration, treatment, and adaptation.
- Support basic fire science research, including improvement of existing fire behavior models to better predict fire weather, hazard, ignition, spread, and effects.
- Continue adaptation of fire and fuel management techniques commensurate with improved understanding of their efficacy and long-term impacts on ecosystem structure and function.
- Continue monitoring to track the effectiveness of fuel treatments and evaluate progress towards meeting statewide goals. Incorporate econometric modeling and comprehensive risk modeling to capture best strategies, practices, and treatments that meet local area needs.

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