CALIFORNIA'S FORESTS AND RANGELANDS

2017 ASSESSMENT

California Department of Forestry and Fire Protection

Fire and Resource Assessment Program

California's Forests and Rangelands:

2017 Assessment

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CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION

FIRE AND RESOURCE ASSESSMENT PROGRAM

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DIRECTOR'S FOREWORD

California's forest and rangelands are cherished resources that occupy over 80 percent of the State's land base. The forest land base alone stretches across 33 million acres, or one-third of the state. The mixture of climate, topography, and other environmental conditions supports an impressive variety of ecosystems and forest types. The variety of tree species in California includes some of the largest, tallest, and oldest trees in the world. Also, the diversity of California's forests supports a broad range of services that include: clean water, clean air, and habitat for fish and wildlife, as well as open space and recreation. Forests are managed for a variety of uses under a range of ownership types, including public working forests and forest reserves, as well as private industrial and nonindustrial forests. In addition, urban forests are becoming increasingly important for the climate, environmental, and aesthetic benefits that they provide.

This Assessment documents a number of serious challenges and threats to forest and rangelands that are impacting economic and environmental sustainability. In recent years, the frequency and severity of pest and wildfire events are unlike what we have experienced in the past, forcing us to reexamine our land and fire management policies and practices. Past Assessments raised issues related to land conversion and management practices, which have in part been addressed through actions such as revisions to the Forest Practices Rules, incentives for improved forest and range management, and use of conservation easements to protect working ranches and timberlands as well as important natural areas. However, current issues relate to overall ecosystem health at a landscape scale, and will require collaboration, cooperation, and investment in implementing science-based solutions that balance the objectives of different landowners and stakeholders. Even for issues where we are trending towards agreement, such as restoring natural fire regimes, finding solutions can be a complex process.

The response of forest and range ecosystems to a changing climate is one of the greatest challenges confronting California. Assessment analyses raise concerns over the ability of some timberlands to continue to support commercial tree species in the future, as well as concerns over future distribution and productivity of important rangeland vegetation types. The 2017 fire season was the worst and most tragic on record. Changes in the frequency and severity of disturbance regimes are an additional stress on ecosystem health, public property and safety, public agency budgets, and rural communities. Current forest conditions already seem to carry the imprint of a changing climate. The most recent drought resulted in elevated levels of tree mortality, with over 129 million dead trees across millions of acres of forest land. The severity of this mortality event is unprecedented and raises questions about the resilience of California's forests under a warming climate.

While the Assessment raises serious concerns, it also highlights positive trends and successful efforts that could provide the basis for a sustainable future. For example, multi-agency landscape-level collaborative restoration projects are being implemented to improve ecosystem health and restore natural fire regimes. Community planning efforts are emerging that will result in more fire-adapted communities. New and expanded urban forestry programs are improving the quality of life for urban residents. Conservation easements are now a common tool for protecting important working landscapes and open space. Forests and rangelands are helping meet the state's wood products and renewable energy goals, while contributing to rural economies. Currently, about 86 percent of forest industry timberland acreage is enrolled in a sustainable forestry certification program, and timber growth exceeds removals (harvest plus mortality) for each major ownership group (forest industry, nonindustrial, public).

As we move towards the middle of the 21st century, California's forests and rangelands face increasing threats and greater demands on the economic and environmental services they provide. Californians have proven that they can be at the forefront of tackling challenges such as climate change, where our state has become recognized as a world-leader. California's human capital has always been a major strength, and to continue to devise and implement solutions we will need to successfully draw on the considerable expertise of landowners, industry groups, resource professionals, academia, government, non-profits, and an engaged and informed electorate. Working together we can address the critical issues before us. The indicators presented in the 2017 Forest and Range Assessment report will help monitor our progress towards a sustainable future.

Ken Pimlott

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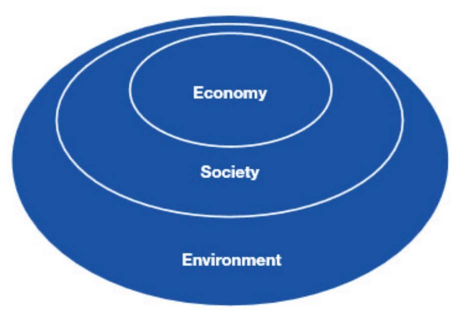
Executive Summary

There is increasing concern about the sustainability of our precious forest and rangelands, as the frequency and severity of mega-disturbances from fire and pests increases, human population demands more from and increases impacts on natural systems, and climate change continues. In California, events such as the recent multi-year drought resulting in over 100 million dead forest trees across 7+ million acres call into question current fire and land management policies and practices, and ultimately whether sustainability is possible under a changing climate and growing population.

Sustainability Definition

The concept of sustainability has a long history in forest management. It was initially limited to principles of sustained yield, to ensure that forest resources were not depleted over time. However, as our understanding of forest ecosystems has evolved, views on sustainability now encompass a complex suite of biotic and abiotic factors that are needed to ensure ecological as well as economic sustainability. This perspective that forest management must balance ecological and human needs is not new, but seems more imperative at a time where environmental conditions are shifting and impacts from disturbance are increasing. This is causing society to reevaluate what is needed to sustain healthy and productive forests. In particular, implementation of state climate change programs in California are requiring a broader definition of sustainability that includes a role for traditional timber production on working forests, but also emphasizes the need to manage forests for carbon, emissions avoidance, and a host of other environmental benefits.

For this report, we adopt a definition of "strong sustainability" based on the United States Forest Service (USFS) 2010 National Report on Sustainable Forests. According to the report, "The core concept of strong sustainability is that the benefits of nature are irreplaceable and that the entire economy is reliant on society, which in turn is entirely dependent on the environment. This emphasizes the interdependencies between our society, our economy, and the natural environment." The report adds that "Through sustainable management, forests can contribute to the resilience of ecosystems, societies, and economies while also safeguarding biological diversity and providing a broad range of goods and services for present and future generations."



Strong Sustainability

Use of Indicators to Evaluate Sustainability

This update to the California Forest and Range Assessment consists of over 40 indicators that collectively describe the status and trends of forest and rangelands across environmental and socio-economic dimensions. The indicators are based in part on the Montreal Process, an internationally recognized evaluation and reporting system. It consists of 7 criteria, each with a set of indicators to evaluate sustainability. FRAP developed and evaluated Montreal-Process-based indicators specific to California in 2003, and expanded the focus of each criterion to include rangelands. This report provides an updated set of indicators to evaluate California's forest and rangeland resources and measure progress towards sustainability.

In the Executive Summary, we evaluate each Montreal Process Criterion (MPC) by synthesizing the Assessment indicators across chapters to identify instances where multiple trends suggest sustainability is at risk. In addition, this allows us to identify policy issues that are part of addressing the problem.

Montreal Process Criterion 1: Conservation of Biological Diversity

Summary

Ecosystems in California are facing unprecedented pressures due to a combination of human disturbance (ⓘ10.3), wildfire (ⓘ4.4), pests (ⓘ5.1, ⓘ5.2), invasive species, and water quality impacts (ⓘ9.1). Climate change, which is disrupting historical disturbance regimes, is introducing uncertainty in how to best conserve and protect habitat and manage for healthy ecosystems (ⓘ10.4).

However, there is growing awareness and action to protect these ecosystems, for example through acquisitions and easements to protect habitat and working landscapes (ⓘ6.3). Sustainability initiatives are changing the way private timberlands are managed (ⓘ1.5). Federal agencies, often working collaboratively with the state and other partners, are involved in various ecological restoration efforts, including restoring natural fire regimes to improve ecosystem health. Research continues to have a critical role for anticipating climate impacts, and adapting policies and practices.

INDICATORS

- ⓘ1.5 Sustainability Initiatives
- ⓘ2.1 Rangeland Conversion
- ⓘ4.4 Wildfire Severity
- ⓘ5.1 Tree Mortality
- ⓘ5.2 Native and Exotic Pests
- ⓘ6.1 Population Trends
- ⓘ6.3 Protected Private Wildlands
- ⓘ9.1 Water Quality
- ⓘ10.1 Species at Risk
- ⓘ10.2 Habitat Structure
- ⓘ10.3 Habitat Degradation
- ⓘ10.4 Habitat Vulnerability to Climate Change
- ⓘ10.5 Protected Habitat
- ⓘ12.1 Renewable Energy

Background

A detailed accounting of wildlife sustainability concerns and conservation strategies is provided by the California Department of Fish and Wildlife's (CDFW) Statewide Wildlife Action Plan 2015 Update. The 2017 California's Forests and Rangeland Assessment focuses on specific concerns related to species at risk, habitat conversion and protection, habitat structure, habitat quality and degradation, and climate change impacts.

Species at Risk

Indicators and key findings strongly suggest that California's plant and animal species are experiencing increasing pressure. Of the approximately 7,500 plants and animals native to California, 408 are listed as threatened or endangered under either the California or Federal Endangered Species Act (ⓘ10.1). Fourteen of 32 salmonid species in California are listed, and scientists are concerned that 45% of salmonid species could be extinct within 50 years. A more

Nearly 1 of 6 California native plant and animal species are considered CDFW Species of Greatest Conservation Need.

comprehensive account of at-risk species in the state is provided by the CDFW list of Species of Greatest Conservation Need (SGCN), which consist of 1,153 species (264 invertebrates, 414 fish and vertebrates, and 475 plants). Nearly 1 of 6 California native plant and animal species are considered SGCN.

Habitat Conversion and Protection

Since 1850 about 98,000 acres of California forest and rangeland per year on average has been converted to other uses, mainly to agriculture and urban development. More recent rates (1992–2012) have been much lower, with about 25,000 acres per year converted to urban (ⓘ2.1).

Just under 58% of forest and range habitats are protected from conversion through public or conservation organization ownership, or more recently by a growing trend of purchasing conservation easements on private lands (ⓘ6.3). In 2016, conservation easements protected about 448,000 acres of forestland and 1.24 million acres of rangeland, many of which are working landscapes where timber management and grazing continue to contribute to local economies. High elevation vegetation types such as Red Fir, Subalpine Conifer and Aspen are at least 85% protected in almost all regions through public ownership. Nearly 80% of hardwood woodland habitat types are privately owned and thus have low protected status (e.g. Blue Oak Woodland (17%), Valley Oak Woodland (17%), Foothill Pine (24%) and Coastal Oak Woodland (35%)) (ⓘ10.5). The current uneven pattern of protected areas across ownerships and elevations creates issues for habitat connectivity. Easements are one way to expand and connect biologically important fragmented areas into more viable habitats.

Habitat Structure

There are continued concerns related to forest structure and wildlife habitat needs. Stand age and structure varies significantly by ownership group. Forests on private working lands are dominated by early- to mid-seral stand ages, while most late-seral stands (> 200 years old) are found on public lands. Currently 13% of California conifer forests are over 200 years old (ⓘ10.2), and are mostly high elevation types such as western white pine and lodgepole pine.

The Sustainable Forests chapter (Chapter 1) documents numerous trends that signify a change in the way California timberland is being managed, some of which could benefit wildlife. This includes increased use of uneven-aged silvicultural practices, managing forests to capture carbon, ecological restoration of Forest Service working forests, and new initiatives where agencies work collaboratively to improve forest health and resiliency, in part by restoring natural fire regimes.

Habitat Quality and Degradation

California's current population of 39.5 million residents is expected to grow by 354,000 new residents annually (ⓘ6.1), with consequential new development and infrastructure. The Conservation Biology Institute quantified terrestrial landscape intactness in the state based on a myriad of human impacts. Habitat types with extensive human disturbance (low intactness) are primarily coastal, foothill and riparian types, including Valley Foothill Riparian (71% low intactness), Desert Riparian (49%), Valley Oak Woodland (43%), and Coastal Scrub (33%) (ⓘ10.3).

Human settlement has also led to the introduction and spread of non-native invasive species, with dramatic ecological effects on plant and animal communities. Non-native invasive plants can decrease desirable plant biodiversity by out-competing native plants, changing soil fertility, increasing soil erosion, and altering fire frequency intervals. Detected occurrences of forest pest species (native and non-native insects and diseases) have tripled since the 1950's, and one third to one half are now non-native (ⓘ5.2).

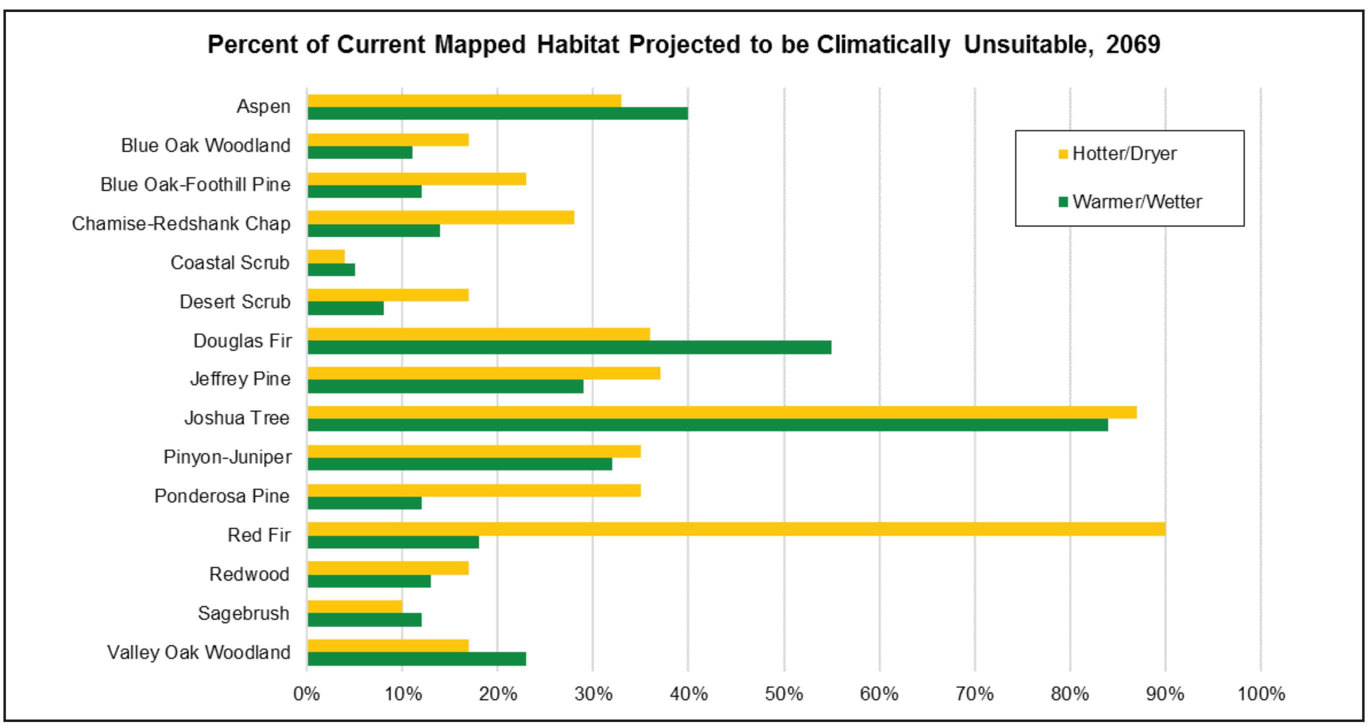
Recent trends indicate that fires are becoming more frequent, larger, and more severe (ⓘ4.4). Unlike fires representative of historic natural regimes, these larger "megafires" can alter habitat composition for long periods of time, lead to localized vegetation type conversions, warm streams, and alter flow and water volume. Post-fire hydrologic changes can increase sedimentation, initiate debris flows and endanger aquatic species and other terrestrial wildlife species. Megafires also kill small mammal, reptile, and amphibian species seeking shelter in burrows that survive in less intense natural historic fires. Such events could have profound effects on already compromised species that are vulnerable to stochastic population fluctuations.

Aquatic habitats are also vulnerable to a wide range of human impacts, resulting in degradation of water quality (ⓘ9.1), competition from invasive aquatic plants and animals, water temperature and turbidity impacts from vegetation changes, and impacts from wildfire events.

While meeting the State's renewable energy goals (ⓘ12.1) has many positive environmental benefits, large-scale wind and solar projects represent yet another impact on habitat quality. Minimizing these impacts will require considering conservation measures versus new energy development, promoting small-scale renewable energy options, and factoring in habitat considerations in the site selection process for large projects.

Climate Change Impact

Climate change imposes an additional threat to wildlife habitat. Modelling efforts under different climate scenarios predict that the quantity, quality and spatial distribution of habitat types will change. The figure shows the percent of the current distribution of each habitat type that will no longer be climatically suitable for that type by 2069, under two climate scenarios (ⓘ10.4). Habitat types such as Joshua Tree are projected to be severely impacted under both dry and wet future climate scenarios, and climatic impacts are already being observed. Model results also provide the spatial distribution of new areas that are projected to become climatically suitable for a given habitat type in the future, though actual future migration will depend on adaptability to various factors such as soils, competition with other vegetation, and disturbance regimes.



Policy Issues

The Statewide Wildlife Action Plan 2015 Update includes a full accounting of conservation strategies. The following table includes a set of the most relevant policy issues for forest and rangelands.

MPC1: Policy Issues for Conservation of Biological Diversity	
Policy Issues	**Options and Opportunities**
Protect Forest and Rangelands from Conversion	Resume Williamson Act state government subvention payments to counties. Sustain and increase efforts to protect biologically important areas and working landscapes through easements. Continue state and local efforts to reduce sprawl.
Wildlife Habitat Connectivity	Coordinate land acquisitions and easements to connect biologically important areas to each other, connect upland and downslope habitats, and expand and connect ecologically fragmented areas into more viable habitats.
Adaptation to Climate Change	Improve overall ecosystem health (see MPC3). Support research and adaptive management approaches for changing management practices to maintain resilient ecosystems as climate changes.
Water Quality and Riparian and Fish Habitat	Support increased capacity for CA Department of Fish and Wildlife to expand effective stream science, fisheries and watershed recovery and restoration and regulatory enforcement. Encourage stakeholder partnerships to protect local and regional habitats.
Ecosystem Health	Ecological restoration projects and treatments to restore natural fire regimes should include consideration of biodiversity and wildlife habitat.

Montreal Process Criterion 2: Maintenance of Productive Capacity

Summary

Maintaining productive capacity includes protecting forest and rangelands from conversion, or from being withdrawn from production through legal or administrative action. It also involves ensuring timber, grazing, and fire management policies and practices do not diminish site conditions and productivity.

Conversion rates to urban in recent years have been about 25,000 acres per year, almost all former rangeland (ⓘ2.1). Working landscapes are increasingly being protected from conversion through conservation easements (ⓘ6.3).

About 80% of productive forestland in the state is timberland that is available for timber production, only 20% is in reserved status. However, a variety of constraints limit more active management on both public and private lands.

INDICATORS

- ⓘ1.1 Growth, Removals, Mortality
- ⓘ1.2 Timberland Restoration
- ⓘ1.3 Silvicultural Methods
- ⓘ1.5 Sustainability Initiatives
- ⓘ2.1 Rangeland Conversion
- ⓘ2.3 Federal Grazing Allotments
- ⓘ4.4 Wildfire Severity
- ⓘ5.1 Tree Mortality
- ⓘ5.2 Native and Exotic Pests
- ⓘ6.3 Protected Private Wildlands

The Forest Practice Rules have evolved and forest managers are participating in various sustainability initiatives (ⓘ1.5) that are having a positive effect on sustainability. Overharvesting of existing growing stock does not appear to be an issue, as growth exceeds harvest and mortality on timberlands for each ownership group (ⓘ1.1). Significant concerns remain related to forest health and current stand conditions, due to past fire and land management policies and practices (see MPC3).

Climate change is introducing uncertainty and new concerns. Projections vary between climate models and emissions scenarios, but as much as 8% (1.4 million acres) of California timberland could no longer have suitable conditions to support commercial forest species by 2069. Similarly, climate change is projected to impact the distribution and quality of important rangeland vegetation types, with associated changes in productivity. There is evidence that we are experiencing secondary impacts of climate change, including increased frequency and severity of wildfire (ⓘ4.4) and pests (ⓘ5.1, ⓘ5.2), creating significant impacts on vegetation and site conditions, and timber and range operations.

Under two different future climate scenarios, between 3% and 8% of California timberlands will no longer have suitable conditions to support commercial forest species by 2069.

Background

California has some of the most productive land in the world for growing timber and grazing livestock. Since American colonization, about 98,000 acres of California forest and rangeland per year has been converted to agriculture, urban development and other uses (ⓘ2.1). This led to state programs under the Williamson Act (1965) and Forest Tax Reform Act (1976) aimed at protecting these lands from conversion through tax incentives. More recently, a growing awareness of the economic, social, and environmental importance of these lands is driving trends towards "smart growth" that reduces sprawl, and efforts to protect open spaces and working landscapes through land acquisitions and conservation easements (ⓘ6.3). In recent years, annual conversion of forest and rangeland to urban has averaged about 25,000 acres, almost all of it rangeland.

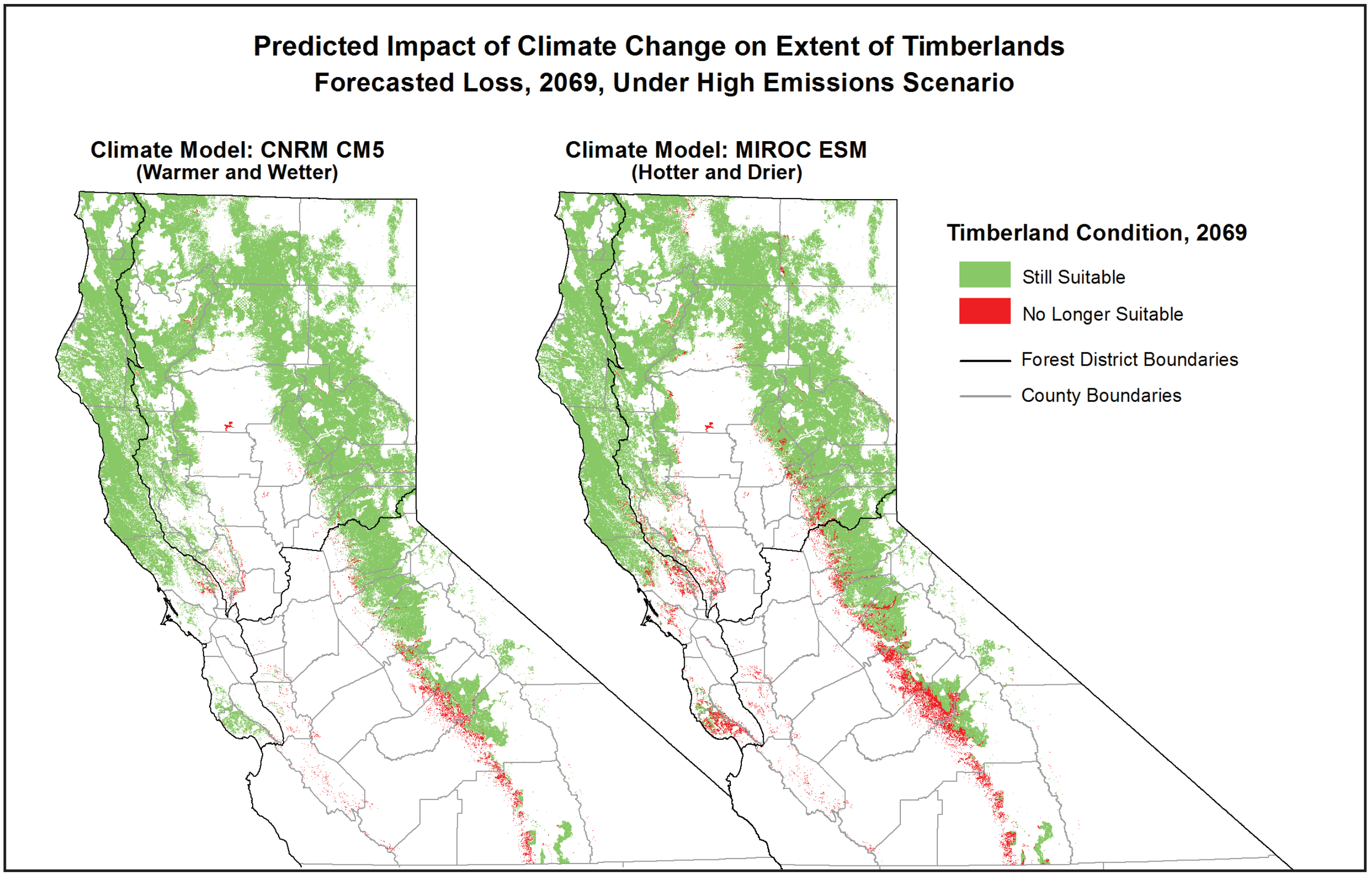
Even though about 80% of productive forestland in the state is available for timber production, a variety of constraints limit more active management on both public and private lands. In some parts of the state, lack of wood processing facilities severely limits marketing opportunities. Federal agencies such as the Forest Service have a limited budget that restricts more active management to meet harvesting and restoration goals. Landowner assistance programs have limited resources for providing smaller private owners with technical or financial assistance for planning and conducting management operations.

Productive capacity is also influenced by past timber, grazing, and fire policies and practices, and the resulting condition of the land and vegetation. For timberlands, MPC3 gives a detailed summary of issues related to forest health that are a major concern for the ongoing ability of these lands to grow timber. Based on forest inventory data (from FIA), stand condition (ⓘ1.2) is a major issue including understocked, overstocked, and hardwood dominated timberlands. The Forest Practice Rules have evolved and forest managers are participating in various sustainability initiatives (ⓘ1.5) that are having a positive effect on sustainability. Overharvesting of existing growing stock does not appear to be an issue, as growth exceeds harvest and mortality on timberlands for each ownership group (ⓘ1.1).

For rangelands, comprehensive statewide monitoring data is lacking for range condition. However, invasive plant species, many of them non-native, continue to persist and spread, lowering the forage quality for livestock over large areas of grasslands and oak woodlands. They can form monotypic stands that may decrease forage production by as much as 50–75%. The trend in reduced federal grazing allotments (ⓘ2.3) could impact the ability of certain ranchers to remain viable, where leased lands are an integral component of their overall operations.

Climate Change Impact

An emerging concern is the impact of climate change on productive capacity. Under the high greenhouse gas emission scenario simulated in two different climate models, by 2069 between 3–8% of California timberlands will no longer have suitable conditions to support the tree species that are of primary commercial value in California. These former timberlands will likely transition into montane hardwood, oak woodland, shrub, or grassland, with different ecological and economic values. For both modeled scenarios, most of these losses are in the Southern Forest District, especially in lower elevations of the southern ranges of the Sierra Nevada. Many of these areas are currently experiencing high mortality from extended drought, forest pests, and large wildfire events. These impacts are consistent with climate model predictions and observed impacts occurring across drier forests in the Western U.S.



Similarly, climate change is projected to impact the distribution of important rangeland vegetation types, with associated changes in productivity. Changes in precipitation patterns, and drought frequency and severity, could also have major impacts on ranching operations.

Climate change is projected to have other impacts on productivity, which vary by region and vegetation type. Growth and mortality rates for different timber species will be impacted, and there is evidence that in some areas tree growth rates could increase. There will also be changes in composition for mixed species vegetation types. For example, since the recent drought, some annual grassland areas in eastern San Luis Obispo County changed in grass species composition from soft chess (*Bromus hordeaceus*), which is considered good forage, to red brome (*Bromus madritensis*) which is of lower forage quality. Because red brome is already dominant in annual grassland areas further south, this is consistent with the type of change expected with a warming climate. It remains to be seen whether this change is permanent, or whether soft chess returns with better rainy seasons.

There is evidence that we are experiencing secondary impacts of climate change, including increasing frequency and severity of disturbance events from wildfire (ⓘ4.4) and pests (ⓘ5.1, ⓘ5.2), which are having significant impacts on vegetation condition, and timber and range operations. On timberlands, this has contributed to a major increase in acres filed for harvesting under Emergency Conditions (1052.1(b)) (ⓘ1.3). In 2015, these filings accounted for 10%, 23%, and 89% of total acres filed for harvest in the Coast, Northern, and Southern Forest Districts, respectively. Efforts to improve forest health (see MPC3), and restore natural fire regimes on both forest and rangelands will be critical for maintaining productive ecosystems that are resilient to the impacts of climate change.

Policy Issues

MPC2: Policy Issues for Maintenance of Productive Capacity	
Policy Issues	**Options and Opportunities**
Forest and Rangelands Conversion	Resume Williamson Act subvention payments to counties. Sustain and increase efforts to protect working landscapes through easements.
Forest and Rangeland Health	See MPC3 for detailed discussion of forest health issues. Restoring natural fire regimes would also improve rangeland health.
Climate Change	Improve overall ecosystem health (see MPC3) to maintain resiliency and reduce climate change impacts. Support research and adaptive management approaches for changing management practices to maintain resilient ecosystems as climate changes.
Landowner Assistance	Continue and enhance efforts to provide technical and financial assistance to small landowners to improve productivity, and forest and rangeland health. Expand CAL FIRE nursery operations to provide seedlings to landowners for replanting following tree mortality from pest outbreaks and wildfire.

Montreal Process Criterion 3: Maintenance of Forest Ecosystem Health and Vitality

Summary

Current stand conditions (ⓘ1.2, ⓘ4.1) and trends related to climate change and disturbance regimes combine to raise serious concerns about forest health. California has recently experienced widespread forest tree mortality, pest outbreaks, and uncharacteristically severe wildfires. Trends suggest a continued increase in wildfire activity (ⓘ4.3), wildfire severity (ⓘ4.4), tree mortality from pests and drought (ⓘ5.1), and incidence of non-native pests (ⓘ5.2). These trends are consistent with secondary impacts related to climate change, specifically changes in temperature (ⓘ7.1), precipitation patterns (ⓘ7.2), and cumulative water deficit (ⓘ9.4). Assessment analyses also raise concerns about the ability of various forest types to persist in some areas under future climate conditions (ⓘ10.4).

Background

Current tree stocking levels (ⓘ1.2), departure from historic fire regimes (ⓘ4.1), and increased fire severity (ⓘ4.4) (particularly in yellow and mixed conifer forests) are significant components of the forest health problem, and are symptomatic of past and current fire and land management policies. The Assessment chapters suggest numerous opportunities to address these problems, many of which are already being implemented (ⓘ4.5), but at insufficient levels due to various constraints. For example, the Forest Service has developed ecological restoration goals to create more resilient forest stands, but funding levels are not adequate to meet treatment

INDICATORS

ⓘ1.2 Timberland Restoration
ⓘ1.3 Silvicultural Methods
ⓘ4.1 Fire Return Interval Departure
ⓘ4.3 Wildfire Activity
ⓘ4.4 Wildfire Severity
ⓘ4.5 Vegetation Treatments
ⓘ5.1 Tree Mortality
ⓘ5.2 Native and Exotic Pests
ⓘ7.1 Temperature
ⓘ7.2 Precipitation
ⓘ9.4 Cumulative Water Deficit
ⓘ10.4 Habitat Vulnerability to Climate Change

Current stand conditions and trends related to wildfire, pests, and climate combine to raise serious concerns about forest health, particularly for yellow pine and mixed conifer forests.

goals. Improving stand conditions on nonindustrial lands is constrained by lack of participation in active forest management, in part due to regulatory costs and limited government funding for technical and/or financial assistance. In many parts of the state, lack of wood processing (including biomass energy) infrastructure constrains the ability of small owners to market timber, and all owners to market low value removals typical of thinning or salvage operations.

Tree Stocking Levels

Based on 2006–2015 forest inventory data (FIA), total acres potentially in need of treatment to improve stocking ranges from 5.5 to 9.5 million, which includes overstocked, understocked, and higher site hardwood-dominated timberlands (ⓘ1.2). Stocking is an issue on public, forest industry, and nonindustrial timberlands. Overstocked stands range from 0.6 to 4.7 million acres (depending on the definition of overstocking) and have elevated fire and pest risk that can threaten these stands as well as surrounding landscapes.

Hardwood dominated timberlands are a natural component of the landscape, but have expanded in some areas due to past disturbances or management. Restoration treatments to commercial conifer species are more economically feasible on higher site quality lands, such as the 1.4 million acres in sites 1, 2, and 3. About 41% of these acres are in the tanoak/laurel type, typically areas on the North Coast region where redwood and Douglas-fir have been displaced by hardwoods due in part to past timber management.

Fire Return Interval Departure

Fire Return Interval Departure (FRID) measures the departure of current fire regimes from historic (pre-European settlement) regimes, in terms of average number of years between burn events. Acres by vegetation group are characterized by degree of departure, or condition class (ⓘ4.1).

Areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are burning less frequently than they did in the pre-settlement era, with over 75% of these vegetation types by area in the high departure class. This is most evident in the Sierra Nevada, Southern Cascades and Klamath-North Interior mountain ranges. Some shrub-dominated areas are burning more frequently than in the pre-settlement era, with 20% by area in moderate and 3% in high departure across the state (and much higher in the South Coast region).

Fire Return Interval Departure by Vegetation Group, 2016

Vegetation Group	Mapped Area (million acres)	Percent of Mapped Area in Each Condition Class					
		-3	-2	-1	1	2	3
		< Fire more frequent than reference -			- Fire less frequent than reference >		
Conifer	16.2	<1%	2%	<1%	15%	11%	71%
Hardwood	7.5	<1%	<1%	3%	6%	14%	76%
Mixed Conifer-Hardwood	6.1	<1%	<1%	1%	5%	13%	80%
Shrub	16.0	3%	20%	16%	17%	22%	22%
All	**45.8**	**1%**	**8%**	**7%**	**13%**	**15%**	**56%**

Fire Severity

Yellow pine/mixed conifer are the most extensive forests in the state. These forests evolved with, are adapted to, and were sustained by frequent low-severity fires, with 4–13% of wildfire area burning at high severity in the pre-settlement era, supporting fine-scale variation of forest structure. Interruption of natural fire frequencies (ⓘ4.1) and changes to forest structure from over a century of fire suppression and timber harvest have resulted in overly dense, structurally homogenous forests with too few large, fire-tolerant trees. High-severity burning that is out of the natural range of variability for these forests may lead to long-term changes in forest area, composition, or structure. The increasing incidence of large, spatially simple patches of high-severity fire are of particular concern, as they may lead to large-scale tree regeneration failure and type conversion to shrub- or grass-dominated vegetation, as well as having negative impacts on soil productivity, water quality, wildlife habitat, and carbon storage.

For at least 30 years the average proportion of high severity in yellow pine/mixed conifer wildfires (23–32%) has been outside the historical range (4–13%). High severity patches are becoming larger and less complex in yellow pine/mixed conifer forests, leading to regeneration failure, reduced snowpack retention, and increased erosion potential.

Policy Issues

To address forest health concerns, the February, 2018 Little Hoover Commission Forest Management report has nine recommendations which align well with opportunities provided in this assessment. This includes:

> "Recommendation 8: The Tree Mortality Task Force should evolve into a forest management planning entity, with dedicated funding.
>
> - It should help set a strategic direction for forest management, identify measurable goals, decide how to track results and recommend course corrections to better achieve those goals.
> - It should advise on how to incorporate technology in assessing and improving forest health.
> - This should include reviewing the planning process and developing recommendations on where streamlining can occur."

This entity could provide for an ongoing multi-agency landscape-level approach to solving institutional and/or policy issues that could facilitate more rapid and widespread implementation of the recommendations in the Commission report, opportunities in this assessment, and goals/objectives/targets from the Forest Carbon Plan.

Some of the policy issues identified in the Assessment most relevant to forest health include:

MPC3: Policy Issues for Maintenance of Forest Ecosystem Health and Vitality	
Policy Issues	**Options and Opportunities**
Restoration of Natural Fire Regimes	Support collaborative landscape-level efforts, to meet Forest Service and State treatment goals and improve forest health across all ownerships.
Wood Processing Infrastructure Deficit	The Little Hoover Commission called for the state to develop a long-term plan for forest materials. This could lead to more specific tactics such as grants for community wood processing infrastructure.
Nonindustrial Forest Management	Reduce barriers for more active management to maintain productive and resilient forests, including regulatory cost reduction, increased marketing options, and increased availability of technical/financial assistance.
Adapting Policies and Practices for Climate Change	Support critical research needed to anticipate changes and adapt policies and practices for climate change.

Montreal Process Criterion 4: Soil and Water Resources

Summary

The sustainability of California's water resources is being tested. With a large and growing population, the demand for water continues to increase, while supply and supporting water infrastructure are limited. At the same time, our water resources are threatened by climate change, including increased drought frequency and changing disturbance regimes (e.g. wildfire and pest outbreaks) that impact the ability of forests to deliver our water supply.

INDICATORS

- ⓘ4.3 Wildfire Activity
- ⓘ4.4 Wildfire Severity
- ⓘ7.1 Mean Annual Temperature
- ⓘ9.1 Water Quality
- ⓘ9.2 Snow Pack
- ⓘ9.3 Spring Runoff
- ⓘ9.4 Cumulative Water Deficit

Forest Practice Rules (FPR) have evolved and been strengthened to protect soil and water resources on forestlands through rules related to Water and Lake Protection Zones (WLPZ), road maintenance, and water crossings. Monitoring studies confirm that these rule changes are in fact having an impact on reducing erosion and improving water quality.

Rangeland practices are not regulated under a comprehensive system similar to the FPRs. However, under the Clean Water Act the Total Maximum Daily Load (TMDL) provides a way to monitor the impacts of grazing, and take corrective action when necessary. There are rare instances where the TMDL process has been used to require additional actions on both forest and rangelands that impact land management practices.

There are signs that California can achieve sustainable water use. Water use efficiency has increased in recent decades; irrigation in agricultural crops are using less water; water conservation in urban areas has made great reductions in time of need. There is also a growing recognition that healthy forest and rangelands, including urban forests, are critical to our social and economic well-being. This is translating into various ecological restoration actions that will improve the sustainability of soil and water resources.

Background

Healthy forests play an important role in the hydrologic cycle, promoting infiltration, holding soil on slopes, and maintaining the delivery of high-quality water to streams and downstream uses. While forests play a pivotal role in maintaining the delivery of high-quality water, these resources have been undervalued. In many watersheds, the type of management and fire exclusion has resulted in forests that are either at risk from fire and pests, or have already been impacted. In addition, post-fire erosion from large wildfires and other disturbances can negatively impact water quality, downstream water storage, and other critical water infrastructure.

An estimated 60% of California's water supply comes from forest areas. Restoration of headwater forests is essential to provide a reliable source of water to downstream uses.

Indicators and key findings suggest that California's climate and hydrology is changing, resulting in warmer annual temperatures, with increases in both maximum and minimum temperatures (ⓘ7.1). In turn, warmer temperatures are causing declining snowpack (ⓘ9.2) and altering the timing of spring runoff (ⓘ9.3). As snowmelt begins to occur early in the spring we are likely to see longer dry periods and an increase in wildfire activity (ⓘ4.3) across a longer fire season. In addition, as evapotranspiration from forest vegetation increases under warmer temperatures, vegetation becomes further stressed by prolonged drought conditions. When these climatic factors are combined with high-risk stands, forests face increased threat from both pests and severe wildfires.

Soil Erosion and Water Quality

On private timberlands, the Forest Practice Rules (FPR) establish minimum standards for forest management. These rules include protections for both soil and water resources. The Board of Forestry's Monitoring Study Group (MSG) acts as an advisory committee to the Board on evaluating the effectiveness of FPR. FPR that are designed to minimize erosion and protect water quality include Water and Lake Protection Zones (WLPZs), road construction and maintenance, and road water crossings. A recent MSG study (2008–2013) found that forest canopy exceeded WLPZ standards for Class I and Class II watercourses. In addition, road-related FPRs were found to be effective in preventing erosion and sediment transport into stream channels. Water course crossings with their direct proximity to streams can represent a higher risk of impairment to water quality. The same MSG study found approximately two-thirds of THP watercourse crossings meet or exceed FPR standards.

Rangeland practices are not regulated under a comprehensive system similar to the FPRs. However, under the Clean Water Act the Total Maximum Daily Load (TMDL) provides a way to monitor the impacts of grazing, and take corrective action when necessary. Water quality indicators show that a greater proportion of rangeland water courses show higher levels of impairment compared to forested streams (ⓘ9.1). Water quality impacts from grazing tend to be associated with nutrient concentrations, bacteria and sediment.

Wildfire Activity

Wildfire activity has increased dramatically in recent decades and currently averages over 500,000 acres burned annually (ⓘ4.3). In addition, the proportion of landscape that burns at high severity in pine/mixed-conifer wildfire is well beyond the historic range. The combination of more extensive areas burned and greater proportion at high severity places a greater risk to post-fire erosion and water quality. Mudslides such as those following the 2017 Thomas fire, in Ventura and Santa Barbara counties, illustrate the elevated risk to public safety.

Protection and Restoration of Headwater Forests

Headwater forests play a critical role in our water supply and water management system. They are threatened by factors ranging from climate change, to changes in disturbance regimes and management approaches that vary among mixed ownership. Forests with high stand densities compete for limited resources and are subject to higher disturbance and mortality rates. The conditions result in changes to disturbance regimes that can impact water resources. Many of the management actions taken to reduce wildfire risk and improve forest health can also serve to restore and enhance water resources in headwater forests. In addition, mountain meadows are an important feature in headwater regions that have been degraded and in some cases impaired to the point that they no longer provide the hydrologic function associated with meadows.

Policy Issues

MPC4: Policy Issues for Soil and Water Resources	
Policy Issues	**Options and Opportunities**
Water Supply and Quality Protection and Improvement on Livestock Grazed Rangelands	Federal and State programs providing funding and technical assistance to build and/or maintain livestock watering infrastructure according to BMPs.
Protection and Restoration of Headwater Forests	Prioritize funding for restoration of headwater forests, target fuel reduction and expanded use of prescribed fire and managed fire, restoration of forests subject to severe wildfire. Restoration of mountain meadows. Where practical, work with ranchers to develop agreements to retire or modify grazing practices in allotments with ecologically and hydrologically important mountain meadows.

Montreal Process Criterion 5: Forest Contribution to Global Carbon Cycles

Summary

Forests play a fundamental role in regulating global carbon cycles by storing carbon in above-ground vegetation and in soils, and exchanging CO_2 with the atmosphere. As global warming increases (ⓘ7.1), there are concerns that forests will struggle to adapt to rapid changes in climate and altered disturbance regimes. As a result, some forest types may not be sustainable under future climate conditions.

From 2006–2015, California forests functioned as net carbon sinks, as more carbon was added through growth than was removed via harvest, mortality, pests, or wildfire (ⓘ7.4). However, the long-term sustainability of our forests to continue to operate as net sinks is at risk. Current stand conditions combined with the increasing frequency of mega-disturbance events from wildfire (ⓘ4.3), pests (ⓘ5.2) and associated tree mortality (ⓘ5.1) have the potential to drastically impact the quantity, quality and stability of carbon storage in affected areas.

In addition, as temperatures continue to increase due to climate change, the quality of life in many urban areas in the state will be negatively impacted by impervious surfaces (ⓘ3.2) absorbing solar radiation to create Urban Heat Islands (UHI). Urban forest tree canopy cover (ⓘ3.1) will be increasingly important for mitigating these effects through direct shading, lowering temperatures through evaporative cooling, and reducing energy consumption.

INDICATORS

- ⓘ1.6 Carbon Offset Projects
- ⓘ3.1 Tree Canopy Cover
- ⓘ3.2 Impervious Surfaces
- ⓘ4.3 Wildfire Activity
- ⓘ4.4 Wildfire Severity
- ⓘ5.1 Tree Mortality
- ⓘ5.2 Native and Exotic Pests
- ⓘ7.1 Temperature
- ⓘ7.2 Precipitation
- ⓘ7.3 Carbon Storage - Forests
- ⓘ7.4 Carbon Sequestration
- ⓘ9.3 Spring Runoff
- ⓘ9.4 Cumulative Water Deficit
- ⓘ12.2 Biomass Energy

Background

California has among the most productive temperate forests in the world, which provide numerous ecosystem services, from timber to fresh water to wildlife habitat. Our forests also serve as vital sinks for atmospheric CO_2 (a primary greenhouse gas), in living and dead standing plants, down logs, forest litter, soils, and long-lived durable wood products (ⓘ7.3, ⓘ7.4). Through natural processes and proper sustainable management, these carbon banks can continue to function through time, sequestering biologically active and atmospheric carbon for timescales from decades to centuries. Managing to maintain forest health, with associated benefits including carbon, is summarized under MPC3, and climate impacts to productive capacity are addressed under MPC2. The FRAP Assessment report provides estimates of carbon storage and sequestration rates by major ownership groups. A more comprehensive reporting of carbon stored in forests and wood products can be found in the Board of Forestry and Fire Protection's AB 1504 report (AB 1504 California Forest Ecosystem and Harvested Wood Product Carbon Inventory: 2006–2015).

Managing for forest health is the overarching principle for maintain long-term sustainable carbon storage on forest lands.

Climate Trends and Implications

Over the last 100 years, air temperature has shown steady increases, and future climate change scenarios predict that trend to continue (ⓘ7.1). By contrast, the annual amount of precipitation has shown no clear trend (ⓘ7.2). However, increases in temperature alone will result in changes in spring runoff (ⓘ9.3), and increases in climatic water deficit (ⓘ9.4). Altering these climate drivers can result in changes in tree growth, range and distribution of species, and disturbance regimes. These include changes in the amount (ⓘ4.3) and intensity (ⓘ4.4) of wildfires, pest infestations (ⓘ5.2), and other agents of disturbance, which have implications for the quality and stability of California's forest carbon sinks.

Carbon Storage and Sequestration Rates

In 2015, total carbon storage in above and belowground living and dead plant materials in California's forests is just over 2 billion metric tons. Two-thirds of carbon storage is found on federal, state, and other public lands. Total carbon storage is greatest across the Sierra/Cascades (0.95 billion metric tons), Klamath/Interior Coast Ranges (0.57 billion metric tons), and North Coast regions (0.27 billion metric tons). Based on changes in the aboveground live tree pool in 2015, California forests sequestered 0.79 metric tons (MT) CO_2e/acre/year, equating to 23.9 MMT CO_2e/year. For perspective, this would be equivalent to sequestering 5% of the total greenhouse gas emissions reported in the state for 2015.

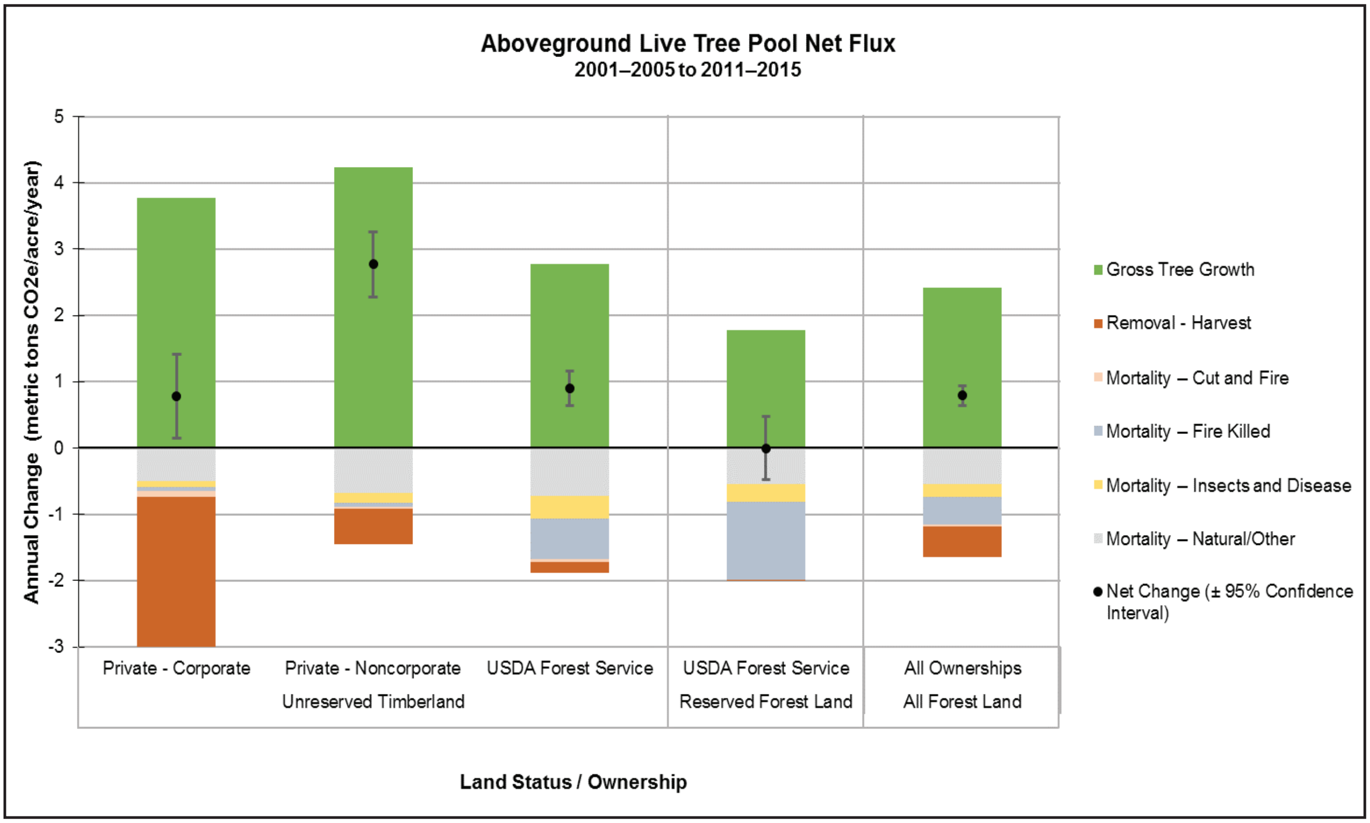
When flux from all forest pools are accounted for, as well as non-CO_2 emissions from fire and flux from forest land-use conversions, net sequestration is 32.8 MMT CO_2e/year. When forest biomass is burned for energy (ⓘ12.2) instead of fossil fuels or burning on-site, there can be additional climate mitigation benefits in the form of avoided fossil fuel or fire emissions. Additional climate mitigation benefits are possible if wood is used in place of more energy-intensive products like cement or steel. These potential substitution benefits can be difficult to quantify.

Carbon Sequestration by Ownership Groups

Fire and land management policies involve trade-offs between carbon sequestration, carbon storage in live trees versus wood products, and risk of loss from wildfire and pests. For example, intensive management for wood products as practiced by forest industry (often on the most productive timberlands in the state) results in high rates of sequestration, low levels of mortality, and harvest resulting in carbon storage in wood products. These lands sequester an estimated 0.75 MT CO_2e/acre/year in the live tree pool, not including additional carbon flux in other forest or harvested wood product pools. Conversely, reserved lands are associated with much higher levels of carbon storage, but much lower levels of sequestration, and higher rates of tree mortality. Mortality outpaces growth in the live tree pool on USFS reserve forestlands at the rate of -0.20 MT CO_2e/acre/year.

Forest Carbon Projects

The relatively new concept of "carbon forests" (ⓘ1.6), where landowners are compensated for adjusting management practices for carbon considerations, underscores that there are different notions of how to manage for carbon. Carbon forest projects approved by the Air Resources Board (ARB) typically involve uneven-aged management and longer rotations. The majority of ARB projects are in the wetter and cooler north coast redwood forests, where growth rates can be sustained over longer periods using uneven aged systems, and where risk from fire and pests is relatively low. In drier forests of the Sierra and Cascades, aboveground carbon storage in trees has greater risk of loss from wildfire and pest outbreaks. In these regions, there are numerous carbon projects approved by the Climate Action Reserve (CAR) that involve intensive even-aged management with inventory control to maximize sequestration, along with somewhat longer rotations before harvest.



Measures to Promote Sustainable Management of California's Forest Carbon Resources

In many forest types current stocking levels reflect over a century of fire suppression and may not represent stand densities that are resilient to disturbances common to California forests such as fire or pest outbreaks. Additionally, as the forests age in unharvested stands, growth rates slow. Older forests tend to store more carbon, but they might not accumulate new carbon as quickly as younger, fast growing stands. Consequently, the stocks and flux represented in this report may not be sustainable in the future without forest management.

Forests perform a wide range of ecosystem services and are managed for a wide range of economic, ecological, and aesthetic values. Not all of these values and objectives are compatible with minimizing net carbon emissions to the atmosphere, but opportunities for integrating carbon goals with existing management goals likely exist. If mature forests are approaching carbon sink saturation due to slowing tree growth rates and there are no other management concerns, or there is a need to reduce stand densities for other forest health objectives, climate mitigation strategies can aim to maximize the sum from forest ecosystem carbon stocks, harvested wood product carbon stocks, and wood material and energy substitution to maintain and enhance forest ecosystem carbon stocks while also increasing carbon benefits from harvested wood products.

Managing for healthy forests is essential for their continued carbon sequestration, and is a central goal of the state government through such measures as AB 1504, AB 32 Carbon Offset Projects, Timber Harvest Plans, and the Forest Carbon Plan. Under AB 32, more than 350,000 acres of California forest are now registered as carbon projects (ⓘ1.6). Various new funding sources such as the Greenhouse Gas Reduction Fund and Timber Regulation and Forest Restoration Fund (AB 1492) are now available in part to support projects promoting forest health. Adjusting to the effects of a changing climate will require ongoing research and adaptive management to maintain resilient forests under dynamic conditions.

The Forest Carbon Plan provides information on statewide strategies to maintain and enhance long-term forest carbon storage. Also, see the Safeguarding California report and AB 32 Scoping Update for additional discussion of policy issues and strategies for carbon management on forest lands.

Policy Issues

MPC5: Policy Issues for Forest Contribution to Global Carbon Cycles	
Policy Issues	**Options and Opportunities**
Forest Health	See MPC3; Forest Carbon Plan; Safeguarding California (Forestry Chapter)
Increase Carbon Storage in Forests and in Wood Products	Forest Carbon Plan
Urban Heat Islands	Maintain and enhance urban tree cover.

Montreal Process Criterion 6: Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

Summary

Forests (including urban forests) and rangelands in California provide a wide range of benefits including wood products, livestock forage, recreation, water, carbon storage, renewable energy, and amenity values. However, these ecosystems have been stressed by past land and fire management policies and practices, and continued population growth. Indicators suggest increasing stress on ecosystem health from climate change, and from associated changes in disturbance regimes related to fire and pests. Increasing stress on ecosystems threatens the sustainability of the numerous services provided by these lands, and to lives and property from more frequent and severe disturbance events.

Economic indicators show signs of a resilient economy with low unemployment, but income inequality is increasing and wage growth has stagnated. Economic activity from wood products and grazing are becoming a relatively smaller component of rural economies, as they diversify and transition towards more service-based industries. There are also many social factors that limit participation in rural economic growth and prosperity.

INDICATORS

- ⓘ1.4 Timber Harvest
- ⓘ2.2 Beef Cattle Farms
- ⓘ6.1 Population Trends
- ⓘ8.1 Relative Performance
- ⓘ8.2 Economic Trends
- ⓘ8.3 Economic Prosperity
- ⓘ8.4 Social Stress
- ⓘ8.5 Economic Structure
- ⓘ11.1 Structure Loss
- ⓘ11.2 Housing by Hazard Class
- ⓘ11.3 Housing in WUI
- ⓘ12.1 Renewable Energy
- ⓘ12.2 Biomass Energy

Background

Forest and rangelands provide wood products, grazing for commercial livestock, and a host of essential environmental services. Timber harvesting and cattle ranching operations in California have declined in recent decades and are now a smaller part of the overall economy (ⓘ1.4, ⓘ2.2). However, the demand for renewable energy, carbon storage, water and other ecosystem services from these lands is increasing. In addition, forest and rangelands provide

Ecosystem health is a foundation for maintaining socio-economic benefits. It represents a bridge between the environment, the services it provides, and human well-being.

recreational opportunities and other amenities that are part of the reason people live in or near these lands. In urban areas, trees provide a different suite of benefits that improve environmental conditions and quality of life.

At a time when forest and rangelands are being asked to maintain and enhance environmental benefits, these same landscapes are under increasing stress from population growth (ⓘ6.1) and development patterns (ⓘ11.2, ⓘ11.3), climate change, and more frequent and severe fire and pest events. Increased environmental stress can result in declining ecosystem health that threatens sustainability of socio-economic benefits including the economic well-being as well as quality of life for rural communities.

Declining ecosystem health can also increase the threat from fire and pest events for rural residents, with devastating consequences. Recent examples include massive drought-induced tree mortality, extreme losses of life and property from wildfire events, and post-fire flood and mudslide events. Opportunities exist to accelerate and augment various efforts to restore ecosystem health (see MPC3), which can reduce these threats, create economic activity, and contribute towards sustainability of socio-economic benefits.

In urban areas, population growth and climate change combine to threaten quality of life. Vulnerable groups tend to have higher levels of exposure to environmental impacts and are at greater risk to declining ecosystem health. Local government along with various private organizations are becoming increasingly active in implementing and expanding programs to sustain and enhance the myriad of quality of life benefits provided by urban forests.

California's economy has been resilient and has shown signs of recovery from the most recent recession (ⓘ8.1), but there is variability among rural communities based on the degree of connectedness to larger metropolitan areas. In addition, there are populations at risk and vulnerable households that are associated with increased hardship that degrade the quality of life and exclude some from participating fully in economic growth and prosperity. Diversification of rural economies is important for their sustainability, including how forest and rangelands are used (e.g. renewable energy, recreation, niche markets, value added products), and the types of industries that rural communities support.

Rural Economies - Trends

In recent decades, the structure (ⓘ8.5) of the rural economy has become less dependent on forest products. For example, jobs in timber employment shrank by 50% from 1998 to 2015. By contrast, in the last 15 years (2001–2015) non-government service-related employment accounted for 77% of the total share of jobs. The forest products industry is still an important component of rural California, but it is a smaller part of the overall economy. While timber production and forest sector jobs has been declining for decades, there is still a demand for wood products that is supported by imported lumber.

The economy in rural California outperforms nation-wide non-metro (rural counties) in terms of employment, population, and increases in personal income (ⓘ8.1). Similar to statewide figures, unemployment is low (ⓘ8.4) and jobs have been increasing for several years since the recession. However, while per capita income has risen 75% since 1970 (ⓘ8.3) there are strong signs of income inequality and stagnate wages. For example, average earnings per job has remained flat, showing an increase of only 3% from 1970–2016.

Wildfire - Community Impacts

As wildfire activity and severity have increased in recent decades, communities have faced elevated risk and structure loss has increased (ⓘ11.1). Statewide, the Wildland Urban Interface (WUI) footprint spans across 17.7 million acres, including 1 million acres of Interface, 1.3 million of Intermix, and a 15.3-million-acre influence zone. There are an estimated 2.2 million housing units within the WUI footprint, 83% of which are in dense Interface, and 17% of which are in more sparsely populated Intermix (ⓘ11.3). In addition, over one million housing units fall within a Very High Fire Hazard Severity Zone (ⓘ11.2).

1.2 million houses within the WUI footprint are in areas classified as residing in a Very High Fire Hazard Severity Zone.

For communities in rural fire-prone areas, the threat to public safety, loss of property, and rising economic costs of fire suppression and post-fire recovery are becoming unsustainable. This is driving a need to reevaluate land use planning, pre-fire management, and investments in ecosystem health.

Renewable Energy

Based on current trends (ⓘ12.1), meeting the Governor's Renewables Portfolio Standard (RPS) mandate (SB 350) that utilities procure 50% of their electricity from renewables by 2030 will require a continuing major expansion of solar and wind energy production. Public policies can affect the balance of large solar and wind facilities versus small-scale use for homes and businesses, and whether large projects are sited on leased public lands or private lands with lower ecological values (e.g. marginal agricultural lands). Renewable energy industries provide a relatively new economic opportunity for some rural areas, but also another demand and potential impact on forest and rangelands.

Current trends (ⓘ12.2) also suggest that biomass energy will not be a significant contributor to renewable energy expansion. However, about 9 small biomass plants are in various stages of development because of SB 1122 (2012), which supports plants that supply 3 MW or less to the grid, and use for feedstock forest residues from sustainable forest management, fire threat reduction, or defensible space clearance activities. While too small to make much contribution to RPS targets, these plants could be important in certain localities for improving forest health, reducing fire risk, and supporting rural economies.

Policy Issues

MPC6: Policy Issues for Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

Policy Issues	Options and Opportunities
Limited Job Opportunities in Rural Communities	Increase education and training opportunities for rural communities. Provide incentives for businesses to locate in rural disadvantaged communities. Support Governor's designation of Opportunity Zones. http://dof.ca.gov/Forecasting/Demographics/opportunity_zones/
Expanding Renewable Energy to Meet 2030 Targets for 50% Energy from Renewable Sources	Support policies for small-scale renewable energy that contribute to the local economy. Promote urban programs that increase energy conservation.
Declining Health and Well-being	Improve access to health care. Support programs that address opioid addiction and return people back into the workforce.
Restoring Ecosystem Health	See MPC3
Maintain Urban Quality of Life	Continue to support local urban forestry programs, including tree planting and maintenance.

Montreal Process Criterion 7: Legal, Institutional and Economic Framework for Conservation and Sustainable Management

Summary

Overall, California is a leader in promoting sustainability. California has an advanced and effective system for environmental assessment, monitoring, regulation, and enforcement to address sustainability of forests and rangelands. Historically, federal laws for endangered species, clean water, clean air, and environmental protection represent minimum standards that California often exceeds with State laws.

INDICATORS

- ⓘ1.5 Sustainability initiatives
- ⓘ11.4 Community Planning
- ⓘ12.1 Renewable Energy
- ⓘ12.2 Biomass Energy

California has a variety of programs and initiatives that augment the considerable federal resources devoted to education, monitoring and assessment, research, funding for collaborative projects, and landowner assistance. It also has a population that is generally engaged in environmental issues in terms of activism, volunteerism, and voting.

Background

This criterion is broad, and will be summarized for the following topics: legislation, policies, and programs; taxation, economic policies, and investment; collaboration and partnerships; public participation; research and education; and assessment and monitoring.

In 2011, under AB 32 California became the first state to adopt a cap and trade policy for greenhouse gas emissions.

Legislation, Policies, and Programs

Environmental issues are complex and this is reflected in the laws, regulations, policies, and institutions that govern sustainable management of forest and rangelands. Agencies that oversee forests and rangelands operate at the federal, state, regional, and local levels of government. Laws and authorities often overlap, which at times can result in conflicts.

The division of regulatory authority between federal and state environmental laws can result in duplicative oversight in some areas. State policies can differ and be at odds with federal policies, and California often requires a higher level of environmental protection than required under federal law. Examples include:

- Environmental impact disclosure and review for projects under the California Environmental Quality Act (CEQA).
- Reduced greenhouse gas emissions through the nation's first cap and trade program under AB 32, and local planning that supports "sustainable communities" under SB 375 to reduce emissions from transportation and limit sprawl that can impact forest and rangelands.
- Protection of threatened and endangered species through the California Endangered Species Act.
- Support for renewable energy through the Renewables Portfolio Standard (RPS) initially established under SB 350 that requires utilities to procure 50% of their electricity from renewable energy sources by 2030 (ⓘ12.1). The state has also promoted biomass energy through various executive actions and legislation (ⓘ12.2).

For non-federal timberland, Forest Practice Rules and related regulations have evolved to address improved environmental protection, and in some instances, lower the cost of compliance (e.g. through Nonindustrial Timber Management Plans). In addition, there are numerous sustainability initiatives (ⓘ1.5) that are changing how forests are managed, for example through voluntary sustainable forestry certification programs, and managing forests to capture carbon in return for compensation in the form of carbon offsets.

Conversely, the sustainable management of rangelands is addressed through federal and state laws such as the Clean Water Act, Endangered Species Act, and Porter-Cologne Act. Instead of a more comprehensive state regulatory approach such as the Forest Practice Rules, the approach to rangelands involves education, incentives, Best Management Practices, and regulatory mechanisms to correct problems when they arise.

California also has a variety of programs and initiatives that augment the considerable federal resources devoted to education, monitoring and assessment, research, funding for collaborative projects, and landowner assistance. For example, the California Forest Improvement Program (CFIP) provides cost-share assistance to landowners with up to 5,000 acres for management planning, site preparation, tree planting, timber stand improvement, fish and wildlife habitat improvement, and land conservation practices.

Taxation, Economic Policies, and Investment

California has unique tax-based policies that improve the profitability of resource-based industries, and limit conversion to other land uses. Conversion of timberland is relatively rare, in part due to tax and zoning policy established under the Forest Taxation Reform Act of 1976. Conversion of rangeland is more common, despite efforts to limit conversion under the Williamson Act (1965).

Under the State's cap and trade program, since 2012 quarterly auctions have generated $4.4 billion which by law must be used to reduce greenhouse gases. A portion of these funds have been used for watershed and wetlands restoration, and landscape-level multi-agency projects to improve forest health.

AB 1492 (2012) required a 1% tax on lumber products, with the funds devoted to a variety of efforts related to environmental restoration and protection. The bill also included provisions to reduce regulatory costs to make California wood products more competitive with imports.

Revenues generated from cap and trade and the lumber tax represent a relatively stable source of funding for environmental restoration, as opposed to past efforts through ballot initiatives that provided funding for limited periods.

Collaboration and Partnerships

There are numerous examples in California of collaborative landscape-level projects designed to improve forest health, reduce fire threat, and contribute to local economic development. There are programs that support these collaborative efforts at the federal (e.g. Joint Chiefs' Landscape Restoration Partnership, National Cohesive Wildland Fire Management Strategy, Collaborative Forest Landscape Restoration Program) and state levels (e.g. CAL FIRE Forest Health California Climate Investments grant program, Sierra Nevada Conservancy Watershed Improvement Program). They are also supported by collaborative agreements such as the Fire MOU Partnership. Collaboration is also fostered through the Good Neighbor Authority and the Wyden Amendment. The Good Neighbor Authority allows the Forest Service to issue agreements or contracts to allow states to perform watershed restoration and forest management services on National Forest System lands. The Wyden Amendment is similar, but in addition to State agencies, it allows local government and non-profits to enter into partnership agreements with the Forest Service for watershed restoration projects that are either on or adjacent to National Forest Service lands.

At the local level, there is active participation in collaborative efforts including Fire Safe Councils, watershed groups, urban forestry projects, and various efforts organized by Resource Conservation Districts. In terms of collaborative fire planning, of 1,338 identified Communities at Risk, 66% are either covered by a Community Wildfire Protection Plan (CWPP), and/or are recognized by the Firewise program (ⓘ11.4).

Public Participation

Volunteerism

California's human resources have always been a main source of our strength. Californians volunteer their time for a variety of efforts related to sustainability, including education efforts, data collection and monitoring, creek and watershed restoration, control of invasive species, trail maintenance, fire prevention and suppression, urban forestry projects, and more.

Voter Support for Natural Resource Initiatives

California voters have a long history of supporting ballot initiatives related to resource protection, enhancement, and sustainability. Specific voter-approved measures are provided below.

Year	Title	% Approval
1972	Coastal Zone Conservation Act	55%
1988	Wildlife, Coastal and Park Land Conservation Bond Act	65%
2002	The California Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act	55%
2006	The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act	54%

More recently, in 2010 62% of voters rejected the California Jobs Initiative, which would have eliminated the cap and trade program established under AB 32.

Public Activism

Natural resource issues, including timber harvesting, often elicit passionate responses from stakeholders. In previous decades, it was not unusual for this to result in relatively extreme activism, ranging from tree sitting to disruption of Board of Forestry meetings. While these passions still exist, instances of more extreme activism have dissipated. Contributing factors could include a policy environment that has addressed at least the most pressing concerns, and industrial timberland owners that appear to be committed to long-term management in the state, and concerned with their public image as evidenced by voluntary participation in certification programs (ⓘ1.5).

In 2010 62% of voters rejected the California Jobs Initiative, which would have eliminated the cap and trade program established under AB 32.

Research and Education

Numerous assessment trends, including those related to climate change and associated disturbance regimes, suggest an increasingly dynamic social, economic, and environmental landscape. The role of research and education are increasingly important to monitor conditions and adjust policies and practices accordingly. However, some trends also point to a decline or uncertainty for some important funding sources.

Education programs are a critical component of supporting sustainable management, and can reduce the need for more comprehensive and costly regulatory approaches. Education efforts related to range management are conducted by UC Cooperative Extension, Resource Conservation Districts, and others.

For timberlands, CAL FIRE is active in administering state and federal forestry assistance programs for landowners, demonstrating sound management practices on eight demonstration state forests, and providing research and educational outreach to the public on forest pests such as Sudden Oak Death. Education is also provided by the California Licensed Foresters Association (CLFA), Society for American Foresters (SAF), UC Cooperative Extension, federal agencies such as the Forest Service, and universities and community colleges. Education is also an important component of supporting urban forestry programs, with outreach and education conducted by groups such as the California Urban Forests Council (CAUFC).

The University of California Division of Agriculture and Natural Resources (UC ANR) supports sustainable farming, livestock production, and timber management through various research and education efforts, including UC Cooperative Extension. The UC ANR Strategic Vision 2025 describes a series of initiatives to address sustainability. However, due to reduced funding, UC ANR's "boots on the ground" footprint has decreased 35% from FY 2002–03 to FY 2015–16.

Research related to forests and rangelands is conducted at various University of California and other academic institutions across the state, as well as the Forest Service's Pacific Southwest Research Station.

Assessment and Monitoring

In addition to the FRAP Assessment, there are numerous statewide planning efforts required by law conducted by state agencies such as Department of Fish and Wildlife, Department of Water Resources, and the Governor's Office of Planning and Research. Monitoring efforts are in place within different agencies to track the status and condition of various measures of sustainability for different resources, which supplied much of the data used in the body of this assessment.

The use of indicators as performance measures, relatively advanced in the fields of economics and education, are not at an advanced stage or coordinated across natural resources agencies. There is an opportunity in the future to collaborate on a more comprehensive system to develop, track, and communicate environmental indicators. One component of this would be the performance measures being developed to measure the state's forest practice regulatory program as required under AB 1492.

Policy Issues

MPC7: Policy Issues for Legal, Institutional and Economic Framework for Conservation and Sustainable Management

Policy Issue	Options and Opportunities
Research and Education	With increasing pressures on forests and rangelands, including climate change, research and education are more important than ever to develop the proper science-based policies and practices to adapt to changing conditions.
Collaboration	Continue to develop and support mechanisms to foster collaborative landscape-level initiatives, particularly for improving ecosystem health and restoring natural fire regimes.
Funding	Continue to develop stable funding sources for critical sustainability programs and initiatives.
Assessment	Agencies need to collaborate to develop and implement a more comprehensive and coordinated system to track and communicate environmental indicators.

Introduction

CALIFORNIA OVERVIEW

Vegetation and Ownership

California has a diverse natural landscape which ranges from conifer and hardwood forest and woodlands in the mountain and coastal areas, to shrub and herbaceous rangelands in the south coast, north interior and central valley, to desert habitats in the southeast (Figure I.1). Based on mapped vegetation data, forest and rangeland cover types occupy about 80% of California (Table I.1). Over half of the state is in public (federal, state, or local government) ownership (Figure I.2) including about 61% of the 80 million acres of forest and rangelands.

Table I.1: Statewide Area of Major Vegetation Type by Owner Group (Acres in Thousands)

Major Vegetation Type	Private	USFS	BLM	NPS	Other Public	Total[1]
Forestland						
Conifer Forest	6,532	10,334	362	1,082	554	18,865
Hardwood Forest	2,307	1,270	193	141	206	4,116
Forest and Rangeland						
Conifer Woodland	480	861	482	366	145	2,335
Hardwood Woodland	4,459	287	164	21	597	5,527
Rangeland[2]						
Herbaceous[3]	9,260	513	401	61	870	11,105
Desert	3,411	185	10,382	4,807	4,193	22,977
Shrub	4,725	6,076	2,365	351	1,391	14,908
Total Forest and Rangeland	**31,174**	**19,526**	**14,349**	**6,829**	**7,956**	**79,833**
Other						
Agriculture	10,752	2	26	0	234	11,013
Barren/Other	472	925	629	645	381	3,052
Urban	4,512	13	58	5	233	4,822
Water[4]						1,841
Total (Forest, Range, Other)[5]	**46,910**	**20,466**	**15,062**	**7,479**	**8,804**	**100,561**

[1] Totals may not add up due to rounding.
[2] Rangeland refers to "primary" rangeland, and does not include conifer forest, which has rangeland forage potential and is often grazed by livestock
[3] Includes wetlands
[4] Areas classified as water are not assigned an ownership
[5] These acreages are based on digital map-based data, and are somewhat different than those used throughout this Assessment from the Forest Service's Forest Inventory and Analysis (FIA) data, which are derived using a sample-based system

Data Sources: Vegetation, FRAP, v15_1; Ownership, FRAP, v15_1.

Based on sampling data from the Forest Service, for the 32 million acres of forestland in the state, about 61% is publicly owned, including about 48% by the Forest Service (Table I.2). Forestland includes 16.6 million acres of timberland, defined by the Forest Service as capable of producing over 20 cubic feet/acre/year of wood with commercial value and not withdrawn from timber utilization by statute or administrative regulation. About 20% (6.5 million acres) of forestland is in reserved status (e.g. wilderness areas and parks).

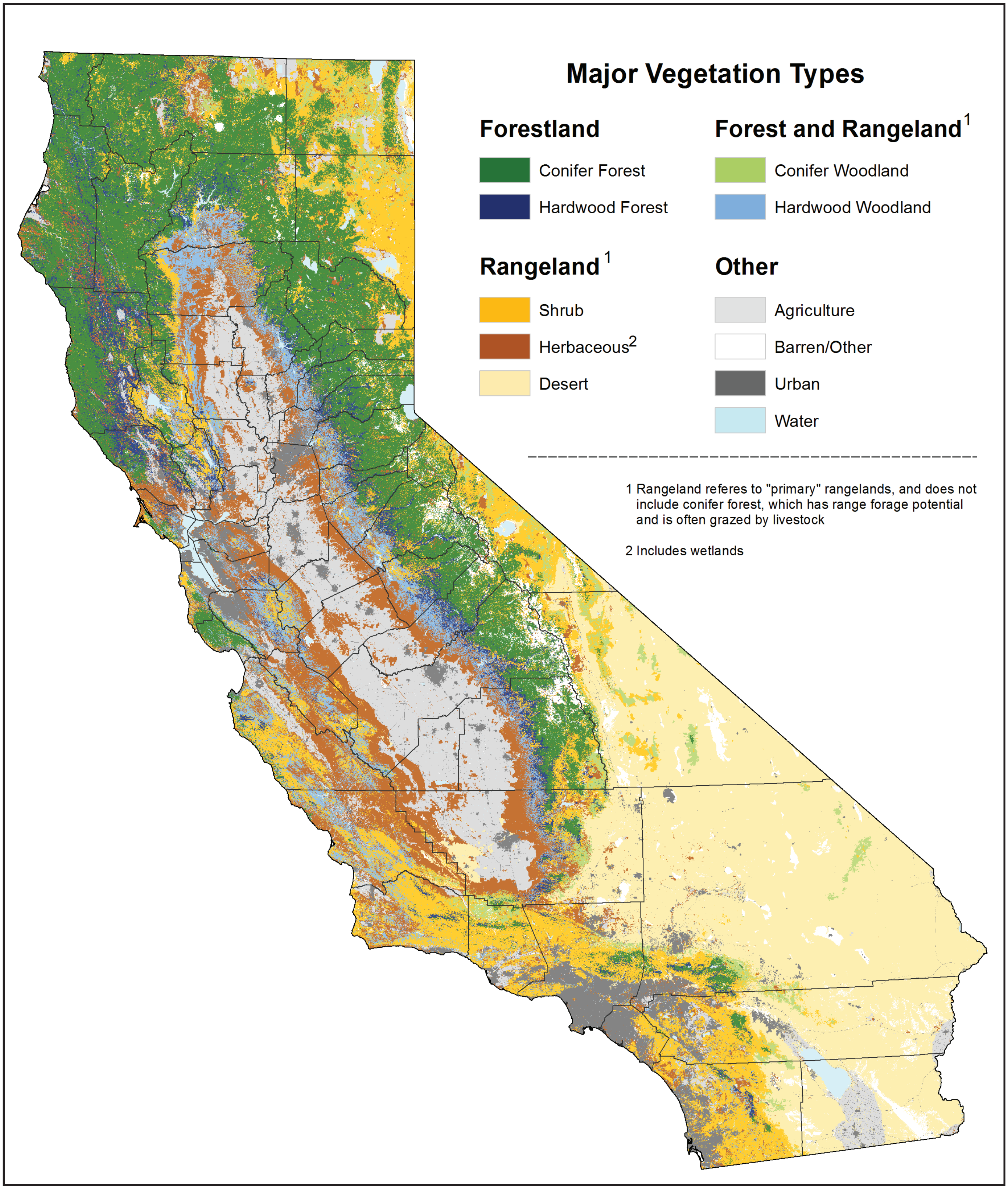


Figure I.1: Major Vegetation Types in California

Data Source: Vegetation, FRAP, v15_1.

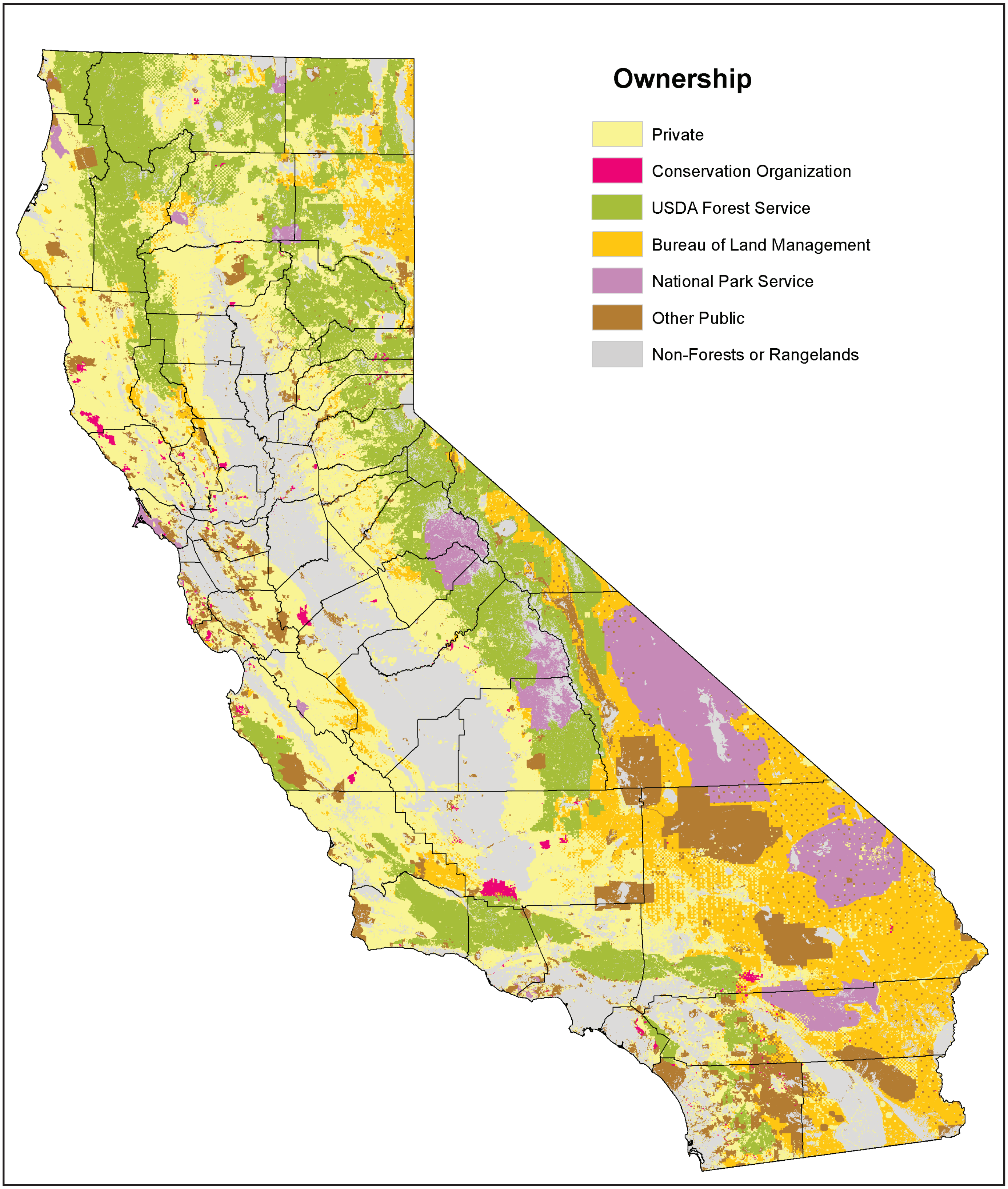


Figure I.2: California Land Ownership of Forest and Rangelands

Data Source: Ownership, FRAP, v15_1.

About 61% of rangeland is publicly owned (Table I.2). However, for herbaceous (primarily grassland, the most productive type for grazing), about 83% is privately owned (Table I.1).

Tables with area of forestland, timberland, and rangeland (reserved and unreserved) by owner group are provided for each CAL FIRE ecoregion in Appendix I.1.

Table I.2: Statewide Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved) by Owner Group (Acres in Thousands)

	Ownership Group					
Land Status	**Private**	**USFS**	**BLM**	**NPS**	**Other Public**	**Total**
Unreserved Forestland						
Timberland	7,252	8,871	297	0	157	16,577
Other Unreserved Forestland	5,140	2,440	932	0	346	8,858
Total Unreserved Forestland	**12,392**	**11,311**	**1,229**	**0**	**503**	**25,435**
Reserved Forestland[1]						
Reserved Productive Forestland	0	2,782	50	972	333	4,137
Other Reserved Forestland	0	1,231	212	462	466	2,371
Total Reserved Forestland	**0**	**4,013**	**262**	**1,434**	**799**	**6,508**
Forestland Total	**12,392**	**15,324**	**1,491**	**1,434**	**1,302**	**31,943**
Unreserved Rangeland	**22,687**	**5,829**	**9,895**	**0**	**5,851**	**44,262**
Reserved Rangeland[2]	**0**	**2,167**	**3,904**	**5,641**	**1,538**	**13,250**
Rangeland Total	**22,687**	**7,996**	**13,799**	**5,641**	**7,389**	**57,512**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

LEGAL REQUIREMENTS

The State Mandate

By State law (PRC 4789) CAL FIRE must periodically assess California's forest and rangeland resources. The previous effort was *California's Forests and Rangelands: 2010 Assessment*. Assessment results are used by the State Board of Forestry and Fire Protection (Board) to develop and update a forest policy statement for California. In 2010, the strategy report produced by FRAP as part of the Assessment process served as the policy statement.

The Federal Mandate

The 2010 Assessment shifted focus to a format developed by the USDA Forest Service for state forestry assessments, in response to the 2008 Farm Bill. Each chapter included analyses of threats and assets to generate "Priority Landscapes", for more efficiently targeting potential areas for investment and treatment.

The 2017 Assessment was developed in cooperation with our federal partners, including the Forest Service; however, the focus has changed to an indicator-based approach for tracking the state's progress towards sustainability.

Related Efforts and Supporting Documents

The 2017 Assessment takes into consideration various existing planning efforts; these range from local plans such as Community Wildfire Protection plans to statewide plans, like the State Wildlife Action Plan, the State Water Plan, and the Forest Carbon Plan. The Assessment also integrates work related to renewable energy and to climate change from the California Energy Commission, the Air Resources Board, California Department of Fish and Wildlife, and various academic institutions. Many other reports and data sources were used in the preparation of this Assessment, including extensive use of forest inventory data from the Forest Service's Forest Inventory and Analysis (FIA) program.

Outreach and Public Input

The Assessment reflects input from a variety of agencies and stakeholders (see Acknowledgements). Beginning in 2015, CAL FIRE held a series of nine meetings of the Forest and Rangelands Assessment Steering Committee (FRASC). Each FRASC meeting focused on a specific topic and involved a different set of stakeholders to identify important issues and begin to formulate a draft set of indicators.

Based on the FRASC meetings, we posted a set of draft indicators on the internet, and stakeholders rated each indicator and submitted comments. We used the ratings and comments to assemble a final list of 47 California Forest and Rangeland Indicators (CFRI).

ASSESSMENT OVERVIEW

Assessment Organization and California Forest and Rangeland Indicators (CFRI)

The Assessment is organized into 12 chapters, each with a set of indicators. When a chapter statement is supported by a CFRI, the symbol "ⓘ" is used with the chapter/indicator number. For example, (ⓘ4.2) refers to the Fire Threat CFRI.

Table I.3: Assessment Chapters and California Forest and Rangeland Indicators (CFRI)
Chapter 1: Sustainable Working Forests
ⓘ1.1 Net Growth of Growing Stock on Timberland
ⓘ1.2 Timberland in Need of Restoration Treatment to Reduce or Increase Stocking
ⓘ1.3 Timberland Harvested by Silvicultural Method
ⓘ1.4 Timber Harvest from Private and Public Lands
ⓘ1.5 Timberland Managed Under Forest Certification, or Other Sustainable Forestry Standards
ⓘ1.6 Acres of Forestland Being Managed as Carbon Offset Projects
Chapter 2: Sustainable Rangelands
ⓘ2.1 Rangeland Conversion
ⓘ2.2 Beef Cattle Farms by Size Class
ⓘ2.3 Federal Grazing Allotments
Chapter 3: Urban Forestry
ⓘ3.1 Tree Canopy Cover
ⓘ3.2 Impervious surfaces (percent of urban area)
ⓘ3.3 Air Pollution (PM 2.5, and Ozone)
ⓘ3.4 Days over 90 degrees Fahrenheit (F)
Chapter 4: Wildfire
ⓘ4.1 Fire Return Interval Departure
ⓘ4.2 Fire Threat
ⓘ4.3 Wildfire Activity – Trends in Burned Area
ⓘ4.4 Proportion of High Severity Fire in Yellow Pine/Mixed-Conifer Forests
ⓘ4.5 Fuel Treatment Area
Chapter 5: Forest Pests
ⓘ5.1 Area of Tree Mortality from Forest Pests and Drought
ⓘ5.2 Number of Native and Exotic Forest Pest Species Occurrences

Chapter 6: Population Growth and Development Impacts
ⓘ6.1 Recent and Projected Population Trends
ⓘ6.2 Rangeland under California Land Conservation Act ("Williamson Act") contracts
ⓘ6.3 Private Forest and Rangeland Under Conservation Easements, or Conservation Organization Owned
Chapter 7: Climate Change
ⓘ7.1 Average Annual Air Temperature
ⓘ7.2 Annual Precipitation
ⓘ7.3 Total Ecosystem Carbon Pools by Ownership, Ecoregion
ⓘ7.4 Change in Ecosystem Carbon Pools by Ownership Group
Chapter 8: California's Non-Metro Regional Economy
ⓘ8.1 Relative Economic Performance
ⓘ8.2 Economic Trends
ⓘ8.3 Economic Prosperity
ⓘ8.4 Economic Stress
ⓘ8.5 Economic Structure
Chapter 9: Water
ⓘ9.1 California Stream Condition Index
ⓘ9.2 Snow Pack (April 1st)
ⓘ9.3 Spring Runoff
ⓘ9.4 Cumulative Water Deficit
Chapter 10: Wildlife Habitat
ⓘ10.1 Number of Threatened and Endangered Species Listed Under the California (CESA) and/or Federal Endangered Species Act (ESA)
ⓘ10.2 Forest Stand Age Class by Ownership
ⓘ10.3 Terrestrial Intactness of California Wildlife Habitat Relationships (CWHR) Types Based on Human Impacts
ⓘ10.4 Projected Impacts of Climate Change on the Extent of California Wildlife Habitat Relationships (CWHR) Types
ⓘ10.5 California Wildlife Habitat Relationships (CWHR) Types Protected from Conversion
Chapter 11: Reducing Community Wildfire Risk
ⓘ11.1 Number of Structures Destroyed by Wildfire Annually
ⓘ11.2 Housing Units by Fire Hazard Severity Zone (FHSZ) Class
ⓘ11.3 Housing Units and Wildfire Threat Within the Wildland Urban Interface (WUI)
ⓘ11.4 Number and Percent of Communities at Risk (CAR) that are Firewise Communities or Covered by a Community Wildfire Protection Plan (CWPP)
Chapter 12: Renewable Energy
ⓘ12.1 Contribution of Renewable Energy Sources to California Electricity Generation
ⓘ12.2 Contribution of Forest Biomass to California Electricity Generation

Appendix I.1 Forest and Rangeland Acres by Ecoregion

Regional Variations

Each ecoregion in California (Figure I.3) is unique in terms of climate, topography, geology, and soils. Each ecoregion supports unique biological communities that provide different types and levels of economic outputs and ecosystem services. This Appendix provides a table for each ecoregion with acres of forestland, timberland, and rangeland, including reserved lands.

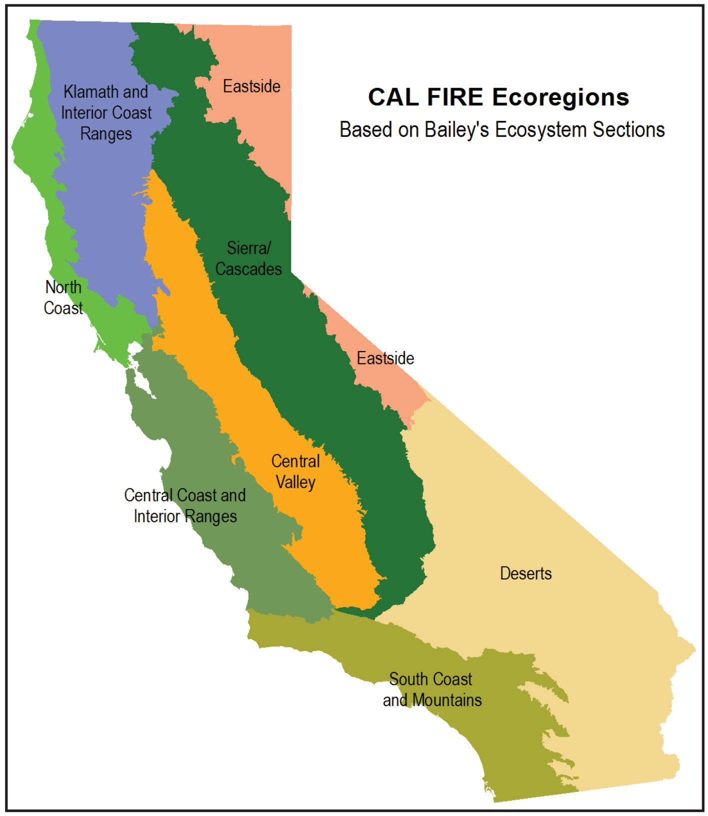


Figure I.3: CAL FIRE Ecoregions
Data Source: CAL FIRE Ecoregions, FRAP, v15_1.

Table I.4: Central Coast and Interior Ranges - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)

Land Status	Ownership Group					
	Private	USFS	BLM	NPS	Other Public	Total
Unreserved Forestland						
Timberland	197	2	0	0	15	214
Other Unreserved Forestland	909	83	63	0	99	1,154
Total Unreserved Forestland	**1,106**	**85**	**63**	**0**	**114**	**1,368**
Reserved Forestland[1]:						
Reserved Productive Forestland	0	30	0	0	80	110
Other Reserved Forestland	0	124	5	6	237	372
Total Reserved Forestland	**0**	**154**	**5**	**6**	**317**	**482**
Forestland Total	**1,106**	**239**	**68**	**6**	**431**	**1,850**
Unreserved Rangeland	5,415	306	329	0	621	6,671
Reserved Rangeland[2]	0	371	210	33	236	850
Rangeland Total	**5,415**	**677**	**539**	**33**	**857**	**7,521**

[1] *Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).*
[2] *Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.*

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.5: Central Valley - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)						
	Ownership Group					
Land Status	**Private**	**USFS**	**BLM**	**NPS**	**Other Public**	**Total**
Unreserved Forestland						
Timberland	0	0	0	0	0	0
Other Unreserved Forestland	80	0	0	0	4	84
Total Unreserved Forestland	**80**	**0**	**0**	**0**	**4**	**84**
Reserved Forestland[1]						
Reserved Productive Forestland	0	0	0	0	0	0
Other Reserved Forestland	0	0	0	0	6	6
Total Reserved Forestland	**0**	**0**	**0**	**0**	**6**	**6**
Forestland Total	**80**	**0**	**0**	**0**	**10**	**90**
Unreserved Rangeland	2,472	0	58	0	103	2,633
Reserved Rangeland[2]	0	0	0	0	188	188
Rangeland Total	**2,472**	**0**	**58**	**0**	**291**	**2,821**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.6: Eastside - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved) by Owner Group (Acres in Thousands)						
	Ownership Group					
Land Status	**Private**	**USFS**	**BLM**	**NPS**	**Other Public**	**Total**
Unreserved Forestland						
Timberland	304	699	32	0	0	1,035
Other Unreserved Forestland	228	829	456	0	40	1,553
Total Unreserved Forestland	**532**	**1,528**	**488**	**0**	**40**	**2,588**
Reserved Forestland[1]						
Reserved Productive Forestland	0	55	0	0	6	61
Other Reserved Forestland	0	106	54	66	9	235
Total Reserved Forestland	**0**	**161**	**54**	**66**	**15**	**296**
Forestland Total	**532**	**1,689**	**542**	**66**	**55**	**2,884**
Unreserved Rangeland	1,115	1,455	1,725	0	245	4,540
Reserved Rangeland[2]	0	210	49	1	95	355
Rangeland Total	**1,115**	**1,665**	**1,774**	**1**	**340**	**4,895**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.7: Klamath Interior Coast Range - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)						
	Ownership Group					
Land Status	**Private**	**USFS**	**BLM**	**NPS**	**Other Public**	**Total**
Unreserved Forestland						
Timberland	1,676	2,587	133	0	20	4,416
Other Unreserved Forestland	1,216	380	119	0	29	1,744
Total Unreserved Forestland	**2,892**	**2,967**	**252**	**0**	**49**	**6,160**
Reserved Forestland[1]						
Reserved Productive Forestland	0	1,318	6	60	7	1,391
Other Reserved Forestland	0	275	24	35	31	365
Total Reserved Forestland	**0**	**1,593**	**30**	**95**	**38**	**1,756**
Forestland Total	**2,892**	**4,560**	**282**	**95**	**87**	**7,916**
Unreserved Rangeland	2,548	519	267	0	67	3,401
Reserved Rangeland[2]	0	247	42	5	24	318
Rangeland Total	**2,548**	**766**	**309**	**5**	**91**	**3,719**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.8: North Coast - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)						
	Ownership Group					
Land Status	**Private**	**USFS**	**BLM**	**NPS**	**Other Public**	**Total**
Unreserved Forestland						
Timberland	2,050	23	48	0	64	2,185
Other Unreserved Forestland	198	7	0	0	7	212
Total Unreserved Forestland	2,248	30	48	0	71	2,397
Reserved Forestland[1]						
Reserved Productive Forestland	0	12	43	43	154	252
Other Reserved Forestland	0	0	0	7	50	57
Total Reserved Forestland	0	12	43	50	204	309
Forestland Total	**2,248**	**42**	**91**	**50**	**275**	**2,706**
Unreserved Rangeland	778	1	6	0	55	840
Reserved Rangeland[2]	0	0	6	63	46	115
Rangeland Total	**778**	**1**	**12**	**63**	**101**	**955**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.9: Sierra Cascades - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)

Land Status	Ownership Group					
	Private	USFS	BLM	NPS	Other Public	Total
Unreserved Forestland						
Timberland	2,990	5,420	84	0	56	8,550
Other Unreserved Forestland	2,258	793	250	0	89	3,390
Total Unreserved Forestland	**5,248**	**6,213**	**334**	**0**	**145**	**11,940**
Reserved Forestland[1]						
Reserved Productive Forestland	0	1,246	2	869	75	2,192
Other Reserved Forestland	0	581	96	266	72	1,015
Total Reserved Forestland	**0**	**1,827**	**98**	**1,135**	**147**	**3,207**
Forestland Total	**5,248**	**8,040**	**432**	**1,135**	**292**	**15,147**
Unreserved Rangeland	4,543	1,760	543	0	171	7,017
Reserved Rangeland[2]	0	671	213	247	118	1,249
Rangeland Total	**4,543**	**2,431**	**756**	**247**	**289**	**8,266**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Table I.10: South Coast Mountains and Deserts - Area of Forestland, Timberland, and Rangeland (Reserved and Unreserved), by Owner Group (Acres in Thousands)

Land Status	Ownership Group					
	Private	USFS	BLM	NPS	Other Public	Total
Unreserved Forestland						
Timberland	35	139	0	0	2	176
Other Unreserved Forestland	250	349	44	0	77	720
Total Unreserved Forestland	**285**	**488**	**44**	**0**	**79**	**896**
Reserved Forestland[1]						
Reserved Productive Forestland	0	121	0	0	11	132
Other Reserved Forestland	0	144	33	83	62	322
Total Reserved Forestland	**0**	**265**	**33**	**83**	**73**	**454**
Forestland Total	**285**	**753**	**77**	**83**	**152**	**1,350**
Unreserved Rangeland	5,816	1,789	6,966	0	4,590	19,161
Reserved Rangeland[2]	0	669	3,384	5,291	832	10,176
Rangeland Total	**5,816**	**2,458**	**10,350**	**5,291**	**5,422**	**29,337**

[1] Withdrawn from timber utilization through statute or administrative designation (Forest Service definition).
[2] Lands with permanent legal protection, and typically dedicated for a specific puplic purpose or program.

Data Sources: FIA Program, USDA Forest Service, 2016; Ownership, FRAP, v15_1.

Chapter 1: Sustainable Working Forests

This chapter provides a synthesis of indicators, key findings, and opportunities related to sustainable working forests.

SUMMARY

Indicators and key findings support trends that vary by forest ownership group.

Forest industry in California operates under statutory and regulatory mandates requiring a demonstration of long-term sustained yield. Inventory data confirm that growth exceeds harvest and mortality on industry lands (ⓘ1.1). About 86% of industrial timberland is under some form of voluntary third-party forest certification (ⓘ1.5).

Nonindustrial forestland owners manage for a range of objectives. Based on the National Woodland Owner Survey [2], the most common reasons for owning forestland in California are scenic beauty, residence or vacation home, protecting nature, passing the land to heirs, and investment property. Federal and state programs continue to be important sources of technical and financial assistance to small landowners for their forest management planning and activities. Currently, active management on 11% of nonindustrial timberland is facilitated by a Nonindustrial Timber Management Plan (ⓘ1.5).

On public timberlands (primarily owned by USDA Forest Service), stand condition in terms of stocking levels (ⓘ1.2) and deviation from historic fire regimes (ⓘ4.1) are major issues. According to the Forest Service, “nearly a century of fire exclusion in California, coupled with other management decisions on both private and public land, has resulted in forests that are at an increasing risk of loss due to large scale disturbances.” The Agency further states “only an environmental restoration program of unprecedented scale can alter the direction of current trends.” Forest Service goals set in 2011 for California include treatments to improve forest resiliency and other ecological restoration activities such as restoring degraded meadows, reforestation of burned areas, increasing habitat connectivity, restoring natural fire regimes, and decreasing the impact of invasive species [3]. To achieve their goals, the Forest Service would need to find the resources to increase ecological restoration activities from the current 200,000 acres a year to approximately 500,000 acres per year [4].

INDICATORS

- ⓘ1.1 Growth, removals, mortality
- ⓘ1.2 Timberland restoration
- ⓘ1.3 Silvicultural methods
- ⓘ1.4 Historic timber harvest
- ⓘ1.5 Sustainability initiatives
- ⓘ1.6 Carbon Forests

California imports about 80% of the lumber and 90% of all wood products used in the state [5-7]. Meeting in-state demand requires importing lumber and wood products from other states and countries that may have less restrictive rules on forest practices. However, numerous statewide factors and trends are impeding more active timber management to meet our demand for wood products. These include a decline in the skilled workforce and physical infrastructure such as sawmills and biomass plants (ⓘ1.4, ⓘ12.2), the impact of global competition on prices of lumber and wood products, elevated risk from changing climate and disturbance regimes, and regulatory costs. Public sentiment against timber harvest is another factor that state and federal agencies must address, as part of the Timber Harvesting Plan review process for private lands, and the public input process for public land planning and management.

Opportunities are emerging to improve forest health and/or enhance the levels of certain ecosystem services provided by working forests. On the North Coast, there are numerous examples of working forest acquisitions by conservation organizations, voluntary participation in carbon offset programs (ⓘ1.6), and use of conservation easements to diversify income and influence management direction. The result is a significant and increasing portion of timberland being managed under longer rotations and uneven-aged management regimes (ⓘ1.3).

In other parts of the state, both public and private forests face much higher risks, as demonstrated by current widespread tree mortality in the Sierra Nevada and recent large stand-replacing wildfires. Current high stocking levels and past fire exclusion are major concerns (ⓘ1.2). The scope and scale of treatments needed at the landscape level to address these critical issues is significant and challenging, given limited wood processing infrastructure and funding. However, there are numerous examples of collaborative landscape-level projects designed to improve forest health, reduce fire threat, and contribute to local economic development. There are programs that support these collaborative efforts at the federal level (e.g. Joint Chiefs' Landscape Restoration Partnership, National Cohesive Wildland Fire Management Strategy, Collaborative Forest Landscape Restoration Program) and state level (e.g. CAL FIRE Forest Health Initiative/Greenhouse Gas Reduction Fund (GGRF) grant program, Sierra Nevada Conservancy Watershed Improvement Program).

Statewide, there are numerous opportunities to support and improve sustainable management:

- Continue to explore, implement, and support ways to increase active sustainable management on nonindustrial timberlands.
- Create additional distributed infrastructure to diversify log and biomass markets, such as community based small mills, portable mills, and biomass plants.
- Expand research and support for new wood-based products to increase marketing options and/or the utilization value of harvested timber.
- Support collaborative landscape-level projects that involve state and federal agencies, local communities, and other stakeholders for improving economic and environmental sustainability.
- Promote more active sustainable management of National Forests to improve forest health, reduce wildfire threat, and support local economies.
- Expand research and support to select appropriate genetic sources for adapting new plantings for climate change.

KEY FINDINGS

Key findings and indicators are grouped below for the five topics covered in this chapter.

The Resource Base

- Based on our modeled scenarios, in the future a portion of current timberlands will no longer be suitable for growing the tree species that are of primary commercial value in California. Statewide, there is a projected loss of between .6 (3%) and 1.4 million acres (8%) of timberland under the warmer/wetter and hotter/drier climate change scenarios, respectively. These former timberlands will likely transition into oak woodland, brush, or grassland, with different ecological and economic values (e.g. for grazing).

- Conservation easements are an increasingly effective tool for preserving timberlands with important environmental or social values, and for protecting working forests from conversion or being subdivided (ⓘ6.3).

- Invasive plants, many of which are not native to California, are having a major impact on both working forests and other forestlands.

ⓘ1.2 Timberland in Need of Restoration Treatment to Reduce or Increase Stocking

- ⓘ Total acres potentially in need of treatment to improve stocking ranges from 5.5 to 9.5 million, depending on whether overstocked stands are based on a 100% or 60% Stand Density Index (SDI) rule. Stocking is an issue on public, forest industry, and nonindustrial timberlands.

- ⓘ Using the 100% SDI rule, only about 4% of public timberlands are overstocked. Using the 60% rule, about 32% are overstocked.

- ⓘ Hardwood dominated timberlands are a natural component of the landscape, but have expanded in some areas due to past disturbances or management. Restoration treatments are more economically feasible on higher site quality lands, such as the 1.4 million acres in sites 1, 2, and 3. About 41% of these acres are in the tanoak/laurel type, typically areas on the North Coast region where redwood and Douglas-fir have been displaced by hardwoods due in part to past timber management.

Management Context

- Forest Service goals set in 2011 include treatments to improve forest resiliency and other ecological restoration activities such as restoring degraded meadows, reforestation of burned areas, increasing habitat connectivity, restoring natural fire regimes, and decreasing the impact of invasive species [3]. To achieve their goals, the Forest Service would need to find the resources to increase ecological restoration activities from the current 200,000 acres a year to approximately 500,000 acres per year [4].

- Regulations affecting timber harvesting on private lands have increased in terms of the scope of activities regulated, including impacts on threatened and endangered species, water quality and forest roads.

ⓘ1.1 Net Growth of Growing Stock on Timberland

- ⓘ On forest industry timberlands, the most actively managed lands, growth exceeded harvest and mortality by an average of almost 22 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).

- ⓘ On nonindustrial timberlands, a portion of which are actively managed, growth exceeded harvest and mortality by an average of over 85 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).

- ⓘ On Forest Service timberlands, which are managed for multiple objectives including ecosystem services, growth exceeded harvest and mortality by an average of over 33 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).

ⓘ1.3 Timberland Harvested by Silvicultural Method

ⓘ There has been a steady significant decline in total acres harvested over the 1997–2015 period. Harvested acres in 2015 was about half of 1997 harvest acres.

ⓘ Acres harvested using uneven-aged systems have been fairly constant, despite the decline in total harvest acres. Thus, the percentage of acres harvested using uneven-aged systems has increased, from an average of 29% of harvested acres over the 1997–2001 period, to 41% over the 2011–2015 period. In the Coast District 54% of the 2011–2015 period harvest acres were uneven-aged.

ⓘ Widespread tree mortality from drought, pests, and wildfire have contributed to a major increase in acres filed for harvesting under Emergency Conditions (1052.1(b)). In 2015, acres harvested under Emergency Conditions comprised 10%, 23%, and 89% of total acres filed for harvest in the Coast, Northern, and Southern Forest Districts, respectively.

Forest Products Sector

California imports about 80% of the lumber and 90% of all wood products used in the state. Meeting in-state demand requires importing lumber and wood products from other states and countries that may have less restrictive rules on forest practices.

ⓘ1.4 Timber Harvest from Private and Public Lands

ⓘ The total volume harvested in 2015 was 72% lower than in 1955.

ⓘ The contribution from public lands to total harvest volume over the 1955–1990 period averaged about 38%. Since 2000, it has averaged only about 18%.

ⓘ The number of sawmills declined from 675 in 1956 to only 30 in 2012.

ⓘ Since 2000, private harvest levels (the bulk of which are forest industry) have averaged 1,363 million board feet. Annual fluctuations have been as much as 35% over this average and 46% under.

Management Initiatives

Several collaborative projects involving local communities, forest managers and environmental groups exist in forested regions. The most comprehensive of these is the Sierra Nevada Conservancy “Sierra Nevada Forest and Community Initiative.” These projects are indicative of a general interest in promoting forest health and the sustainability of rural communities.

ⓘ1.5 Timberland Managed Under Forest Certification, or Other Sustainable Forestry Standards

ⓘ Forest industry landowners with over 50,000 acres of timberland have about 3.9 million acres in mandatory “Option (a)” or Sustained Yield Plans. This represents 91% of industrial timberland and 53% of all private timberland.

ⓘ About 86% of forest industry and 14% of nonindustrial timberland is certified by a sustainable forestry program.

ⓘ A significant and increasing acreage of timberland is under modified management (Nonindustrial Timber Management Plan or Carbon Offset Project), much of which gives additional emphasis to ecosystem services.

ⓘ1.6 Acres of Forestland Being Managed as Carbon Offset Projects

ⓘ As part of California's "cap and trade" program, as of 10/26/2017 the Air Resources Board (ARB) had issued carbon offsets for Compliance forest projects in California on about 207 thousand acres. There are also 64 thousand acres of Early Action projects in the state. In addition to ARB projects, there are 85 thousand more acres of projects in California registered with the Climate Action Reserve (CAR).

ⓘ All California projects are "improved forest management," which can take different forms. The current ARB projects typically involve combinations of reduced harvest levels, longer rotations, and uneven-aged management. Some CAR projects involve intensive even-aged management with actions to maintain stocking for optimal growth, and extended rotations for culmination of carbon growth.

Landowner Assistance

Federal and state programs continue to be important sources of technical and financial assistance to small landowners for their forest management planning and activities.

DISCUSSION

California's forestland (defined by having at least 10% tree canopy cover) comprises 32 million acres, almost a third of the state. Forestlands provide a wide range of benefits (e.g. water, recreation, wildlife habitat, forest products, grazing, carbon storage and sequestration) and face numerous threats (e.g. wildfire, development, pests, climate change), all of which are covered in other Assessment chapters. The magnitude of these threats and the potential for lost benefits is obvious in the recent extreme mortality event that has killed over 100 million trees in the state [9]. Figure 1.1 shows levels of mortality due to extended drought and subsequent attack by forest pests. The mortality crisis is being addressed by a cooperative effort through the Tree Mortality Task Force [10].

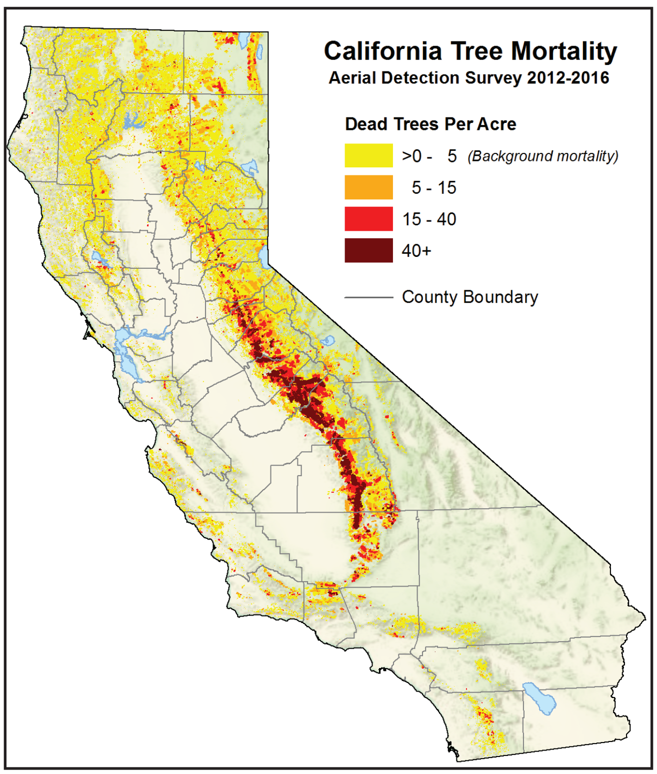


Figure 1.1: Current Levels of Tree Mortality from Extended Drought and Subsequent Attack by Forest Pests.

Data Source: Aerial Detection Survey, USDA Forest Service, 2012–2016.

This chapter focuses on longer-term trends, issues, and opportunities related to sustainable "working" forests (potentially available for timber production) and timberland. Timberland represents the land base that could potentially be managed for forest products, and is defined by the Forest Service as land capable of producing over 20 cubic feet/acre/year of wood with commercial value and not withdrawn from timber utilization by statute or administrative regulation [11].

Sustainability

In California, the public interest in maintaining and enhancing sustainable working forests is implemented based on numerous federal, state, and local laws, rules, regulations, and ordinances. For non-federal lands, the primary regulatory framework is provided by the Z'Berg-Nejedly Forest Practice Act (1973), implemented through the Forest Practice Rules (FPR). The FPR require preparation of a Timber Harvesting Plan (THP) by a Registered Professional Forester (RPF), which is considered the functional equivalent of a California Environmental Quality Act (CEQA) Environmental Impact Report (EIR). A summary of how the FPR address sustainability is provided below, for the three components of sustainable forestry [12].

<u>Inventory Management</u>

- Timberland preservation: restrictions on timberland conversion to alternative uses
- Post-harvest re-stocking: specific requirements for re-stocking after timber harvest
- Sustained yield: owners of over 50,000 acres of timberland are required to meet Maximum Sustained Production under a Sustained Yield Plan (SYP) or "Option (a)"
- Emergency rules: provisions for addressing stands damaged by fire, pests, etc.

<u>Ecological and Environmental Protection</u>

- Water quality protection: stream course protection rules related to harvest practices and road construction

- Wildlife habitat protection: retaining/recruiting late seral habitat in watercourse and lake zones for habitat connectivity, protection for threatened and endangered species, snag and downed wood considerations

Community Support and Socio-Economic Benefits

- Public input: THP review includes multi-agency participation and a formal process for public input

- Specific provisions for protection of archaeological, historical, and cultural sites

- Maximum Sustained Production (MSP) provisions for large landowners contribute to a sustained level of economic activity and local employment

The regulatory framework has undergone various revisions since its inception, including measures to provide additional protection for water quality, and fish and wildlife habitat. Changes have also addressed regulatory efficiency and cost of compliance, while maintaining or strengthening environmental protection.

Further improvements to the regulatory system are provided by AB 1492 (2012). This bill created the Timber Regulation and Forest Restoration Fund through a 1% tax on retail sales of lumber and engineered wood products. AB 1492 includes provisions to:

- Develop performance measures "...to provide transparency for both the regulated community and other stakeholders."

- Create a funding source for restoration of forests, fish and wildlife habitat, and for water quality improvement.

- "Modify current regulatory programs to incorporate, and provide incentives for best practices, and develop standards or strategies, where appropriate, to protect natural resources, including the development of plans that address road management and riparian function on an ownershipwide, watershedwide, or districtwide scale."

Overall, AB 1492 improves the state's ability to monitor the economic and environmental consequences of timber regulation, provide for a more efficient regulatory process that potentially takes a broader view than individual harvest plans, and fund critical restoration activities.

The Resource Base

Timberland Ownership

Over half of California timberland is in public ownership (Figure 1.2), primarily by the Forest Service. About a quarter of timberland is owned by forest industry, including much of the higher site quality lands. The remaining timberland (18%) is owned by a diverse group of smaller nonindustrial owners. There have been no significant changes in the proportions of forestland owned by public agencies and private owners since the 2010 Assessment [13].

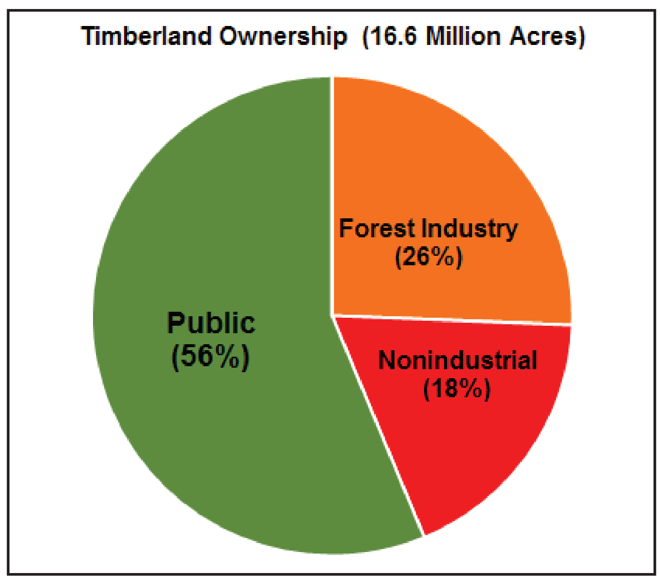


Figure 1.2: California Timberland Ownership.

Data Source: [13] Harris, 2017.

Development Impacts

Conversion of timberland to urban or agricultural uses is a relatively minor issue in California [13]. However, working forests are also impacted by subdivision of large parcels, which can result in holdings too small to be effectively managed for timber. Conservation easements are an increasingly effective tool for preserving timberlands with important environmental or social values, and for protecting working forests from conversion or being subdivided (ⓘ6.3).

Stocking Levels

Current mortality levels and recent stand-replacing wildfires have called into question forest and fire management policies, and specifically whether the problem has been exacerbated by overstocked forest conditions. To explore this question, we used two different rules for identifying overstocked stands based on Stand Density Index (SDI):

- Stands exceeding 60% SDI - lower threshold of the self-thinning zone, where competition due to tree density begins to induce tree mortality.
- Stands exceeding 100% SDI - upper limit of self-thinning zone.

Table 1.1 shows that depending on the Stand Density Index (SDI) rule applied, public timberlands that are overstocked range from about 0.4 million acres (100% SDI rule) to 3 million acres (60% rule) (ⓘ1.2). Using the 60% rule, there are 4.7 million acres of public and private timberland that are overstocked and potentially at risk from wildfire and/or forest pests.

SDI provides a reasonable measure of stocking for industrial forests where timber production is the primary concern. For public timberlands dominated by multiple-use and ecological restoration goals, other measures of stand structure may be more appropriate.

Contrast of planted plantation and nonplanted land, 12 years after the Fountain Fire, Shasta County. Photo by Jianwei Zhang, courtesy of USDA Forest Service.

However, by any measure forest health and condition is an issue. For example, for the Forest Service to achieve their goals, they would need to find the resources to increase ecological restoration activities from the current 200,000 acres a year to approximately 500,000 acres per year [4].

Hardwood dominated timberlands are a natural component of the landscape, but have expanded in some areas due to past disturbances or management. Restoration treatments are more economically feasible on higher site quality lands, such as the nearly 1.4 million acres in sites 1, 2, and 3. About 41% of these acres are in the tanoak/laurel type, typically in areas of the North Coast region where redwood and Douglas-fir have been displaced by hardwoods due in part to past timber management.

Understocked stands and areas with widespread wildfire or pest damage are potentially in need of reforestation. Although forest industry landowners generally replant after large disturbance events, nonindustrial owners typically do not unless technical and/or financial assistance is available through programs like the California Forest Improvement Program (CFIP) [14].

Table 1.1: Understocked, Overstocked, and Hardwood Dominated Timberland (thousand acres)

	Commercial Conifer Species			
Owner	Understocked	Overstocked (60% Rule)	Overstocked (100% Rule)	Hardwood Dominated (FIA Site 1,2,3 only)
Public	2,141	3,024	395	393
Forest Industry	1,015	1,058	145	443
Nonindustrial	296	639	68	549
Total	3,451	4,722	609	1,385

Data Source: [13] Harris, 2017. Data applies to 2006–2015.

The Forest Service has a major challenge trying to reforest its backlog of burned acres, where appropriate. As of 2016, the Forest Service had well over 250,000 acres in need of reforestation. During FY 2016 just over 15,000 acres were reforested, primarily by planting but to a lesser extent through certification of natural regeneration [15]. Funding is an ongoing issue; however, one new funding source is the Greenhouse Gas Reduction Fund (GGRF). During FY 2016, GGRF funds were awarded to three collaborative landscape-level projects that included reforestation work in the Sierra National Forest, Shasta-Trinity National Forest (through the Watershed Research and Training Center), and Tahoe National Forest/Lake Tahoe Basin Management Unit (through the Sierra Nevada Conservancy) [16].

Overall, the total acres potentially in need of treatment to improve stocking (including understocked, overstocked, and site 1-3 hardwood dominated) ranges from 5.5 to 9.5 million, depending on which rule is used for categorizing overstocked stands. Stocking is an issue on public, forest industry, and nonindustrial timberlands.

Invasive Plants

Invasive plants, many of which are not native to California, are having a major impact on both working forests and other forestlands. Nearly one in eight plant species in Sequoia and Kings Canyon National Parks is non-native [17]. The National Park Service considers invasive plants to be the largest threat to biodiversity within Yosemite National Park [18], where 275 non-native plant species have been documented. Redwood National and State Parks have identified 200 species of exotic plants, over thirty of which are invasive species [19]. Numerous additional invasive plant species have the potential to inflict severe damage in the state, but so far have been contained through various efforts related to public education, detection, and control.

For private working forests, invasive species are an important part of management plans, for both timber production and protecting environmental values. For example, the goal of Green Diamond's invasive species program "is to provide control measures for all those species capable of threatening native biodiversity or sound and sustainable forest management." Survey results reported in their management plan show the prevalence of various exotic invasive plants on Green Diamond lands (in Humboldt County) as a percent of surveyed areas. Some of the more common invasive plants mentioned include French broom (60%), pampas grass (40%), English holly (15%), and Scotch broom (15%) [20]. Special considerations may be required for protecting threatened and endangered species impacted by invasive plants. For example, the Fruit Growers Multi-Species Habitat Conservation Plan (HCP) has specific provisions to protect the endangered plant species Yreka phlox from invasive weeds such as Marlahan mustard and yellow starthistle in Siskiyou County [21].

The Forest Service cites problems with invasive plants such as yellow starthistle, Scotch broom and French broom, riparian habitat species such as giant reed and tamarisk, and spotted knapweed and diffuse knapweed [22]. Lack of funding is an issue for limiting the introduction and spread of these and additional species in the future.

Climate Change Impact

Models that simulate future climatic conditions and the response of different tree species allow us to estimate climate change impact on the working forest land base. Future conditions were modeled under a high emission scenario (RCP8.5) that best matches the current global trajectory [23]. Two Global Climate Models (GCMs) were used:

1) CNRM CM5: Under this warmer and wetter scenario, by the end of this century mean annual minimum temperatures increase by 3.26°C and total annual precipitation increases 35% (+ 5.8 inches) under the RCP8.5 emissions scenario.

2) MIROC ESM: Under this hotter and drier scenario, by the end of this century mean annual minimum temperatures increase by 3.95°C and total annual precipitation decreases by 26% (- 6.9 inches) under the RCP8.5 scenario.

Based on our modeled scenarios, in the future a portion of current timberlands will no longer be suitable for growing the tree species that are of primary commercial value in California (Douglas-fir, coast redwood, Jeffrey pine, ponderosa pine, red fir, sugar pine, white fir, incense cedar). Figure 1.3 shows model results for the two climate models for 2069. The red areas are current timberlands where 2069 climatic conditions no longer support any commercial forest tree species. Statewide, there is a projected loss of between 0.6 (3%) and 1.4 million acres (8%) of timberland under the warmer/wetter and hotter/drier climate change scenarios, respectively. These former timberlands will likely transition into oak woodland, brush, or grassland, with different ecological and economic values (e.g. for grazing).

For both models, most of these losses are in the Southern Forest District, especially in lower elevations of the southern range of the Sierra Nevada. By 2069 the District could lose between 0.4 million acres (15% of District timberland) under the warmer/wetter scenario, and 0.8 million acres (29%) under the hotter/drier scenario. Many of these areas are currently experiencing high mortality from what could be characterized as secondary impacts of climate change - mortality from extended drought, forest pests, and large wildfire events.

Overall impacts in other districts are much less, the highest being a projected 6% loss in the Coast District under the hotter/drier scenario. The two unique climate projections result in significantly different results for areas like Santa Cruz County. Under the hotter/drier scenario most timberlands in the county are projected to be climatically unsuitable for growing commercial species, while under the warmer/wetter scenario there appears to be minimal impact.

This analysis looked only at the extreme case of areas that are no longer climatically suitable for growing any commercial timber species. Other significant impacts could occur related to having less options for which species to grow, inability to grow higher valued species,

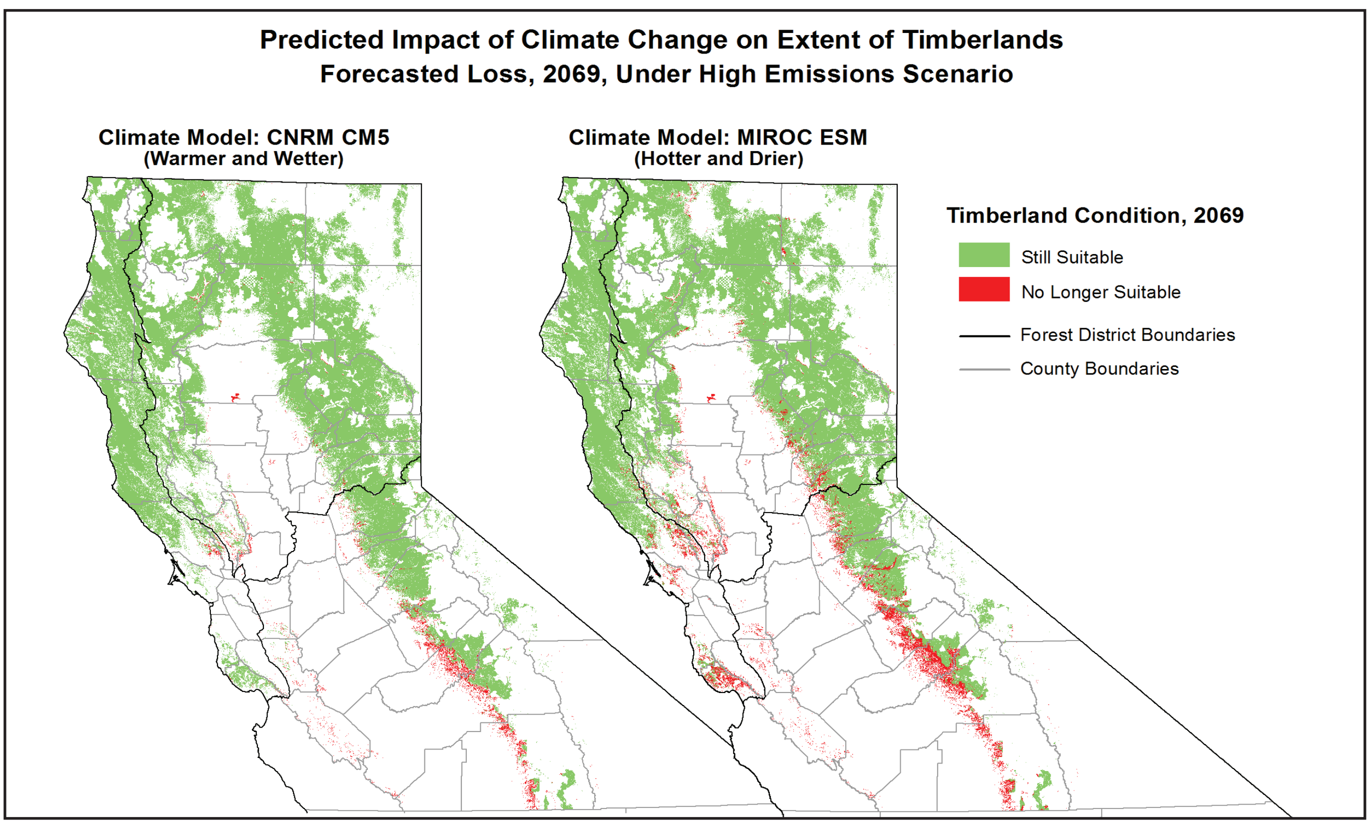


Figure 1.3: Predicted Impact of Climate Change on Extent of Timberlands Under Two Global Climate Models and High Emissions Scenario, 2069.

Data Source: [23] James H. Thorne, et. al, 2017; Management Landscape, FRAP, v15_1.

changes in stocking capability and growth rates, and higher secondary impacts from forest pests and wildfire.

Model simulations also looked at areas that are currently climatically unsuitable for commercial conifers that become suitable at some point in the future. While future climate may support commercial tree species, other factors such as soils, competition from other vegetation, and disturbance regimes could prevent commercial species from ever occupying these new sites.

Climate change also creates research challenges for selecting appropriate species mixes and stocking levels, for both post-harvest restocking and for restoration efforts. The impact of climate change on disturbance regimes also underscores the need for research to better understand how to manage for resilient forests in the face of increasing threats.

Management Context

California timberland has a diverse set of owners with different management objectives, described below.

Forest Industry

For forest industry (4.2 million timberland acres), timber production is the primary objective, but sustainable forestry is practiced as required by the Forest Practice Rules (FPR) and voluntary participation in third-party certification programs. All owners of over 50,000 acres (91% of industrial lands) are required to demonstrate sustained yield (Maximum Sustained Production) through a Sustained Yield Plan or "Option (a)" (ⓘ1.5). In addition, about 86% of forest industry land is enrolled in a voluntary third-party certification program (ⓘ1.5). Management for sustained yield by forest industry is confirmed by data indicating that growth exceeds harvest and mortality (ⓘ1.1).

Industrial forest owners are exploring options for diversifying their income sources, ranging from selling carbon offsets to sale of conservation easements. Industrial owners on the North Coast, with the most productive timberland, are in the forefront of new management initiatives, but there are instances where these are being applied in other regions as well.

Nonindustrial

Nonindustrial private lands (3.0 million acres of timberland) include a diverse group of owners that own land for a variety of objectives. Based on The National Woodland Owner Survey [2], the most common reasons these owners cite for owning forestland in California are scenic beauty, residence or vacation home, protecting nature, passing the land to heirs, and investment property.

The state has tried to encourage more active sustainable management of these lands, for example by allowing owners of up to 2500 acres of timberland to streamline the Timber Harvesting Plan process by preparing a Nonindustrial Timber Management Plan (NTMP). NTMPs have a core requirement for an assessment of long-term sustained yield based on an uneven-aged silvicultural prescription. Plans also must include provisions for protecting environmental and ecological values. As of May 2015, there were 773 approved NTMPs covering about 320,000 acres. Management of other nonindustrial lands is diverse and sporadic, and timber harvest is sometimes done for purposes such as wildfire hazard reduction, control of exotic species, or enhancement of various ecosystem services [2]. Overall, timber growth on nonindustrial ownerships far exceeds harvest and mortality, resulting in an accumulation of volume (ⓘ1.1).

Public

The Forest Service administers 8.9 million acres of the 9.3 million acres of publicly owned timberland. Stand condition in terms of stocking levels (ⓘ1.2) and deviation from historic fire regimes (ⓘ4.1) are major issues. According to the Forest Service, "nearly a century of fire exclusion in California, coupled with other management decisions on both private and public land, has resulted in forests that are at an increasing risk of loss due to large scale disturbances." The Agency further states "only an environmental restoration program of unprecedented scale can alter the direction of current trends." Forest Service goals set in 2011 for California include treatments to improve forest resiliency and other ecological restoration activities such as restoring degraded meadows, reforestation of burned areas, increasing habitat connectivity, restoring natural fire regimes, and decreasing the impact of invasive species [3]. To achieve their goals, the Forest Service would need to find the resources to increase ecological restoration activities from the current 200,000 acres a year to approximately 500,000 acres per year [4].

Harvest from Forest Service land declined steeply (ⓘ1.4) after the listing of the northern spotted owl under the Endangered Species Act in 1989 and passage of additional federal regulations, along with changes in federal timber programs to address potential issues with the California spotted owl. It has stabilized at a level that since the year 2000 has been about 18% of total harvest in the state (ⓘ1.4). This level of harvest currently results in a net accumulation of volume since growth exceeds harvest and mortality (ⓘ1.1). However, at least one study has called into question whether this trend will continue under current management direction [8].

The Forest Service is involved in initiatives and partnerships based upon an "all lands" approach, recognizing that since ecosystems do not acknowledge ownership boundaries effective management requires collaborative efforts. For example, this approach is currently being applied to fire hazard reduction in the Highway 50 corridor between Placerville and the Tahoe Basin. In that project the Forest Service, CAL FIRE, California Department of Transportation (Caltrans), the local Resource Conservation District (RCD), private landowners, and the public are planning and executing projects that will provide defense against major wildfires like the 2014 King Fire.

Other public lands managed for multiple uses including timber production include certain Bureau of Land Management (BLM) lands, state forests administered by CAL FIRE, and even properties owned by local agencies (e.g., the City of Arcata Community Forest). Other public forestlands such as national and state parks are not actively managed for timber.

Tribal Lands

There are four reservations in California that are actively managed for timber production and other uses in accordance with their forest management plans (Hoopa, Round Valley, Tule River, and Yurok). The Hoopa Reservation was one of the first properties in California to undergo certification for sustainable management - by Forest Stewardship Council (FSC). Both the Yurok and the Round Valley tribes have projects that have been approved by the Air Resources Board (ARB) for sale of carbon offsets through improved forest management.

The Management Landscape

FRAP has developed the "Management Landscape" applied to productive forestlands (including timberland plus productive forest withdrawn from timber production) to characterize how unique owner objectives translate into timber management emphasis (Figure 1.4). Management emphasis relates not only to harvest volume, but also to the silvicultural systems and practices used to grow and harvest timber and the level of associated ecosystem services provided.

Statewide, only 17% of productive forestland (typically forest industry owners) is high timber emphasis, where

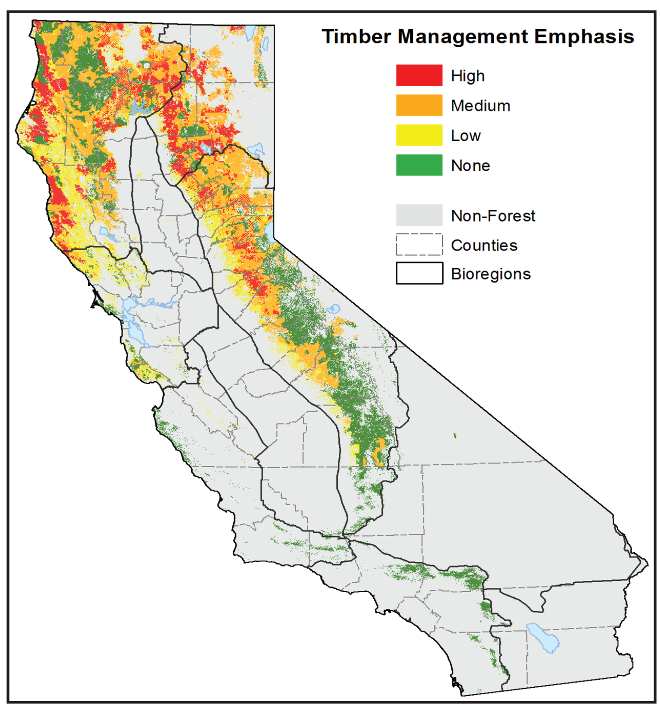


Figure 1.4: Timber Management Emphasis Classes.

Data Source: Management Landscape, FRAP, v15_1.

timber harvest is the primary objective (Figure 1.5). In California, high timber emphasis is different than in other states or even what was practiced here in the past. This is due to changes to the FPR including sustained yield requirements for large owners, voluntary enrollment in third-party certification programs, and other factors. Owners with high timber emphasis use both even and uneven-aged silvicultural systems.

The prevailing emphasis level in the state is medium (36%), which can be characterized as multiple-use management, primarily using uneven-aged silvicultural systems. This includes Forest Service timberlands; nonindustrial owners managing under a Nonindustrial Timber Management Plan (NTMP); conservation organizations managing working forests; and forest industry, nonindustrial, and tribal owners with lands enrolled in the ARB carbon offsets program.

Almost a fifth of productive forest (19%) is in low timber emphasis. This is typically nonindustrial lands where timber is not one of the primary objectives for owning land.

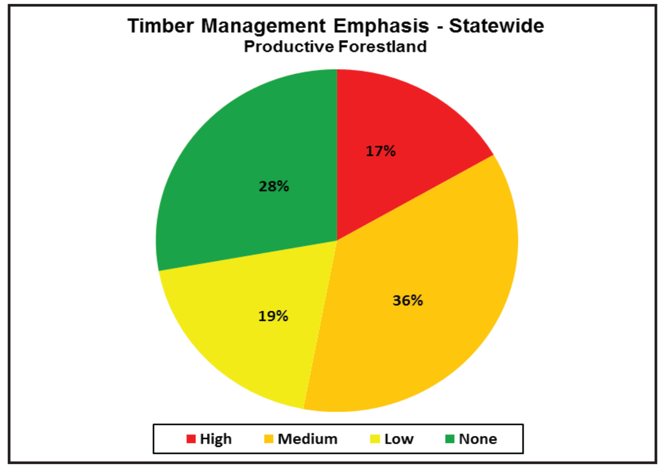


Figure 1.5: Percentage of California Productive Forest by Timber Management Emphasis Class.

Data Source: Management Landscape, FRAP, v15_1.

Finally, 28% of productive forest is either legally or administratively withdrawn from timber production (e.g. wilderness, parks), or is in areas where timber harvest is not a viable option due to lack of wood processing infrastructure (e.g., southern California).

Figure 1.6 shows a more detailed view of management classes for Mendocino County. New management initiatives are concentrated here and in Humboldt counties,

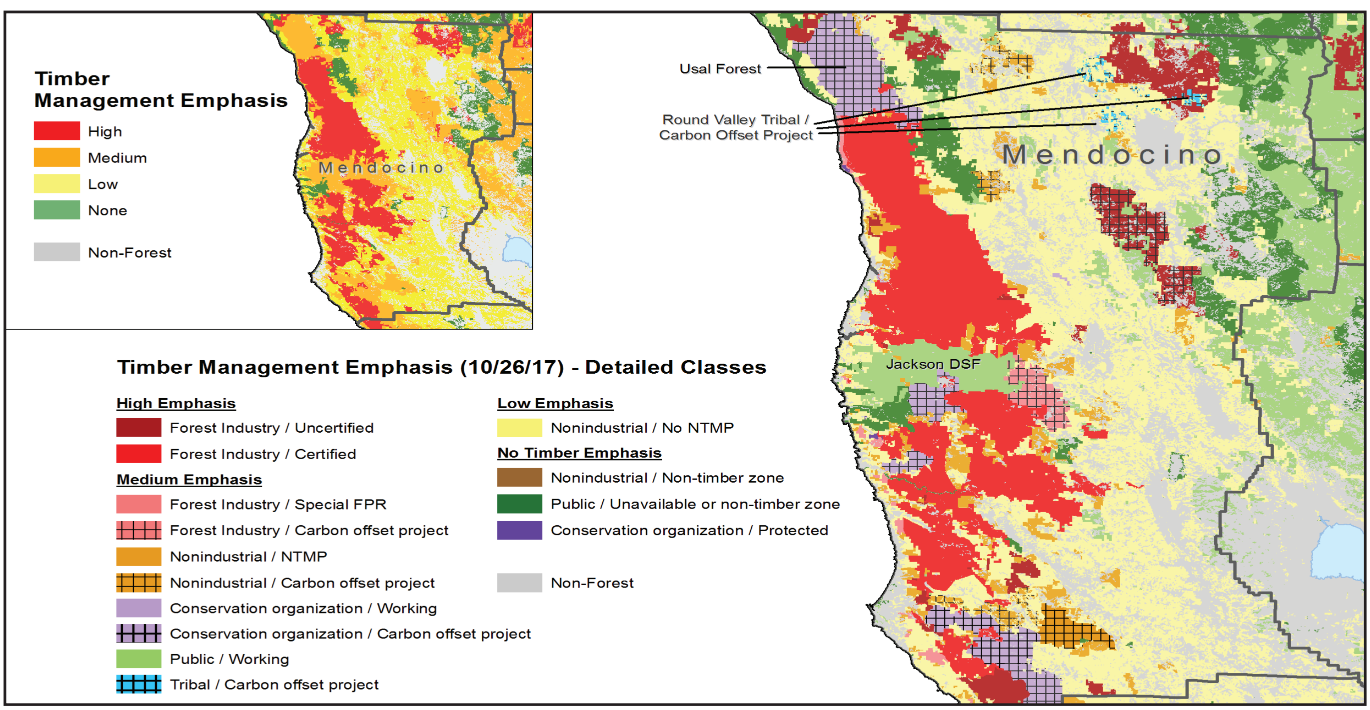


Figure 1.6: Detailed Management Landscape Classes for Mendocino County as of October 26, 2017.

Data Sources: Management Landscape, FRAP, v15_1; [41] Air Resources Board, 2017; Forest Practice System (FPS), CAL FIRE, 1997–2015.

typically on highly productive timberland. Forest industry lands here tend to have third-party certification for sustainable management. There are carbon offset projects on timberlands owned by forest industry, numerous nonindustrial private holdings, conservation organizations, and tribes. Conservation organizations are very active here in purchasing lands or easements to conserve working forests.

Silvicultural Practices

Changes in management emphasis are also reflected in terms of trends in harvesting activity and silvicultural practices (Figure 1.7). There has been a steady significant decline in total acres harvested over the 1997–2015 period. Harvested acres in 2015 were about half of 1997 harvest acres. Acres harvested using uneven-aged systems have been fairly constant, despite the decline in total harvest acres. Thus, the percentage of acres harvested using uneven-aged systems has increased, from an average of 29% of harvested acres over the 1997–2001 period, to 41% over the 2011–2015 period. In the Coast District, 54% of the 2011–2015 period harvest acres were uneven-aged.

Widespread tree mortality from drought, pests, and wildfire have contributed to a major increase in acres filed for harvesting under Emergency Conditions (1052.1(b)). In 2015, Emergency Conditions acres comprised 10%, 23%, and 89% of total acres filed for harvest in the Coast, Northern, and Southern Forest Districts, respectively.

The Forest Products Sector

California imports about 80% of the lumber and 90% of all wood products used in the state [5-7]. Meeting in-state demand requires importing lumber and wood products from other states and countries that may have less restrictive rules on forest practices. However, numerous statewide factors and trends are impeding more active timber management to meet our demand for wood products.

Current and historic timber harvesting (Figure 1.8) shows a major decline; the total volume harvested in 2015 was 72% lower than in 1955 (ⓘ1.4). The number of sawmills follows a similar trend; there were 675 sawmills in 1956 and only 30 in 2012. Numerous factors are cited as reasons for these declines:

- Historically high timber harvest levels in the 1950's coinciding with the post-WWII housing boom

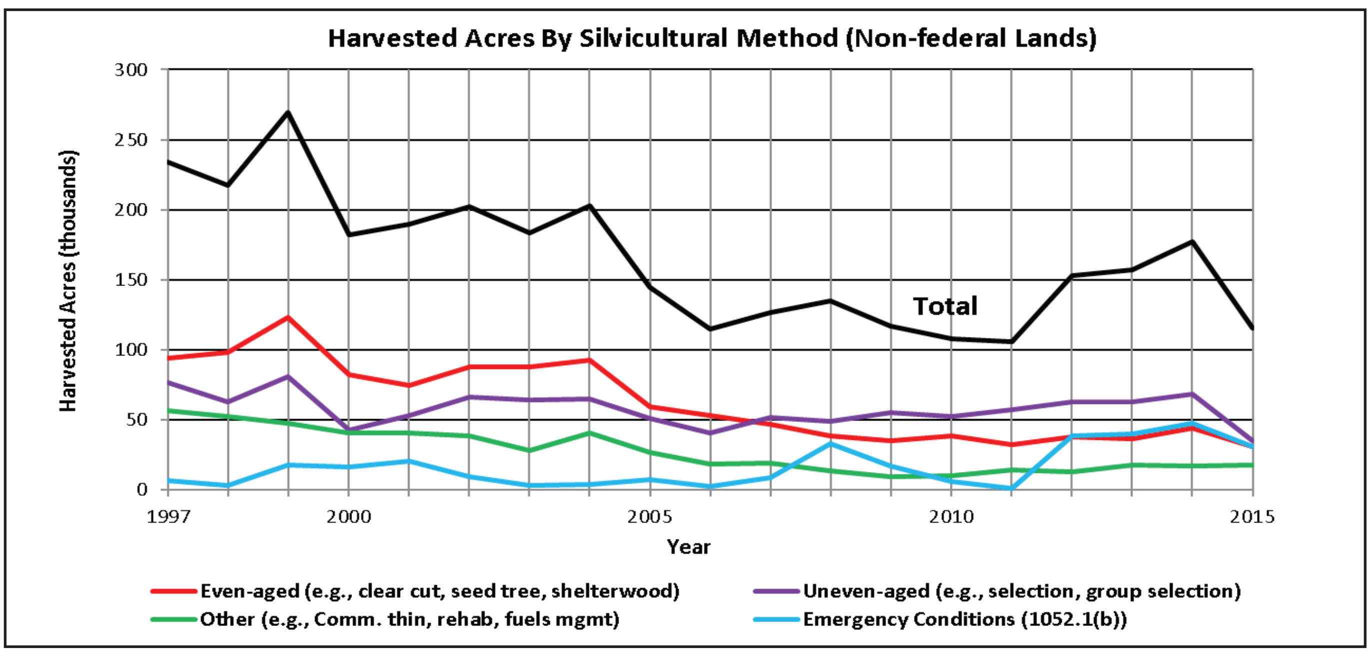


Figure 1.7: Harvest Acres by Silvicultural Method (Non-federal Lands).

Data Source: Forest Practice System (FPS), CAL FIRE, 1997–2015.

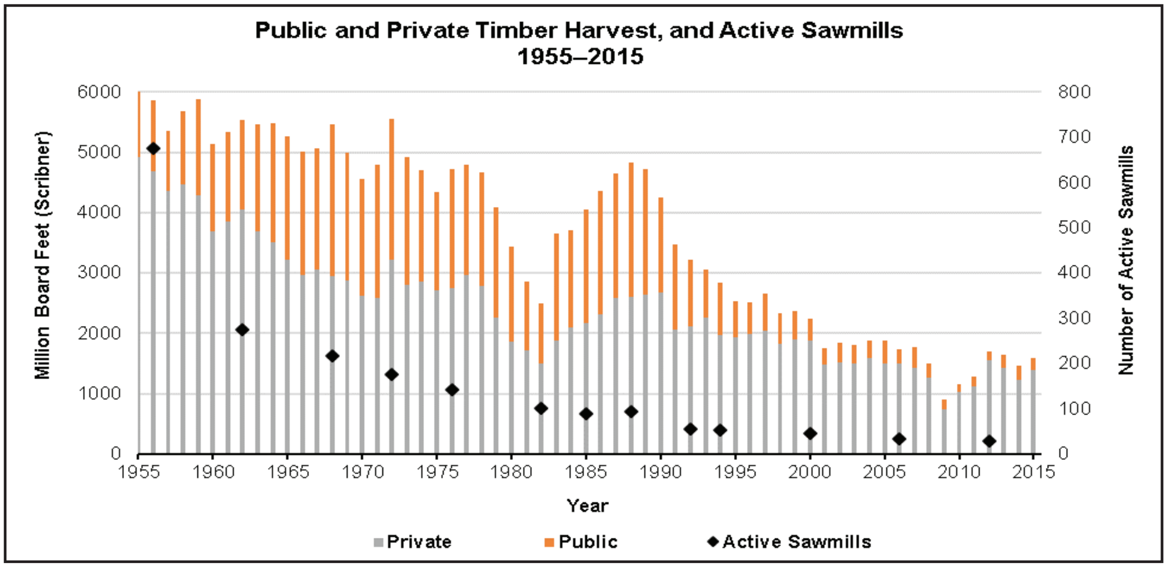


Figure 1.8: Public and Private Timber Harvest, and Active Sawmills, 1955–2015.

Data Sources: Timber Harvest Statistics, CA Board of Equalization, 1955–2015; Resource Bulletin PNW-RB-35, USDA Forest Service, 1970; General Technical Report PNW-GTR-908, USDA Forest Service, 2015.

- Forest industry transitioning from harvest of old-growth timber to management of second-growth
- Regulation of timber harvest on private lands, including the Z'Berg-Nejedly Forest Practices Act (effective 1/1/74), and requirements for large industrial owners to manage for long-term sustained yield since the late 90's
- Policy and regulatory changes and a greater focus on ecological integrity resulting in reduced timber harvest on federal lands. The contribution from public lands to total harvest volume over the 1955–1990 period averaged about 38%. Since 2000, it has averaged only about 18%.
- Various market forces including concentration of milling capacity into larger more efficient mills in fewer locations [24], and increased foreign competition and use of wood substitutes [25]

Since the late 1990's, forest industry owners with over 50,000 acres have been required to demonstrate management on a sustained yield basis through either a Sustained Yield Plan (SYP) or "Option (a)." Since 2000, private harvest levels (the bulk of which are forest industry) have averaged 1,363 million board feet. Annual fluctuations have been as much as 35% over this average and 46% under. Future harvest levels are likely to fluctuate around this average based on various economic, regulatory, and environmental factors, as well as the capacity of infrastructure to process harvested materials. As Table 1.2 shows, harvest levels for forest industry for the years 2000, 2006, and 2012 have been stable. The table also suggests an increasing relative importance for

Table 1.2: Timber Harvest by Forest Industry, Nonindustrial, and Public Owners

	2000		2006		2012	
	Harvest	% of Harvest	Harvest	% of Harvest	Harvest	% of Harvest
Forest Industry	1,075	48%	943	54%	1,000	70%
Nonindustrial	801	36%	556	32%	185	13%
Public	364	16%	229	13%	232	16%
Data Note: Volume in million board feet (Scribner)						

Data Sources: [26] Morgan et al., 2012; [1] Morgan et al., 2004.

forest industry harvest, which made up 70% of all harvest volume by 2012.

The decline in sawmills shown in Figure 1.8 is of concern, particularly to nonindustrial owners left with limited or no options to market their timber. Currently, in the Sierra Nevada, lack of wood processing infrastructure combined with relatively low value material limits the ability of landowners faced with extensive tree mortality to sell their timber and secure funds for reforestation. For those landowners, the export market is sometimes their only alternative.

While traditional wood processing capacity has declined, diversified markets and advancements in resource utilization and manufacturing technology creates potential opportunities [24]. From 2006–2012, the state lost three sawmills and three pulp and board facilities, but gained one decorative bark facility, and four facilities falling in the "Other" category [24]. Since 2012, new facilities include a small-log sawmill in Yreka (Fruit Growers), post/pole manufacturer in Anderson (Alta California Roundwood), and incorporation of logs into the raw material supply for the one remaining particle board plant in California (Ampine, Martell) [13]. Bioenergy represents another area of possible expansion (discussed in detail in Chapter 12, Renewable Energy).

Management Initiatives

Private Timberland

Table 1.3 summarizes private timberland acreage covered by the main regulatory and voluntary initiatives in the state, including third-party certification programs. Forest industry landowners with over 50,000 acres of timberland have about 3.9 million acres in mandatory "Option (a)" or Sustained Yield Plans. This represents 91% of industrial timberland and 53% of all private timberland. About 86% of forest industry and 14% of nonindustrial timberland is enrolled in a voluntary third-party certification program. Finally, a significant and increasing acreage of timberland is under modified management (Nonindustrial Timber Management Plan or Carbon Offset Project), much of which gives additional emphasis to ecosystem services.

As of March 2017, the ARB had identified 20 compliance and early action forestry projects in California, totaling over 270,000 acres (ⓘ1.6). All but one California project is in or adjacent to Humboldt and Mendocino counties, typically in highly productive timberland with relatively low fire and pest threat. All California projects are "improved forest management," involving combinations of reduced harvest levels, longer rotations, and uneven-aged management. In addition, there are over 85,000 acres of projects registered with the Climate Action Reserve (CAR). Some CAR projects involve

Table 1.3: Timberland Managed Under Sustainability Initiatives or Certification

	Forest Industry		Nonindustrial	
Regulatory or Voluntary Initiatives	**Thousand Acres**	**%**	**Thousand Acres**	**%**
"Option (a)" or Sustained Yield Plan¹	3,873	91%	-	-
Nonindustrial Timber Management Plan (NTMP)	-	-	320	11%
Program Timber Environmental Impact Report (PTEIR)	61	1%	26	1%
Carbon Offset Projects²	203	2%	72	4%
Third Party Certification				
Forest Stewardship Council	1,560	37%	57	2%
Sustainable Forestry Initiative	2,000	47%	-	-
American Tree Farm System	100	2%	366	12%
One or More Certification Program (no double counting)	3,660	86%	423	14%

Data Notes:
1. Owners with more than 50,000 acres of timberland are required by law to demonstrate Maximum Sustained Production (MSP) through one or the other of these initiatives. 2. Includes compliance and early action projects.

Data Sources: Forest Industry, FRAP, v15_2; Forest Practices Systems, CAL FIRE, 1997–2015; PTEIR reports, CAL FIRE, 2017. [41] Air Resources Board, 2017; [42] Climate Action Reserve, 2017.

intensive even-aged management with actions to maintain stocking for optimal growth, and extended rotations for culmination of carbon growth.

Collaborative Projects

There are numerous examples in California of collaborative landscape-level projects designed to improve forest health, reduce fire threat, and contribute to local economic development. There are programs that support these collaborative efforts at the federal (e.g. Joint Chiefs' Landscape Restoration Partnership, National Cohesive Wildland Fire Management Strategy, Collaborative Forest Landscape Restoration Program) and state levels (e.g. CAL FIRE Forest Health Initiative/Greenhouse Gas Reduction Fund grant program, Sierra Nevada Conservancy Watershed Improvement Program). They are also supported by collaborative agreements such as the Fire MOU Partnership [27].

The Sierra Nevada Watershed Improvement Program (WIP)

WIP is a coordinated, integrated, collaborative program to restore the health of California's primary watershed through increased investment and needed policy changes. The WIP builds upon the broad consensus that the pace and scale of science-based, ecological restoration need to dramatically increase in order to stem the tide of large, uncharacteristic wildfires, widespread tree mortality and further degradation of these ecosystems. The WIP focuses on increased investment, policy and process improvements and increased wood/biomass utilization infrastructure. This effort is being organized and coordinated by the state's Sierra Nevada Conservancy (SNC) and the United States Forest Service in close partnership with additional federal, state, and local agencies, and diverse stakeholders.

South Fork American River (SOFAR) Cohesive Strategy Project

The South Fork American River Watershed was proposed for implementing the National Cohesive Wildland Fire Management Strategy because of the many values at risk threatened by complex fire issues associated with drought, climate change, fuel loading, insects and disease [28]. Communities, infrastructure, public and private timber, water, power, recreation, protected species, and fire frequency are all reasons that this watershed is a high priority for collaborative action. A major component of SOFAR is the Fire Adapted 50 project.

Before and after photos of the Fire Adapted 50 project, showing a reduction in surface in ladder fuels. Photos by Richard Harris.

Good Neighbor Master Agreement and Fire Adapted 50

The "Good Neighbor Master Agreement" between the California Natural Resources Agency and the Forest Service was finalized in January 2016. The Good Neighbor Authority allows the Forest Service to issue agreements or contracts to allow states to perform watershed restoration and forest management services on National Forest System lands.

Under the terms of this agreement the El Dorado National Forest transfers $908,000 to CAL FIRE to conduct fuel treatments in the Highway 50 corridor between Camino-Pollock Pines and Echo Summit. This project complements major fuel treatments funded by CAL FIRE in the Sly Park area that are being implemented in 2017. The work funded by the good neighbor agreement will "help create fire-adapted communities, resilient landscapes and safe and effective fire response, which are the three goals of the National Cohesive Strategy" [29].

The Sustainable Forest Action Coalition

The Sustainable Forest Action Coalition is a group that is focused on improving relationships between local communities and the Forest Service to achieve goals of forest restoration while enhancing local economies. In California, it has the support of 20 counties, several Chambers of Commerce, forest industry and other local organizations. Formed in 2010, most of the Coalition's efforts have been directed to setting up meetings between its representatives, Congressional representatives and Forest Service management to discuss common goals. Its stated objective is "to work at the State and Federal level to bring regulatory reform to restore our watersheds through healthy forests while maintaining and expanding the existing forest products and bioenergy infrastructure."

Federal Stewardship Contracts

There are dozens of stewardship contract projects in California providing economic opportunities to local communities [30]. In some cases, stewardship contracts have served the purpose of creating relationships to involve local communities in the co-management of federal lands. For example, the Weaverville Community Forest consists of Forest Service and BLM lands being managed by the local community to reduce fuel loads and generate timber for supplying the local mill [31].

Landowner Assistance

Historically, the primary sources of financial and technical assistance to landowners have been the Natural Resources Conservation Service (NRCS) through its Environmental Quality Incentives Program (EQIP) and Healthy Forests Reserve Program, and CAL FIRE through its California Forest Improvement Program (CFIP). The EQIP program has recently changed in emphasis to address landowner needs related to tree mortality, but overall improved forest health and productivity are the goals of the program.

CAL FIRE also administers the California Forest Legacy Program (part of the national program administered by the Forest Service), which is aimed at securing protection of working forests through conservation easements and fee acquisition. California competes annually for congressionally appropriated funds with other states. To date, California has acquired nearly 111,000 acres of forestland conservation easements or properties utilizing over 22 million federal dollars and an undetermined amount of state and private funds [13].

The Timber Regulation and Forest Restoration Fund (TRFRF) Program (AB 1492) is a relatively new potential source of funding, in part for forest restoration projects [32]. The Program is funded by a 1% assessment on lumber and engineered wood products sold at the retail level. A portion of these funds have been provided to the CAL FIRE CFIP program.

The University of California Cooperative Extension, Northern California Society of American Foresters (SAF), California Licensed Foresters Association (CLFA), Resource Conservation Districts (RCDs), and other organizations offer technical assistance and educational workshops, trainings and webinars to resource management professionals and landowners.

Opportunities

Continue to Explore, Implement, and Support Ways to Increase Active Sustainable Management on Nonindustrial Timberlands

Increasing active management on nonindustrial timberland is dependent on factors such as regulatory costs, availability of technical and financial assistance, and ability to market timber based on access to wood processing infrastructure. Voluntary options such as Nonindustrial Timber Management Plans that reduce regulatory costs while enhancing environmental protection have had success, with about 11% of nonindustrial timberlands enrolled (ⓘ1.5). There are pending actions to extend the option to properties between 2,500 and

15,000 acres through a Working Forest Management Plan (WFMP).

The TRFRF Program potentially benefits nonindustrial owners through streamlined THP processing, planning watershed studies that may provide useful information for cumulative impacts assessments, and funding for forest restoration projects [32].

Widespread tree mortality and wildfires have impacted nonindustrial owners, who often are unable to conduct reforestation operations unless technical and/or financial assistance is available through programs like the California Forest Improvement Fund (CFIP) [14]. Given the extent and magnitude of mortality, increased support from federal and state programs is critical for small landowners.

Create Additional Distributed Infrastructure to Diversify Log and Biomass Markets, such as Community Based Small Mills, Portable Mills, and Biomass Plants

Primary wood processing infrastructure diversification may include small, semi-stationary sawmills located in communities adjacent to or within forested areas. One effect may be to improve log markets for small, non-industrial forest owners. At least one source estimated there are about 2,000 portable sawmills in California, with perhaps 20% of them accounting for 80% of the production [13]. The Urban, Salvaged and Reclaimed Wood network is one example of a group that is trying to assist small sawmill owners. The Forest Service also recently awarded a grant to assist in organizing and marketing lumber and other products produced by small sawmills, primarily in rural areas located closer to major tree mortality in the Sierra Nevada. One strategy to increase production may be to focus efforts on the small, semi-stationary mills or ones that consume a minimum amount of material rather than trying to reach out to all owners.

Portable sawmill. Photo by Joseph Obrien, USDA Forest Service.

The Renewable Energy chapter documents the ongoing decline in the number of biomass plants in California (ⓘ12.2). However, at least 9 small biomass plants are in various stages of development because of SB1122 (2012), known as the Bioenergy Market Adjusting Tariff (BioMAT). These small plants could help facilitate needed treatments to improve forest health and reduce fire threat in localized areas.

Expand Research and Support for New Wood-Based Products to Increase Marketing Options and/or the Utilization Value of Harvested Timber

New products have the potential to provide additional employment and economic benefits for rural economies. There is a long history in the state of efforts to capture value from under-utilized source materials such as hardwoods, often with limited success [33]. Technological advances create additional opportunities, ranging from turning forestry residues into jet fuel [34] to laminated wood products strong enough to be used for skyscrapers [35]. New engineered wood products ("mass timber") offer a range of new opportunities [36]. In addition, there is research that suggests that increasing the use of wood over alternative materials in building construction will have significant positive results for greenhouse gas emissions [37].

California needs marketing options for salvage material from the current mortality crisis. There is an active movement in California to promote the utilization of urban, reclaimed and salvaged wood, including trees damaged by fire or forest pests. For example, one company (Far West) has experienced high demand for blue stained pine slabs over the past year [38].

Support Collaborative Landscape-Level Projects that Involve State and Federal Agencies, Local Communities, and other Stakeholders for Improving Economic and Environmental Sustainability

As detailed in this chapter, there are numerous examples of successful collaborative efforts underway in California. The primary constraint on collaborative projects is funding. While support for these efforts by federal agencies has been strong, there is uncertainty about future funding levels that will be appropriated by Congress.

Collaborative projects have also been funded through state competitive grant programs such as the Greenhouse Gas Reduction Fund (GGRF). For FY 2016, the GGRF forest health grant program was reconfigured to focus on multi-activity "landscape-scale" projects [16]. The intent was to fund activities (including reforestation, fuel reduction, pest management, conservation and biomass utilization) that are part of collaborative, large-scale cohesive management plans which aim to improve overall forest health across the landscape, and where the collective effect of all funded activities is a greenhouse gas (GHG) benefit. GGRF grants were awarded for projects on the Sierra National Forest, Shasta-Trinity National Forest (through the Watershed Research and Training Center), and Tahoe National Forest/Lake Tahoe Basin Management Unit (through the Sierra Nevada Conservancy).

Promote More Active Sustainable Management of National Forests to Improve Forest Health, Reduce Wildfire Threat, and Support Local Economies

Timber harvest targets for national forests are established in Washington DC and allocated to the Forest Service regions. Consequently, there is limited latitude to change those targets at the local level. There are, however opportunities to encourage achieving the targets. Lack of federal funding and staffing are often limiting factors, so opportunities that support additional federal funding or bring in additional state or private resources can be effective (e.g. the GGRF grants discussed in the previous opportunity). One approach that is advocated by the Forest Service in California is stewardship contracting. Stewardship contracting allows the Forest Service to award projects to public or private entities to conduct management activities on national forest land. Under the terms of these contracts local timber supplies can be increased, employment opportunities are created and revenues are produced by the sale of the timber. These revenues in turn, are retained at the local Forest level rather than sent to the Treasury and can be used to fund restoration and management projects.

Additional opportunities are provided by The Good Neighbor Authority, which allows the Forest Service to issue agreements or contracts to allow states to perform watershed restoration and forest management services on national forest lands. The "Good Neighbor Master Agreement" between the California Natural Resources Agency and the Forest Service was finalized in January 2016. This agreement is currently being used for the Forest Service to fund CAL FIRE fuel treatments in the Highway 50 corridor between Camino-Pollock Pines and Echo Summit.

Active management also includes pre-fire projects to improve forest health and restore natural fire regimes, as discussed in the Wildfire chapter. The Forest Service is involved with various state and local agencies and other stakeholders in numerous cooperative projects that include prescribed fire.

Expand Research and Support to Select Appropriate Genetic Sources for Adapting New Plantings for Climate Change

Reforestation based on seed zones alone is being called into question because of uncertain future climate. Forest managers have accepted the need to adapt reforestation practices to assure successful regeneration. Forest Service specialists have recommended utilizing seed from sources that are one elevation band (500 feet) up and/or one seed zone south to north from the proposed planting site [39]. Their alternative suggestion is to use seed orchards from breeding zones (twice the size of a seed zone) that contain broadly adapted selections, based on their growth and adaptation to environmental variability.

Experiments and studies relevant to this opportunity are currently being conducted by Forest Service researchers. Some are modeled on the classic "common garden" approach which tests how trees derived from seed from different sources perform in replicated locations. In one experiment at the King Fire, 12 sources of ponderosa and sugar pines are being evaluated under "operational" conditions to determine if source influences growth. The source locations are correlated with climatic variables which can be evaluated in relation to observations of growth [13]. The findings of this study and others like it will have application to future reforestation practices.

One very promising tool that pertains to this opportunity is the Seedlot Selection Tool (SST) [40]. The SST is a web-based mapping application designed to help managers match seedlots with planting sites based on climatic information. The SST can be used to map current climates or future climates based on selected climate change scenarios. The SST is not currently being used in California but there is effort underway to encourage its adoption by the Forest Service and others [39]. California could partner in this effort and in funding this tool.

Additional suggestions related to this opportunity include providing funding for field studies of natural regeneration to detect signs of failure; rejuvenating of cone collections to replace older seedlots in storage at the Placerville Nursery and L.A. Moran Reforestation Center; and increasing emphasis on genotype selection for drought avoidance and tolerance traits. Considering the limitations of tree improvement programs and common garden studies, it would also be advisable to design and conduct experiments testing the ability of trees to resist multiple stressors including drought, temperature, insects and pathogens.

Tree planting, Plumas National Forest. Photo courtesy of USDA Forest Service.

Indicator: Net Growth of Growing Stock on Timberland ⓘ1.1

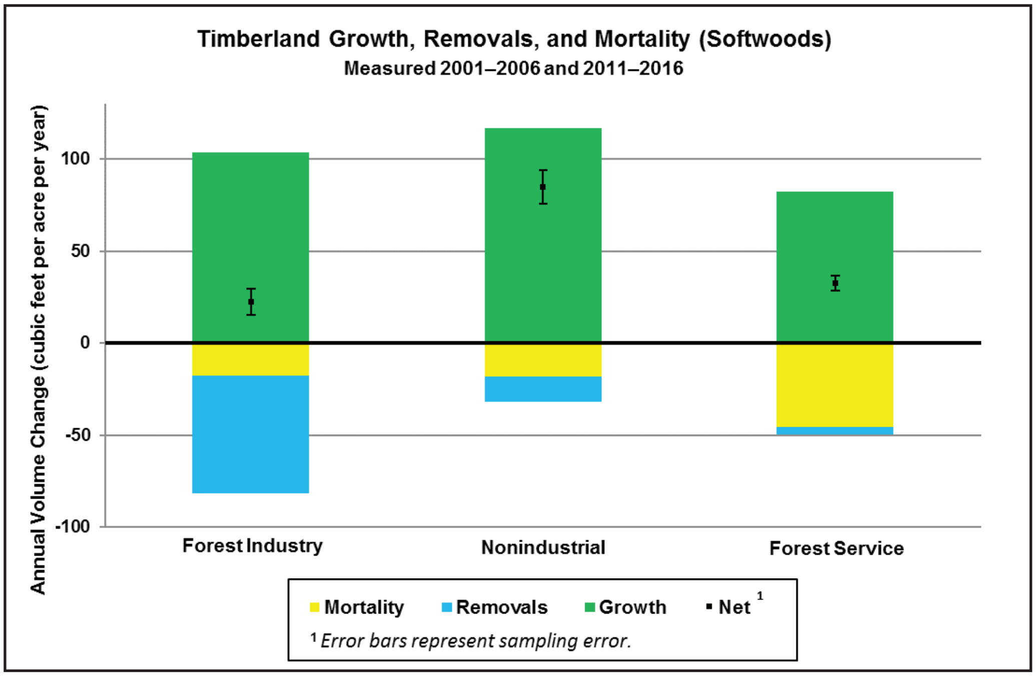
Which Montreal Process Criterion does the indicator evaluate?

MPC2: Maintenance of productive capacity of forest ecosystems

Why is this indicator important?

For managed timberlands, net growth of softwoods (commercial conifer species) provides a measure of whether harvest levels can be sustained. In California, forest industry manages under statutory and regulatory mandates requiring long-term sustained yield.

What does the indicator show?



Key findings:

- ⓘ On forest industry timberlands, the most actively managed lands, growth exceeded harvest and mortality by an average of 22 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).
- ⓘ On nonindustrial timberlands, a portion of which are actively managed, growth exceeded harvest and mortality by an average of over 85 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).
- ⓘ On Forest Service timberlands, which are managed for multiple objectives including ecosystem services, growth exceeded harvest and mortality by an average of over 33 ft^3/acre/year over the re-measurement period (2001–2006 to 2011–2016).

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Forest Inventory Data	FIA Program, USDA Forest Service, 2001–2016.	****

Indicator: Timberland in Need of Restoration Treatment to Reduce or Increase Stocking

ⓘ1.2

Which Montreal Process Criterion does the indicator evaluate?

MPC 2: Maintenance of productive capacity of forest ecosystems

MPC 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is this indicator important?

For lands managed for timber, timberland that is over- or understocked is not operating at its potential productivity for timber. Overstocked timberland may be at increased risk from severe wildfire, insects and disease that can lead to catastrophic losses. Understocked stands and certain hardwood dominated lands represent potential areas for reforestation.

What does the indicator show?

This indicator shows timberland acres with tree stocking issues where treatments may be warranted to improve stand conditions. Overstocking includes separate estimates based on exceeding 100% of stand density as determined from Stand Density Index (SDI) values (i.e. the upper limit of the self-thinning zone), and 60% SDI (the lower threshold, where competition due to tree density begins to induce tree mortality). It does not include areas potentially in need of restoration due to recent fire events or drought-related mortality. SDI provides a reasonable measure of stocking for industrial forests where timber production is the primary concern. For public timberlands dominated by multiple-use and ecological restoration goals, other measures of stand structure may be more appropriate.

Key findings:

- Total acres potentially in need of treatment to improve stocking ranges from 5.5 to 9.5 million, depending on whether overstocked stands are based on a 100% or 60% Stand Density Index (SDI) rule. Stocking is an issue on public, forest industry, and nonindustrial timberlands.

Understocked, Overstocked, and Hardwood Dominated Timberland (thousand acres)

	Commercial Conifer Species			Hardwood Dominated (FIA Site 1,2,3 only)
Owner	Understocked	Overstocked (60% Rule)	Overstocked (100% Rule)	
Public	2,141	3,024	395	393
Forest Industry	1,015	1,058	145	443
Nonindustrial	296	639	68	549
Total	3,451	4,722	609	1,385

- Using the 100% SDI rule, only about 4% of public timberlands are overstocked. Using the 60% rule, about 32% are overstocked.
- Hardwood dominated timberlands are a natural component of the landscape, but have expanded in some areas due to past disturbances or management. Restoration treatments are more economically feasible on higher site quality lands, such as the 1.4 million acres in sites 1, 2, and 3. About 41% of these acres are in the tanoak/laurel type, typically areas on the North Coast region where redwood and Douglas-fir have been displaced by hardwoods due in part to past timber management.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Forest Inventory Data	FIA Program, USDA Forest Service, 2006–2015.	****

Indicator: Timberland Harvested by Silvicultural Method ⓘ1.3

Which Montreal Process Criterion does the indicator evaluate?

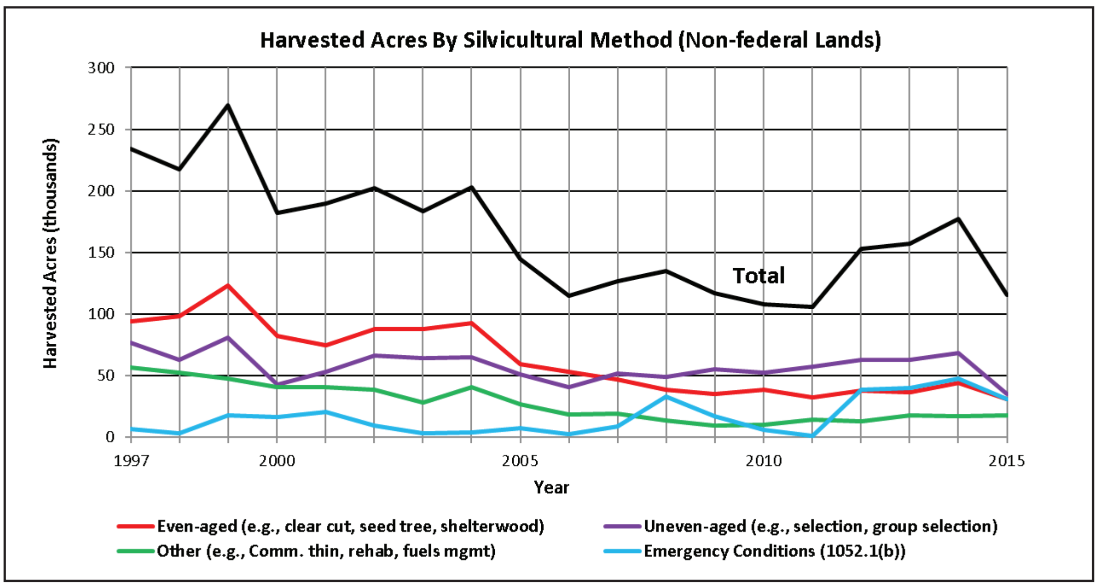
MPC2: Maintenance of productive capacity of forest ecosystems

MPC3: Maintenance of forest ecosystem health and vitality

Why is this indicator important?

The silvicultural methods applied to timberland affect productivity, harvest levels, risk from fire and pests, and provision of various ecosystem services.

What does the indicator show?



Key findings:

- ⓘ There has been a steady significant decline in total acres harvested over the 1997–2015 period. Harvested acres in 2015 was about half of 1997 harvest acres.
- ⓘ Acres harvested using uneven-aged systems have been fairly constant, despite the decline in total harvest acres. Thus, the percentage of acres harvested using uneven-aged systems has increased, from an average of 29% of harvested acres over the 1997–2001 period, to 41% over the 2011–2015 period. In the Coast District, 54% of the 2011–2015 period harvest acres were uneven-aged.
- ⓘ Widespread tree mortality from drought, pests, and wildfire have contributed to a major increase in acres filed for harvesting under Emergency Conditions (1052.1(b)). In 2015, acres harvested under Emergency Conditions comprised 10%, 23%, and 89% of total acres filed for harvest in the Coast, Northern, and Southern Forest Practices Districts, respectively.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Timber Harvest Statistics	Forest Practice System, CAL FIRE, 1997–2015.	****

Indicator: Timber Harvest from Private and Public Lands ⓘ1.4

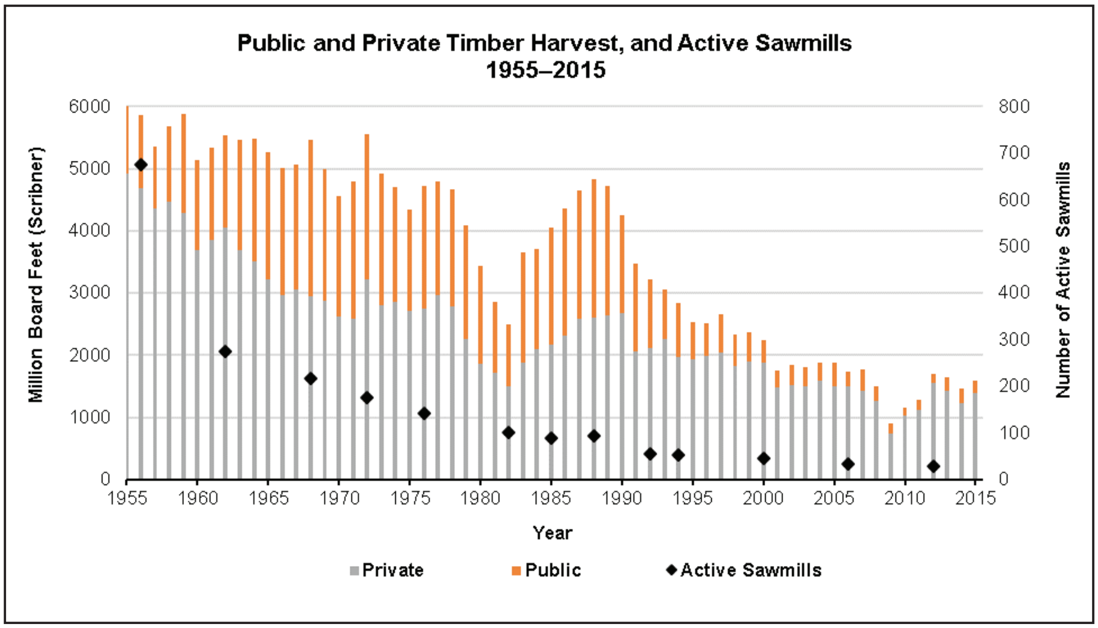
Which Montreal Process Criterion does the indicator evaluate?

MPC 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is this indicator important?

Timber harvest levels are an indicator of sustained yield by public and private owners. Decades ago, there were public concerns about overharvesting, particularly on private lands. However, since the late 90's, large industrial owners (defined by having 50,000 + acres) have been required to manage on a sustained yield basis.

What does the indicator show?



Key findings:

ⓘ The total volume harvested in 2015 was 72% lower than in 1955.

ⓘ The contribution from public lands to total harvest volume over the 1955–1990 period averaged about 38%. Since 2000, it has averaged only about 18%.

ⓘ The number of sawmills declined from 675 in 1956 to only 30 in 2012.

ⓘ Since 2000, private harvest levels (the bulk of which are forest industry) have averaged 1,363 million board feet. Annual fluctuations have been as much as 35% over this average and 46% under.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Historic Timber Harvest	Timber Harvest Statistics, CA Board of Equalization, 1955–2015.	****
Forest Products Infrastructure	USDA Forest Service Resource Bulletin PNW-35, USDA Forest Service, 1970; General Technical Report PNW-GTR-908, USDA Forest Service, 2015.	****

Indicator: Timberland Managed Under Forest Certification, or Other Sustainable Forestry Standards

ⓘ1.5

Which Montreal Process Criterion does the indicator evaluate?

MPC6: Maintenance and enhancement of long term multiple socioeconomic benefits to meet the needs of societies

Why is this indicator important?

Certification and other sustainable forestry standards indicate that land is being managed to achieve defined criteria for sustainable harvest levels and provision of ecosystem services.

What does the indicator show?

Timberland Managed Under Sustainability Initiatives or Certification				
	Forest Industry		Nonindustrial	
Regulatory or Voluntary Initiatives	**Thousand Acres**	**%**	**Thousand Acres**	**%**
"Option (a)" or Sustained Yield Plan[1]	3,873	91%	-	-
Nonindustrial Timber Management Plan (NTMP)	-	-	320	11%
Program Timber Environmental Impact Report (PTEIR)	61	1%	26	1%
Carbon Offset Projects[2]	203	2%	72	4%
Third Party Certification				
Forest Stewardship Council	1,560	37%	57	2%
Sustainable Forestry Initiative	2,000	47%	-	-
American Tree Farm System	100	2%	366	12%
One or More Certification Program (no double counting)	3,660	86%	423	14%

Data Notes:
1. Owners with more than 50,000 acres of timberland are required by law to demonstrate Maximum Sustained Production (MSP) through one or the other of these initiatives. 2. Includes compliance and early action projects.

Key findings:

- Forest industry landowners with over 50,000 acres of timberland have about 3.9 million acres in mandatory "Option (a)" or Sustained Yield Plans. This represents 91% of industrial timberland and 53% of all private timberland.
- About 86% of forest industry and 14% of nonindustrial timberland is certified by a sustainable forestry program.
- A significant and increasing acreage of timberland is under modified management (Nonindustrial Timber Management Plan or Carbon Offset Project), which gives additional emphasis to ecosystem services.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Certification	Forest Industry, FRAP, v15_2.	****
NTMPs	Forest Practice System, CAL FIRE, 1997–2015.	****
PTEIR	PTEIR reports, CAL FIRE, 2017.	*****
Carbon Offset Projects	[41] Air Resources Board, 2017; [42] Climate Action Reserve, 2017	*****

Indicator: Acres of Forestland Being Managed as Carbon Offset Projects

ⓘ1.6

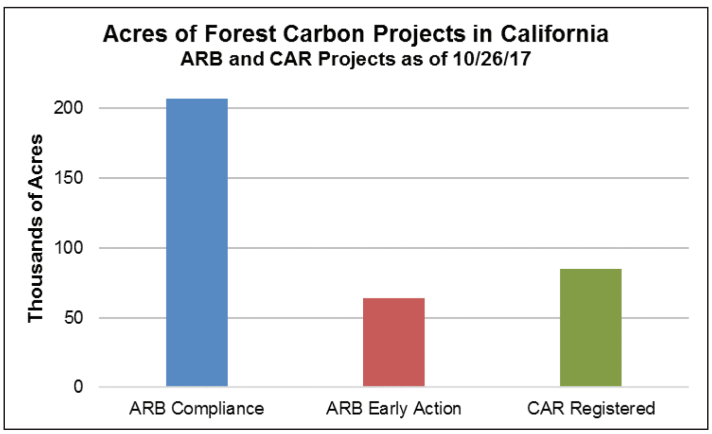
Which Montreal Protocol Criteria does the indicator evaluate?

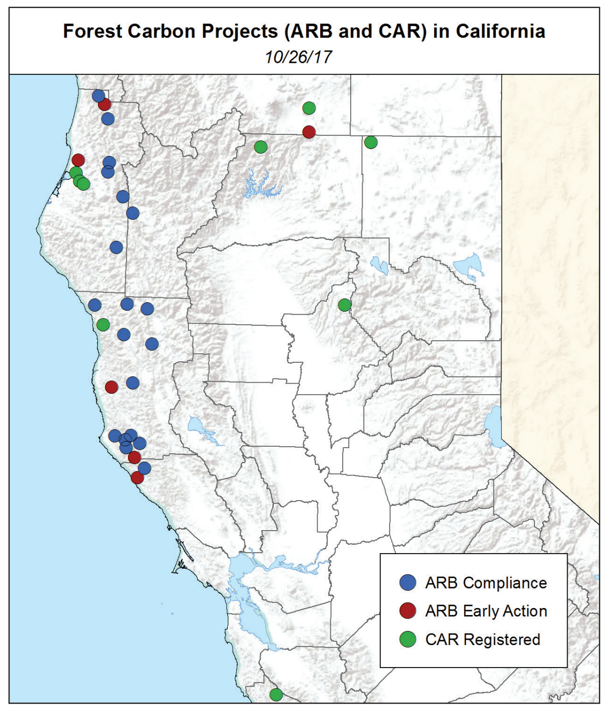
MPC5: Maintenance of forest contribution to global carbon cycles

Why is the indicator important?

As part of the California "cap and trade" program (AB 32), the California Air Resources Board (ARB) has developed protocols for "U.S. Forest Projects," of which there are three project types: improved forest management, reforestation, and avoided conversion. Forest landowners can be issued carbon offsets by ARB or through the voluntary carbon market by registries such as the Climate Action Reserve (CAR). Landowners participating in these projects can sell offsets to increase or diversify income.

What does the indicator show?





Key Findings:

- ⓘ As part of California's "cap and trade" program, as of 10/26/2017 the Air Resources Board (ARB) had issued carbon offsets for Compliance forest projects in California on about 207 thousand acres. There are an additional 64 thousand acres of Early Action projects in the state. In addition to ARB projects, there are an additional 85 thousand acres of projects in California registered with the Climate Action Reserve (CAR).
- ⓘ All California projects are "improved forest management," which can take different forms. The current ARB projects typically involve combinations of reduced harvest levels, longer rotations, and uneven-aged management. Some CAR projects involve intensive even-aged management with actions to maintain stocking for optimal growth, and extended rotations for culmination of carbon growth.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
ARB Projects	[41] Air Resources Board, 2017.	*****
CAR Projects	[42] Climate Action Reserve, 2017.	*****

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Chapter 2: Sustainable Rangelands

This chapter provides a synthesis of rangeland indicators and key findings, and how they relate to issues of sustainable rangelands.

SUMMARY

California rangelands encompass over 57 million acres of annual and perennial grasslands, oak savannas, shrublands, hardwood and conifer woodlands, and deserts [1]. They provide a variety of important ecosystem services, such as wildlife habitat, water quality, open space, recreation, and carbon storage and sequestration [2, 3]. Rangelands also produce forage for grazing by domestic livestock, which can be an important component of rural economies.

Well over half of the state's rangeland is utilized for the grazing of commercial livestock [4]. In 2015, cattle and calves ranked as the fourth highest value agricultural commodity in the state ($3.4 billion) [5]. Sheep and lamb inventories in California were the highest in the nation in 2013 and lamb production was second only to Texas [6].

INDICATORS

ⓘ2.1 Rangeland Conversion

ⓘ2.2 Beef Cattle Farm Size

ⓘ2.3 Federal Grazing Allotments

Rangeland forage quantity and quality depend heavily on the amount of annual precipitation. Exotic species such as cheatgrass, medusahead, and star thistle continue to persist and spread, lowering forage quality for livestock over large areas of grasslands and oak woodlands [7]. Climate change is projected to impact the distribution and quality of important rangeland vegetation types, with associated changes in productivity.

The recent 2011–2016 drought greatly reduced available forage in most regions, due to direct impacts on forage production as well as access to suitable water sources. Ranchers were forced to adapt their operations to minimize losses and protect rangeland resources through increased use of supplemental feed, reduced herd sizes, and early weaning of calves [8, 9].

Rangelands also serve as the primary source for conversions to irrigated agriculture and residential/commercial development. Since European colonization in the late 1700s, nearly 16 million acres of California have been converted to development and irrigated agriculture – almost all of it from rangeland [4]. More recently, from 1992–2012, rates of permanent rangeland conversion (to urban) have averaged about 25,000 acres per year (ⓘ2.1). The USDA Natural Resources Conservation Service (NRCS), as well as numerous public agencies and private conservation organizations, have programs to protect working rangeland landscapes from conversion, through either acquisitions or conservation easements (ⓘ6.3). Williamson Act (WA) contracts administered by counties continue to be important to ranchers for maintaining viable livestock operations (ⓘ6.3). However, the cessation since 2009 of subvention WA payments (subsidizing reduced property tax assessments) from the state to counties has compromised the future status of this important program. If state government subvention payments to counties are not soon resumed, the program may experience significantly declining participation, with severe tax impacts on ranchers and farmers. Survey results suggest that the net result could be the sale of 20% of ranch acreage, much of which would be converted to other uses [10].

About half of beef cattle farms are less than 50 acres; however, larger ranches produce most commercial range-fed cattle in the state (ⓘ2.2). Surveys reveal that many small operators are in the business for the lifestyle rather than for profitability [11]. Large ranching operations near public land holdings often depend on grazing leases, for example U.S. Forest Service (USFS) or Bureau of Land Management (BLM) grazing allotments, to meet annual feed requirements for their herds. However, over the last 60 years, changes in authorized Animal Unit Months (AUMs) on both USFS and BLM lands show reductions in annual use for livestock grazing, on the order of 40% and 78% respectively (ⓘ2.3). Lands owned by state and local government can also be important sources of forage for private ranches. In some cases, ranchers are paid for "targeted grazing" to manage vegetation and reduce fuel loads in parks and open space.

Trends in farm sizes, federal grazing allotments, rangeland conversion, and productivity impacts from invasive species and climate change all combine to suggest a downward future trend in statewide livestock production from rangelands. Maintaining sustainable livestock operations, especially in rural regions where it represents a significant portion of the landscape, will in part depend on continued trends that allow ranchers to diversify income from various sources. Due to uncertain and often low economic returns, many ranchers supplement their income by taking outside employment, producing for niche markets, providing recreation opportunities, or earning income from sale of easements [11]. Various state and federal programs and services are available that provide education, technical assistance, cost-sharing and grants, and other services.

Ranchers have numerous motivations to apply land stewardship practices that protect and enhance environmental values: ranches are typically also the owners' place of residence, and are often passed on to future generations; environmental quality can translate into economic returns from tourism, recreation, hunting, or sale of easements; and avoidance of additional regulations, for example those associated with the federal Endangered Species and Clean Water Acts. Sustaining the level of ecosystem services provided by rangelands, including working ranches, is a major issue. Increased use of conservation easements (ⓘ6.3), particularly in areas most at risk of conversion, is a positive sign that the importance of these lands is being recognized. Water quality is a continuing concern (ⓘ9.1), which is being addressed primarily by education and incentive based initiatives. There are a few specific cases where water quality impacts from grazing have led to corrective actions under the federal Clean Water Act Section 303d. Survey results show that over two-thirds of ranchers are receptive to the possibility of financial incentives for improving environmental quality [12], and continued funding for these efforts is important to sustain and enhance ecosystem services.

To address sustainability, in 2010 the Sustainable Rangelands Roundtable (SRR) [13] created a set of five sustainable rangeland management criteria with 64 indicators, modeled after the Montreal Process Criteria for forest management. However, the data to support tracking the SRR indicators is often lacking, despite the existence of several federal programs for monitoring rangeland conditions. This severely limits our ability to answer important questions about trends in range productivity, soil erosion, water quality, range practices and investments, habitat quality, and oak removals and regeneration.

This chapter provides a diverse set of opportunities to improve the sustainability of rangeland production and ecosystem services. These generally involve initiatives to protect rangelands from development pressures, provide incentives for management that maintains and enhances ecosystem services, and improve the profitability of ranching operations for the benefit of local economies.

KEY FINDINGS

Key findings and indicators are grouped below for the five topics covered in this chapter.

The Resource Base

- California rangelands encompass over 57 million acres of annual and perennial grasslands, oak savannas, shrublands, hardwood and conifer woodlands, and deserts.

- Exotic species such as cheatgrass, medusahead, and star thistle are now spreading and lowering the forage quality for livestock over large areas of grasslands and oak woodlands.

- Research indicates that climate change will alter the extent of rangeland vegetation types, as well as the productivity of individual types in different areas of the state.

ⓘ2.1 Indicator: Rangeland Conversion

- ⓘ Nearly 16 million acres, almost all of it formerly rangeland, has been converted to other uses since the arrival of Europeans in California. From 1850, over the course of 167 years, this represents an average historical conversion rate of about 95,000 acres per year.

- ⓘ From 1992–2012, conversions of rangelands to urban occurred primarily in the Southern California, San Francisco Bay Area, and Central Valley Regions.

- ⓘ Over that period, rangeland conversions to urban peaked in 2004–2006 at about 37,000 acres per year, dropping by 67% (12,000 acres/year) since the onset of the recession.

- ⓘ From 1992–2012, the Farmland Mapping and Monitoring Program (FMMP) recorded the net loss of rangelands to urban averaged about 25,000 acres per year statewide.

Management Context

- About 22 million acres of rangeland are privately owned, and about 35 million publicly owned.

- About 17 million acres of private rangelands are grazed by livestock. Federal BLM and Forest Service rangelands contain about 7 million and 7.6 million acres of grazing allotments, respectively.

- The water quality issues associated with range livestock operations include erosion and sedimentation, increases in stream temperature caused by streamflow diversions and losses of riparian vegetation, and nutrient and fecal coliform inputs from livestock wastes.

- The most recent measures of stream quality on California rangelands show about 40% of streams in good condition, but about 50% in poor or very poor condition (ⓘ9.1).

ⓘ2.2 Indicator: Beef Cattle Farms by Size Class

- ⓘ The number of beef cattle farms over 2,000 acres declined from a peak of 1,521 in 1987 to 1,020 in 2012, a 33% decline. This could be due to being developed, split into smaller farms, aggregated into larger farms, or being acquired by government agencies or conservation groups.

- ⓘ The number of beef cattle farms less than 50 acres increased from its lowest number of 4,542 in 1997 to 5,893 in 2012, a 30% increase. This is still 20% less than the 7,343 small farms that existed in 1982.

ⓘ2.3 Indicator: Federal Grazing Allotments

- ⓘ Long-term (50–60+ year) changes in authorized Animal Unit Months (AUMs) on both USFS and BLM lands show reductions in their annual use for livestock grazing, on order of 40% and 78% respectively.

- Since 2001 grazing use trends for these lands have been relatively flat.

- Long-term reductions in authorized AUMs have been due to changes in federal policy (e.g. the Rescissions Act of 1995, the National Forest Management Act, and additions to the National Park System), the spread of brush and timber vegetation (lack of historical fire regime), and to changes in management, e.g. to accommodate new listings of endangered species, and for the protection of natural resources.

The Range Livestock Industry

- The volatility of beef market prices, typically low returns on investments, long distances to meat processing facilities, and year-to-year uncertainties of annual forage production (e.g. due to recent widespread drought conditions), continue to make the ranching business difficult for many livestock operators.

- Access to meat processing plants can be a constraint to livestock marketing.

- The economics of range livestock operations, particularly on smaller properties with smaller herds suggest that most operators are in the ranching business for reasons other than profit.

Management Initiatives

- The marginal profitability of many range livestock operations has caused ranchers and their families to seek additional sources of income to support their lifestyle. There are a variety of options available to ranchers to diversify and enhance income sources, and improve sustainable management practices.

- Targeted grazing is used as a tool to manage vegetation and reduce fuel loads in parks and open space. In some cases, fees are paid to herd managers.

- At least 1.2 million acres of California rangeland are under conservation easements by various private organizations and governmental agencies.

Landowner Assistance

- The online technical report provides a detailed description of the various agencies and organizations that provide programs to assist rangeland owners.

- Resource Conservation Districts (RCDs) assess local conservation needs, and develop priorities and programs to meet those needs. RCDs provide various services including education and outreach, demonstration projects, and promoting best management practices. RCDs can also serve as a conduit for funding to support various types of projects, for example for erosion control, fuels reduction, water conservation or quality improvements, or watershed plans.

DISCUSSION

Rangelands are defined (in PRC 4789.2(i)) as "...lands on which existing vegetation, whether it grows naturally or through management, is suitable for grazing or browsing of domestic livestock for at least a portion of the year." Rangelands provide a wide range of benefits (e.g. livestock grazing, water, recreation, open space, wildlife habitat, carbon storage and sequestration) and face numerous threats (e.g. wildfire, development, pests, climate change), all of which are covered in other Assessment chapters.

Sustainability

The State interest in maintaining sustainable rangelands is in part reflected in laws to limit rangeland conversion (e.g. Williamson Act). However, unlike working forests where the state regulates specific management practices, the state interest in sustainable rangelands is expressed through programs that provide education, promotion of best management practices and water quality plans, incentives and grants for improved management, purchase of certain lands with high ecosystem values, and use of easements to maintain working landscapes.

Trends in farm sizes, federal grazing allotments, rangeland conversion, profitability, and productivity impacts from invasive species and climate change, all combine to suggest a downward future trend in statewide livestock production. Maintaining sustainable livestock operations, especially in rural regions where it represents a significant portion of the landscape and economic base, will in part depend on continued trends that allow ranchers to secure income from various sources.

Sustaining the level of ecosystem services provided by rangelands, including working ranches, is a major issue. Favorable trends include increasing potential for ranchers to diversify and potentially increase income by managing for multiple values, increased use of easements to preserve working rangelands and modify management to enhance ecosystem services, continued investment in education and incentive based programs to promote sustainable management, and existing institutional mechanisms that define corrective actions when problems arise.

To address sustainability, in 2010 the Sustainable Rangelands Roundtable (SRR) [13] created a set of five sustainable rangeland management criteria with 64 indicators, modeled after the Montreal Process Criteria for forest management. The data to support tracking the SRR indicators is often lacking, despite the existence of several federal programs for monitoring rangeland conditions. This was a limiting factor for selection of range indicators for this assessment. It also severely limits our ability to answer important questions about trends in range productivity, soil erosion, water quality, range practices and investments, habitat quality, and oak removals and regeneration.

Another important step towards sustainability is the 2007 effort of the California Rangeland Conservation Coalition and The Nature Conservancy to prioritize areas for conservation over about 28 million acres of the Sierra foothills and southern coast range [14]. Areas were prioritized based on numerous biological values, current degree of human disturbance, and threat of future development. Efforts such as this will help public agencies and other organizations make efficient use of available resources for purchase of land acquisitions and easements to protect rangeland ecosystem services and working landscapes.

Photo by: UC Cooperative Extension, 2014.

The Resource Base

California rangelands encompass over 57 million acres of grasslands, savannas, shrublands, deserts, wetlands, and woodlands that are dominated by grasses, grass-like plants, forbs and shrub species (Figure 2.1). While upland conifer and hardwood forests contain grazing resources, they are viewed as secondary to the primary rangeland base.

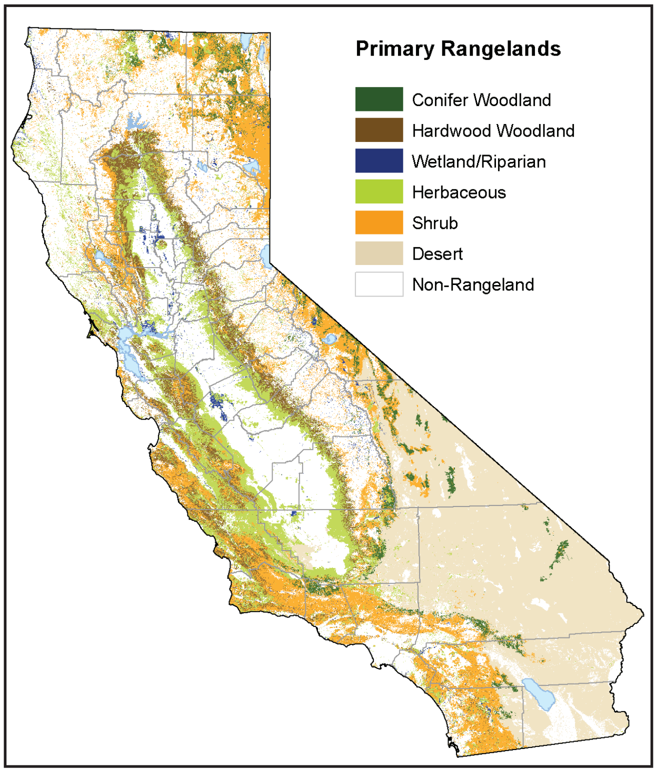


Figure 2.1: Distribution of Rangeland Major Vegetation Types in California, as Defined by PRC 4789.2(i).

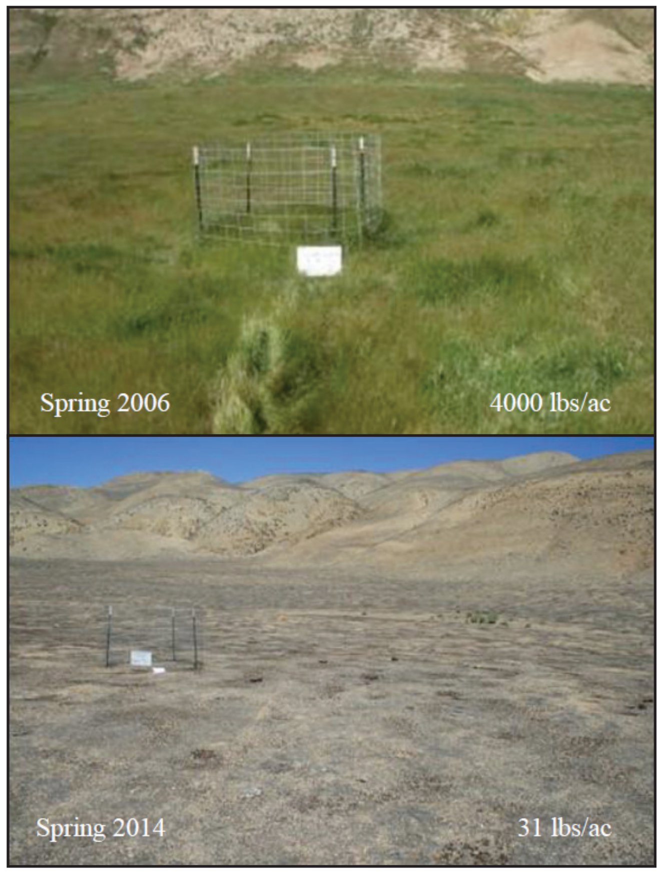
Data Source: [1] FRAP, 2015.

Colusa County rangelands. Photo by: Loren Kerns, 2012.

Rangeland Productivity

The procedures for estimating the productivity of rangeland are generally based on quantifying forage availability in terms of an "animal unit month" or AUM, which is the amount of forage needed to support a 1000-pound cow and her calf for one month. Rangeland productivity varies by vegetation type and is highly dependent on annual precipitation.

As shown in Table 2.1, herbaceous (grasslands), hardwood woodland, and wetlands/riparian are generally considered the most productive grazing lands in the state.



Impact of precipitation on spring forage production for a high rainfall year (2005–2006) and a dry year (2013–2014), eastern San Luis Obispo county. Photo courtesy of Royce Larsen.

Vegetation Changes and Productivity

Rangeland plant communities of all types are susceptible to changes that can affect their productivity and the ecosystem services they provide. Two major causes of change in the composition of California's rangeland plant communities are the introduction of invasive plant species and successional changes promoted by fire suppression.

Exotic species such as cheatgrass, medusahead, and star thistle continue to persist and spread, lowering the forage quality for livestock over large areas of grasslands and oak woodlands. They can form monotypic stands that may decrease forage production by as much as 50–75% [7]. Riparian ecosystems can be invaded by other species, including Himalayan blackberry, perennial pepperweed, giant reed, tamarisk and numerous exotic herbaceous species. In addition to affecting the availability and quality of forage in uplands and riparian areas, invasive species may change nutrient cycles, soil moisture availability, fire frequency and intensity, and alter the structure and suitability of wildlife habitat.

Successional changes in rangeland vegetation types often involve the partial or total conversion of annual or perennial grasslands to shrub or tree-dominated communities. Although the areal extent of these changes is less significant compared to invasive species, they nevertheless may be locally quite important. For example, invasion of grasslands and shrublands in northeastern California by western juniper has had a significant impact on ecosystem services and wildfire risk [15], and is one of the principal reasons for the proposed listing of the sage grouse as an endangered species. The invasion of desert vegetation types by exotic grasses such as red brome and cheat grass has been attributed to nutrient enrichment by atmospheric nitrogen deposition and perhaps increased precipitation [16, 17]. There is a concern that the increased abundance of fine fuels in the desert may lead to higher frequency, intensity and size of wildfires [18].

Rangeland Conversion

Nearly 16 million acres, almost all of it former rangeland, has been converted to other uses since the arrival of Europeans in California. Rangelands continue to be permanently converted to other uses, but at slower rates than the long-term historical average. From 1992–2012, conversions of rangelands to urban occurred primarily in the Southern California, San Francisco Bay Area, and Central Valley Regions. Over that period, rangeland conversions to urban peaked in 2004–2006 at about

Photo by Sheila Barry, courtesy of UC Cooperative Extension.

Table 2.1: Estimated Mean Annual Forage Production by Rangeland Major Vegetation Type			
Major Vegetation Type	**Grazing Capacity (AUMs/acre)**	**Area (million acres)**	**Total AUMs (millions)**
Conifer Woodland	0	2	0
Herbaceous	0	11	8
Shrub	0	15	5
Desert	<0.1	23	<2.3
Hardwood Woodland	0	6	6
Wetland/Riparian	2	0	1
Total	N/A	58	17.9*
* Excludes desert			

Data Source: [1] FRAP, 2015; [4] FRAP, 2003.

37,000 acres per year, dropping by 67% (12,000 acres/year) since the onset of the recession (ⓘ2.1). From 1992–2012, the Farmland Mapping and Monitoring Program (FMMP) recorded the net loss of rangelands to urban averaged about 25,000 acres per year statewide.

To protect rangelands (and agricultural lands) from conversion, the California Land Conservation Act, or "Williamson Act" (WA), was enacted in 1965 (ⓘ6.2). In return for giving up the rights of development (on a ten-year horizon), the ranch owner with a WA contract has their assessed property tax burden significantly decreased. The state government makes up the tax differential, through subvention payments to counties. County participation in the program is voluntary, but only Del Norte, Yuba and Inyo counties have never been a part of it.

However, subvention payments by the state ceased in 2009, due to severe budget shortfalls. As a result, Imperial County pulled out of WA contracts completely, and several other counties in recent years have not been consistently tracking or submitting statistics on landowner participation. Thus far, all participating counties are allowing lands under existing WA contracts to maintain their tax benefits, even at the loss of considerable annual tax revenue. However, some less-wealthy counties are no longer accepting applications for new WA contracts on their agricultural lands [19]. If state government subvention payments to counties are not soon resumed, the program may experience significantly declining participation, with severe tax impacts on ranchers and farmers. Survey results suggest that the net result could be the sale of 20% of ranch acreage, much of which would be converted to other uses [10].

Patterns of Development

Over the long-term, California's growing population (ⓘ6.1) continues to spur new residential and commercial development. Most new development in recent years has occurred not on rangelands, but within existing urban areas and croplands (e.g. in the Central Valley), both of which fall outside of the purview of this assessment. Because of this, rangelands have largely been spared from most recent development.

Based on statewide acreage, the largest threat to rangeland from development is to smaller parcels at the margins of large urbanized areas, especially those in proximity to major transportation corridors. Due to habitat fragmentation, invasive species, impacts from domestic pets, and other adverse impacts associated with human habitation, the overall value of these rangelands for ecosystem services is typically lower than for other larger, more intact and remote locations. On the other hand, the value of rangelands on the urban fringe may be high for purposes such as open space. Rangelands that may be compromised in other respects, when protected and restored as public parks and open space, can fulfill that vital role. Recent examples of development on the urban fringe include the Livermore Valley and environs of Alameda County (Bay Area), the Perris Valley and Coachella Valley of Riverside County, and the vicinity of Paso Robles in San Luis Obispo County.

In a handful of more remote rural areas, whole new housing communities have been or are being established across significant tracts of rangelands with high ecological value. Some communities are extensive and actively growing, such as Bear Valley Springs and Stallion Springs in the Tehachapi region of Kern County, and the Carmel Valley of Monterey County. If approved, the Yokohl Valley development, still in the planning phase for eastern Tulare County, would eventually create 10,000 new high-priced homes, and cover 56 square miles of the Sierran foothills [20]. Centennial, a wholly new municipality planned as a part of the Tejon Ranch, is slated to eventually house more than 70,000 residents on 18 square miles of rangeland [21].

Conversion to Agricultural Lands

Nearly all of California's agricultural lands were the result of conversion of rangelands. Conversions to irrigated or dry-farmed agricultural lands can be temporary, since these lands can revert to rangeland when cultivation ceases. Rates of conversion moving forward will be limited due to availability of suitable sites, and issues related to water.

Oak Woodlands

Woodland dominated by various native oak species comprises most of the oak/hardwood woodland vegetation type. Oak woodland is an iconic vegetation type that many residents consider symbolic of California [22]. The vegetation type has consequently received a significant amount of educational, research and regulatory attention. Most oak woodlands are privately owned and most are utilized for livestock grazing. The primary threats to oak woodland include disease and insects (sudden oak death, gold spotted oak borer and polyphagous shot borer) and land development. Lack of adequate regeneration has also been identified as an issue affecting sustainability of some oak woodlands.

Oak woodlands, Colusa County. Photo by: Hyperflange Industries, 2015.

More than one million acres of oak woodland have already been developed for urban and rural residential uses. Between 1984–1994 an estimated 29,000 acres of oak woodland were lost to development [22]. In response to development threats, the Oak Woodland Conservation Act was passed in 2004. Since then, 21 counties have adopted oak woodland management plans to help conserve oak woodlands and to qualify them for conservation funding from the Wildlife Conservation Board [23].

Climate Change Impact on Rangelands and Rangeland Productivity

Research indicates that climate change will alter the extent of rangeland vegetation types, as well as the productivity of individual types in different areas of the state. In a recent report from California Department of Fish and Wildlife, vegetation macrogroups were given a mean vulnerability rank based on results for two future emission levels and two climate models. Among the macrogroups most associated with rangelands in the state, ranks varied from Moderate (California Foothill and Valley Forests and Woodlands) to Mid-High (California Grassland and Flowerfields, Wet Mountain Meadow, Big Sagebrush Scrub), to high (Great Basin Pinyon-Juniper Woodland, Great Basin Dwarf Sagebrush Scrub, Great Basin Upland Scrub). Vegetation types associated with rangeland will likely lose a portion of their current extent, and in some cases migrate to new areas with suitable future climate [24].

However, even in areas where a vegetation type persists, there could be impacts on range productivity due to changes in species composition, precipitation patterns, competition from other species, changes in growing season, changes in disturbance regimes from fire and pests, and changes in availability of suitable water sources for livestock. For example, since the recent drought, annual grassland areas in eastern San Luis Obispo County changed in grass species composition from soft chess (*Bromus hordeaceus*), which is considered good forage, to red brome (*Bromus madritensis*) which is of lower forage quality [8]. Red brome is already dominant in annual grassland areas further south, so this change is consistent with the type of change expected with a warming climate. It remains to be seen whether this change is permanent, or whether soft chess returns with better rainy seasons.

Management Context

Rangeland Ownership

Rangeland is comprised of both private (40%) and public (60%) ownership (Table 2.2). Historically, nearly all rangelands have been managed as "working landscapes" – i.e. expanses of land that are not in reserved status, but are utilized for economic purposes including the grazing of livestock, and limited harvesting of hardwoods for fuel and other uses. Maintaining these working landscapes in a sustainable manner can be key to their long-term preservation. A primary objective for sustaining working rangelands is to help enable ranch owners to remain in the commercial livestock business.

About 17 million acres of private rangeland is used for livestock grazing. The predominant use of these lands is for raising cattle in either cow-calf or stocker operations. Grazing of sheep/lambs and goats occupies a much smaller area of rangeland. Horses and exotic livestock (e.g., buffalo) represent a small percentage of all grazing uses.

Public rangelands are primarily owned by the Bureau of Land Management (BLM) and the Forest Service. The BLM currently has about 7 million acres of rangeland in grazing allotments [24], while the Forest Service has about 7.6 million [25].

Trends in Ranch Size

The size of working ranches has been changing, which has important implications (ⓘ2.2). Generally, large ranches are considered more "intact," have higher habitat value and levels of ecosystem services, and tend to be committed to ranching as a long-term objective. As a result, they often provide the best opportunity to maintain working ranches and their associated ecosystem values through easements. The number of beef cattle farms over 2,000 acres declined from a peak of 1,521 in 1987 to 1,020 in 2012, a 33% decline. This could be due to being developed, split into smaller farms, aggregated into larger farms, or being acquired by government agencies or conservation groups.

Grazing Leases and Federal Grazing Allotments

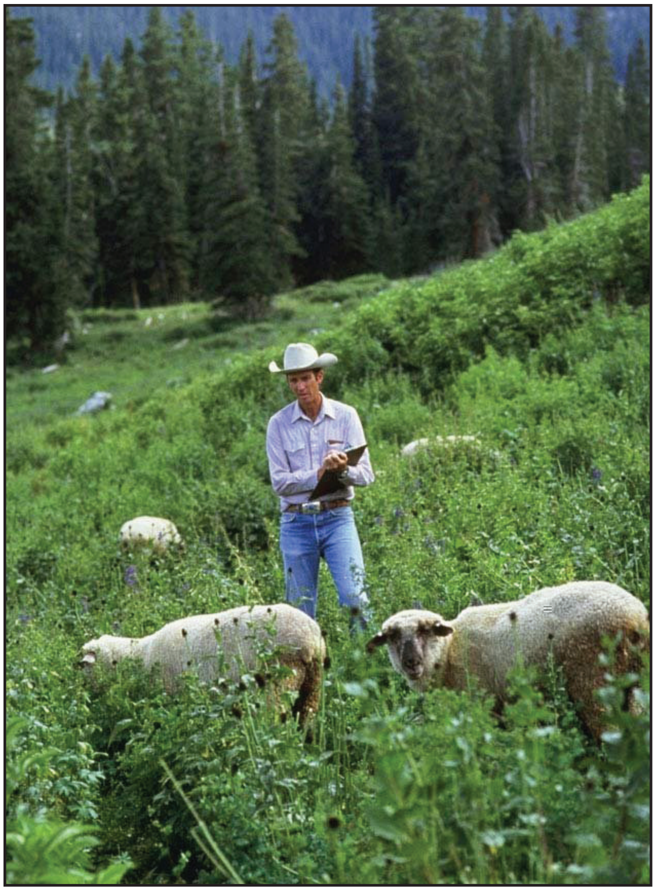
Profitability of some livestock operations is directly dependent on leased land from public agencies (federal, state, and local) as well as private lands. Historically, contracts for leasing of federal lands (grazing allotments) have played a major role in providing forage for regional livestock. However, the role of federal grazing allotments is diminishing, both statewide and particularly on more marginal grazing lands in poor forage production areas such as deserts (ⓘ2.3).

The number of AUMs issued for commercial livestock grazing on both BLM and Forest Service lands in California has plummeted over the past 60 years. In 1953, the BLM authorized 900,000 AUMs, but for the past 15 years that number has averaged around 200,000, a 78% drop. Large commercial livestock grazing allotments on BLM lands are in many cases being retired across both the Mojave and Colorado deserts [26]. The value of these areas for native wildlife such as bighorn sheep, as well as the preservation of other natural resources, has been deemed much higher than the value of livestock production from these lands. Historically these have been used by sheep operations, which forage primarily in the spring, mostly on native forbs. Very low grass and forb productivity and limited access to water have been large disincentives for grazing cattle on these lands. Although browse shrubs such as saltbush and bitterbrush can, where available, make up somewhat for the lack of grass.

Table 2.2: Rangeland Major Vegetation Types in Public and Private Ownership (thousand acres)

Habitat Type	Private Ownership	Public Ownership	Total
Conifer Woodland	460	1,875	2,335
Hardwood Woodland	4,403	1,125	5,527
Shrubland	4,654	10,254	14,908
Herbaceous	9,070	2,035	11,105
Desert Shrubland	3,188	18,726	21,913
Desert Woodland	192	874	1,065
Wetland/Riparian	341	320	661
Total	22,307	35,209	57,515

Data Source: [1] FRAP, 2015.



Since the mid-1960s, the Forest Service grazing authorizations have dropped about 40%, from 500,000 AUMs to close to 300,000 in recent years. The number of active allotments and permitted AUMs have been reduced for a variety of reasons, such as to improve rangeland ecological conditions or to reduce conflicts with other uses. Others have had trees and shrubs invade former areas of grazing such as meadows over the years, greatly reducing forage available to livestock. In some cases, the cost of maintaining the infrastructure necessary for grazing of livestock exceeds the benefit to the rancher from the available cattle forage.

To set yearly federal allotment AUM fees, stemming from the Public Range Improvement Act of 1978 (PRIA), the USFS and BLM track standardized metrics of costs incurred by beef ranchers, and prices received by beef ranchers, on an annual basis. Since 1964, the rates charged to livestock owners for allotments has been set near or close to the allowable minimum of $1.35 per AUM. Recently it has risen to $2.10 per AUM [27].

Calculation of grazing fees is a controversial issue, and critics believe that the PRIA-set fees have not accurately reflected the value of the benefit received by the livestock operators that have public land grazing permits, and should be set much higher [27]. They point to the fact that grazing fees charged on nearby private lands can exceed the PRIA rate by a factor of 10 or more. The low pricing can lead to some producers abusing the privilege, and to having an unfair (taxpayer subsidized) competitive advantage over those without federal allotments. However, the ranching industry believes the low rates are largely offset by numerous non-AUM related costs to the livestock owner associated with having an allotment permit, such as constructing and maintaining grazing infrastructure, transporting and overseeing the herd, etc. [27].

Environmental Impacts of Range Management

Rangelands provide a wide variety of important ecosystem services, such as wildlife habitat, water quality, open space, recreation, and carbon storage and sequestration [2, 3], which are discussed in other Assessment chapters. Ranchers have numerous motivations to apply land stewardship practices that protect and enhance environmental values: ranches are typically also the owners' place of residence, and are often passed on to future generations; environmental quality can translate into economic returns from tourism, recreation, hunting, or sale of easements; and avoidance of additional regulations, for example those associated with the federal Endangered Species and Clean Water Acts. Two of the main environmental concerns related to range management are impacts on water quality, and on oak regeneration, as discussed below.

Water Quality

The water quality issues associated with range livestock operations include erosion and sedimentation, increases in stream temperature caused by streamflow diversions and losses of riparian vegetation, and nutrient and fecal coliform inputs from livestock wastes [28, 29]. Impacts depend on the season of use, grazing intensity and the type of livestock.

One measure of water quality, the California Stream Condition Index (CSCI), translates data about individual Benthic Macro Invertebrates (BMI) found living in a stream into an overall measure of stream health. CSCI data for the most recent monitoring period (2009–2012) shows about 40% of rangeland streams in good condition, but close to 50% in poor or very poor condition (ⓘ9.1). Grazing is one of many factors that can impact stream health, and the CSCI data does not measure impacts of the various causal agents.

In 2004, the State Water Resources Control Board adopted policies for regulating nonpoint source pollution that affect rangelands. A total of 42 of the almost 5,000 water quality impairments on the 2012 list of Section 303-d of the Clean Water Act impaired waters for California include grazing as a potential source [30]. There are a few specific cases where water quality impacts from grazing have led to corrective actions under the federal Clean Water Act Section 303d. For example, in the Tomales Bay Watershed, the regional water board has required ranchers to develop water quality plans, and conduct an annual monitoring and certification process.

The impact on water quality from grazing on high mountain meadows, primarily Forest Service grazing allotments, is a controversial topic. Researchers at the University of California, Davis have been evaluating the results of a long-term project to monitor meadow conditions [31]. As of early 2015, preliminary results were available for three national forests (Inyo, Sierra and Sequoia). Those results indicate that for all three forests, 43–74% of re-measured plots in meadow range allotments were in excellent/good condition and stable. Between 5–22% of re-measured plots were in a fair but downward trending condition. No remeasured plots were in poor condition. The outcomes of the entire study should provide insights into the effectiveness of the riparian and meadow management guidelines throughout the Sierra Nevada national forests.

Oak Regeneration

Concerns related to lack of adequate regeneration of oak woodland species is well documented, for blue oak (*Quercus douglasii*) [32], valley oak (*Q. lobata*), Engelmann oak (*Q. engelmannii*) [33, 34] and more recently coast live oak (*Q. agrifolia*) [35]. Both cattle and sheep grazing impact oak regeneration [36]. Extensive research has been done related to minimizing grazing impacts, artificial regeneration, and protecting young oaks from grazing (available through The Oak Woodland Conservation Workgroup, UCANR) [37]. Findings from these studies will assist ranchers in improving oak regeneration, for example through modified grazing practices or by physically protecting seedlings.

The Range Livestock Industry

In 2015, cattle and calves ranked as the fourth highest value agricultural commodity in the state [5]. Sheep and lamb inventories in California were the highest in the nation in 2013 and the production of lambs was second only to Texas [6]. The apparent vitality of the livestock industry in general does not reflect the status of the range livestock industry because it includes production feedlots, dairies, and related intensive livestock husbandry. The range livestock industry is characterized by being extensive, commonly requiring large amounts of land that provide open space and other environmental services to the state's residents.

Long-term trends have not been positive for profitability of cattle ranching, but projections provide some hope for future improvements. Nationwide, beef production has been relatively flat since the 1990s. However, over the next ten years, production is expected to increase almost 12%, and per capita beef consumption increase by 2.7% [38].

Since at least the mid-1960s, the price of beef received by ranchers has been diverging relative to the prices paid by ranchers for the various inputs needed to raise it (Figure 2.2). The continuing divergence of the two trends has greatly eroded the profitability of domestic livestock operations.

Moreover, livestock producers have historically faced a high degree of economic uncertainty from year to year. For example, between 2010–2015, the price of beef shot up from $88 per hundredweight (cwt) to $149 per cwt

[38]. However, by November 2016 prices had dropped precipitously back down to $92 per cwt [39]. In California, the 2011–2015 drought greatly reduced available rangeland forage and pushed grazing fees and feed costs significantly higher.

Access to markets can be problematic, particularly for more remote ranches. There are 26 meat-processing plants in California, not all of which handle beef. Most of these are relatively small, with the largest plants in Tulare and Coalinga. Most cow-calf producers sell their animals to brokers who ship them to the mid-west. Ranchers who truck their cattle to stockyards risk incurring higher transportation costs to market their cattle when those stockyards close, as happened in San Luis Obispo County in 2014. For ranchers seeking to exploit niche markets such as organic and grass-fed beef, regulations and access to retail markets may pose constraints; there are only a few processing plants for specialty meats.

Grazing Intensity

In years of relatively normal precipitation, there is no indication that grazing use exceeds forage production on a statewide basis. Specific instances of overgrazing may occur due to chronically excessive stocking, excessive stocking too early in the growing season, or failing to provide vegetation sufficient periods of rest. Residual dry matter (RDM) is the basis for measuring annual grassland condition and is determined at the start of the upcoming growing season each year (fall). The University of California Cooperative Extension has published a factsheet detailing monitoring methods and the amounts of residual biomass that should remain on the soil surface at the time the fall rains begin. Residue levels from that publication are sometimes specified in grazing leases on public and private land as a means of ensuring that proper grazing use is not exceeded.

Management Initiatives

The marginal profitability of many range livestock operations has caused ranchers and their families to seek additional sources of income to support their lifestyle. Outside employment is one option, but it may not be available to ranchers in more remote locations. Another option is to diversify the activities on the ranch by promoting hunting, wildlife viewing, camping and other recreational pursuits. Converting a portion of rangeland to more intensive agricultural uses such as

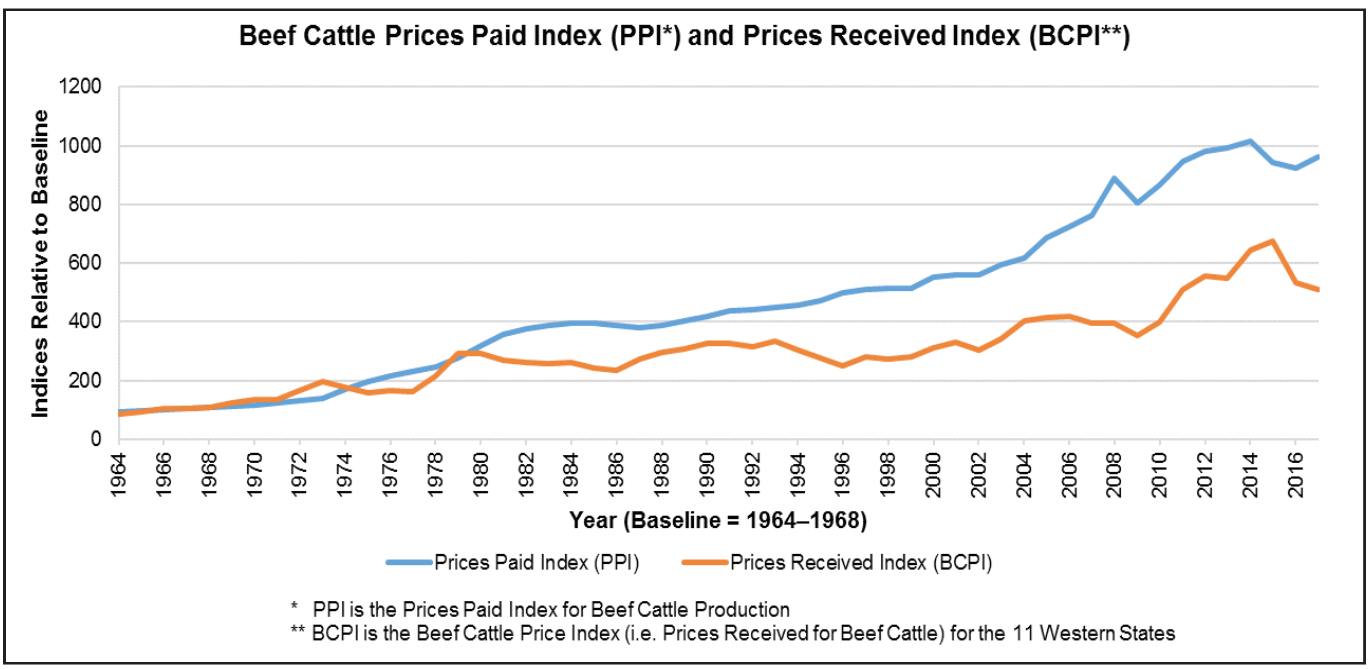


Figure 2.2: Indices of Prices Received (by ranchers) versus Prices Paid (by ranchers) per hundredweight (cwt) of beef cattle, using the period from 1964–1968 as the baseline (= 100).

Data Source: USDA National Agricultural Statistics Service (NASS), Annual Agricultural Prices Report, 1964–2017.

orchards and vineyards also occurs on land with adequate water supplies [40].

There are a variety of options available to ranchers to diversify and enhance income sources, and improve sustainable management practices. Several options are provided below, and other public incentive and cost-share initiatives are in the Landowner Assistance section that follows.

Conservation Easements

Conservation easements are increasingly becoming a secondary income source for ranchers (ⓘ6.3). At least 1.2 million acres of California rangeland are under conservation easements by various private organizations and governmental agencies [41]. Conservation easements are used by land trusts and public agencies to secure protection for specified resource values on working landscapes while allowing the continuation of management activities. As part of the easement contract, the landowner retains title but certain restrictions may apply, such as prohibiting development or certain management practices. The contract may apply to an entire property or to a portion of a property, such as a riparian zone with special environmental attributes. In exchange for granting the easement, the landowner may be paid a fee based on an appraisal of the trade-off value. Funding for easements comes from a variety of sources, such as the Wildlife Conservation Board, Natural Resources Conservation Service (NRCS), open space districts, land trusts and conservation organizations. The landowner will also typically realize a reduction in property taxes over and above the effects of a Williamson Act contract due to a reduced assessed value.

Targeted Grazing

Targeted grazing and browsing represents a potential source of revenue for some operators, and involves using cattle, sheep and goats to achieve specific vegetation management objectives. Targeted grazing has been used to reduce fuel loads in parks and open space, control or eliminate noxious or invasive weeds, and to improve wildlife habitat [42]. It also provides evidence of the beneficial environmental and ecological services provided by livestock operations and in that sense, promotes good public relations for the industry. Targeted grazing and browsing have become a topic for education, training and information exchange among range livestock operators, researchers and agencies.

Niche Products

Niche products represent an additional potential source for income diversification. They are characterized by highly specialized products made for a specific clientele or market. Niche markets for cattle and cattle products in California are very small and take many forms. Examples include beef sold through cooperatives and farmers markets, grass-fed beef, and organically certified beef.

Landowner Assistance

A summary of the various agencies and organizations that provide programs to assist rangeland owners is shown in Table 2.3 [43].

Resource Conservation Districts (RCDs) often play a crucial role in these efforts. RCDs assess local conservation needs, and develop priorities and programs to meet those needs. RCDs provide various services including education and outreach, demonstration projects, and promoting best management practices. RCDs can also serve as a conduit for funding to support various types of projects, for example for erosion control, fuels reduction, water conservation or quality improvements, or watershed plans.

Opportunities

Opportunities to improve the sustainability of rangeland production and ecosystem services generally involve initiatives to protect rangelands from development pressures, provide incentives for management that maintains and enhances ecosystem services, and improve the profitability of ranching operations for the benefit of local economies:

- Support the use of Williamson Act (WA) contracts to reduce rangeland development pressure.
    - Restore state participation in providing WA subvention payments to counties, so that they continue participating in the program.
    - Promote WA participation by rangeland owners without contracts.
- Increase funding to agencies that have active programs that purchase rangeland conservation easements, to protect rangelands from conversion and improve profitability through property tax relief.
- Support strategic scheduling of available rangeland.
    - Coordinate the scheduling with local ranchers of available proximate grazing lands, particularly among governmental and private conservation land managing entities.
    - Plan grazing timing strategically to eliminate invasive plant species when they are palatable to livestock.

Table 2.3: Landowner Assistance Programs for Rangelands

	Agency or Organization, Program(s)	Assistance Provided
Federal	Natural Resources Conservation Service (NRCS)	
	Conservation Stewardship Program (CSP)	Payments for conservation practices
	Environmental Quality Incentives Program (EQIP)	Cost-share for protecting/enhancing ecosystem services
	Conservation Innovative Grants (CIG)	Grants for watershed, regional or state innovative conservation projects
	Agriculture Conservation Easement Program (ACEP)	Funding for conservation easements on working farms and ranches
	Other	Preparation of conservation plans and engineering project design
	Farm Services Agency	
	Emergency Conservation Program (ECP)	Funding to repair disaster damage, drought relief, water conservation projects
	Other	Insurance and loan programs
	U.S. Fish and Wildlife Service	
	Partners for Conservation	Cost-sharing for habitat restoration, technical assistance
State	CAL FIRE Vegetation Management Program	Funding for treatments such as prescribed fire
	University of California Cooperative Extension	Education, technical assistance
	Sierra Nevada Conservancy	Grants for planning, restoration, acquisitions and easements
	California Department of Food and Agriculture	
	State Water Efficiency and Enhancement Program	Funding for water conservation measures
	California Department of Fish and Wildlife	
	Private Lands Management Program	Technical assistance, other benefits
	California Strategic Growth Council	
	Sustainable Agricultural Lands Conservation (SALC) program	Funding for easements
Other	Ducks Unlimited	Funding to enhance wetlands and increase waterfowl populations
	National Fish and Wildlife Foundation	Projects to control exotic plants
	Local government/special districts, conservation organizations	Easements and acquisitions

Date Source: [43] Harris, R., 2017.

- Explore opportunities that would reduce barriers to augment livestock processing facilities to lower travel costs for livestock owners.

- Explore opportunities to support niche marketing of rangeland products.

- Continue and enhance funding for grants and cost-sharing, for ranchers to maintain and upgrade their watering infrastructure, and other range improvements that protect and enhance ecosystem services.

- Support expanded use of targeted grazing on both public and private lands to control invasive plants, reduce fuel loads, and meet other landowner objectives.

Indicator: Rangeland Conversion

ⓘ2.1

Which Sustainable Rangelands Roundtable Criterion does the indicator evaluate?

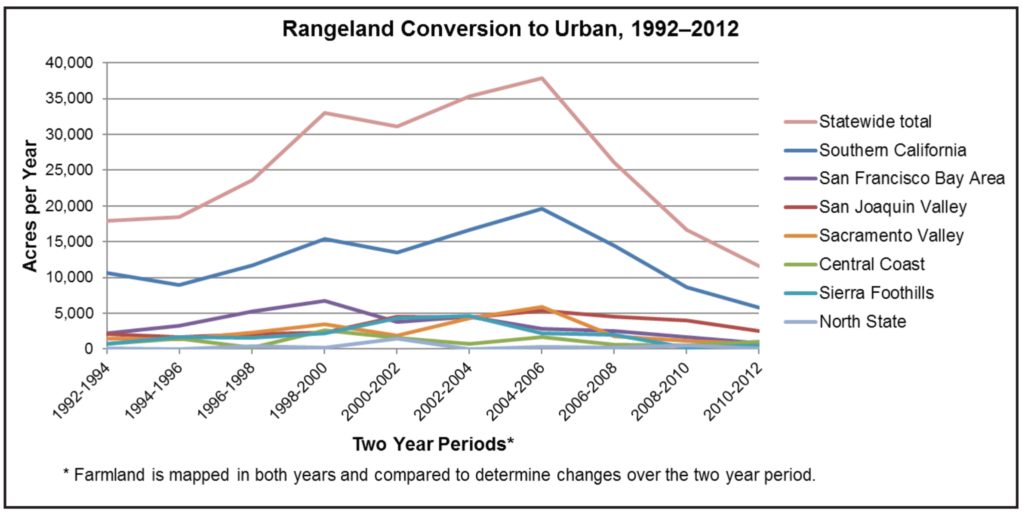
SRR Criterion II: Indicators for conservation and maintenance of plant and animal resources on rangelands (same as Montreal Process Criterion 1, but for rangelands).

SRR Criterion III: Maintenance of rangeland productive capacity (same as Montreal Process Criterion 2, but for rangelands).

Why is this indicator important?

Reduction in total rangeland due to conversion to other land uses reduces the availability of forage for grazing livestock. It can also reduce ecosystem services and have other environmental impacts.

What does the indicator show?



Key Findings:

- Nearly 16 million acres, almost all of it former rangeland, has been converted to other uses since the arrival of Europeans in California. From 1850, over the course of 167 years, this represents an average historical conversion rate of about 95,000 acres per year.
- From 1992–2012, conversions of rangelands to urban occurred primarily in the Southern California, San Francisco Bay Area, and Central Valley Regions.
- Over that period, rangeland conversions to urban peaked in 2004–2006 at about 37,000 acres per year, dropping by 67% (12,000 acres/year) since the onset of the recession.
- From 1992–2012, the Farmland Mapping and Monitoring Program (FMMP) recorded the net loss of rangelands to urban averaged about 25,000 acres per year statewide.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Land Conversion	Farmland Mapping and Monitoring Program, Dept. of Conservation, 1992–2012.	****

Indicator: Beef Cattle Farms by Size Class

ⓘ2.2

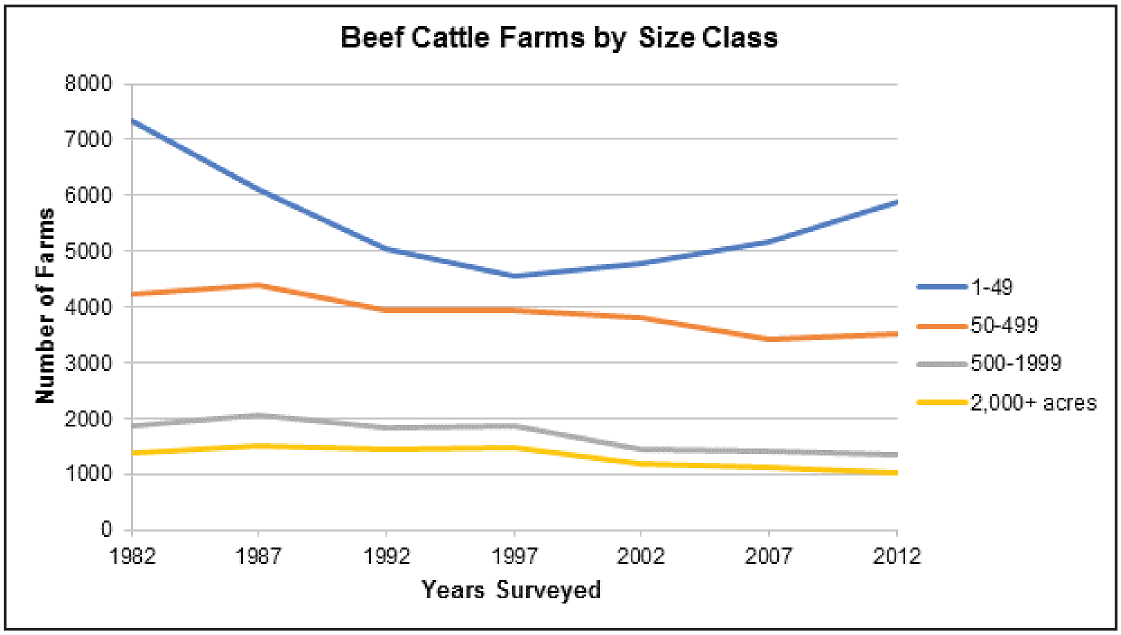
Which Sustainable Rangelands Roundtable Criterion does the indicator evaluate?

Criterion IV: Social and Economic Indicators of Rangeland Sustainability (similar to Montreal Process Criterion 6)

Why is this indicator important?

Larger farms tend to have less human disturbance, and provide a higher level of ecosystem services, and are candidates for maintaining the working landscape through conservation easements or other mechanisms.

What does the indicator show?



Key Findings:

ⓘ The number of beef cattle farms over 2,000 acres declined from a peak of 1,521 in 1987 to 1,020 in 2012, a 33% decline. This could be due to being developed, split into smaller farms, aggregated into larger farms, or being acquired by government agencies or conservation groups.

ⓘ The number of beef cattle farms less than 50 acres increased from its lowest number of 4,542 in 1997 to 5,893 in 2012, a 30% increase. This is still 20% less than the 7,343 small farms that existed in 1982.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Farm Size	[44] USDA Census of Agriculture, 2012.	****

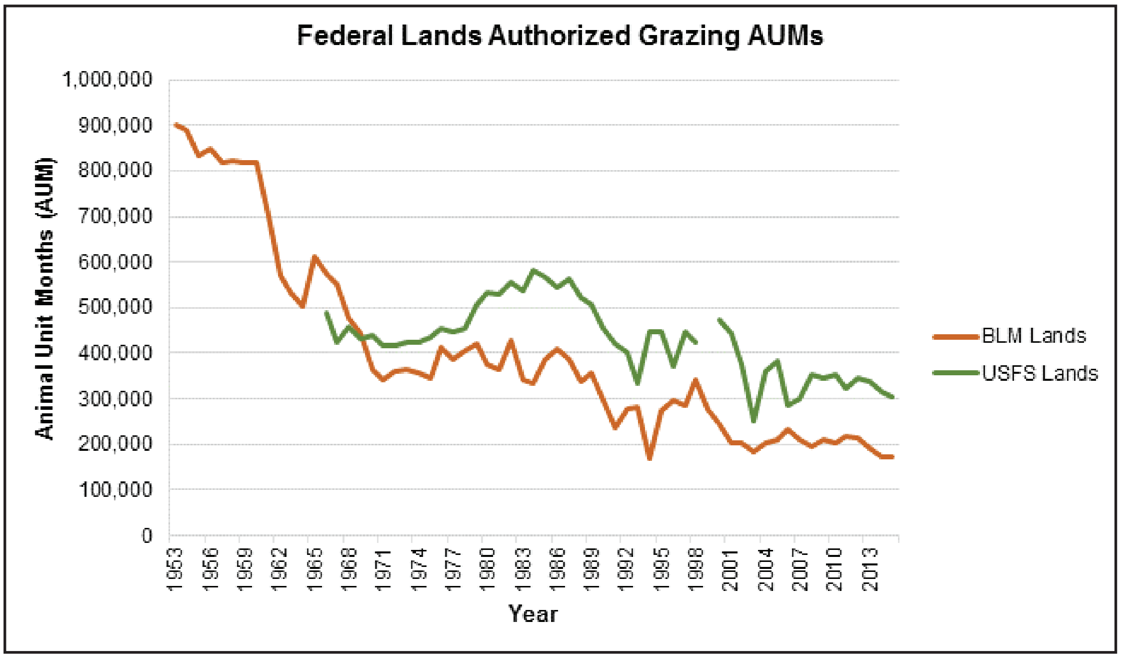
Indicator: Federal Grazing Allotments

ⓘ2.3

Which Sustainable Rangelands Roundtable Criterion does the indicator evaluate?
Criterion III: Maintenance of rangeland productive capacity (similar to Montreal Process Criterion 2)

Why is this indicator important?
Public land grazing allotments are important for keeping some private ranches economically viable, particularly in the regions of northeastern California and the eastern Sierra Nevada.

What does the indicator show?



Key Findings:

- Long-term (50–60+ year) changes in authorized Animal Unit Months (AUMs) on both Forest Service (USFS) and BLM lands show reductions in their annual use for livestock grazing, on order of 40% and 78% respectively.
- Since 2001 grazing use trends for these lands have been relatively flat.
- Long-term reductions in authorized AUMs have been due to changes in federal policy (e.g. the Rescissions Act of 1995, the National Forest Management Act, and additions to the National Park System), the spread of brush and timber vegetation (lack of historical fire regime), and to changes in management, e.g. to accommodate new listings of endangered species, and for the protection of natural resources.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Federal Lands Authorized Grazing AUMs	[45] Bureau of Land Management, United States Forest Service, and High Country News, 2016.	****

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Chapter 3: Urban Forestry

This chapter provides a synthesis of urban forest indicators and key findings from the online technical reports [1, 2], and how they relate to issues of urban forest management.

INDICATORS

- ⓘ3.1 Tree Canopy Cover
- ⓘ3.2 Impervious Surfaces
- ⓘ3.3 Air Pollution
- ⓘ3.4 Urban Heat

SUMMARY

Creating and maintaining healthy urban forest ecosystems is becoming more critical due to warming temperatures (ⓘ3.4), urban development creating more impervious surfaces (ⓘ3.2), the need to mitigate ongoing problems with air pollution (ⓘ3.3), and for the variety of other benefits provided.

The urban area in California encompasses 5% of the land base and supports almost 95% of the population. Statewide, impervious surfaces in census-defined Urban Areas (UAs) increased 20% between 2000 and 2010, to about 1.9 million acres (ⓘ3.2). Roads, parking lots, buildings and other impervious surfaces in urban areas absorb solar radiation, making the environment warmer and creating Urban Heat Islands (UHI). Climate change is producing more frequent heat waves [3] and warmer temperatures that are likely to expand and intensify UHI. This raises concerns for higher energy consumption, elevated emissions of air pollutants and greenhouse gases, compromised human health and comfort, and impaired water quality.

One of the more effective strategies to mitigate the negative impacts of UHI is to increase canopy cover by planting urban trees. The benefits of urban forests in California include: CO_2 storage and sequestration (110 MMT/year); air pollution removal (23,700 MT/year); rainfall interception, improved water quality runoff; reduced energy use; and jobs and economic value to the State economy.

However, tree canopy in urban areas is unevenly distributed in the state. For California's 211 UAs, the average statewide Urban Tree Canopy (UTC) is 15% (ⓘ3.1). Only 44 UAs exceed the American Forests goal of 25% UTC. An analysis was conducted [4], to identify areas with the highest degree of heat island effects and air pollution, in order to locate priority landscapes for tree planting and maintenance. The uneven distribution of UTC across the state and within individual cities leads to an inequitable distribution of environmental benefits. Additional considerations for future analyses would include disadvantaged communities where the environmental benefits from urban trees are often most needed.

KEY FINDINGS

Key findings and indicators are grouped below for the five topics covered in the online technical reports, which includes a more detailed discussion of each topic area.

Urban Forest Benefits

- The average annual cost associated with planting and maintaining an urban street tree is $19/tree and their benefit is $110.63/tree. The return on investment is $5.82 for every $1 spent.

- The estimated CO2 stored in urban forests in California totaled 103 million metric tons in 2015.

- Annually, the amount of CO2 sequestered from urban forests is assessed at 7.2 million metric tons/year. The amount of CO2 avoided was estimated to be 1.3 million metric tons/year. Assuming a price of $12.02/metric ton, these annual amounts are equal to about $87 million/year for annual CO2 sequestered, and $16 million/year for avoided emissions.

- Total pollution removal (BVOC + VOC) is estimated at almost 24 thousand metric tons with a value of $1.1 billion.

Tree Canopy Cover

- California urban tree canopy is estimated to occupy 791,680 acres, with an estimated 159.3 million trees and approximately 1,000 square feet of tree canopy per person.

- There are approximately 9.1 million urban street trees, about 1 for every 4 residents.

- Urban tree canopy is not evenly distributed, and 61.4% of urban areas have less than 10% tree canopy cover.

ⓘ3.1 Indicator: Tree Canopy Cover

- ⓘ Average Urban Tree Canopy (UTC) varies from 3% in Imperial County, to 66% in Tuolumne County. Of California's 58 Counties, 55 have urban areas, and only 12 of these exceed the 25% UTC American Forests goal.

- ⓘ For all of California's 211 census-defined UAs, the average statewide UTC cover is 15%. Only 44 of these exceed the American Forests goal of 25% UTC.

Impervious Surfaces

- The percentage of the urban area in each county that is covered by impervious surfaces varies significantly, from 61.1% in San Francisco to 1.8% in Sierra County.

ⓘ3.2 Indicator: Impervious Surfaces

- ⓘ Census-defined UAs in California have a high concentration of impervious surfaces – about 15% of UAs had ≥70% impervious surface area.

- ⓘ Statewide, the total area of impervious surfaces has increased close to 20% in all UAs from 2000-2010 to close to 1.9 million acres, while the urban population has increased by 10.6%.

- ⓘ Statewide, about 36% of the total land area within all UAs is impervious. This average varies greatly among climatic regions, from 19% in the Interior West, to 46% in the densely populated Southern California Coast area.

Air Pollution

ⓘ3.3 Indicator: Air Pollution

- ⓘ The San Joaquin Valley and South Coast air basins still exceed 8 hour ozone standards 80 to 90 days a year. Recent years show trends toward improvement in these regions and in the Sacramento Valley.

Recent trends in number of PM2.5 days over the standard vary by air basin region. The 24 hour PM2.5 level standards in the San Joaquin Valley have lately exceeded over 40 days a year; in all other air basins it is generally less than 10.

Urban Heat

3.4 Indicator: Days over 90 Degrees Fahrenheit (F)

40% of census-defined Urban Areas (UAs) ranked high for urban heat, with more than 74 days in a year with a maximum temperature of more than 90°F.

Southern California climate zones had an annual average of seven more days over 90°F in the last decade, than in the 1980's.

DISCUSSION

California Urban Areas (UAs), as defined by the U.S. Census, are concentrated in metropolitan areas and encompass about 5% (8,316 square miles, or 5.3 million acres) of land and support 95% of the population (35.4 million people, a 10.6% increase from 2000 Census). There are 211 defined UAs; these are the most populated areas in the State. As a result of increases in population, between 2000 and 2010 there has been an estimated 20% increase in the amount of impervious surfaces associated with UAs (ⓘ3.2). The expansion of UAs combined with warming temperatures (ⓘ3.4) has put an increased demand on urban forests to mitigate against urban heat, air pollution, and other environmental pollutants. Urban trees provide shading that mitigates against the effects of a warmer climate and provide a broad range of benefits. More communities are realizing that urban forests are a critical resource and that increased investment and planning to manage the resource is needed. The following sections provide a statewide assessment of the benefits derived from urban trees, stressors acting against these resources, and implications of managing urban forests. See the online technical report titled, "Biomass, Carbon Sequestration, and Avoided Emissions: Assessing the Role of Urban Trees in California" for additional information [1].

Urban Forest Benefits

Urban forests provide an abundance of benefits such as recreation, pollution reduction, carbon storage, heat island mitigation, storm water control, noise reduction, increased wildlife habitat, increased property values, and energy conservation. It is generally agreed that trees pay us back far more in benefits than the cost to plant and maintain them. Benefits vary with tree size and location, and increase in hotter climates.

Environmental conditions and elements of urban area, including tree canopy cover, access to open space, and density of impervious surfaces impacts quality of life of the residents, and can vary greatly across regions, counties, and even local jurisdictions (See Urban Area Distribution Table 3.1). The majority of large urban areas with populations greater than 100,000 and tree canopy cover less than the state average of 15%; tend to be in the hotter Inland and South-West Desert regions. Urban forestry efforts that target specific neighborhoods' needs can often provide the most benefits, and recent studies suggest that larger trees are a better investment than smaller ones and yield net benefits sooner [5].

Tree Canopy Cover (ⓘ3.1)

Urban Tree Canopy (UTC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. The UTC manages storm water by intercepting rainfall that would otherwise run off of paved surfaces to the urban drain system, picking up pollutants in route, and landing in the local waterways.

Our UTC acts as an urban umbrella providing shade and protection from the scorching sun. This helps to reduce the urban heat island effect by lowering the air temperature resulting in lower heating/cooling costs. This is particularly important in many urban California cities where daytime summer temperatures often exceed 100°F. There are 35 UA's that have a population of greater than 100,000, representing close to 90% of the urban population.

Unfortunately, UTC is often lacking in areas that could benefit from its offerings. Statewide, the urban tree canopy is estimated to occupy 790,855 acres, an average of 15% of all urban area, and almost 1,000 square feet of tree canopy per person, although the urban canopy is not evenly distributed. Large proportions, 61%, of urban areas in California are considered having low tree canopy cover (2-10%).

Photo courtesy of Sacramento Street Foundation.

Table 3.1: Urban Area Distribution of Population, Impervious Surfaces, Open Space, and Tree Canopy by County

	2010 Census			Percent of Total Urban Acres			Percent Change 2000-2010	
County	Population	Total Acres	UA Acres	Impervious	Open Space	Tree Canopy	Population	Urban Area
Alameda	1,506,939	525,652	174,989	46.0%	6.8%	13.9%	5.3%	16.9%
Amador	15,075	387,808	4,934	21.0%	0.4%	24.4%	26.1%	23.0%
Butte	178,416	1,073,364	54,115	21.9%	3.5%	36.1%	9.1%	12.8%
Calaveras	11,208	663,634	6,637	10.6%	0.4%	23.8%	54.4%	41.0%
Colusa	14,624	740,069	3,165	31.7%	1.5%	12.3%	67.2%	48.0%
Contra Costa	1,043,726	514,412	196,645	30.9%	5.8%	18.3%	13.0%	19.6%
Del Norte	18,976	787,038	7,641	18.7%	6.2%	42.3%	1.7%	7.6%
El Dorado	118,231	1,143,263	48,422	14.9%	8.9%	44.1%	21.4%	25.5%
Fresno	829,998	3,847,088	136,945	39.7%	1.6%	13.8%	20.0%	21.1%
Glenn	16,628	849,265	5,408	30.1%	1.2%	9.1%	13.2%	32.0%
Humboldt	94,561	2,593,446	30,220	21.9%	2.8%	30.9%	10.9%	20.2%
Imperial	144,129	2,868,280	27,228	30.9%	1.4%	3.5%	23.3%	27.8%
Inyo	9,935	6,545,228	2,739	17.2%	22.6%	21.5%	-1.7%	4.6%
Kern	753,938	5,224,097	141,401	34.7%	2.7%	6.8%	32.6%	24.6%
Kings	136,381	890,581	25,230	32.0%	1.7%	6.7%	23.8%	19.4%
Lake	43,257	850,834	17,232	14.4%	1.6%	15.3%	44.5%	43.5%
Lassen	10,285	3,020,874	3,431	27.8%	1.2%	8.3%	-23.5%	31.6%
Los Angeles	9,760,499	3,040,691	921,840	44.5%	6.5%	11.7%	3.2%	6.2%
Madera	101,864	1,378,105	25,345	18.9%	0.5%	10.2%	26.7%	19.0%
Marin	235,952	530,043	54,653	23.0%	20.6%	47.8%	2.0%	9.0%
Mendocino	48,110	2,482,019	18,769	17.9%	1.3%	32.4%	8.9%	25.0%
Merced	219,300	1,266,246	44,853	25.8%	1.3%	9.4%	27.4%	25.0%
Modoc	2,910	2,690,180	1,223	23.6%	0.0%	8.6%	14.0%	43.7%
Mono	7,693	2,004,404	2,127	26.5%	13.7%	27.6%	39.5%	30.3%
Monterey	374,315	2,413,581	68,646	27.3%	7.0%	20.1%	6.9%	25.1%
Napa	118,194	504,692	26,305	30.3%	4.4%	24.4%	12.4%	20.6%
Nevada	57,150	623,230	30,578	10.7%	3.8%	48.9%	11.4%	22.4%
Orange	3,005,763	606,762	339,919	46.2%	8.0%	13.7%	5.8%	7.7%
Placer	300,393	961,453	91,290	23.8%	6.1%	29.9%	56.1%	38.9%
Plumas	5,197	1,672,604	2,356	23.4%	0.7%	12.1%	118.3%	67.5%
Riverside	2,088,429	4,673,968	456,930	29.3%	2.1%	6.5%	45.2%	29.9%
Sacramento	1,389,927	636,354	213,190	38.4%	7.4%	15.5%	16.8%	19.5%
San Benito	42,002	889,903	7,324	32.6%	0.9%	5.6%	3.5%	27.1%
San Bernardino	1,941,928	12,867,333	403,731	29.0%	3.0%	6.3%	18.8%	20.8%
San Diego	2,993,087	2,896,400	504,835	35.9%	9.1%	15.6%	8.3%	15.1%
San Francisco	806,231	148,410	30,318	61.1%	17.1%	20.6%	3.6%	1.2%
San Joaquin	627,391	912,987	101,226	43.6%	2.5%	8.7%	24.8%	27.9%
San Luis Obispo	225,098	2,313,945	62,726	20.6%	5.0%	18.6%	19.0%	23.2%
San Mateo	705,298	474,216	91,160	37.2%	9.8%	26.1%	0.9%	2.6%
Santa Barbara	402,626	2,425,029	68,116	26.4%	4.8%	19.0%	3.4%	8.3%
Santa Clara	1,762,844	834,578	211,971	43.9%	4.4%	16.8%	6.5%	9.6%
Santa Cruz	231,662	388,599	51,052	20.9%	8.8%	39.4%	8.2%	17.8%
Shasta	125,321	2,462,334	49,843	20.8%	3.0%	21.4%	12.3%	17.3%
Sierra	9	615,785	5	1.8%	0.0%	11.5%	na	100.0%
Siskiyou	15,344	4,062,320	7,860	21.1%	1.3%	23.0%	6.7%	28.2%
Solano	397,983	579,963	73,643	37.9%	6.9%	11.8%	6.7%	28.0%
Sonoma	424,102	1,131,482	92,505	26.9%	3.6%	23.5%	9.9%	16.2%
Stanislaus	473,396	969,138	76,754	38.8%	3.1%	13.3%	17.5%	16.5%
Sutter	80,718	389,434	15,808	32.6%	0.7%	15.4%	23.0%	19.6%
Tehama	30,787	1,895,792	10,568	25.4%	0.9%	13.7%	15.3%	21.8%
Tulare	374,029	3,096,750	71,885	30.6%	1.3%	7.9%	27.5%	22.0%
Tuolumne	28,255	1,455,651	20,108	7.8%	1.5%	66.5%	-0.4%	31.5%
Ventura	797,668	1,413,278	143,916	29.7%	10.4%	10.4%	11.0%	16.9%
Yolo	186,931	655,063	30,487	41.3%	3.5%	16.2%	23.4%	32.6%
Yuba	53,234	412,153	11,986	24.6%	3.6%	10.8%	29.2%	33.0%

Data Notes: The counties of Alpine, Mariposa, and Trinity do not have any urban areas and are not depicted on this table. Census definition of urban changed between 2000-2010 resulting in 15% of the 2000 urban areas not being included in 2010. The percent change in urban area has been adjusted to reflect real change.

Data Sources: UA Acres: 2000 and 2010 Census; Impervious Surfaces: NLCD, 2011; Open Space: CPAD, 2014; Tree Canopy: EarthDefine, 2013.

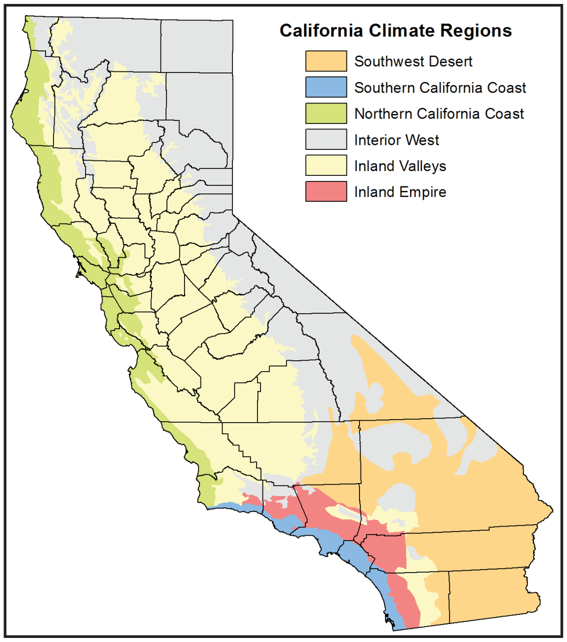


Figure 3.1: Climate Regions Map

Data Source: [1] Bjorkman, et al., 2015.

California has six very different climate regions where the growing condition of trees, building energy use patterns and rainfall vary significantly. The climate region map (Figure 3.1) depicts the climate regions used to estimate urban tree benefits in our OTR [1]. The following table and charts depict estimated values of a few urban tree benefits in each of these climate regions that were developed with the use of transfer functions. On a Statewide level, the value of these benefits is significant: annual CO2 sequestered is 7.2 million metric tons ($86.7 million a year) — or the equivalent of taking 1,537,275 passenger cars off the road each year. Annual pollution (NO2, O3, SO2, PM10, and VOC) removed 3,395 metric tons ($56.4 million a year); annual interception of storm water is 196.7 million cubic meters ($325.8 million a year), or the equivalent of the water used in 627,586 homes in California per year; and annual energy effects for cooling/heating cost resulted in a savings of $568.6 million a year [1].

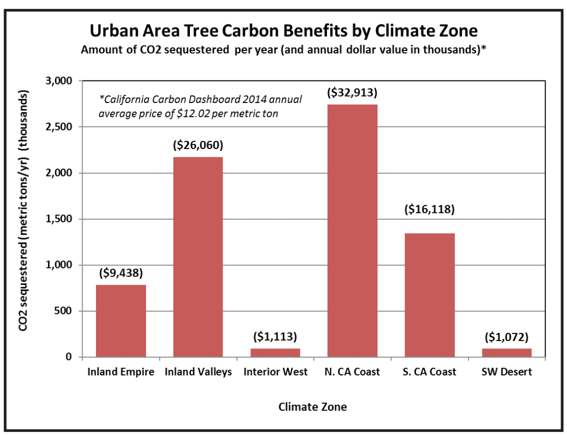


Figure 3.2a: Value of CO2 Sequestered by Climate Zone

Data Source: [1] Bjorkman, et al., 2015.

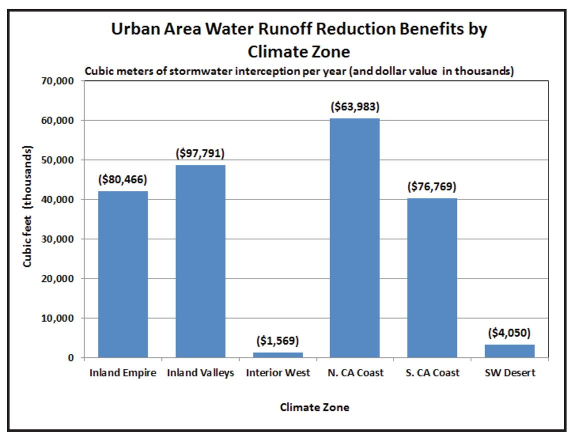


Figure 3.2b: Value of Water Runoff Reduction by Climate Zone

Data Source: [1] Bjorkman, et al., 2015.

Table 3.2: Urban Area Tree Benefits by Climate Zone

	UA State Total	Climate Zones					
		Inland Empire	Inland Valleys	Interior West	N. CA Coast	S. CA Coast	SW Desert
Urban Tree Canopy (Acres)	790,855	115,971	266,985	12,575	208,764	172,571	13,991
Carbon CO2 sequestered (metric tons/yr) CO2 sequestered ($1000/yr)	 7,225,191 $86,715	 785,169 $9,438	 2,171,692 $26,060	 92,592 $1,113	 2,745,568 $32,913	 1,340,972 $16,118	 89,198 $1,072
Pollution Total Pollutant Removal(metric tons/yr) Total Pollutant Removal ($1,000/yr)	 3,537 $56,239	 -553 $1,749	 5,252 $57,879	 285 $3,403	 -5,025 -$47,077	 3,484 $38,706	 93 $1,580
Energy Savings Total Energy Savings ($1,000/yr)	 $568,630	 $202,824	 $259,285	 $9,850	 $49,755	 $29,100	 $17,813
Stormwater Runoff Reduction Interception (m3) Interception ($1000)	 $324,628	 42,129,470 $80,466	 48,707,690 $97,791	 1,187,552 $1,569	 60,550,834 $63,983	 40,194,111 $76,769	 3,194,190 $4,050

Data Source: [1]. Bjorkman, et al., 2015.

Urban Forest Stressors

Urban Heat (ⓘ3.4)

The term "heat island" describes developed areas, usually urban, that are hotter than nearby rural areas. The US Environmental Protection Agency (EPA) reports that the "air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality" [6]. Public health concerns associated with heat waves can be more of a threat to the health of the vulnerable, including children and those over 65 years of age.

The combination of a warming climate with expanding urban areas and increased impervious surface is a recipe for increased urban heat and air pollution. Many of California's largest cities have limited urban tree canopy cover and are subject to warming temperatures. About 40% of urban areas have 74 or more days a year that exceed 90°F (ⓘ3.4). Additionally, research has shown that temperatures in urban areas have increased at a higher rate compared to rural vegetated areas [7].

Research has shown that urban trees reduce summer air temperatures by absorbing water through their roots and evaporating it through their leaves in a process called evapotranspiration and by providing shade. Summer temperatures can be reduced 2-9° F (1-5° C) by evapotranspiration and shaded surfaces can be 20-45° F (11-25° C) cooler than unshaded materials. Cooler building surfaces and walls reduce the amount of heat transmitted into the air and the building, reducing air conditioning needs. Research shows that urban trees combined with strategies for green roofs, changing surface albedo and other strategies can substantially mitigate UHI effects [8].

Impervious Surfaces (ⓘ3.2)

As urban areas grow, more development occurs and the natural landscape is replaced by many impervious surfaces including roads, buildings, housing developments, sidewalks, and parking lots.

Impervious surfaces can increase the urban heat island (UHI) effect. Research has shown increases in temperature (min., max., and avg.) attributed to increases in impervious surface were most pronounced in minimum air temperatures [7]. In addition, impervious surfaces can impact local stream flow and water quality. Water quality problems can occur when development and other urban pollution creates sediment laden water runoff. Runoff is created when the water cannot be absorbed adequately into the available ground soils because the density of urban impervious surfaces. Urban water runoff occurs with rain, urban activities such as watering of lawns, or even from a tributary where construction is taking place.

In California, imperious surfaces increased 20% from 2000 to 2010, which is faster than the population grew. About 15% of urban areas have >70% impervious surface (ⓘ3.2), and 40% have more than 74 days a year with a maximum temperature greater than 90°F. Urban expansion, combined with increased impervious surfaces and warmer temperatures result in a high urban heat threat and more urban heat islands in many UAs.

Air Pollution (ⓘ3.3)

The American Lung Association 2016 State of the Air report [9] found that California has some of the worst air pollution in the country, and despite continued improvements in air quality, 80% of Californians are still at risk from unhealthy air. Los Angeles and Bakersfield metropolitan areas top the country's pollution list for ozone and particle pollution.

Particulate matter in the air varies in size and comes in liquid and solid form. Particles less than 2.5 micrometers in diameter (PM2.5) are called "fine" particles, and are 30 times smaller than a single human hair. Sources of PM2.5 include dust from roads, agricultural operations, construction, wood burning and other activities. Fine particle pollution has been shown to cause many serious health effects, including heart and lung disease, and exposure to PM2.5 can contribute to death.

Children, the elderly, and people suffering from heart or lung disease, asthma, or chronic illness are most sensitive to the effects of PM2.5 exposure because these small particles can move deep into the lungs when we breathe.

Ozone is the main ingredient of smog. At ground level it is a serious pollutant in urban areas that is formed by chemical reactions between nitrogen oxides (NOX) and volatile organic compounds (VOC) in the presence of sunlight and heat. Ozone is more likely to form in warmer temperatures. For 2016, 33 counties in California did not meet ozone standards when compared to US EPA ozone measures. Ozone can cause lung irritation, inflammation, and worsening of existing chronic health conditions, even at low levels of exposure.

Trees can both add and reduce VOCs. Trees emit VOCs from their leaves; the emission rate varies by species. However, because the chemical reaction between the NOX and VOCs are temperature dependent and trees generally lower air temperatures, increased tree canopy can lower overall VOC emissions and ozone levels in urban areas.

Urban forests help filter out air pollutants by depositing pollutants in canopy, sequestration of CO2 in woody biomass and reducing air temperatures. According to Nowak et al., (2014), “the greater the tree cover, the greater the pollution removal, and the greater the removal and population density, the greater the value of human health benefits” [10]. The value of these benefits is considerable across the state, and maximum results are achieved when the efforts and benefits are focused in highly populated areas.

Urban Forest Commitment

For this report commitment was measured with data gathered from the 2014 Arbor Day Foundation’s Tree City USA, CAL FIRE Urban & Community Forestry Grant awards from 2010-2014, and the 2014 USDA Forest Service’s Community Accomplishment Reporting System (CARS) for Urban and Community Forestry programs. Data elements from these three urban forestry programs were aggregated to a county level to represent the local support for urban forestry efforts. Based on the metrics (shown below, Figure 3.3), the greatest level of investment has been in counties in the Bay Area, South Coast and Inland Empire.

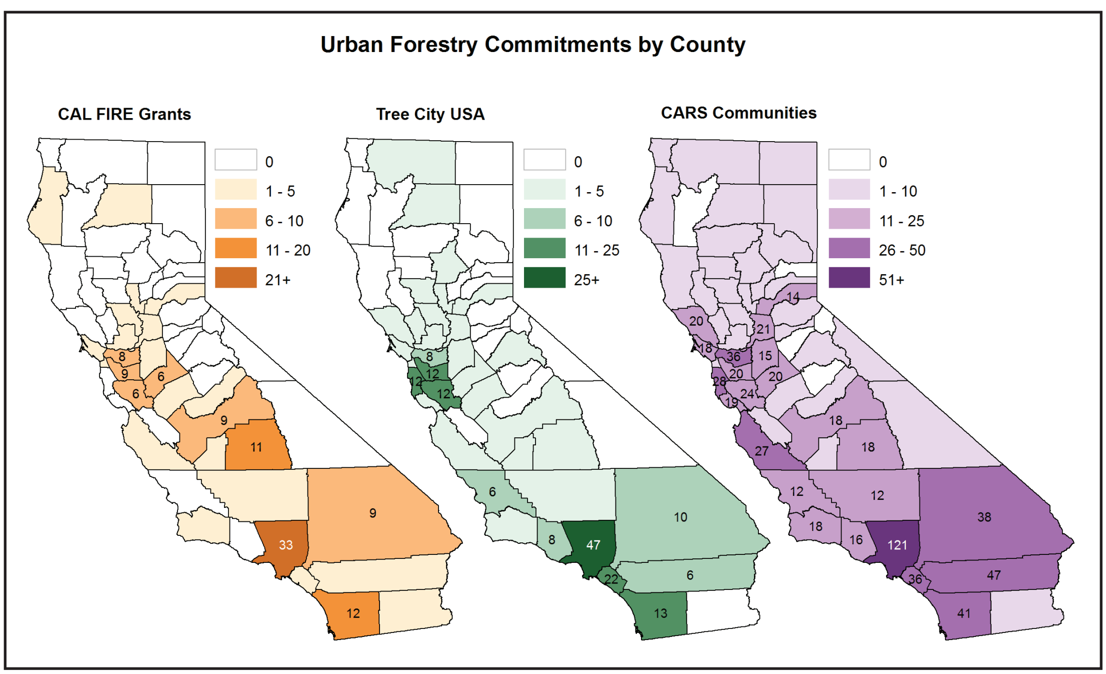


Figure 3.3: Urban Forestry Commitment by County. Not all urban forestry enhancement efforts are tracked, and comprehensive data is not readily available. However, these program efforts measure a portion of the total urban forestry effort, and indicate a level of commitment and support.

Data Source: Tree City USA, 2014; CAL FIRE Urban & Community Forestry Grants, 2010-2014; USFS CARS, 2014.

Statewide, 44% of cities (213 of 482) participated in the 2014 Arbor Day Foundation's Tree City USA campaign. Between 2010 and 2014, a total of 174 urban forest related projects were funded at close to 28 million dollars through various sources, administered by the CAL FIRE Urban Forestry Program.

The United States Forest Service measures successful management of the urban forest by the number of communities (Census Designated Places, or CDP) that have achieved some or all four Community Accomplishment Reporting System (CARS) parameters. Of California's 1523 CDPs, 977 were in an urban area. In 2014, 762 of the CDPs had at least one of the CARS parameters, and about 30% had achieved more than one, showing a commitment to urban forestry efforts.

Urban Forest Management

Management and maintenance of the urban forest is complex because while each community may have goals and environmental concerns, there is little consistency in how urban forests are designed and planned in the state. The ability to quantify urban forest benefits and understand that these benefits outweigh the associated costs can be a challenge for many communities, so often the urban forest infrastructure may be considered as a lower priority or even as expendable. However, development without guidelines to conserve the urban forest leads to decreased natural resources, and increases the potential for urban heat islands and air pollution. Policies and ordinances that recognize the value of trees by providing guidelines for inclusion, preservation, and protection, are among the best means for managing and maintaining tree canopy cover.

Management should also consider environmental justice among communities to reduce inequitable distributions of environmental burdens, such as pollution and heat islands caused by a lack of tree canopy and vegetation. Economically disadvantaged communities generally have fewer environmental amenities, more environmental burdens and less access to the decision making processes. Establishing plans in these communities often requires more effort from the Urban Forestry Program because community leaders are often inundated with other issues, such as lack of resources and high crime, and don't perceive planting trees as a priority. However, increasing the urban forest in these areas can reduce energy bills, incidents of asthma and crime [11].

Indicator: Tree Canopy Cover ⓘ3.1

Which Montreal Protocol Criteria does the indicator evaluate?

MPC5: Maintenance of forest contribution to global carbon cycles

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

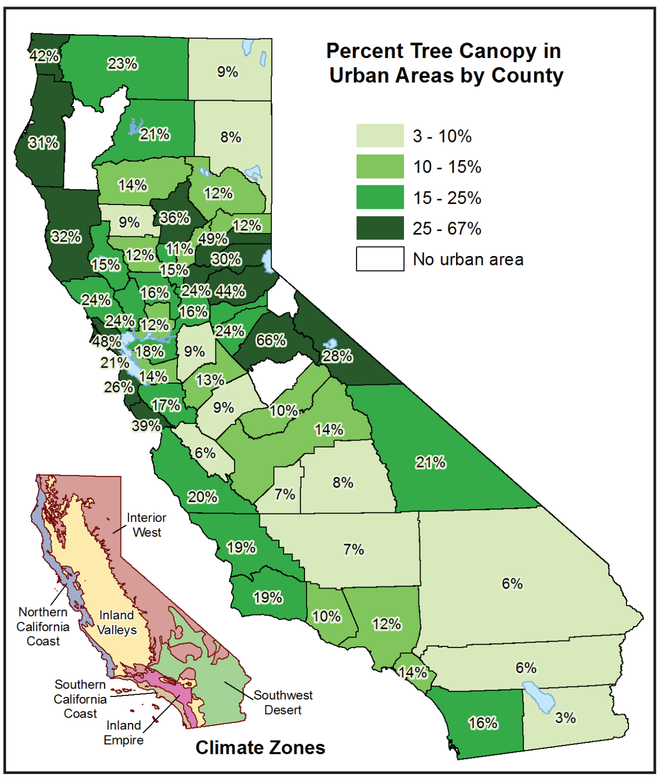
Why is the indicator important?

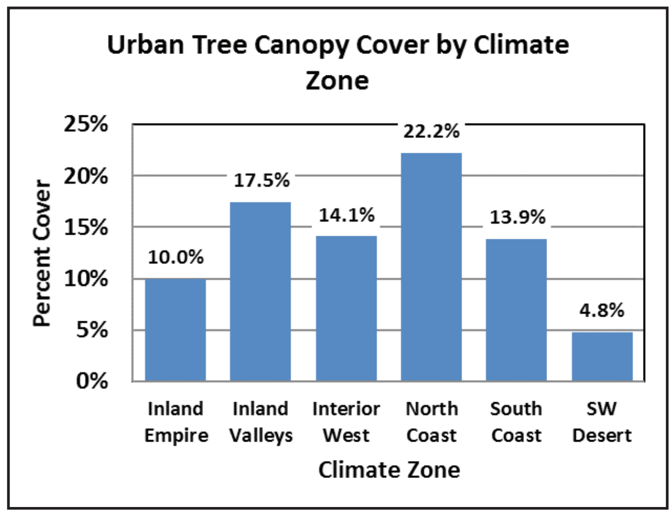
The percent of tree canopy cover in urban areas is one direct measure of the potential for urban forest to provide cooling and habitat needs, as well as other benefits (e.g. carbon storage, storm water interception, energy benefits, air pollution reduction).

Are there known targets or policy goals?

American Forests recommends an average of 25% tree canopy for urban areas in the dry west; more specifically, 18% cover for urban residential, 35% for suburban residential, and 9% in commercial areas.

What does the indicator show?





Key Findings:

- Average Urban Tree Canopy (UTC) varies from 3% in Imperial County, to 66% in Tuolumne County. Of California's 58 Counties, 55 have urban areas (UAs), and only 12 of these exceed the 25% UTC American Forests goal.

- For all of California's 211 census-defined UAs, the average statewide UTC cover is 15%. Only 44 of these exceed the American Forests goal of 25% UTC.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Tree Canopy	[1] Bjorkman, et al., 2015. NAIP (2012) imagery processed by EarthDefine LLC.	****

Indicator: Urban Impervious Surfaces (percent of urban area) ⓘ3.2

Which Montreal Protocol Criteria does the indicator evaluate?

MPC5: Maintenance of forest contribution to global carbon cycles

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

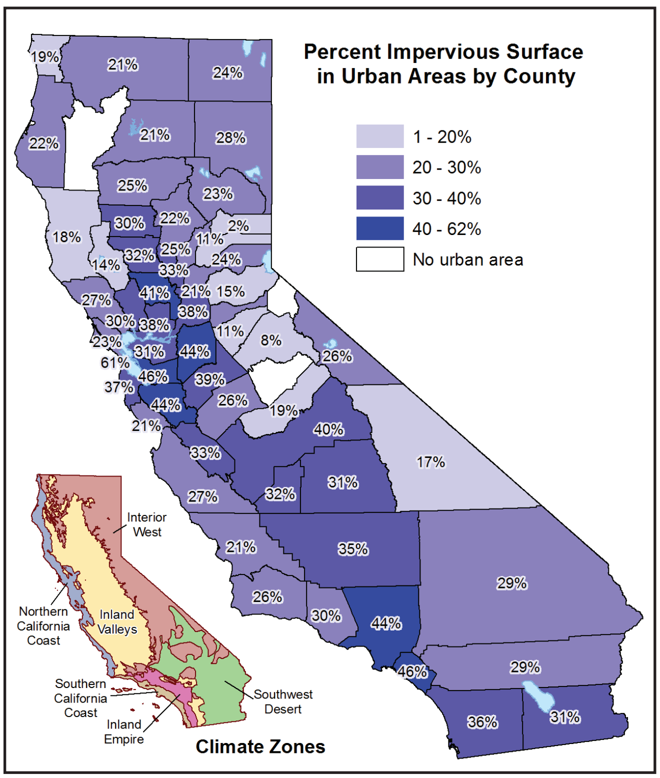
Why is the indicator important?

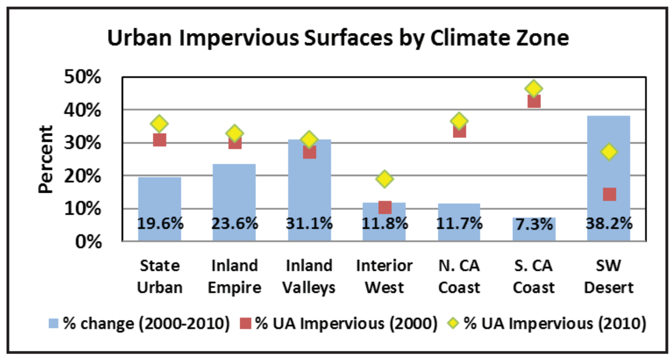
High concentrations of impervious surfaces in hot census-defined Urban Areas (UAs) contribute to increased heat island effect resulting in hotter air temperatures. Developed surfaces (e.g. roads, houses, sidewalks) are often impervious to water, resulting in excessive storm water runoff from these surfaces to receiving water bodies.

Are there known targets or policy goals?

There are many standards and targets depending on program and agency goals.

What does the indicator show?





Key Findings:

ⓘ Census-defined UAs in California have a high concentration of impervious surfaces – about 15% of UAs have ≥70% impervious surface area.

ⓘ Statewide, the total area of impervious surfaces has increased close to 20% in all UAs from 2000-2010 to close to 1.9 million acres, while the urban population has increased by 10.6%.

ⓘ Statewide, about 36% of the total land area within all UAs is impervious. This average varies greatly among climatic regions, from 19% in the Interior West, to 46% in the densely populated Southern California Coast area.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Impervious Surface	[1] Bjorkman, et al., 2015. (Derived from 2011 NLCD Impervious and 2010 US Census Urban-Rural).	****

Indicator: Air Pollution (PM2.5, and Ozone)

ⓘ3.3

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

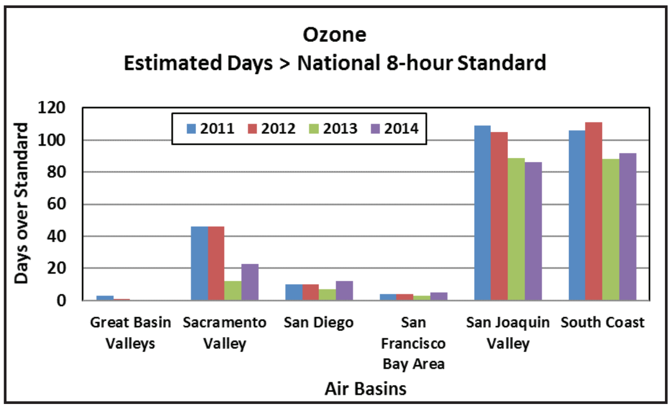
Why is the indicator important?

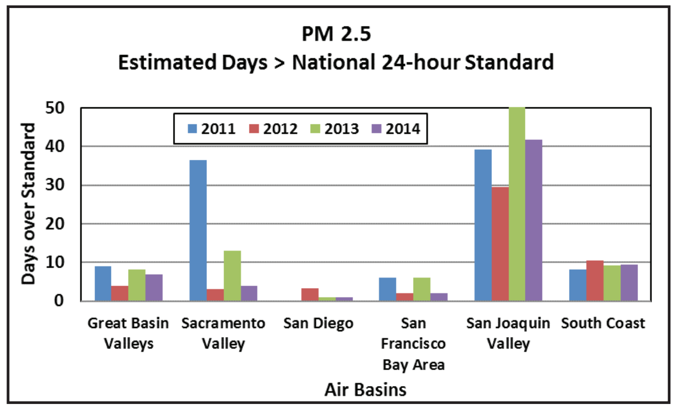
Air pollution can be reduced when natural vegetation is present in urban areas to absorb harmful pollutants from the air, including fine particles and gases.

Are there known targets or policy goals?

The California Air Resources Board (ARB) sets ambient air quality standards for the state. The goal is to have the Air Quality (AQ) within acceptable public safety ranges, and minimal non-attainment days.

What does the indicator show?





Key Findings:

ⓘ The San Joaquin Valley and South Coast air basins still exceed 8-hour ozone standards 80 to 90 days a year. Recent years show trends toward improvement in these regions and in the Sacramento Valley.

ⓘ Recent trends in number of PM2.5 days over the standard vary by air basin region. The 24-hour PM2.5 level standards in the San Joaquin Valley have lately exceeded over 40 days a year; in all other air basins it is generally less than 10.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Ranked Air Pollution (road class + Air Pollution Index)	[1] Bjorkman, et al., 2015. AirPollutionIndex 2011-2014 (derived from Air Resources Board, 2010 US Census, and 2014 ESRI Street layer data).	****

Indicator: Days over 90 Degrees Fahrenheit (F) ⓘ3.4

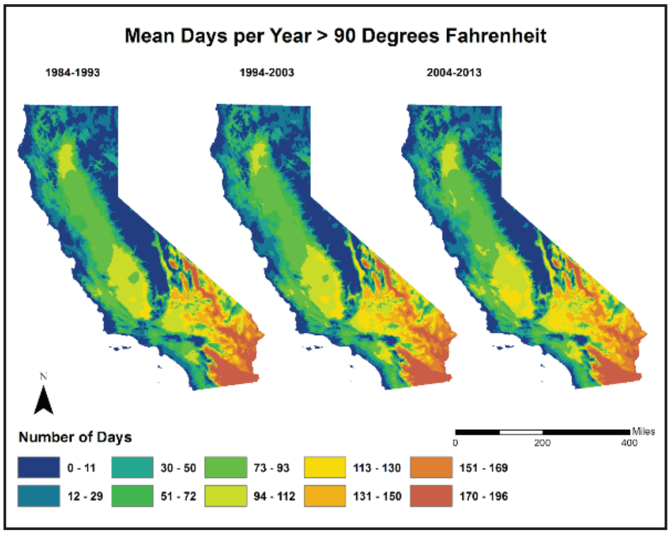
Which Montreal Protocol Criteria does the indicator evaluate?

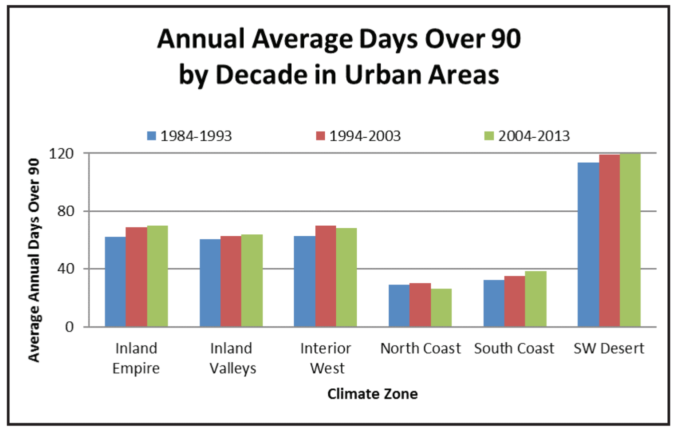
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

The number of days over 90°F is one way of measuring potentially harmful heat in urban settings that can lead to unhealthy air quality and a host of health ailments in sensitive groups.

What does the indicator show?





Key Findings:

ⓘ 🔑 40% of census-defined Urban Areas (UAs) ranked high for urban heat, with more than 74 days in a year with a maximum temperature of more than 90°F.

ⓘ 🔑 Southern California climate zones had an annual average of seven more days over 90°F in the last decade than in the 1980's.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Urban Temperature	[1] Bjorkman, et al., 2015. Urban heat threat (derived from 1981-2013 Prism Climate Data and 2010 US Census Urban-Rural).	****

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Chapter 4: Wildfire

In this chapter, we explore the condition of the fire-prone landscapes of California, how wildfires are acting on natural systems in recent decades, and what strategies will be required to meet the fire management challenges of the 21st century.

SUMMARY

Altered fuel conditions, changing climate conditions, and millions of people and homes in or near wildlands are all likely contributing to increasing fire activity and impacts. Managing wildfire has become a complex endeavor that requires balancing fire protection with ecological needs and societal demands.

Much of California's wildland vegetation is adapted to periodic burning, but natural fire regimes have been disrupted by over a century of fire exclusion, land management and human-caused ignitions. Over the last century, 80% of the natural landscape, excluding grasslands, has burned at a frequency that is significantly higher or lower than pre-settlement times (moderate or high departure) (ⓘ4.1). These disruptions have contributed to the current distribution of hazardous fuels in forests, and to short fire intervals in many shrublands, resulting in over 25 million acres classified as Very High or Extreme Fire Threat (ⓘ4.2). Over 2.2 million housing units exist in the Wildland Urban Interface (WUI) (ⓘ11.3), placing increased demands on fire management organizations. Climate change has created additional stress on ecosystems (ⓘ9.4), altering fuel conditions and extending the fire season.

Over the last three decades, California wildfires burned an average of 558,000 acres annually, with a marked increase in area burned since 2000. Much of this increase has been in conifer forests (ⓘ4.3). Eight of the ten largest wildfires in modern state history have occurred since 2000, including several high-profile "mega-fires". Fire exclusion in frequent-fire adapted forests has contributed to uncharacteristic patterns of high severity fire (ⓘ4.4) with potentially long-lasting effects. Fuel management activities, including prescribed and managed wildfire and mechanical fuel treatment, averaged about 261,000 acres annually (ⓘ4.5) over the last decade, but this represents only a fraction of treatment needs.

Living sustainably in the fire-prone landscapes of California will require broad recognition of the inevitability of fire, which will in turn necessitate enhanced investment in and novel approaches to risk evaluation, fuel management, forest health, land use planning and community adaptation. As we move headlong through the 21st century, fire managers and landowners in California are challenged to effectively utilize available resources and tools to create resilient landscapes, reduce loss of life and property, and stem rising management costs, while enhancing our compatibility with the fire environment in which we live.

INDICATORS

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

KEY FINDINGS

ⓘ4.1 Indicator: Fire Return Interval Departure

ⓘ Areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are burning less frequently than they did in the pre-settlement era, with over 75% of these vegetation types by area in high positive departure. This is most evident in the Sierra Nevada, Southern Cascades and Klamath-North Interior mountain ranges.

ⓘ Many shrub-dominated areas are burning more frequently than their reference regime, with 23% by area in moderate- or high-negative departure across the state. This problem is particularly acute in the South Coast Region, where over 48% of shrublands are in moderate- or high-negative departure.

ⓘ4.2 Indicator: Fire Threat

ⓘ More than 25 million acres in California (32% of burnable wildland vegetation) is classified as Very High or Extreme Fire Threat.

ⓘ Areas of Extreme Fire Threat are concentrated in the South Coast and Mountains ecoregion (26%).

ⓘ The Klamath-North Interior region has a high proportion of Very High Fire Threat (64%).

ⓘ The Sierra-Cascades region is classified in roughly equal proportions of High (45%) and Very High (40%) Fire Threat, with areas of Very High threat concentrated in the low- to mid-elevations.

ⓘ Fire Threat in the North Coast region is mostly Moderate to High, owing to the relative infrequency of fire in recent decades.

ⓘ4.3 Indicator: Wildfire Activity – Trends in Burned Area

ⓘ Approximately 708,000 acres burned annually in California since 2000, up from an average of 343,000 acres for the period 1980–1999, and 186,000 acres annually from 1960–1979.

ⓘ Annual rates of burning in forest and shrub-dominated vegetation, and average size of large fires (>1000 acres) have increased significantly over the last 17 years.

ⓘ Fires in shrub-dominated vegetation historically burned the most area annually between 1960 and 2009. Since 2010, more forest vegetation has burned annually than shrub on average.

ⓘ Eight of the ten largest and most damaging wildfires in terms of both area burned and structures destroyed have occurred since 2000.

ⓘ4.4 Indicator: Fire Severity in Yellow Pine/Mixed-conifer Forests

ⓘ For at least 30 years the average proportion of high severity in yellow pine/mixed-conifer wildfires (23–32%) has been outside the historical range of 4–13%.

ⓘ High severity patches are becoming larger and less complex in yellow pine/mixed-conifer forests, leading to many negative ecological consequences, including reduced regeneration potential and snowpack retention, and increased erosion potential.

ⓘ4.5 Indicator: Fuel Treatment Area

ⓘ The average annual area treated by federal and state agencies over the last 10 years is about 261,000 acres with a range from ~159,000 to ~381,000 acres.

ⓘ Federal agencies have treated the most area annually by a large margin (93%).

ⓘ CAL FIRE performed 15,755 acres of mechanical treatment and 13,941 acres of prescribed burn, meeting 105% and 70% of the targets set by the Director for FY 2016–17, respectively.

ⓘ The average number of acres treated every year is small in comparison to fire protection and ecological needs, representing approximately 1.0% of the state's area in high positive departure.

DISCUSSION

For millennia, wildfire has been a natural process shaping the state's ecosystems and sustaining critically important ecosystem services, including wildlife habitat, water quality and storage, carbon sequestration, nutrient cycling, recreation, timber, and others. Many of the ecological communities that provide these services depend upon periodic fire for control of vegetation structure and maintenance of resilience to disturbances, including fire itself. At the same time, fire that has effects outside of the range to which systems are adapted can cause long-term, undesirable change. This paradox – that landscapes both require fire for long-term health, and are threatened by fires that deviate from a manner that sustains them, is just one of the many challenges facing land managers. Additional pressures of development, whereby people's property and safety are placed in proximity to natural systems that are destined to burn, create the modern duality of managing fire: we need more "good" fire that can maintain ecosystem integrity, and less "bad" fire that threatens both long-term ecosystem function and human health and welfare. In an era of changing climate and increasing wildfire activity, the challenges of a good fire/bad fire paradigm have never been clearer, nor the opportunities so great.

Landscape History and Condition

Fire is understood to have been a primary force that has shaped structure, composition, spatial extent, patterns, and heterogeneity of California's wildlands, recurring at varying intervals in virtually all vegetation types [1, 2]. It is estimated that between 4.5 and 12 million acres burned annually prior to Euro-American settlement [3], although there was significant variability in pre-settlement fire regimes between vegetation types and regions [4, 5]. In addition to natural ignitions from lightning, Native Americans intentionally ignited fire on the landscape for various purposes that included maintaining an open landscape free of shrubs, managing wildlife, and favoring certain plants for the manufacture of baskets and other cultural items [6]. Evidence suggests that fire activity was also closely connected to climate for millennia [7].

Surface fire, central Sierra Nevada. Photo: University of California.

This relationship between fire, Native Americans and climate in California began to change with Native American depopulation in the Spanish Mission era. The gold rush and subsequent Euro-American settlement corresponded with a marked decline in burning. Climate and fire activity were further decoupled after implementation of fire suppression policy across the west, resulting in a deficit of low and moderate severity fire on the California landscape [8, 9]. 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 change in many ecosystems over the last century.

In more recent decades, fire activity has been increasing in California and across the western United States, and a novel fire-human-climate relationship appears to be developing in forested systems, as increases in fire activity have been linked to decreased fuel moistures, increasing temperatures, extended fire seasons and human-caused ignitions [10-13]. These increases are occurring on a landscape of altered vegetation and fuels, with increased population, embedded structures and other assets at risk. These conditions predispose many California ecosystems to wildfires that can have significant human consequences, or cause long-term, undesirable ecological change.

Landscape: Lower Montane Forests

California's lower montane zone, dominated by yellow pine/mixed-conifer forests, and characterized by relatively frequent fire in the pre-settlement era (5-50-year return intervals), represents a large proportion of coniferous forest in California and has seen the most significant changes over the last century [14-19]. Native American population decline, followed by logging, grazing and fire suppression policies of the late-19th through the 20th century altered forest structure and disrupted the fire regimes which played a significant role in creating and maintaining stand structure and landscape pattern in these forests [20]. For example, by 1900, much of the Lake Tahoe Basin had been logged in support of Comstock Era mining. By 1924, comprehensive fire suppression had been codified in federal policy. At least 20% of the pine and mixed-conifer forests of California had been harvested at least once by 1950 [21]. Between 1930 and 2010, large tree density declined by 50% across the state [22].

2014 King Fire near Pollock Pines, CA. Photo: CAL FIRE.

Over the course of the last century, these disruptions contributed to a multitude of ecosystem changes, including increased tree density and homogeneity, altered age structure and species composition, reduced numbers of large trees, buildup of fuels on the forest floor, and increased horizontal and vertical continuity in forest canopy, creating conditions that more readily support severe fire. Though portions of the landscape are still managed for industrial timber production, vast areas retain the legacy of this early forest management. And while timber harvest declined in the late 20th century, suppression remains the dominant form of fire management today, continuing the exclusion of fire from fire-adapted ecosystems. Increased tree density from fire exclusion has also contributed to drought-related mortality, with 129 million trees killed in the southern Sierra Nevada between 2011–2017 [23, 24]. Under a changing climate, droughts may increase in severity or duration, placing even more stress on these forests [25, 26].

Landscape: Shrub Dominated Ecosystems

Like forests, the shrub-dominated ecosystems of the central and southern California coast regions are adapted to periodic fire. Evidence suggests that frequent fires, small in extent and caused by lighting or Native American ignitions, were likely punctuated by one or two large, wind-driven fires per century, and that fire extent was not primarily controlled by fuel age [27-29]. Dominant plant species in these systems can persist in a regime of high-severity fire, reproducing by basal sprouting or fire-induced seed germination [30, 31]. Native Americans used fire in these areas, likely as a way of maintaining habitable locations for settlements free of brush [32]. Euro-American settlers brought about significant changes in vegetation and fuels through the introduction of non-native annual grasses throughout the region, along with millions of head of livestock.

However, unlike forests, fire in these systems has continued at a frequency that is either consistent with or greater than our understanding of their pre-settlement fire regimes (ⓘ4.1, ⓘ4.3). Currently, millions of people live in or near these fire-prone systems, particularly in the South Coast and Mountains region where over 50% of the state's population is located. 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 protected by CAL FIRE. Large fire events that are driven by warm, dry Santa Ana winds and are difficult to control, have continued to cause significant damage to communities (Table 4.3). Coupled with climate changes, "fire season" for this part of the state has extended into nearly every month of the year. In some areas, fire has burned in significantly shorter intervals than the systems are adapted to, placing them on a trajectory of type conversion from native woody to non-native herbaceous vegetation [33].

Post-fire in California chaparral. Photo: University of California.

Fire Return Interval Departure (ⓘ4.1)

Historical (pre-settlement) fire frequencies have been developed for most woody vegetation types in California, serving as a reference for comparison to current fire activity (Table 4.1) [2]. Significant deviation from historical frequencies can signal potential ecosystem change, such as the buildup of hazardous fuels, changes to vegetation structure and composition, and unsustainable tree densities. Fire Return Interval Departure (FRID) (ⓘ4.1) quantifies the difference between current and reference fire frequencies (departure). Percent FRID (pFRID) scales departure between -100% and 100%, where negative values indicate the time between successive fires is shorter than reference (fire excess), and positive values indicate fire intervals are longer than reference (fire deficit). Condition Class groups pFRID values into low, moderate and high departure classes [5].

U.S. Forest Service (USFS) data for FRID through 2016 [5, 34] indicates that areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are burning much less frequently than pre-settlement reference frequencies, with over 75% of these vegetation types by area in high-positive departure (longer fire return intervals) (Figure 4.1). This is most evident in the Sierra Nevada, Southern Cascades and North Coast-Interior mountain ranges of northern California. By contrast, many shrub-dominated areas are burning more frequently than their reference, with 23% by area in moderate- or high-negative departure across the state. This issue is particularly acute in the southern portion of the state, with over 48% of shrubland vegetation in the South Coast and Mountains region in moderate- or high- negative departure (shorter fire return intervals).

Table 4.1: Pre-Settlement Fire Regimes and Associated Fire Return Intervals (FRI - mean and range) in Years

Pre-settlement Fire Regime	Mean Min FRI	Mean FRI	Mean Max FRI
Chaparral	30	55	90
Coastal Sage Scrub	20	76	120
Oak Woodland	5	12	45
Mixed Evergreen	15	29	80
Yellow Pine	5	11	40
Dry Mixed Conifer	5	11	50
Moist Mixed Conifer	5	16	80
Red Fir	15	40	130
Redwood	10	23	170
Pinyon-Juniper	50	151	250

Data Source: [2] Van de Water and Safford, 2011.

Fire Threat (ⓘ4.2)

Fire Threat (ⓘ4.2) provides a more human-centric measure of fuel conditions and fire potential in the ecosystem, representing the relative likelihood of "damaging" or difficult to control wildfire occurring for a given area. Live and dead vegetative fuels are ranked for their capacity to support high-intensity fire that would be difficult to control (Fuel Rank). The rate of burning over the previous 30 years (Fire Rotation) [35] is calculated by region and broad vegetation type, and classified from low (infrequent) to high (frequent) to give a measure of the likelihood of fire occurrence. Fuel Rank and Fire Rotation class are combined into the single measure of Fire Threat, in which areas of Very High or Extreme Fire Threat are more likely to experience damaging wildfire.

Analysis through 2014 indicates that over 25 million acres in California (32% of burnable wildland vegetation) are classified as Very High or Extreme Fire Threat (Figure 4.2). Extreme Fire Threat is generally restricted

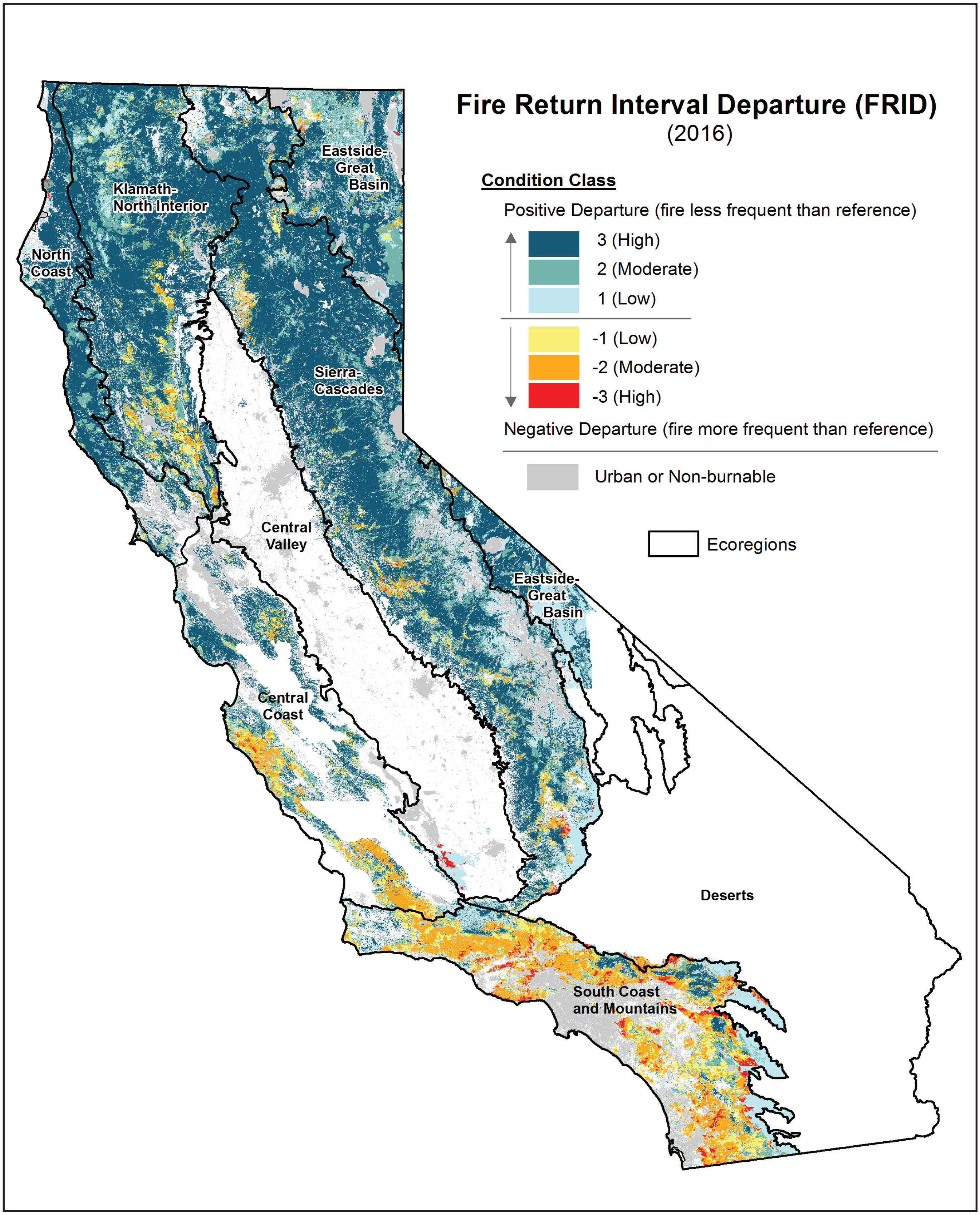


Figure 4.1: Fire Return Interval Departure (FRID) Condition Class, 2016 version. Note that some areas of the state were not mapped, due to lack of fire frequency references, or vegetation data.

Data Source: [34] Safford, H.D. et. al, 2017.

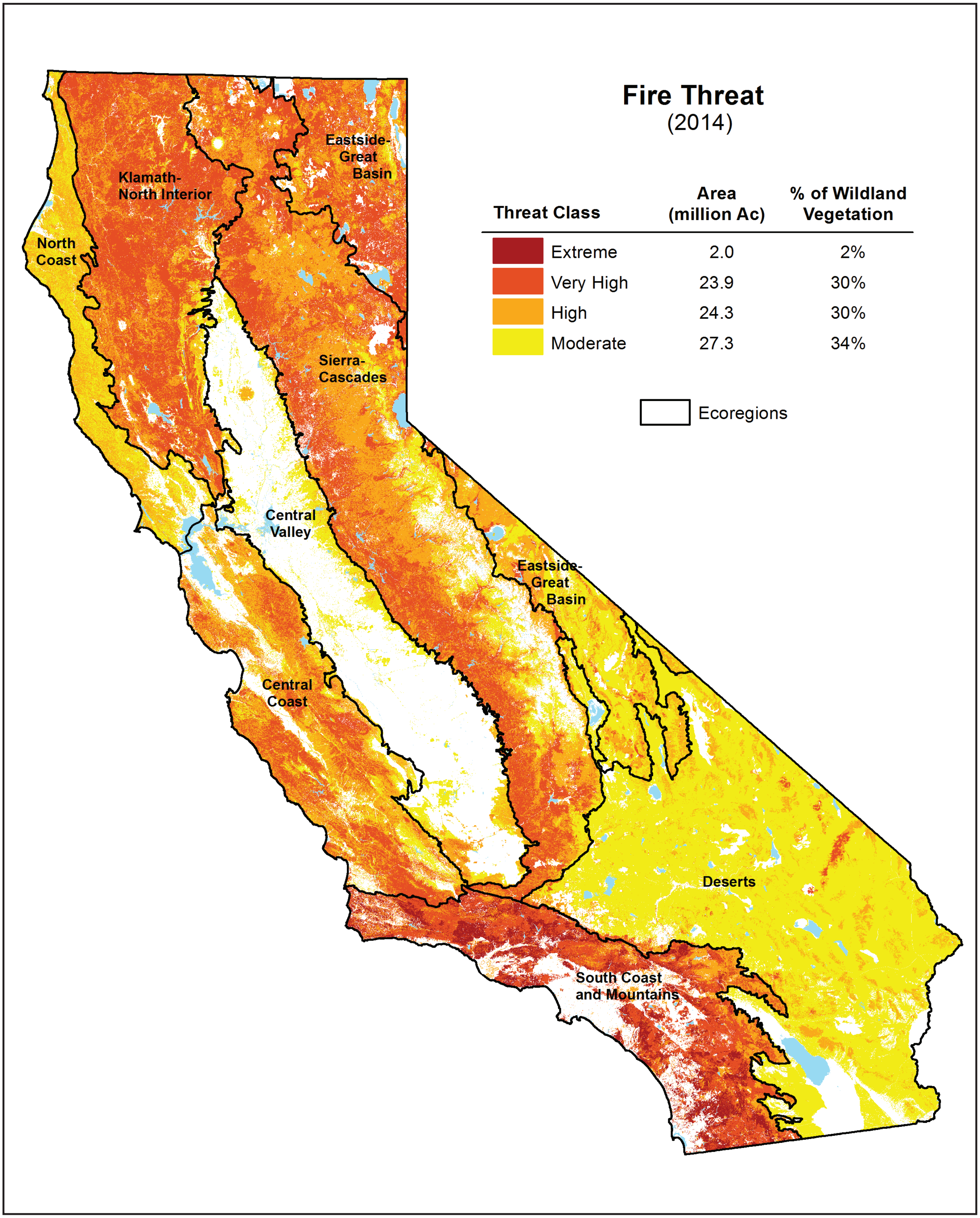


Figure 4.2: Fire Threat, 2014. Note: Areas of Low Fire Threat (little or no fuel, or no burning in the reference period for the vegetation type) are not shown.

Data Sources: [36] CAL FIRE, 2005; [37] LANDFIRE, 2016; [38] CAL FIRE, 2017.

to the shrub-dominated ecosystems of Southern California, owing to their relatively high rate of burning in the reference period (1985–2014), and the typically high-intensity crown fires that they support. Most of the area with Very High Fire Threat is concentrated in the mountainous regions of the state, such as the low- and mid-elevations of the Sierra Nevada, Southern Cascades, and the Klamath-Siskiyou Mountains. The Klamath-North Interior region contains a particularly high proportion of Very High Fire Threat (64%). While much of the North Coast is heavily forested, often with high fuel loads, the relative infrequency of fire in this region over the last 30 years contributes to lower Fire Threat rankings than in neighboring regions. It is important to note that due to the regional nature of this analysis, lower rankings of Fire Threat may indicate lower probabilities or lower intensities of fire, or both, but severe fire is still possible, and the outcomes depend on the particular fuel, weather and terrain characteristics of a given fire.

Wildfire on the Contemporary Landscape

The disruption of fire regimes has created conditions in many California ecosystems that, in concert with climate change and people on the landscape, are manifesting themselves in the form of increased wildfire activity, with ecological, economic and human consequences.

Wildfire Activity (ⓘ4.3)

Annually, wildfires have burned nearly 708,000 acres on average since 2000, close to double the annual average of the prior two decades [39] (Figure 4.3). By decade, this annual average increased significantly in the 1980s, and again in the 2000's, with a peak of over 720,000 acres per year between 2000 and 2009. That decade saw several significant large wildfires, particularly in the South Coast and Mountains region (Table 4.2). Annual area burned since 2010, while slightly less than the 2000's is still significantly higher than any of the decades prior to 2000.

Although the number of large fires (>1000 acres) per year in California has decreased compared to the 2000's, the average size of these fires has increased [38] (Figure 4.5). Indeed, eight of the ten largest fires of the modern era (1960–present) have occurred since 2000, including the Thomas Fire, which burned over 280,000 acres in December of 2017 [40] (Table 4.2).

2017 Thomas Fire. Photo: M. Eliason, Santa Barbara County Fire Department.

Table 4.2: Largest California Wildfires by Size, 1960–2017

Fire Name	Date	County	Area (acres)
Thomas*	December 2017	Ventura & Santa Barbara	281,620
Cedar	October 2003	San Diego	273,246
Rush**	August 2012	Lassen	271,911
Rim	August 2013	Tuolomne	257,314
Zaca	July 2007	Santa Barbara	240,207
Witch	October 2007	San Diego	197,990
Klamath Theater Complex	June 2008	Siskiyou	192,038
Marble-Cone	August 1977	Monterey	177,866
Laguna	September 1970	San Diego	175,425
Basin Complex	June 2008	Monterey	162,818
*Preliminary 12/26/2017 **CA acres only			

Data Source: [39] CAL FIRE, 1960–2016; [40] CAL FIRE, 2017.

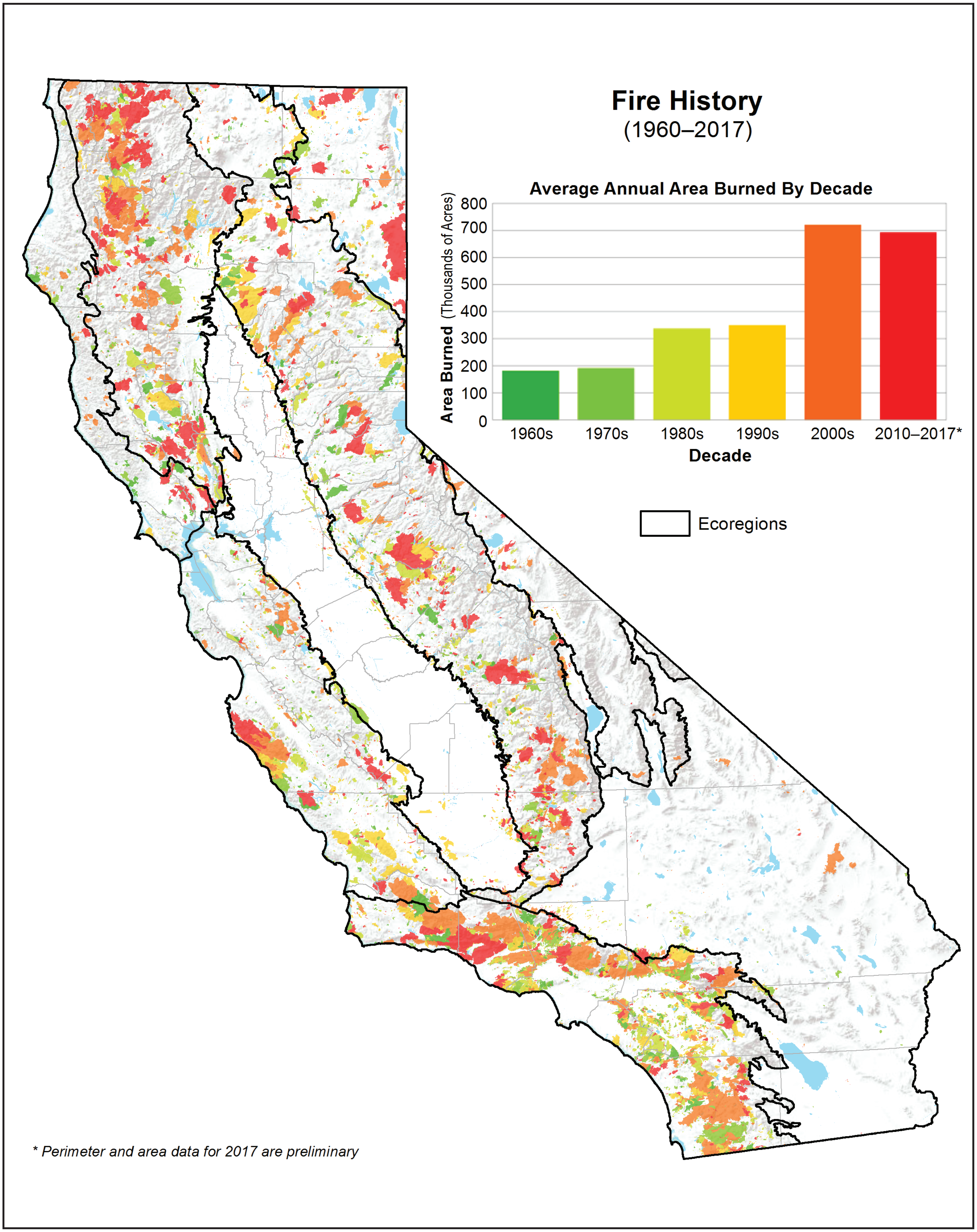


Figure 4.3: California Fire History, 1960–2017. Note: Perimeter and area data for 2017 are preliminary.

Data Sources: [38] CAL FIRE, 2017; [39] CAL FIRE, 1960–2016.

For each decade between 1960 and 2009, shrublands burned the most area annually on average [38] (Figure 4.4). This was primarily due to the semi-regularity of large, wind-driven fires in southern and central California, punctuated by significant fire years in 2003 (Cedar), 2007 (Zaca, Witch), and 2009 (Station). Annual average area burned in forest vegetation has increased each decade since the 1990's, and since 2010, more area has burned on average in forest vegetation than in shrublands (Figure 4.4). Significant timber-dominated fires occurred in 2013 (Rim), 2014 (King, Happy Camp), and 2015 (Rough, Butte). The increasing prevalence of these very large fires (>100,000 acres) across the West, as well as large scale tree mortality events, has led many experts to posit that the US has entered into an era of "mega-fires" or "mega-disturbances" [26, 42-44].

The increase in annual area burned comes amidst a general decline in the number of ignitions since about 1980 [39, 45] (Figure 4.6). In California, the large majority of ignitions are human-caused (85%), resulting in a "fire season" that is 76% longer than lightning-caused fires alone [11]. In the northern parts of the state, lightning ignitions still account for a significant proportion of acreage burned. Increases in wildfire activity have been noted across the West, and linked in part to

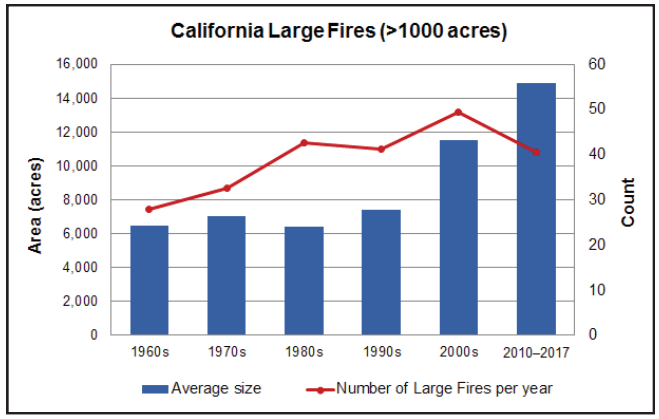


Figure 4.5: Number of Large Wildfires (>1000 acres) and Average Size by Decade, 1960–2017.

Data Source: [38] CAL FIRE, 2017.

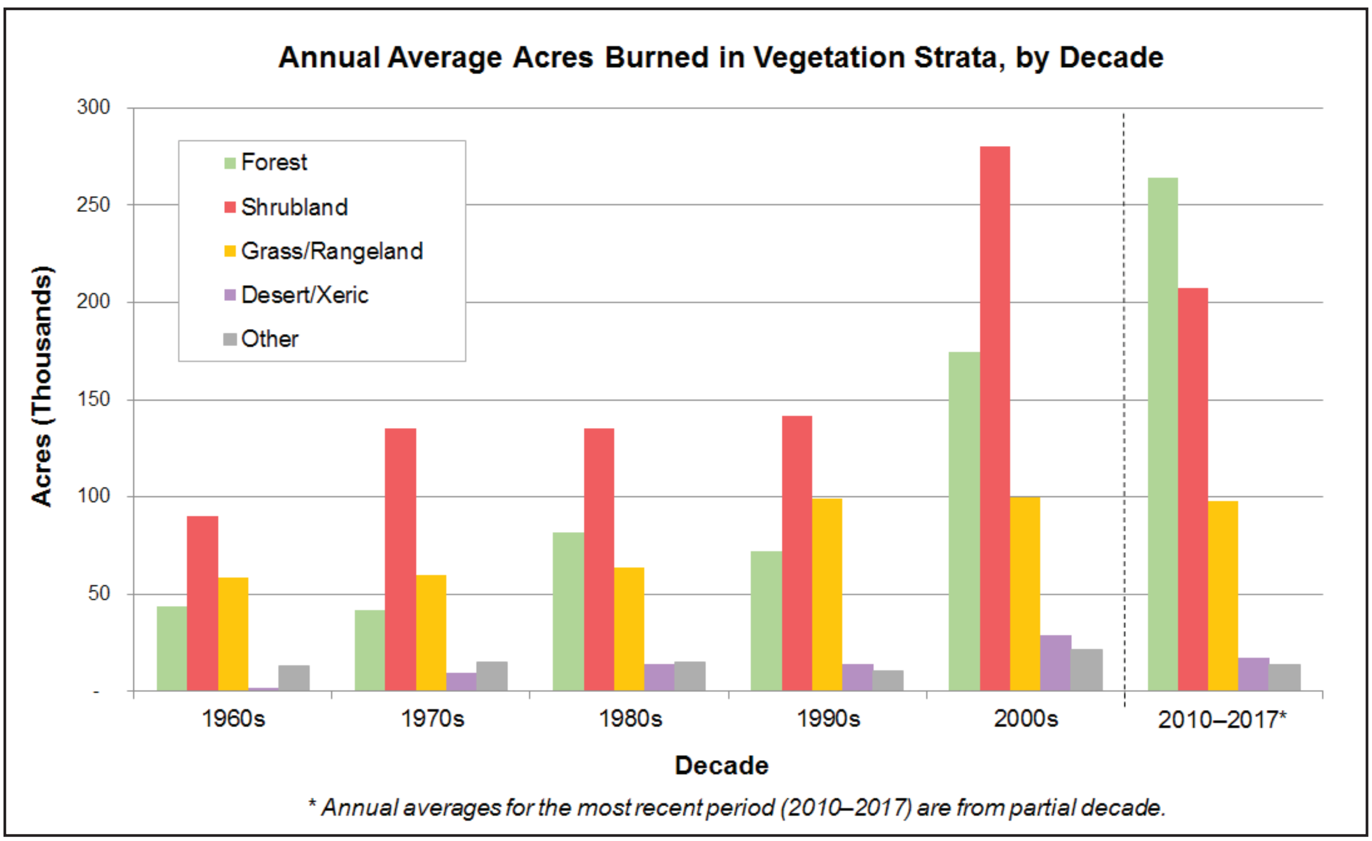


Figure 4.4 Annual Average Acres Burned in Vegetation Strata, by Decade, 1960–2017. Data Note: These values are derived from GIS perimeter data and may differ from total acres burned as reported in Historical Wildfire Statistics (Redbooks).

Data Sources: [38] CAL FIRE, 2017; [41] CAL FIRE, 2015 anthropogenic climate change through warming, earlier spring snowmelt and decreased fuel moisture [10, 12, 13]. In the Sierra Nevada, it is estimated that fire season is 75 days longer now than it was in the 1970's [13].

In response to these new conditions, CAL FIRE now staffs 52 year-round fire engines across the state as of July 2017.

In terms of human impact, the most destructive, deadly, and costly fires in California have occurred largely since 1990 [46] (ⓘ11.1) (Table 4.3). The Tunnel Fire (1991, 25 lives lost, 2,900 structures destroyed) and Cedar fire (2003, 15 lives lost, 2,820 structures destroyed) were devastating, but dwarfed in impact by the October 2017 fires (Central LNU Complex, Mendocino-Lake complex, and others). While still under investigation at the time

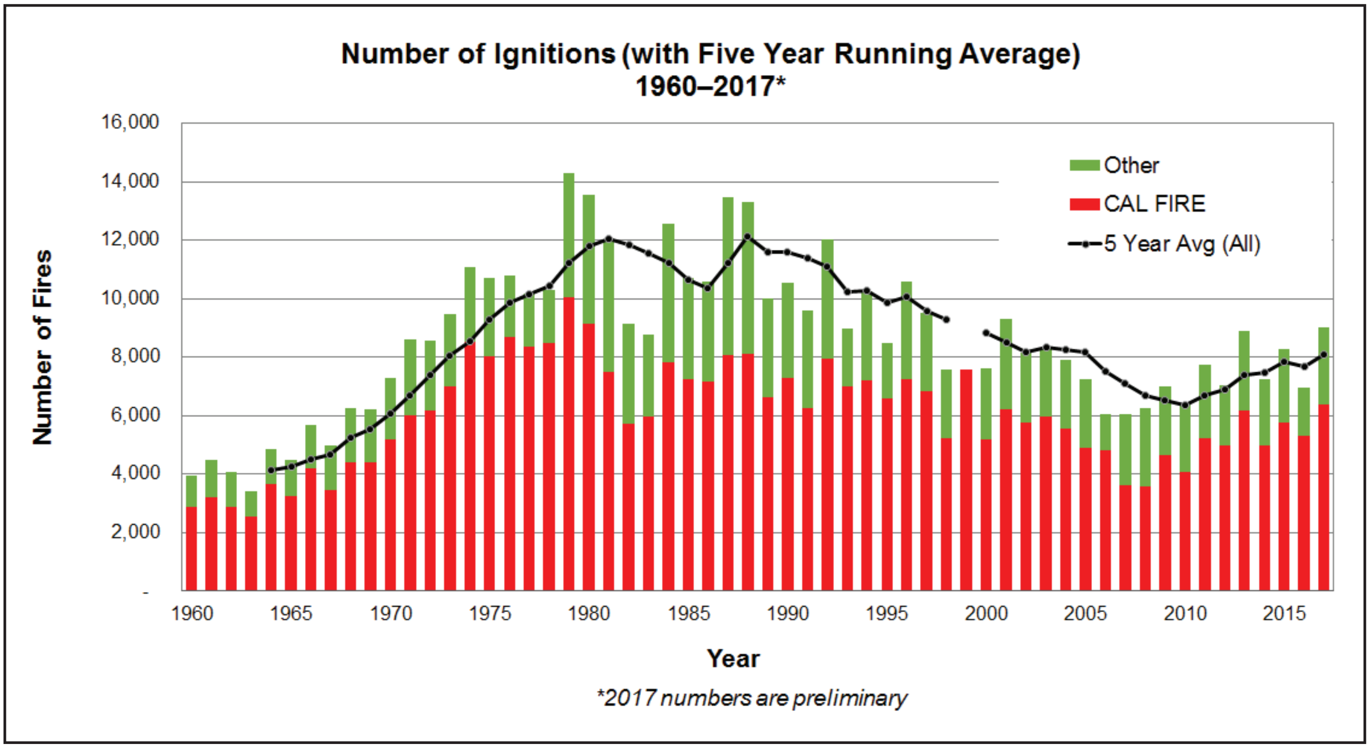


Figure 4.6: Number of Wildfire Ignitions per Year on Lands Under Direct Protection of CAL FIRE and Other Agencies, 1960–2017. Note: Data for year 1998 does not include "other." Data for 2017 are preliminary.

Data Source: [39] CAL FIRE, 1960–2016.

Table 4.3: Most Destructive California Wildfires, 1960–2017

Fire Name	Date	County	Area (acres)	Deaths	Structures Destroyed
Central LNU Complex	October 2017	Sonoma/Napa/Solano	160,170	30	7,779
Tunnel	October 1991	Alameda	1,600	25	2,900
Cedar	October 2003	San Diego	273,246	15	2,820
Valley	September 2015	Lake/Napa/Sonoma	76,067	4	1,955
Witch	October 2007	San Diego	197,990	2	1,650
Thomas*	December 2017	Ventura/Santa Barbara	281,620	1	1,063
Old	October 2003	San Bernardino	91,281	6	1,003
Jones	October 1999	Shasta	26,200	1	954
Butte	September 2015	Amador/Calaveras	70,868	2	921
Mendocino-Lake Complex	October 2017	Mendocino/Lake	38,730	9	707
*Preliminary 12/26/2017					

Data Source: [39] CAL FIRE, 1960–2016; [46] CAL FIRE, 2017.

of this publication, these fires resulted in more than 9,000 structures destroyed and 44 lives lost. Though fuels, land use planning and other factors likely played roles in the outcomes, these fires were all driven by katabatic winds (Santa Ana and Diablo) and burned into urban areas.

While changes over time to funding structures and fiscal policies make it difficult to examine trends, the magnitude of the economic impact from wildfires in recent years are by all accounts unprecedented. Insurance claims resulting from the 2017 fires are expected to exceed $9 billion [47]. The US Forest Service alone had already spent over $2 billion in the 2017 fiscal year on fire suppression, before the October and December fires occurred [48]. As of January 2018, fire suppression expenditures for CAL FIRE are expected to approach $900 million for the fiscal year.

Fire Severity (ⓘ4.4)

In addition to burned area and ignitions, fire severity is an important measure of wildfire impact and outcomes (ⓘ4.4). It represents the effect of fire on the aboveground living vegetation. In shrubland vegetation, fire is mostly binary in nature, either killing the entirety of aboveground vegetation or leaving it intact. In contrast, in low- and mid-elevation conifer forests such as the yellow pine/mixed-conifer dominating large portions of the Sierra Nevada and Klamath-Siskiyou mountains, fire historically burned at low- to moderate severity, killing smaller proportions of overstory vegetation and leaving large fire-resistant trees to persist [17]. Due to fine-grained heterogeneity of stand structure and composition across the landscape, some proportion of high severity fire was likely even in these systems, creating relatively small patches of young, early-seral stage forest.

Techniques have been developed to quantify vegetation mortality resulting from wildfire over large areas, based on multi-spectral satellite imagery from 1984 to the present [49, 50]. Analysis with these methods has shown that for at least the last three decades, high severity fire in yellow pine/mixed-conifer forests in California has been outside the natural range of variability, and appears to be increasing by proportion of area (Figure 4.7). Fires in the most recent decade burned an average of 32% of their areas at high severity. The proportion of high severity fire in these forests prior to modern-era fire regime disruption has been shown to have ranged from 4–13% [17]. In the modern era, annual area burned at high severity is relatively similar in acreage to pre-settlement acreage in yellow pine/mixed-conifer forests, but there is a large modern deficit in the area burned at low and moderate severity [8]. Fire suppression has effectively censored much of the low- and moderate-severity fire from the system. Individual fires, and patches of high severity within fires, are more likely to be larger now than in the pre-settlement era, inconsistent with the relatively fine-grained heterogeneity that previously characterized these forests.

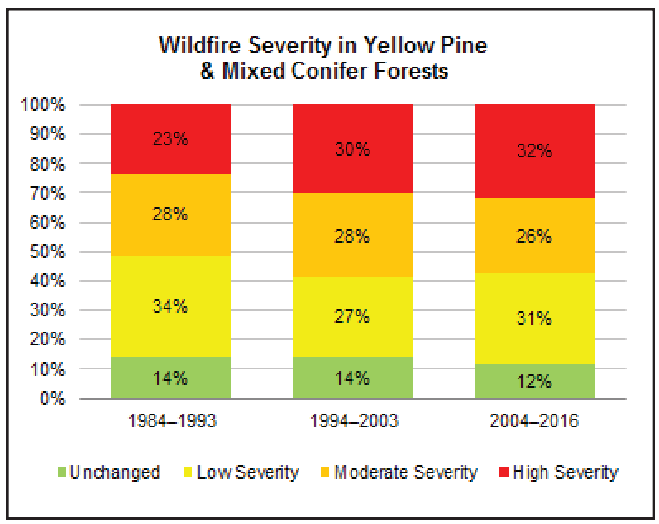


Figure 4.7: Wildfire Severity (Average Proportion per Class by Area) in California Yellow Pine/Mixed-Conifer Forests by Decade, 1984–2016.

Data Sources: [51] U.S. Forest Service, 2017; [52] LANDFIRE, 2016.

Additionally, the shape of high-severity patches also has important ecological implications. Larger and less complex (simpler shaped) patches of high-severity fire can lead to negative or long-term ecological effects, including reduced regeneration potential.

A recent study [53] analyzed high-severity patch size and complexity for 455 California wildfires. High severity patches are becoming larger and simpler in shape, with a striking example being the 2014 King fire which included one contiguous 33,800-acre patch (Figure 4.8). The amount of area that is a significant distance away from high-severity patch edges (and thus seed source) is rapidly accumulating, particularly for USFS lands [53], reducing the capacity for natural regeneration of trees in these burned areas. Furthermore, the overall extent of these patches throughout California is exceeding the USFS capacity to reforest by planting tree seedlings. This is resulting in considerable portions of area in a deforested condition.

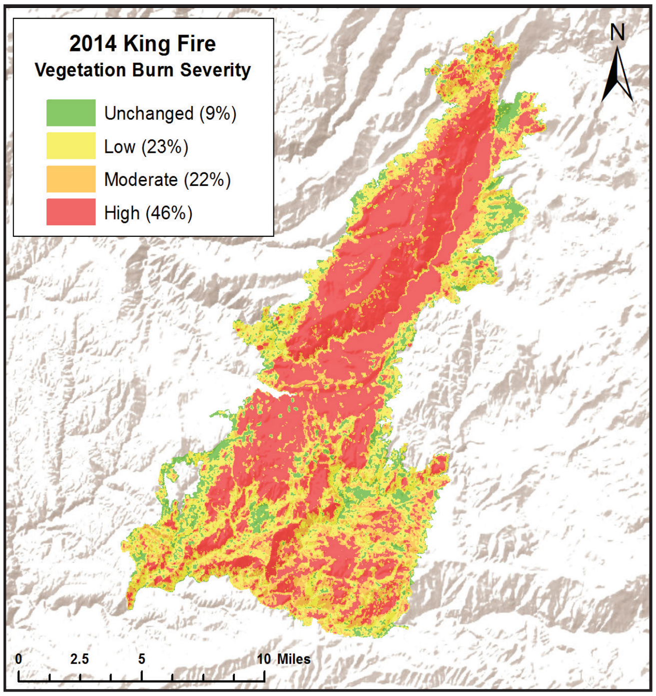


Figure 4.8: 2014 King Fire Vegetation Burn Severity.

Data Source: [51] U.S. Forest Service, 2017.

Fire and Fuel Management

An inadequate understanding of the role of fire in California ecosystems, a belief that even low-intensity fires reduced timber values, and several large and deadly wildfires in the late 19th and early 20th centuries all supported the perception that fire is strictly detrimental and should always be suppressed to protect both people and resources. Eventually enshrined in both policy and public perception, two primary effects of this belief have become apparent. First, in vegetation types adapted to frequent, low- to moderate-intensity fire, fire exclusion has allowed for the buildup of fuel and changes to vegetation structure that create a greater propensity for high severity fire. Second, as California's population grew, the real and perceived effectiveness of fire suppression efforts fed the belief that assets can be placed safely side by side with fire-prone vegetation (ⓘ11.3), even in regions that have continued to burn at or beyond historical rates (ⓘ4.1). In both cases, attempting to comprehensively exclude fire from the landscape has only served to worsen the fire situation. This paradox is now coming into focus, as the altered landscape (ⓘ4.1, ⓘ4.2), climate change (ⓘ9.4), and more people in proximity to wildlands (ⓘ11.3) contribute to increasing wildfire activity and impacts (ⓘ4.3, ⓘ4.4), as well as human costs (ⓘ11.10) (Table 4.3).

Fuel management has long been utilized as a means for fire control, but its techniques and their application in different vegetation types have evolved over the last century. Modern fuel management techniques include the use of fire itself (e.g. prescribed broadcast burning, managed wildfire, and pile burning) as well as mechanical manipulation of fuel volume and structure (e.g. understory thinning, fuel mastication, chipping, planned herbivory). These methods are generally applied in the form of either linear features (i.e. fuel breaks) intended to partition the landscape and facilitate direct suppression or protect assets [54], or as area treatments intended to moderate fire spread and intensity in the absence of suppression resources [55], or as combinations thereof. The use of area treatments to limit fire spread in the shrub-dominated areas of the South Coast

West Camino Cielo Fuel Break, Los Padres National Forest. Photo: US Forest Service/InciWeb.

2001 pre-treatment and 2003 post-treatment photos, mixed conifer stand, Blodgett Forest Researsch Station, Central Sierra Nevada, California. Treatment was mechanical understory thinning and mastication, followed by prescribed burn. Photo: University of California.

region has been shown to be inconsistent with historical fire regimes [29] and largely ineffective at limiting fire size in the contemporary era [28]. However, in forested systems, area treatments have evolved in purpose beyond strictly fire control, with much recent focus on their utility for restoring forests to a condition that can withstand periodic and inevitable natural disturbances without severe, long-term change [56-59].

These techniques have been demonstrated through modeling and real-world wildfires to be effective for both facilitating suppression and moderating fire severity within and outside treated areas [60-69]. The relative benefits and impacts of particular methods, and their ideal amounts, locations and distributions across the landscape and in different vegetation types are topics of continued study and planning [55, 70-75]. The importance of particular methods in fire management strategies varies based on the mission, objectives and constraints of the organization or landowner, with differing degrees of emphasis placed on fire protection and hazard reduction (e.g. near communities or timber plantations), structural restoration (e.g. through tree removal), or process restoration (e.g. reintroduction of frequent, low- or moderate severity fire).

Fuel Treatment Area (ⓘ4.5)

Land managers and scientists today are generally advocating for a significant, but strategic increase in the pace and scale of fuel treatment, particularly in altered forest landscapes, and especially in light of recent large and severe wildfires. State and federal agencies in California have made some progress in this regard, treating an average of about 261,000 acres per year over the last decade, by any method (ⓘ4.5) (Figure 4.9). Treated area declined between 2009–2013, but has increased over the last few years. Federal agencies, primarily the USFS, have treated the most acres annually by a large margin (93%), despite having fire protection responsibility for less than 50% of the state. This disparity is attributable, at least in part, to the complexity for CAL FIRE of performing or facilitating fuel management on private lands of varying ownerships and parcel sizes. Additionally, CAL FIRE's protection responsibility covers areas of private industrial and non-industrial timberland where commercial harvest activity occurs, and these activities are generally not considered treatment. By contrast, the USFS as a single entity directly manages a much larger land base with more contiguous parcels.

However, the average area treated by any agency using any method is still small in comparison to fire protection and ecological needs, representing approximately 1.0% of the state's area in high positive departure (~25 million acres) (ⓘ4.1). The combined area either treated or burned by wildfire represents approximately 3.6% of the state's area in high positive departure (ⓘ4.1) and 3.5% of state's area in very high or extreme Fire Threat (~26 million acres) (ⓘ4.2). Assuming we do not need to treat every acre to strategically protect or restore the landscape, a doubling of current treatment rates to ~525,000 acres per year would allow us to treat about half of the area in high-positive departure in approximately 25 years. It is estimated that federal agencies would need to treat 550,000 acres per year to keep pace with mean historic rates of burning on US Forest Service and National Park Service lands in the Sierra Nevada alone [79]. Across the west, Vaillant and Reinhardt [80] estimate that, even considering "characteristic wildfire" as a form of treatment alongside management actions, National Forest System lands remain in a "disturbance deficit," and that the areas of highest wildfire hazard had the lowest proportion of area treated between 2008 and 2012. Some forested areas may need multiple entries in short succession to meaningfully reduce fire hazard, particularly if using low-intensity prescribed fire as the primary tool. Once areas have been restored, periodic maintenance through prescribed fire, managed wildfire, or other means will be required to prevent recurring buildup of hazardous fuels. These maintenance needs could effectively subsume the entirety of treatment efforts at their current rate [79].

Significant obstacles continue to hinder increases in pace and scale of treatment. Risk aversion to escaped prescribed fire prevents many potential projects, and appropriate weather for safe burning is seasonally limited. Smoke management remains a substantial hurdle, as near-term impacts to air quality from prescribed fire or managed wildfire are weighed against long-term risks from wildfire. Implementation of managed wildfire policies remains problematic, particularly for CAL FIRE, whose primary fire management responsibility is on private lands where fire protection for people and property remains the top priority. Fuel reduction by mechanical means is often costly, has been subject to legal challenges, and is constrained by terrain, protected area status, and other factors [81]. Additionally, over the last

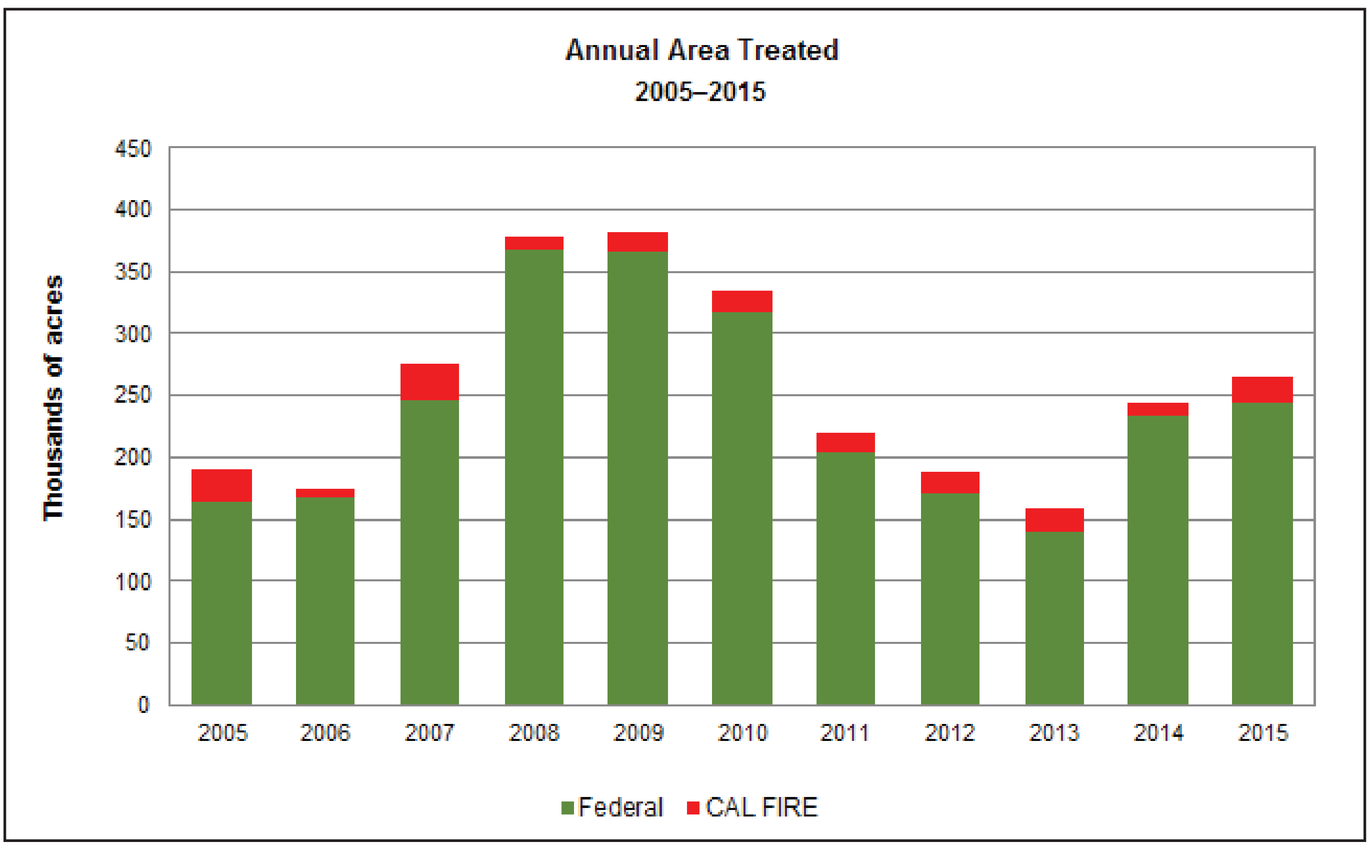


Figure 4.9: Annual Area Treated (Acres) by CAL FIRE and Federal Agencies, 2005–2015.

Data Sources: [76] Grupe, M. and J. Savage, 2017; [77] Griffith, R., 2017; [78] Mediati, T., 2017.

30 years, the infrastructure for processing and marketing the small diameter woody material resulting from mechanical treatments into energy or other products has declined dramatically in California (ⓘ1.4). Federal funding for fuel reduction, vegetation management and ecological restoration has been severely impacted in recent decades, as significant portions of the US Forest Service budget have been instead rerouted towards fire suppression [82, 83].

Prescribed fire, Amador-El Dorado Unit, CAL FIRE, 2017. Photo: D. Passovoy/CAL FIRE.

Strategic Planning and Collaboration

Given the vast nature of the problem (ⓘ4.1, ⓘ4.2) and the entrenched institutional focus on fire suppression, a significant restructuring of fire management programs and priorities will be required to create more resilient landscapes. Fire management agencies in California, including CAL FIRE, have recognized this and are beginning to make progress in the shift, under principles set forth in the National Cohesive Wildland Fire Management Strategy [84]. Established through a collaborative, inter-governmental planning process, the Cohesive Strategy sets forth a national vision that hinges on three primary goals for fire management: 1) restoring and maintaining landscapes, 2) creating fire adapted communities, and 3) safe, effective and efficient wildfire response. California is currently revising its 2010 Strategic Fire Plan, which established a vision of "a natural environment that is more resilient and man-made assets which are more resistant to the occurrence and effects of wildland fire through local, state, federal and private partnerships" [85]. National Forests in the state are undergoing complete revisions to their forest plans, utilizing a risk analysis framework and prioritizing areas for treatment based on values at risk and expected outcomes [75].

In 2015, CAL FIRE, the Sierra Nevada Conservancy, USFS, National Park Service, Sierra Forest Legacy, The Nature Conservancy and other entities signed a Memorandum of Understanding to "increase the use of fire to meet ecological and other management objectives." CAL FIRE's director set a goal for the department to treat 15,000 acres of fuel breaks (non-fire) and 20,000 acres of prescribed fire in the 2016–2017 fiscal year. The USFS has recognized that Region 5 (most of California) would need to treat about 500,000 acres per year to meet restoration and fire protection goals [86]. State departments under the California Natural Resources Agency have recently entered into a "Good Neighbor Authority" agreement with the USFS, intended to facilitate inter-agency collaboration in fuel management projects. CAL FIRE is currently developing a modernization of the environmental review process for fuel management – the Vegetation Treatment Program Environmental Impact Report – that will streamline planning for treatment of the most common vegetation types.

Funding and Investment

Support for and investment in these revised approaches is strengthening, but funding for fuel treatment and restoration remains problematic. In 1995, the USFS spent 16% of its appropriated budget on firefighting; in 2015 it accounted for >50%, significantly reducing the agency's capacity for pre-fire fuel and vegetation management. Recent debate and federal legislative proposals have occurred about fixing this issue [82, 83], and in 2018 a new structure was created for federal spending that addresses wildfire suppression as a discrete cost [48]. However, the procedures do not become operational until 2020. Federal funding initiatives such as the Collaborative Forest Landscape Restoration Program include large projects sites in Shasta and Fresno Counties. At the state level, proceeds from California's Cap and Trade program for reducing greenhouse gas emissions have been directed towards forest health and fire prevention programs, with over $20 million in grants awarded in 2017, and $200 million budgeted for 2018.

Other state programs include the Pre-Fire Management Initiative, Proposition 40 Fuels Reduction Program and the California Forest Improvement Program. However, fuel treatment can be costly to implement, and it is unclear if this increased investment will be sufficient to meet statewide needs.

Investment in fire-related research continues to occur through multiple institutions. The university systems in California, USFS research stations, and other institutions have continued to conduct targeted and long-term studies of wildland fire in California ecosystems, as well as applied research and monitoring for improving forest and land management. The Federal Joint Fire Science Program continues to support scientific information exchange, including the California Fire Science Consortium and other regional exchanges, but its funding for research has declined significantly in recent years. The California Energy Commission has funded a number of research projects related to fire, biomass and energy production. CAL FIRE currently supports research projects in its Demonstration State Forest system and elsewhere.

Land Use and Community Planning and Mitigation

Land use and community planning, reduction of structure vulnerability, and fire prevention education have increasingly come to the forefront of efforts to reduce the societal impacts of wildfire [87-89]. In California alone, there are 2.2 million housing units within the Wildland Urban Interface (WUI), 83% of which are in dense Interface, and 17% of which are in more sparsely populated Intermix (ⓘ11.3). Recent damaging and costly wildfire events have highlighted the critical nature of efforts to reduce structure vulnerability (ⓘ11.1), create fire-adapted communities (ⓘ11.4), and improve land use planning to better recognize extant fire hazard (ⓘ11.2). CAL FIRE has addressed structure "hardening" through its Fire Hazard Severity Zone (FHSZ) program and associated regulations, but many homes in the WUI and State Responsibility Area remain vulnerable, since fire-resistant building codes in FHSZ apply primarily to new construction. CAL FIRE's Fire Prevention program supports land use and fire planning from local to statewide scales, as well as defensible space inspections and fuel management. Organizations such as the California Fire Safe Council and the National Fire Protection Association (NFPA) Firewise Communities Program continue to support local efforts to reduce wildfire hazard and manage risk of loss.

However, significant numbers of communities and structures remain vulnerable to wildfire (ⓘ11.4). Recent wildfires have resulted in unprecedented numbers of home insurance claims in California, placing significant strain on the industry, with several major insurers declining to write new policies or renew existing ones. A recent report by the California Department of Insurance recommends a legislative solution that would require insurers to better recognize homeowner efforts to mitigate wildfire risk, and to give the state broader oversight of how insurers model risk [90].

Fountaingrove neighborhood, Santa Rosa, CA, after the 2017 Tubbs fire. Photo: CAL FIRE.

Opportunities

The ecosystems of California evolved over time with wildfire; our strategies for living in a fire-prone 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. Fire management priorities and policies that focus primarily on suppression only ensure that more of the same destructive wildfires will occur [82, 91, 92]. 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 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 that CAL FIRE believes will improve fire management and resource protection into the future.

Ecosystem Management for Health and Resilience

- Enhance understanding amongst 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 programs and activities.

- Strategically and significantly expand the pace and scale of forest health treatments to reduce hazard, improve forest resilience to disturbance, and encourage long-term stability of ecosystem services, including carbon storage.

- Utilize emergent national fire management policy of fire restoration, including expanded use of prescribed fire and managed wildfire.

- Improve efficiency of vegetation management planning and implementation. Specifically, streamline regulations designed to promote forest health and carbon-positive trends associated with harvest practices (e.g. AB1504).

Strategic Fire and Fuel Management

- Emphasize landscape-level planning consistent with typical modern-era fire events. This requires cross-agency/landowner coordination, and consideration of multiple objectives.

- Restructure funding, enhance current investments, and explore new mechanisms to place greater emphasis on pre-fire management, including 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.

- Develop site-specific plans to prioritize areas for treatment that recognize key elements of fire regime, plant and ecosystem response, and human safety concerns.

- Continue to adapt the fire suppression workforce to better respond to changing trends in wildland fire and evolving ecosystem management strategies.

Land use and Community Planning

- Continue state and federal efforts to engage in local land-use planning to assure that fire risk concerns are understood and mitigated when planning future development.

- Promote sound planning and mitigation in the wildland-urban interface to make communities more resistant to damage from wildfire.

- 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.

- Promote wildfire planning, education, safety, response, and insurance programs that better recognize homeowner and community efforts to mitigate wildfire risk.

Research and Monitoring

- Support ongoing research and establishment of new long-term studies examining the management of fire in fire-adapted ecosystems, particularly with respect to treatment effects and post-fire dynamics of fire hazard, carbon storage, and wildlife habitat.

- Expand forest monitoring in areas of high tree mortality to better understand post-mortality conditions with respect to fire hazards and forest recovery.

- 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.

Indicator: Fire Return Interval Departure

ⓘ4.1

Which Montreal Process Criteria does the indicator evaluate?

MPC3: Maintenance of forest ecosystem health and vitality

Why is the indicator important?

In California's fire-adapted ecosystems, alteration of the frequency of fire (either "deficit" or "excess"), in combination with land use practices and development, has impacted ecosystem structure and function in many places, including changes to fuels, tree density, species composition, wildlife habitat and hydrology. Important feedbacks can result, as altered vegetation changes potential fire behavior, fire severity, and vegetative reproduction. Fire Return Interval Departure (FRID) quantifies the difference between current and reference fire frequencies (departure). Percent FRID (pFRID) scales departure between -100% and 100%, where negative values indicate fire is occurring at a greater frequency than reference (fire excess), and positive values indicate fire is occurring at a lower freqency (fire deficit). Condition Class groups pFRID values into low, moderate and high departure classes.

Are there known targets or policy goals?

Reference fire frequencies have been developed for most vegetation types dominated by woody species in California, but there are no official policy targets.

What does the indicator show?

Fire Return Interval Departure by Vegetation Group, 2016

Vegetation Group	Mapped Area (million acres)	Percent of Mapped Area in Each Condition Class: -3	-2	-1	1	2	3
		< Fire more frequent than reference -			- Fire less frequent than reference >		
Conifer	16.2	<1%	2%	<1%	15%	11%	71%
Hardwood	7.5	<1%	<1%	3%	6%	14%	76%
Mixed Conifer-Hardwood	6.1	<1%	<1%	1%	5%	13%	80%
Shrub	16.0	3%	20%	16%	17%	22%	22%
All	**45.8**	**1%**	**8%**	**7%**	**13%**	**15%**	**56%**

Key Findings:

- Areas dominated by conifer, hardwood, and mixed conifer-hardwood vegetation are burning less frequently than they did in the pre-settlement era, with over 75% of these vegetation types by area in high positive departure. This is most evident in the Sierra Nevada, Southern Cascades and Klamath-North Interior mountain ranges.

- Many shrub-dominated areas are burning more frequently than their reference, with 23% by area in moderate- or high-negative departure across the state. This problem is particularly acute in the South Coast Region, where over 48% of shrublands are in moderate- or high-negative departure.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Fire Return Interval Departure (FRID)	[34] Safford, H.D. et. al, 2017.	****

Indicator: Fire Threat

ⓘ4.2

Which Montreal Protocol Criteria does the indicator evaluate?

MPC3: Maintenance of forest ecosystem health and vitality

Why is the indicator important?

Fire Threat is a measure of the relative likelihood of damaging or difficult to control wildfire. Live and dead vegetative fuels are ranked for their capacity to support high-intensity fire (Fuel Rank). The rate or frequency of burning over the previous 30 years (Fire Rotation) is calculated by region and broad vegetation type, and classified from low (infrequent) to high (frequent) to give a measure of the likelihood of fire occurrence. Fuel Rank and Fire Rotation class are combined into the single measure of Fire Threat, in which areas of Very High or Extreme Fire Threat are more likely to experience damaging wildfire. Fire Threat is not a direct evaluation of fire in an ecological context, but is an important measure for fire managers examining people, communities, and resources at risk from wildfire.

What does the indicator show?

Fire Threat by Ecoregion, 2014

Ecoregion	Area (million acres)	Percent of Area in Each Threat Class			
		Moderate	High	Very High	Extreme
Central Coast	8.2	18%	44%	32%	-
Central Valley	2.9	60%	23%	1%	-
Deserts	19.8	87%	9%	1%	-
Eastside-Great Basin	8.6	29%	37%	30%	-
Klamath-North Interior	10.7	5%	29%	64%	-
North Coast	3.9	53%	43%	-	-
Sierra-Cascades	19.4	10%	45%	40%	-
South Coast and Mountains	7.5	-	19%	51%	26%
Total	**80.9**	**34%**	**30%**	**30%**	**2%**

Key Findings:

- More than 25 million acres in California (32% of burnable wildland vegetation) is classified as Very High or Extreme Fire Threat.
- Areas of Extreme Fire Threat are concentrated in the South Coast and Mountains ecoregion (26%).
- The Klamath-North Interior region has a high proportion of Very High Fire Threat (64%).
- The Sierra-Cascades region is classified in roughly equal proportions of High (45%) and Very High (40%) Fire Threat, with areas of Very High threat concentrated in the low- to mid-elevations.
- Fire Threat in the North Coast region is mostly Moderate to High, owing to the relative infrequency of fire in recent decades.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Vegetation Disturbance 2005–2014	[37] LANDFIRE, 2016.	****
Fuels and Fire Behavior	[36] CAL FIRE, 2005.	****
Historical Fire Perimeters	[38] CAL FIRE, 2017.	****

Indicator: Wildfire Activity – Trends in Burned Area ⓘ4.3

Which Montreal Process Criteria does the indicator evaluate?

MPC3: Maintenance of forest ecosystem health and vitality
MPC5: Maintenance of forest contribution to global carbon cycles

Why is the indicator important?

Fire is an important and inevitable ecological process across much of California. Although thought to have burned significantly more area annually 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 both people 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. 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?

Trends in Wildfire Activity by Vegetation Type

Decade/ Period	Average Annual Area Burned (thousand acres)					
	Forest	Shrubland	Grass/Rangeland	Desert/Xeric	Other	Total
1960s	43.7	90.1	58.6	1.6	13.3	**207.4**
1970s	41.8	135.2	60.0	9.7	14.9	**261.5**
1980s	81.8	135.3	63.6	13.8	14.9	**309.3**
1990s	71.9	141.9	98.9	14.2	10.3	**337.3**
2000s	174.6	279.9	99.5	28.6	21.3	**604.0**
2010–2017	264.0	207.5	97.9	17.3	13.4	**600.1**
1960–1979	42.8	112.6	59.3	5.6	14.1	**234.5**
1980–1999	76.9	138.6	81.3	14.0	12.6	**323.3**
2000–2017	214.4	247.7	98.8	23.6	17.8	**602.3**

Data Note: These values are derived from GIS perimeter data and may differ from total acres burned as reported in Historical Wildfire Statistics (Redbooks).

Key Findings

- Approximately 708,000 acres burned annually in California since 2000, up from an average of 343,000 acres for the period 1980–1999, and 186,000 acres annually from 1960–1979.
- Annual rates of burning in forest and shrub-dominated vegetation, and average size of large fires (>1000 acres) have increased significantly over the last 17 years.
- Fires in shrub-dominated vegetation historically burned the most area annually between 1960 and 2009. Since 2010, more forest vegetation has burned annually than shrub on average.
- Eight of the ten largest and most damaging wildfires in terms of both area burned and structures destroyed have occurred since 2000.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Area Burned (Reported)	[39] CAL FIRE, 1960–2017.	****
Fire Perimeters	[38] CAL FIRE, 2017.	****
WHR Vegetation Type Class	[41] CAL FIRE, 2015.	*****

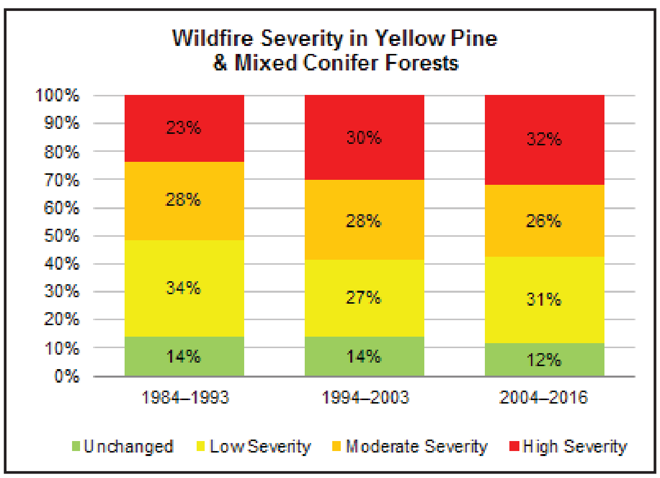
Indicator: Proportion of High Severity Fire in Yellow Pine/Mixed-Conifer Forests

ⓘ4.4

Which Montreal Process Criteria does the indicator evaluate?
MPC3: Maintenance of forest ecosystem health and vitality
MPC5: Maintenance of forest contribution to global carbon cycles

Why is the indicator important?
Yellow pine/mixed-conifer are the most extensive forests in the state. These forests evolved with, are adapted to, and were sustained by frequent fires, with 4-13% of wildfire area burning at high severity, supporting fine-scale variation of forest structure. Interruption of natural fire frequencies (ⓘ4.1) and changes to forest structure from over a century of fire suppression and timber harvest have resulted in overly dense, structurally homogenous forests with too few large, fire-tolerant trees and greater propensity for high-severity fire. Proportions of high-severity burning out of the natural range of variability for these forests may lead to long-term changes in forest area, composition, or structure. The increasing incidence of large, spatially simple patches of high-severity fire are of particular concern, as they may lead to large-scale tree regeneration failure and type conversion to shrub or grass, as well as having negative impacts on soil productivity, water quality, wildlife habitat, and carbon storage.

What does the indicator show?



Key Findings:

ⓘ For at least 30 years the average proportion of high severity in yellow pine/mixed-conifer wildfires (23–32%) has been outside the historical range of 4–13%.

ⓘ High severity patches are becoming larger and less complex in yellow pine/mixed-conifer forests, leading to many negative ecological consequences, including reduced regeneration potential and snowpack retention, and increased erosion potential.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Vegetation Type	[52] LANDFIRE, 2016.	****
Burn Severity	[51] U.S. Forest Service, 2017.	****

Indicator: Fuel Treatment Area

ⓘ4.5

Which Montreal Process Criteria does the indicator evaluate?

MPC3: Maintenance of forest ecosystem health and vitality

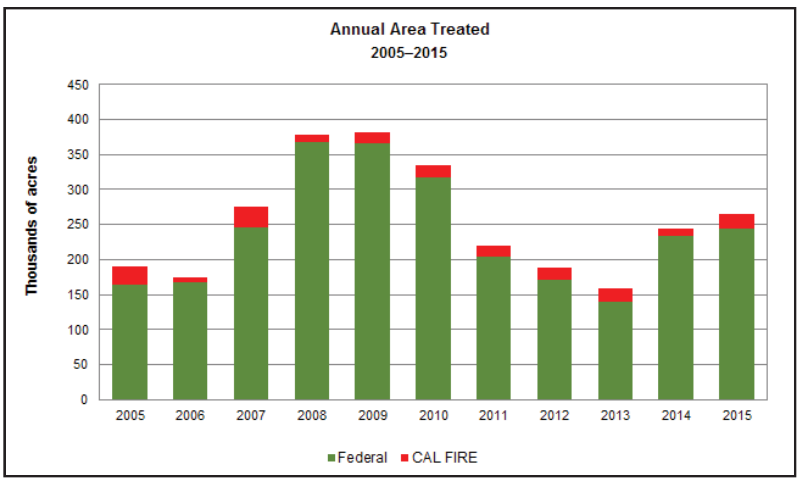
Why is the indicator important?

Due to past land management and fire policy, much of the landscape has not been subject to natural historic fire frequency (ⓘ4.1). This has led to an increase in Fire Threat (ⓘ4.2), posing a danger to important ecosystems and assets, including over 2.2 million housing units in the Wildland Urban Interface (ⓘ11.3).

Are there known targets or policy goals?

In 2016 CAL FIRE signed an inter-agency Memorandum of Understanding (MOU) in order to "increase the use of fire to meet ecological and other management objectives." Also that year, the Director produced a memo calling for 15,000 acres of non-fire fuel breaks and 20,000 acres of prescribed fire to occur within FY 2016-17.

What does the indicator show?



Key Findings:

- ⓘ The average annual area treated by federal and state agencies over the last 10 years is about 261,000 acres with a range from ~159,000 to ~381,000 acres.
- ⓘ Federal agencies have treated the most area annually by a large margin (93%).
- ⓘ CAL FIRE performed 15,755 acres of mechanical treatment and 13,941 acres of prescribed burn, meeting 105% and 70% of the targets set by the Director for FY 2016-17, respectively.
- ⓘ The average number of acres treated every year is small in comparison to fire protection and ecological needs, representing approximately 1.0% of the state's area in high-positive departure.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Federal Fuel Treatment Data	[76] Grupe, M. and Savage, J., 2017; [77] Griffith, R., 2017.	****
State Fuel Treatment Data	[78] Mediati, T., 2017.	****

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Chapter 5: Forest Pests

This chapter provides a synthesis of indicators, issues, and opportunities related to forest pests (limited in this chapter to insects and diseases). Invasive plants are covered separately in Chapter 1 (Sustainable Working Forests) and Chapter 2 (Sustainable Rangelands).

SUMMARY

Forest pests serve an important ecological function by killing weaker trees, thinning overstocked stands, and by creating special habitat elements and a food source for wildlife. They also can reduce timber growth and value, impact recreation value, and increase wildfire risk. Episodic widespread severe pest outbreaks are part of natural cycles. However, there is worldwide concern that the frequency, severity, and size of these outbreaks is increasing, and that climate change is increasing drought and heat stress and driving forest systems outside the range of normal cycles, in part due to an expansion of the geographic and seasonal range of some important pest species [1, 2]. Current levels of tree mortality in California, especially in the southern Sierra, add to these concerns (ⓘ5.1). Assessment indicators support trends of increasing stress on forests due to changing fire regimes (ⓘ4.1, ⓘ4.3, ⓘ4.4), changing seasonal water availability (ⓘ9.2, ⓘ9.3, ⓘ7.2), rising temperatures (ⓘ7.1), overstocked forest stand conditions (ⓘ1.2), and increasing numbers of exotic forest pest species (ⓘ5.2).

Current tree mortality levels have called into question forest and fire management policies. This chapter includes an analysis of historic data that supports the role of active timber management for reducing pest-induced tree mortality, also supported by Chapter 1 (Sustainable Working Forests) (ⓘ1.4). Active management to reduce tree mortality can also include restoring natural fire regimes [3]. High tree mortality levels are a threat to forest health, delivery of ecosystem services, and public safety, and are particularly unacceptable on lands managed primarily for wood products or adjacent to human infrastructure. However, on other lands some level of tree mortality may be acceptable or even desirable for improving wildlife habitat. In addition, there is evidence to suggest that by selectively thinning trees not suited for current climactic conditions, forest pests can assist in creating persistent stands that are adaptable to future conditions under changing climate [4]. The challenge for land managers is ensuring mortality does not create landscape-level conditions that support more widespread pest outbreaks or wildfires. This underscores the importance of landscape-level collaborative planning and project implementation efforts across ownerships.

This chapter provides a list of specific opportunities to reduce pest damage, which generally involve: early detection and containment (especially for exotic pests); policies and programs to limit pest spread; continued research to better understand pest species and how to manage for forest resiliency; support for active management to increase forest resilience and manage risk at the landscape level; and restoration of areas with severe damage to protect public safety, reduce fire risk, and restore healthy forests.

INDICATORS

ⓘ5.1 Tree Mortality

ⓘ5.2 Native and Exotic Pests

KEY FINDINGS

ⓘ5.1 Indicator: Area of Tree Mortality from Forest Pests and Drought

- Since 2002, annual detections of new forest tree mortality have ranged from just over 200,000 acres to over 4.1 million acres per year.

- Since 2002, severe mortality (at least 5 trees per acre) occurred on an average of 25% of all acres with detected tree mortality, and ranged between 16% of acres with detected mortality in 2008 to almost 60% in 2016.

- Of the total acres of detected mortality (2002–2016), 76% of the acres were federal forestlands and 22% were private.

- The percent of total acres detected with severe tree mortality (at least 5 trees per acre) by owner class (2002–2016) was similar for federal (34%), private (34%), and other (32%).

- The Sierra Cascades Bioregion accounted for 66% of detected mortality acres (2002–2016).

- Near-term data indicates a major recent increase in the severe mortality class acreage. Severe mortality is especially prevalent in the south Sierra since 2015.

ⓘ5.2 Indicator: Number of Native and Exotic Forest Pest Species Occurrences

- Occurrences of forest pest species, both native and exotic, has increased from 10 in 1955 to over 30 in recent years, or triple the number of species.

- The ratio of exotic to native pests has been increasing over time. Exotic pests were a minor component of occurrences in the 50's and 60's. The trend line shows they now comprise over one-third of occurrences. In 2007, half of pest species occurrences were exotic species.

- Native bark beetles and wood borers remain a high priority. There are elevated activity levels of fir engraver, western pine, mountain pine, Ips, and red turpentine beetles, flatheaded fir borer, and pine borers throughout the South Coast and Sierra bioregions, and other areas of the state.

- Non-native forest pests such as sudden oak death, pitch canker disease, goldspotted oak borer, and invasive shot hole borers/Fusarium complex are currently of major concern to California forest pest management agencies.

DISCUSSION

Drought-related Tree Mortality, 2012–2016

California experienced five years of drought from 2012–2016 [5] resulting in a massive tree die off in the southern Sierra Nevada. In 2012, there was an increase in western pine beetle, mountain pine beetle and fivespined Ips attacks in low to mid-elevation pine forests [7]. In 2013, oaks in the Sierra foothills dropped their leaves early, a natural defense to limit water loss during periods of water stress and extreme heat [8]. Gray pine mortality was also increasing in these same areas of the southern Sierra in 2013 and continuing in 2014, as well as in areas on the central coast and near Clear Lake. By March of 2015 tree mortality began to increase dramatically, first affecting ponderosa pine, then moving up slope affecting sugar pine, incense cedar and true firs. Drought stress allowed pests to kill trees that might otherwise have survived and resulted in a bark beetle epidemic that threatened to spread statewide. The area of mortality affected by drought, bark beetles and other damage-causing agents between 2010– 2016 is estimated at 7.7 million acres, with over 102 million dead trees (Table 5.1) [9]. New mortality was detected on over 4 million acres in 2016 alone (Figure 5.1) [10].

Table 5.1: Estimated Number of Dead Trees from Insects, Disease and Drought, 2010-2016

Time Period	Estimated Number of Dead Trees
2010	3.1 million
2011	1.6 million
2012	1.8 million
2013	1.3 million
2014	3.2 million
2015	29 million
2016	62 million
Total	102 million

Data Source: Tree Mortality Task Force, 2017; U.S. Forest Service Aerial Detection Surveys, 2010-2016.

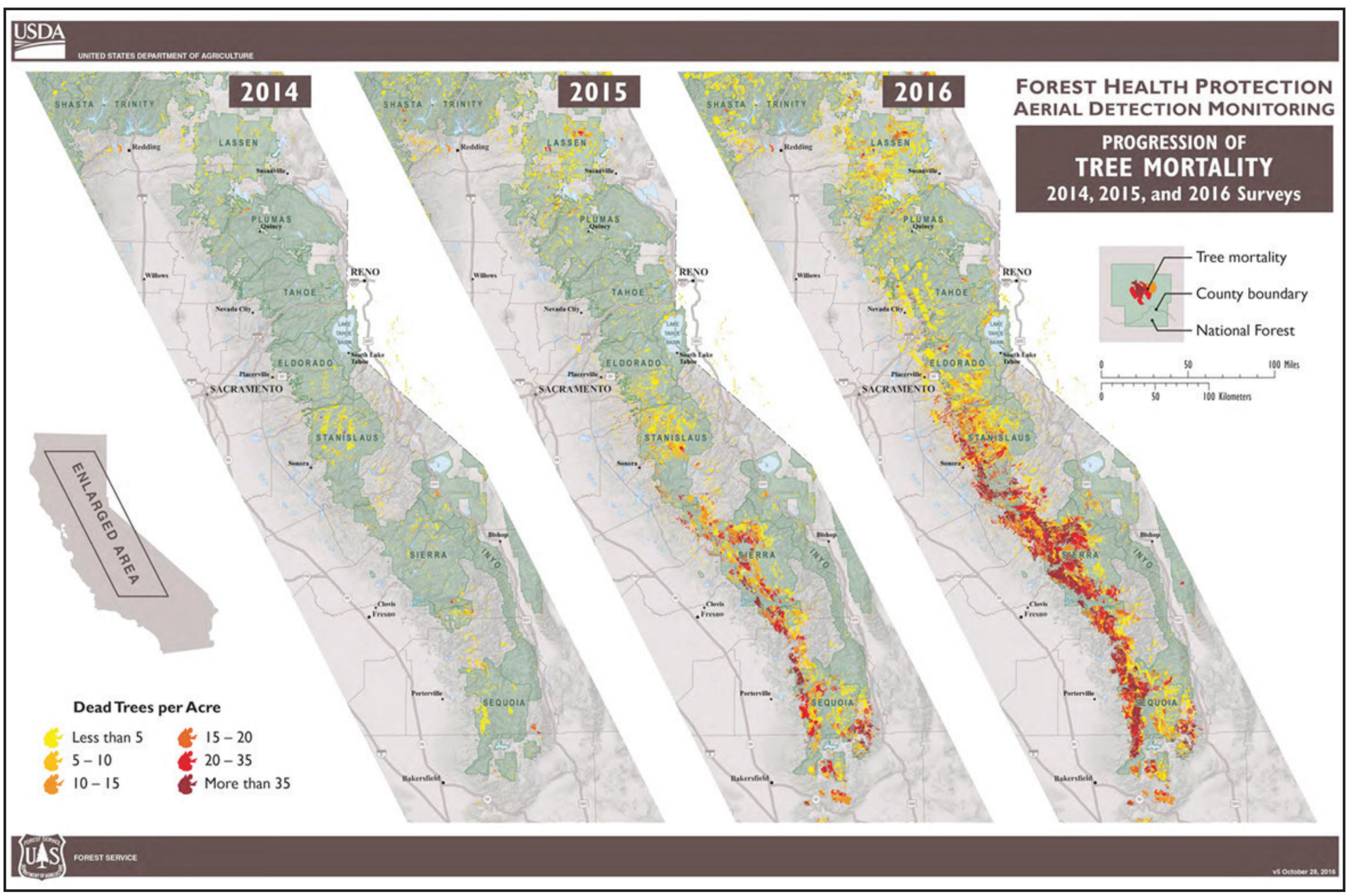


Figure 5.1: Progression of Tree Mortality, 2014-2016.

Data Source: [6] Moore, J., et al., 2016; U.S. Forest Service Aerial Detection Surveys, 2014-2016.

Response to Drought Mortality

An emergency proclamation by Governor Brown in 2015 [11] led to establishment of the California Tree Mortality Task Force (TMTF). Among other edicts, this proclamation "directs state agencies to designate certain areas of the state as High Hazard Zones due to dead and dying trees and the hazards this tree mortality presents." The TMTF identified High Hazard Zones (HHZs) for tree mortality expressed in a two-tier system to identify both direct threats to infrastructure from falling trees (Tier 1) and larger watershed-based zones (Tier 2) to address fire planning and forest health concerns. Since almost 75% of the dead trees were identified in just 10 counties, this led to the designation of 'High Priority Counties,' which became the focus of state and federal assistance coordinated by the TMTF.

Removal of dead trees to protect public safety became the primary focus of federal, state and local governments, particularly within Tier 1 HHZs. Disposal of biomass resulting from removal of dead trees has been a major logistical challenge, in part due to lack of accessible wood processing facilities, and low value of the material. Five of the directives in the Governor's 2015 Emergency Proclamation addressed challenges to increasing utilization of materials for bioenergy as a solution to the disposal problem. Without viable utilization options, much of the material will be burned in piles and in air curtain burners, which require federal permits to operate.

The pace and scale of emerging mortality in 2015–2016 challenged traditional monitoring systems to provide needed information. Additional Aerial Detection Surveys (ADS) were conducted to identify new public safety threats, but the large area affected prohibited rapid turnaround using ADS methods. Aerial detection is a reasonable strategy for detecting mortality in normal years. However, it is not designed or funded to capture key data elements that would be valuable for extreme mortality events. For example, information on biomass, wood volume and affected tree species would help identify options for disposal, utilization, and reforestation.

Current Zones of Infestation

CAL FIRE, with the approval of the California Board of Forestry and Fire Protection (BOF), has broad authority (PRC § 4716) to deal with large scale pest outbreaks through declaration of a Zone of Infestation for native and exotic forest pests. Within a declared Zone, CAL FIRE employees may go on private lands to attempt eradication or control in a manner approved by the BOF. At present, there are Zones of Infestation for bark beetles in the Lake Tahoe basin and the southern California mountains, sudden oak death and pitch canker along the coast, and goldspotted oak borer in parts of San Diego County which may soon be expanded (Figure 5.2). A Zone of Infestation was not declared in response to the widespread mortality that occurred in California since 2015, possibly because the large area and drought conditions required a larger response. Such a response emerged when Governor Brown made an Emergency Proclamation for the dead and dying trees and formed the California Tree Mortality Task Force.

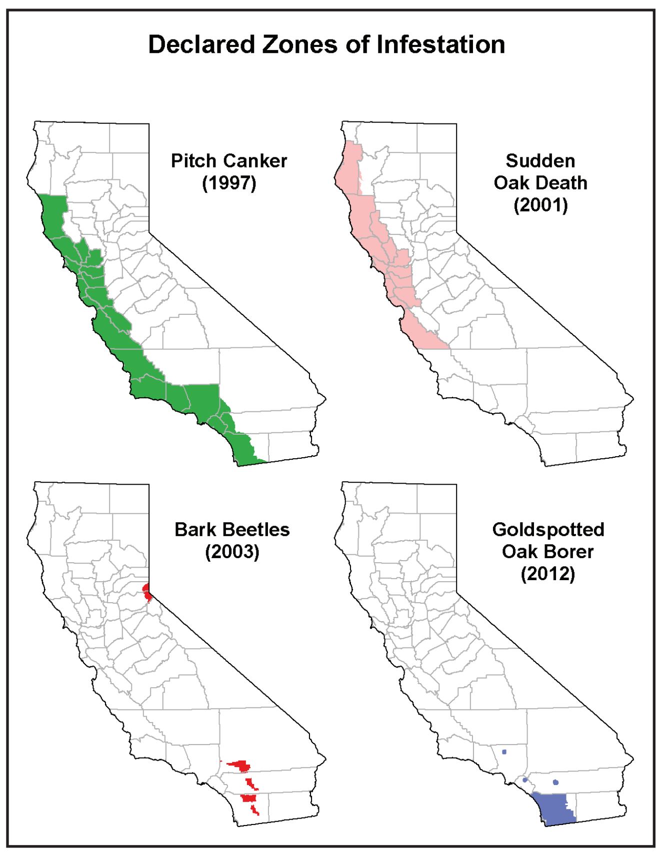


Figure 5.2: Declared Zones of Infestation in California.

Data Source: Zones of Infestation, CAL FIRE, 2017.

Native and Exotic Forest Pest Species Trends

California is home to many native and non-native bark beetles, wood borers, and diseases that impact forest productivity and health by causing defoliation, die back, top kill and in some cases tree death. These insects and diseases also serve important ecological functions such as nutrient cycling, creation of special habitat elements, the provision of a food source for wildlife, and removal of less healthy trees to reduce competition. There is evidence to suggest that through natural selection, forest insects and diseases may thin trees not suited for current climatic conditions [4]. In this way, forest pests can assist in creating persistent stands that are adaptable to future conditions under changing climate [4]. However, when insect populations reach epidemic levels they can even kill well-adapted healthy trees, and become a major threat to public safety, forest health, and delivery of important ecosystem services.

Movement of both native and exotic pests within the state, and from outside of California, remains a major concern. The unregulated movement of firewood through California, importation of wood products, transportation of nursery material, and movement of infested soil on vehicles and hiking boots can transfer forest pests.

Information on trends in the number of native and exotic pests that occur on forestland in California are needed to make decisions related to pest control policies and strategies, education programs, and research to advance our understanding of forest pests and related forest health issues. Figure 5.3 shows trends in native and exotic forest pest occurrence since 1955, based on California Forest Pest Council (CFPC) forest pest condition reports (ⓘ5.2) [12]. Exotic forest pests were a minor component of occurrences in the 50's and 60's,

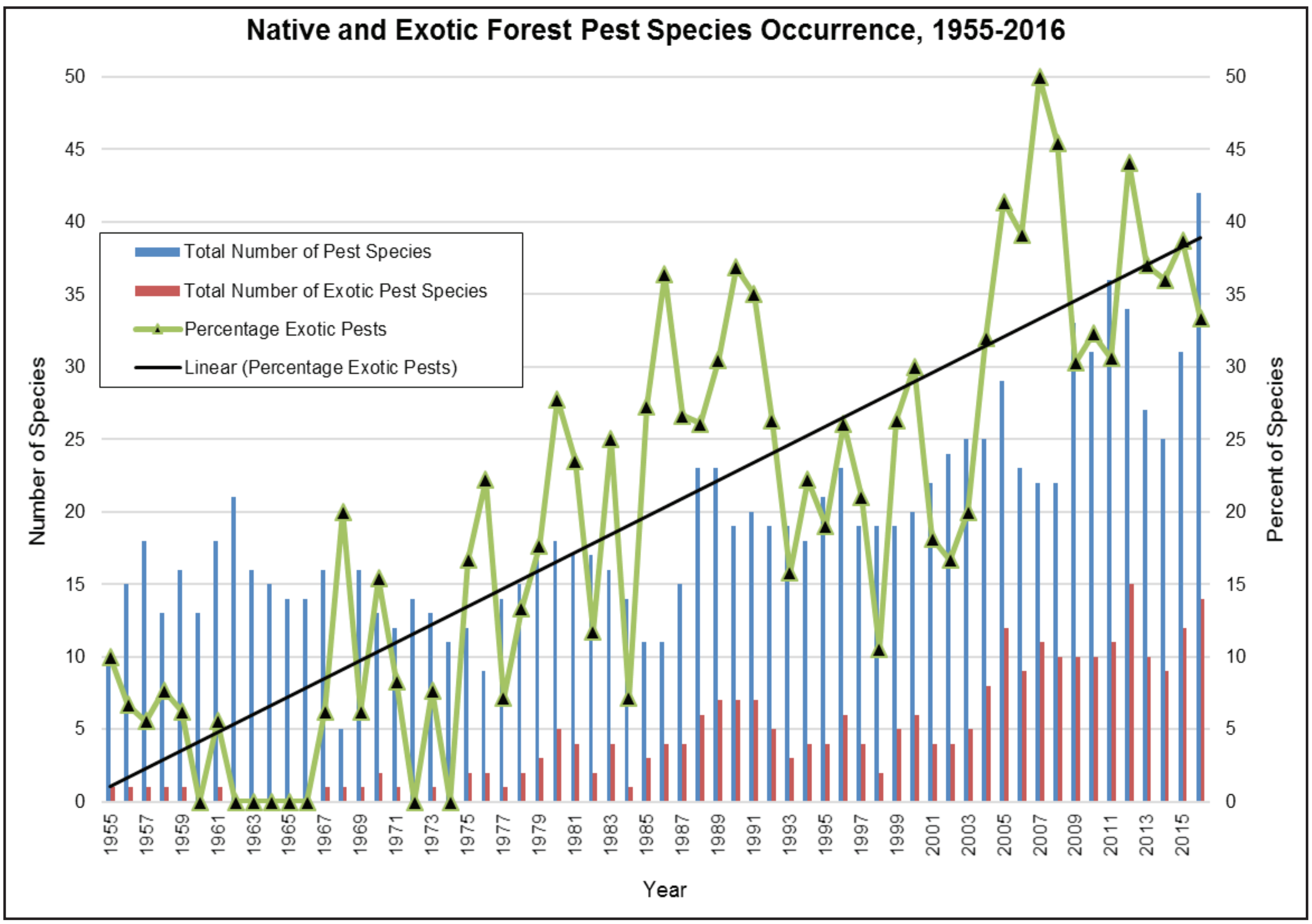


Figure 5.3: Native and Exotic Forest Pest Species Occurrence, 1955–2016.

Data Source: [12] Forest Pest Council, 1955–2016.

but the trend line shows they are steadily increasing. In 2007, half of pest occurrences in California were exotic species. While the recent tree mortality event demonstrates that the native pest species in California are fully capable of doing massive damage, introduction of additional species will likely increase future risk. Some exotic forest pests affect more than 100 host species and if left unchecked could have grave forest health, public safety and economic and environmental consequences.

Forest Pest Species of Concern

Native Forest Pests

Native bark beetles, wood borers, defoliators, fungi and diseases have affected millions of acres in California, negatively impacting forest health, commercial forests, and public safety and are a priority for state and federal regulators charged with protecting forest resources and the public. Native insects and diseases have undergone periodic outbreaks in California nearly every decade since 1955, often related to several years of drought [12]. Areas of attack tend to be in stands under extreme stress due to drought, other insects and diseases or overstocking. Alterations in forest stand structure and composition away from pine and towards younger true firs, in some areas, have increased the spread of forest pests [13]. Because the capacity to remove the material at a reasonable cost is low, due to historically low wood prices and the lack of sawmills in some areas, many infestations have been left untreated and have the potential to spread. Pinyon Ips engraver beetles have dramatically increased mortality in the pinyon pine regions of the state for the first time. The outbreak has been compounded by drought stress, root disease and pinyon leaf scale.

Native defoliator insects have been active throughout the state, but tend to be localized and have not occurred on a statewide basis. Periodic outbreaks have occurred of the Douglas-fir tussock moth, the fruit tree leaf roller, the California oak worm, fall webworms, tent caterpillars and the balsam or white fir sawfly. Douglas-fir tussock moth outbreaks recently occurred in the northern Sierra, defoliating true firs in conjunction with an outbreak of the white fir sawfly in the same area. Some outbreaks have been nearly continual, such as the increase in activity by the lodgepole needle miner in Yosemite National Park and the Modoc budworm in the Modoc region.

Exotic Forest Pests

Non-native (exotic) forest pests have killed millions of trees in California, causing significant commercial, aesthetic, economic and environmental impacts [6]. Unlike native pests, non-native insects and diseases have few natural enemies to help control outbreaks, and local host species often have not co-evolved built-in defenses to repel them. The growing number of non-native introductions of both insects and diseases remains a great concern to forest pest management agencies. Certain exotic pests may not have impacted large areas so far but have the potential to spread and may already have significant local impacts on forest ecosystems. The unregulated movement of firewood through California, importation of wood products, transportation of nursery material, and movement of infested soil on vehicles and hiking boots can transfer forest pests. Rapid recognition, quick control efforts and public education about the risks are key strategies to reduce the impacts from non-native forest pests.

Pitch canker disease, sudden oak death, white pine blister rust and Port-Orford-cedar root disease are examples of non-native diseases currently of major concern in California. The potential for spread and impact of the gypsy moth, the goldspotted oak borer and exotic bark beetles is also a major concern. The newest exotic pests

Tree mortality due to bark beetle and drought, Mariposa County looking east from Miami Lookout in 2016. Photo courtesy of US Forest Service.

include invasive shot hole borers/Fusarium complex, foamy bark canker of oaks and thousand canker disease of walnuts. Also, the state monitors for pests of concern that have yet to arrive in California, including European and Asian gypsy moth, Asian longhorn beetle, emerald ash borer and laurel wilt disease.

Sudden oak death (SOD) has killed millions of tanoak trees and hundreds of thousands of live oak trees throughout the Zone of Infestation (ZOI) along the coast of California. The pathogen that causes SOD can also infect the foliage and twigs of over 100 other species, which does not kill these species, but can lead to increased spread. Sudden oak death continues to slowly spread northward through previously uninfected stands within its potential host range. New spot infestations in the far northern part of the state show the potential for human-induced spread. In 2014, Trinity became the first new California county added to the federal quarantine area in over a decade, illustrating the continued spread of the disease. Many species are stressed by the disease, opening up the potential for attack by secondary pests and building up fuel loads for potential wildfires. Wildfires in areas impacted by sudden oak death have been more erratic and difficult to fight.

The goldspotted oak borer covers an area of about forty square miles in the interior of San Diego County and has killed over three-quarters of the mature black oak and coast live oak in the impacted areas. It has spread into Riverside, Orange, and Los Angeles counties, likely by people moving infested firewood.

Invasive shot hole borers/Fusarium complex (includes both the polyphagous and kuroshio shot hole borer) are thought to be natives to southeastern Asia and have been found in several southern California counties, killing numerous hardwood species. The complex has an extremely wide host range that also includes some woody commercial crop species. It has the potential to impact native and urban forests statewide and is a major concern to state regulators.

Several other non-native insects and diseases have been active in California forestlands:

- Bark beetles, such as the banded elm bark beetle, the Mediterranean pine engraver beetle and redhaired pine bark beetle, all have potential for spread and impact on California's native and urban forest landscapes.

- White pine blister rust is thought to be gradually moving south through the range of sugar pine and into higher elevation five needle pine species.

- Port-Orford-cedar root disease has largely filled in its potential range in California, making it an ongoing management challenge.

- Balsam woolly adelgid has been killing true firs in the north coast region of the state impacting the stand structure and wildfire fuel potential in the areas where it is found.

- Thousand canker disease is killing walnut species in some parts of the state. It is caused by the native walnut twig beetle that appears to have picked up a new species of fungus not previously recorded that causes small cankers in the trees that coalesce to girdle branches and trunks.

- Foamy bark canker is a new disease of oaks in a wide region of southern and central California. It is caused by a new species of fungus carried by the native western oak bark beetle and is impacting oak resources throughout its range.

A tabular listing of individual native and exotic forest pest species, including a "Significance Level" rating based on the number of acres affected by each pest is provided in Appendix 5.1.

Analysis of Tree Mortality Trends from Forest Pests and Drought, 2002–2016

Since 2002, annual detections of acres with new tree mortality from forest pests and drought have varied from just over 200,000 to over 4.1 million acres per year in 2016 (Figure 5.4) [12]. Severe mortality (at least 5 trees per acre) averaged 25% of all tree mortality detection acres over the period and ranged between 16%

of acres in 2008 to almost 60% in 2016. Conifer mortality accounts for about 94% of the mortality acres in the 15-year period, with hardwood mortality representing only 6%. Near-term data indicates a major recent increase in the severe mortality class acreage, especially in the southern Sierra, since 2015.

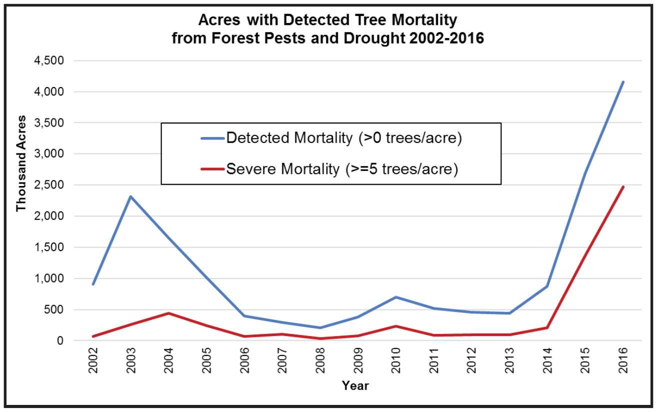


Figure 5.4: Acres with Detected Tree Mortality from Forest Pests and Drought, 2002–2016.

Data Source: [10] USDA Forest Service Aerial Detection Survey Program, 2002-2016.

Mortality by Ownership Class

Of the total acres of detected mortality (2002–2016), 78% of the acres were public forestlands (Table 5.2), even though only 61% of forestland in California is in public ownership. Private forestland owners accounted for 22% of the mortality acres detected, with almost 39% of forestland privately owned. These same proportions are true for severe mortality, because for both owners about one-third of detected mortality was severe.

Mortality by Management Emphasis Class

Productive forestlands (capable of commercial timber production) are managed for a variety of objectives. Federal lands include lands managed for multiple uses that include timber harvest, as well as reserved lands that are off limits for timber harvest. Private lands include forest industry lands managed for high timber emphasis, and nonindustrial lands managed by diverse owners with unique objectives that often do not emphasize timber production. To better understand the relationship between the level of active timber management and mortality levels, we analyzed acres of detected mortality by management emphasis class (Table 5.3) (see Chapter 1 Sustainable Working Forests for detailed class descriptions).

Productive forests managed most actively for timber ("High" class) are typically forest industry lands. This represents 17% of productive forestland, but only 9% of detected mortality acres and 6% of detected severe mortality acres. This strongly suggests that this management

**Table 5.2: Acres with Detected Mortality from Forest Pests and Drought
Percent of Detected Acres, by Owner Class, 2002–2016**

Owner Class	% of Total Forestland	All Mortality		Severe Mortality	
		Million Acres	Percent	Million Acres	Percent
Public	61%	13.2	78%	4.5	78%
Private	39%	3.8	22%	1.3	22%

Data Source: [10] USDA Forest Service Aerial Detection Survey Program, 2002-2016.

**Table 5.3: Acres with Detected Mortality from Forest Pests and Drought
Percent of Detected Acres, by Timber Management Emphasis Class, 2002–2016[1]**

Timber Management Emphasis Class	% of Productive Forestland	All Mortality		Severe Mortality	
		Million Acres	Percent	Million Acres	Percent
High	17%	1.6	9%	0.4	6%
Medium	36%	7.0	41%	2.1	36%
Low	19%	1.3	8%	0.5	9%
None	28%	7.1	42%	2.9	49%

Data Note 1: Includes all public and private forestlands.

Data Source: Management Landscape, FRAP, v15_1.

emphasis class incurs lower mortality and/or is more active in treating/utilizing dead trees.

Productive forests in the “None” class are either reserved lands (wilderness, parks, etc.) or in areas of the state where there is no active timber management due to lack of wood processing infrastructure (e.g. southern California). While these lands represent 28% of the productive forests, they account for 42% of detected mortality acres and 49% of severe mortality acres. Given that these lands primarily provide important ecosystem services such as wildlife habitat, water quality, carbon sequestration, and recreation opportunities, elevated mortality may be acceptable if it does not lead to conditions that support more widespread severe pest or wildfire events.

A surprising result is the relatively low mortality rates observed in the “Low” class, primarily small nonindustrial owners. While owners in this class typically do not actively manage for commercial timber, they may conduct other management actions that limit mortality, or remove dead trees, to meet their unique management objectives.

The “Medium” class includes public productive forestlands managed for multiple uses including timber harvest, and private owners in voluntary programs that result in modified management (Nonindustrial Timber Management Plans, “improved forest management” projects approved by the Air Resources Board carbon offset program, etc.). Mortality on these lands is similar to what would be expected given their relative proportion of productive forests.

Mortality by CAL FIRE Ecoregion

When viewed by CAL FIRE ecoregion (Table 5.4) [10], 66% (11.3 million acres) of acres with detected mortality, and 75% of severe mortality between 2002–2016 were in the Sierra/Cascades. This reflects the impact of the recent drought-related mortality event in the southern Sierra.

Risk of Future Forest Pest Outbreaks

Tree mortality driven by drought and heat often with associated insect outbreaks has been observed globally [1]. Numerous studies correlate tree mortality from insects and disease with increases in water and heat stress, as well as biotic factors such as stand structure and the presence of other stressors such as mistletoe and/or root diseases [1, 2, 14]. Forest pest mortality in the western U.S. is thought to be influenced by forest stand conditions, annual precipitation, and temperature, among other factors. Negron and McMillin [14] found that ponderosa pine mortality caused by bark beetles was positively correlated with tree density and was negatively correlated with elevation and tree diameter, while Fettig et. al. [15] documented the effectiveness of thinning to reduce mortality.

The USDA Forest Health Assessment and Applied Sciences Team (FHAAST) develops periodic nationwide

Table 5.4: Acres with Detected Mortality from Forest Pests and Drought Percent of Detected Acres, by CAL FIRE Ecoregion, 2002–2016[1]

CAL FIRE Ecoregion	Percent of Total Forestland	All Mortality		Severe Mortality	
		Million Acres	Percent	Million Acres	Percent
Central Coast/Interior Ranges	8%	0.4	2%	0.1	2%
Central Valley	1%	<0.1	<1%	<0.1	<1%
Desert	1%	<0.1	<1%	<0.1	<1%
Eastside	7%	2.1	13%	0.5	9%
Klamath/Interior Coast Ranges	26%	1.9	11%	0.4	7%
North Coast	9%	0.4	2%	0.2	3%
Sierra/Cascades	44%	11.3	66%	4.4	75%
South Coast and Mountains	5%	0.9	6%	0.2	4%

Data Note 1: Includes all public and private forestlands.

Data Source: [10] USDA Forest Service Aerial Detection Survey Program, 2002-2016.

forest risk assessments, including a National Insect and Disease Risk Map (NIDRM) [16]. Their report provides a strategic assessment of hazard of mortality due to insects and disease based on ranked and weighted criteria of susceptibility (potential for a pest to become established) and vulnerability (potential for mortality if the pest becomes established) for each tree host/pest combination. NIDRM seeks to identify areas at risk of higher than average background rates of mortality.

Stands that are expected to experience 25% or greater mortality over the 15-year period from 2012–2027 are considered at risk. Mortality is measured in terms of percent basal area (BA) lost, which for many pests results in loss of the oldest and largest trees. Although the modeling and report were conducted before the recent increases in forest pest-related tree mortality in California, the USDA Forest Service 2013–2027 National Insect and Disease Forest Risk Assessment identifies approximately 12% of California's "Treed Area" as at risk (Figure 5.5) [16]. In at-risk areas where stand structure is a major contributing factor, treatments may be warranted to reduce risk. The lack of information on effects of climate change on future forest pest risks is a notable weakness of the current National Insect and Disease Risk Map.

Greenhouse gas emissions are thought to be altering climates globally, potentially increasing the frequency and severity of drought and heat stress on trees and leading to increased insect outbreaks [1]. Climate change is expected to alter tree mortality rates through changes in timing and amount of precipitation, changes in temperature, changing fire regimes and increases in pest attacks. The Sustainable Working Forests chapter (Chapter 1) presents information from climate change scenarios in California that suggest hotter/drier or warmer/wetter areas of the state by the year 2069. Both scenarios highlight potential loss of timberland in the southern Sierra Nevada and in low elevation foothill areas. Such changes could also lead to increased tree stress and subsequent increases in native and exotic forest pest occurrences and tree mortality in many of these same areas.

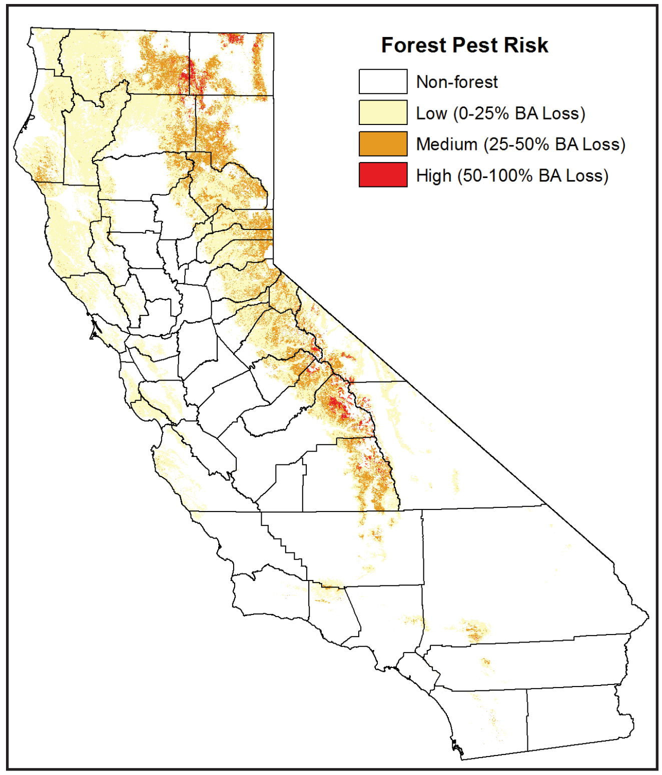


Figure 5.5: Forest Pest Risk Based on Predicted Basal Area Loss, 2012–2027.

Data Source: [14] Krist, F.J.J., et al., 2014.

Opportunities

Opportunities to address current and future pest threats can be grouped into five main categories.

Early Detection and Containment

Rapid recognition, quick control efforts and public education about the risks of forest pests are key strategies to reduce impacts, particularly from non-native forest pests. The California Department of Food and Agriculture maintains 16 agricultural inspection stations as a first line of defense from exotic forest pests. Inspectors at border stations intercept plant material potentially carrying exotic forest pests and prevent it from entering the state. Monitoring and intercepts are also conducted by the Department of Homeland Security at ports and airports, and the Agricultural Commissioner for each county, who use trained biologists to monitor pest conditions in agricultural areas to prevent the spread of injurious pests and diseases into forestlands.

Detection and containment of forest pests in California is also the responsibility of forest pest specialists at CAL FIRE, USDA Forest Service and the California Department of Food and Agriculture. Agency staff provide pest conditions and detections reports and have access to a Forest Pest Observation Database Application (FPODA), which serves as a primary repository for pest observations. The USDA Forest Service Forest Health Protection staff conduct aerial as well as ground surveys for forest pest mortality and damage in California annually. These surveys help monitor forest pest outbreaks, providing early warning if conditions are severe, thus allowing forestland managers and policy makers to respond to emerging outbreaks appropriately. Additional monitoring efforts are conducted by CAL FIRE pest management staff, and other pest professionals.

Coordination is also facilitated by the non-profit California Forest Pest Council, which is open to the public, but primarily made up of state and federal agencies, University of California faculty and cooperative extension staff, and private foresters. Their goals include coordinating the detection, reporting and compilation of pest injury; evaluating forest pest conditions; making recommendations on pest control to forest managers; reviewing policy and legal frameworks for pest management; and fostering education on forest pests and forest health.

Limiting Spread

Limiting the spread of pests requires different efforts at different scales. Education programs can be used to reduce human-caused spread. Regulations can be important to reduce common spread mechanisms, for example in the movement of firewood. Maintaining healthy and resilient forests (discussed below and under Active Forest Management) can also reduce spread.

At the stand level, removal of disease-infected or insect-infested trees in areas damaged by forest pests can protect forest health and public safety as well as help prevent the spread of pests to new areas [17]. In California, non-federal forestlands are governed by the Board of Forestry and Fire Protection (BOF) and the California Forest Practice Rules (FPR) [18]. Regulations governing forest pest management can be found in Sections 4712–4718 of the Public Resources Code (PRC) of California and are also addressed by Technical Addendum #3 to the FPR. These sections declare that "bark beetles, other insect pests or plant diseases which are harmful, detrimental and injurious to timber or forest growth are a public nuisance" [18]. In addition to treatment of slash in a timely fashion, FPR allow or in some extreme cases can require emergency harvesting of infected, infested or damaged timber and sanitation removal of insect or disease attacked trees to maintain or improve the health of a stand. Salvage removal of trees killed by pests or other causes is allowed and all timber operations are to be conducted in a manner that minimizes the build-up of destructive insect populations and the spread of forest diseases.

Beetle infestation on pine tree.

California Public Resources Code 4714 states that "Every owner of timber or timberlands shall control or eradicate such insect pests or plant diseases on lands owned by him or under his control." If he does not do so, the work may be performed as provided in Article 5 of the FPR. CAL FIRE, with the approval of the California Board of Forestry and Fire Protection (BOF) can declare a Zone of Infestation (ZOI) for native and exotic insect and disease pests [PRC 4712–4718]. Within a Zone of Infestation, CAL FIRE employees may go on private lands to attempt eradication or control in a manner approved by the BOF. During such actions, CAL FIRE may make surveys and appraisals to obtain information on infestations and infections, and/or remove live vegetation directly adjacent to dead or dying vegetation that is substantially at risk. Where timber harvest operations are planned in areas which the BOF has declared a Zone of Infestation, the registered professional forester must identify mitigation measures to be taken that reduce the adverse impacts from the timber operation on the potential build-up of insect and disease populations.

Research

Continued research has a critical role to better understand individual pest species and how timber and fire management policies and practices affect forest resiliency. Research is also needed to develop more effective reforestation efforts after major mortality events. The impact of climate change on individual pest species and the resilience of different forest ecosystems represents an entire new area of important research needed to better manage under future conditions.

Active Forest Management

Overstocked forests are an issue in California (ⓘ1.2), resulting in increased competition for scarce resources and elevated susceptibility to forest pests, particularly under drought conditions. For many forest insects and diseases, maintenance of the health of trees and stands through silvics is the best method for control [17]. Results from this chapter and research [17, 19, 20] support the role of active timber and pre-fire management for reducing mortality. Reforestation of harvested areas using tree seed adapted to local conditions reduces susceptibility of planted trees [17] and is required by the FPR [18]. However, the scale of needed forest treatments on public lands exceeds the resources of most agencies. Smaller private landowners may lack the resources to perform treatments without assistance from programs described in Chapter 1 (Sustainable Working Forests). Ability to recover a portion of costs can be compounded by lack of wood processing facilities in some areas, coupled with low wood prices. As a result, overstocked forests or spot infestations often go untreated. Expanded wood processing infrastructure, as well as development of new products, especially those that can utilize source materials from thinning of overstocked or pest-damaged stands, could be beneficial for facilitating additional treatments. Collaborative landscape-level planning and project implementation efforts described in Chapter 1 (Sustainable Working Forests) could be critical for efficient utilization of public budgets and private investments for creating resilient landscapes.

Restoring Forest Health and Public Safety

For areas of severe damage, restoration efforts are needed to protect public safety, reduce fire risk, and restore healthy forests. The need for broad scale reforestation efforts emerged twice in California over the last 15 years, including in southern California (2002–2006) and currently in the southern Sierra Nevada (2015–2017).

Photo courtesy of: US Forest Service, Region 5.

Southern California

Consecutive years of below average precipitation from 1998–2003 combined with overstocked forest conditions [9] resulted in a large-scale insect outbreak between 2001–2004 in conifer and hardwood forests of the southern California mountains. The areas most impacted were the San Bernardino, San Jacinto, Palomar and Cuyamaca/Laguna mountain ranges. The major impacted species included fir, pine, hardwood, pinyon pine, western juniper and subalpine mixed conifer types [21]. The dead trees presented numerous challenges to nearby residents and government agencies. The risks from fire and falling trees made hazard tree removal a top priority during this event, leading to the successful removal of thousands of dead and dying trees in and around wildland urban interface areas.

Southern Sierra Nevada

Severe drought conditions since 2012 led to the death of millions of pine, fir and hardwood trees in the southern Sierra Nevada that threaten structures, powerlines, roadways and other critical infrastructure. With such severe and widespread tree mortality, protection of public safety and forest restoration are once again major concerns. The Governor's emergency proclamation created the California Tree Mortality Task Force and its working groups, including the Forest Health and Resilience Working Group (FHRWG). The main objective of the FHRWG is to develop a strategy to reforest areas deforested by bark beetles, particularly in the counties identified by the TMTF as most impacted. Key parts of the strategy include identifying the seed zones and genotypes with the highest rates of mortality and coordinating seed collection and sowing orders to ensure appropriate seedling sources are available for reforestation on both private and public lands. While funding is a major challenge for all stakeholders, coordination across the multiple public and private landowners needing assistance is also difficult. Incorporating climate change science into reforestation strategies poses a significant challenge and will likely carry a high degree of uncertainty.

Indicator: Area of Tree Mortality from Forest Pests and Drought ⓘ5.1

Which Montreal Protocol Criteria does the indicator evaluate?

MPC2: Maintenance of productive capacity of forest ecosystems

MPC3: Maintenance of forest ecosystem health and vitality

MPC5: Maintenance of forest contribution to global carbon cycles

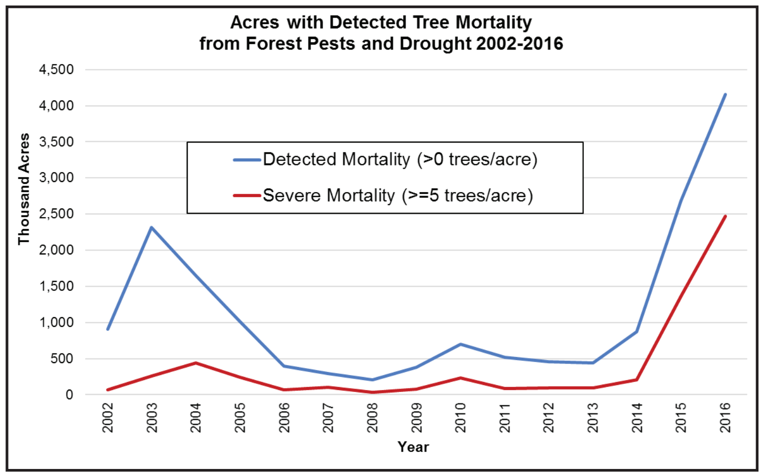
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

Tree mortality caused by forest pests impacts ecosystem health, public safety, timber value, water quality, and wildfire potential. Mapping and analyzing mortality incidence can assist us in developing strategies for maintaining resilient forests.

What does the indicator show?

Aerial Detection Survey (ADS) data is captured from aerial sketching of polygons and attribution of causes, and provides a reasonable if somewhat coarse mapping of new annual mortality.



Key Findings:

ⓘ Since 2002, annual detections of new forest tree mortality have ranged from just over 200,000 acres to over 4.1 million acres per year.

ⓘ Since 2002, severe mortality (at least 5 trees per acre) occurred on an average of 25% of all acres with detected tree mortality, and ranged between 16% of acres with detected mortality in 2008 to almost 60% in 2016.

ⓘ Of the total acres of detected mortality (2002–2016), 76% of the acres were federal forestlands and 22% were private.

ⓘ The percent of total acres detected with severe tree mortality (at least 5 trees per acre) by owner class (2002–2016) was similar for federal (34%), private (34%), and other (32%).

ⓘ The Sierra Cascades Bioregion accounted for 66% of detected mortality acres (2002–2016).

ⓘ Near-term data indicates a major recent increase in the severe mortality class acreage. Severe mortality is especially prevalent in the southern Sierra since 2015.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Tree Mortality	[10] USFS Aerial Detection Surveys, 2002-2016.	***

Indicator: Number of Native and Exotic Forest Pest Species Occurrences

ⓘ5.2

Which Montreal Protocol Criteria does the indicator evaluate?

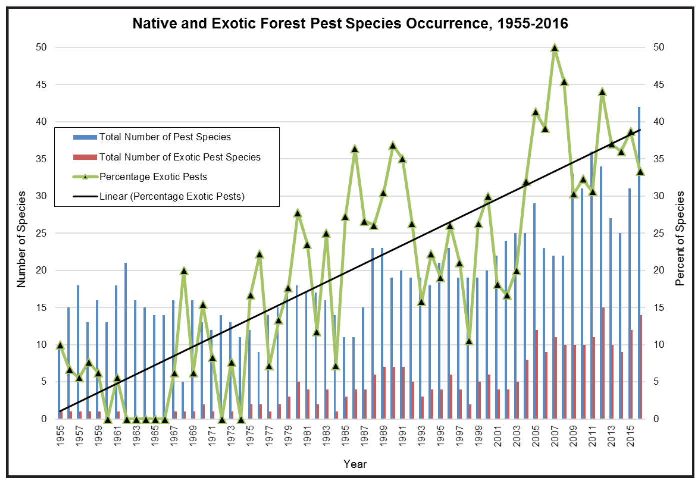
MPC2: Maintenance of productive capacity of forest ecosystems
MPC3: Maintenance of forest ecosystem health and vitality
MPC5: Maintenance of forest contribution to global carbon cycles
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

Trends in the number of native and exotic pest species that occur on forestland in California are helpful in determining priorities for future forest pest management activities. Damage and mortality caused by forest pests have had significant impacts on ecosystem health, public safety, timber value, water quality, and wildfire potential. Forest pests are addressed by Forest Practice Rules including PRC 4712-4718, Title 14, CCR, subchapter 4, 5, & 6 Article 7 and TRA #3.

What does the indicator show?

California Forest Pest Conditions reports document occurrences of active forest insects, diseases and animal damage on an annual basis in California since 1955. Pest detections are reported by federal and state forest health professionals. The data do not distinguish the degree of actual and potential impact associated with a detection.



Key Findings:

- ⓘ Occurrences of forest pest species, both native and exotic, has increased from 10 in 1955 to over 30 in recent years, or triple the number of species.
- ⓘ The ratio of exotic to native pests has been increasing over time. Exotic pests were a minor component of occurrences in the 50's and 60's. The trend line shows they now comprise over one-third of occurrences. In 2007, half of pest species occurrences were exotic species.
- ⓘ Native bark beetles and wood borers remain a high priority. There are elevated activity levels of fir engraver, western pine, mountain pine, Ips, and red turpentine beetles, flatheaded fir borer, and pine borers throughout the South Coast and Sierra bioregions, and other areas of the state.
- ⓘ Non-native forest pests such as sudden oak death, pitch canker disease, goldspotted oak borer, and invasive shot hole borers/Fusarium complex are currently of major concern to California forest pest management agencies.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Forest Pest Conditions	[12] Forest Pest Conditions Report: 1955 – 2013.	***

Appendix 5.1

Utilizing data from the USDA Forest Service Aerial Detection Survey program [10] and annual Forest Pest Condition reports [12], it is possible to assign each forest pest a "Significance Level" rating based on the number of acres affected by each pest or, in some cases, the level of potential damage, as expressed by experts. In general, forest pests that cause less than 10,000 acres of damage or mortality are ranked low, those causing between 10,000 and 100,000 acres of damage are ranked moderate and those that have impacted more than 100,000 acres in the last 15 years are ranked high. Tables 5.5 and 5.6 provide a list of major forest insects and diseases identified by the USDA Forest Service Aerial Detection Survey program in California since 2002, including the Significance Level rating for each pest.

Table 5.5: California Forest Diseases and Significance (2002–2016)

Damage Agent	Scientific Name	Major Damage	Significance Level	Tree Host
NATIVE DISEASES				
Annosus root disease	Heterobasidion annosum	Mortality	Low	Conifers
Anthracnose	Gnomonia spp.	Discoloration	High	Hardwood
Armillaria root disease	Armillaria spp.	Mortality	Low	Multiple
Aspen trunk rot	Phellinus tremulae	Mortality	Low	Aspen
Black stain root disease	Ophiostoma wageneri	Mortality	Low	Conifers
Canker rot of oak	Various	Branch Flagging	Low	Oak
Comandra blister rust	Cronartium comandrae	Branch Flagging	Low	Conifer
Cytospora canker of aspen	Cytospora chrysosperma	Dieback	Low	Aspen
Cytospora canker of fir	Cytospora abietis	Branch Flagging	High	Fir
Diplodia blight	Sphaeropsis sapinea	Branch Flagging	Low	Conifer
Dothistroma needle blight	Mycosphaerella pini	Defoliation	Low	Pine
Elytroderma disease	Elytroderma deformans	Discoloration	Low	Pine
Foliage diseases	Various	Mortality	Low	Various
Lophodermella needle cast	Lophodermella spp.	Defoliation	Low	Pine
Marssonina blight	Marssonina populi	Defoliation	Low	Hardwood
Needlecast	Various	Defoliation	Low	Pine
Root/Butt Diseases	Various	Mortality	Low	Various
Sycamore anthracnose	Apiognomonia veneta	Defoliation	Low	Sycamore
True mistletoe (other)	Phoradendron spp.	Dieback	Low	Hardwood
Western dwarf mistletoe	Arceuthobium campylopodum	Mortality	Low	Pine
Western gall rust	Peridermium harknessii	Branch Flagging	Low	Pine
EXOTIC DISEASES				
Pitch canker	Fusarium subglutinans	Mortality / Branch Flagging	Moderate	Pine
Port-Orford-Cedar root disease	Phytophthora lateralis	Mortality	Low	Cedar
Sudden oak death	Phytophthora ramorum	Mortality	High	Oak / Various
White pine blister rust	Cronartium ribicola	Mortality / Branch Flagging	Low	Pine

Data Source: [12] Forest Pest Council, 1955-2016.

Table 5.6: California Forest Insects and Significance (2002–2016)				
Damage Agent	**Scientific Name**	**Major Damage**	**Significance Level**	**Tree Host**
NATIVE INSECTS				
Alder flea beetle	Altica ambiens	Defoliation	Low	Alder
Balsam fir sawfly	Neodiprion abietis	Defoliation	Moderate	Fir
Bark Beetles	Various	Mortality	High	Pine
Boring Insects	Various	Dieback	Moderate	Various
California fivespined ips	Ips paraconfusus	Mortality	Moderate	Pine
California flathead borer	Melanophila californica	Mortality	High	Conifer
California oakworm	Phryganidia californica	Defoliation	Moderate	Oak
Cedar bark beetles	Phloeosinus spp.	Mortality	Low	Incense Cedar
Douglas-fir beetle	Dendroctonus pseudotsugae	Mortality	Moderate	Fir
Douglas-fir engraver	Scolytus unispinosus	Topkill	Low	Fir
Douglas-fir tussock moth	Orgyia pseudotsugata	Defoliation	Moderate	Fir
Fall webworm	Hyphantria cunea	Defoliation	Low	Multiple
Fir engraver	Scolytus ventralis	Mortality	High	Fir
Flatheaded fir borer	Melanophila drummondi	Mortality	High	Fir
Forest tent caterpillar	Malacosoma disstria	Defoliation	Low	Hardwood
Fruit tree leafroller	Archips argyrospila	Defoliation	Low	Multiple
Ips engraver beetles	Ips spp.	Mortality	Moderate	Pine
Jeffery pine beetle	Dendroctonus jeffreyi	Mortality	High	Jeffrey Pine
Lodgepole needleminer	Coleotechnites milleri	Defoliation / Mortality	High	Pine
Modoc budworm	Choristoneura retiniana	Topkill	Low	Fir
Mountain pine beetle	Dendroctonus ponderosae	Mortality	High	Pine
Multi-Damage (Insect/Disease)	Various	Mortality	High	Various
Needleminer	Various	Discoloration	Low	Pine
Pine engraver	Ips pini	Mortality	Low	Pine
Pine needle sheathminer	Zelleria haimbachi	Defoliation	Low	Pine
Pinon ips	Ips confusus	Mortality	High	Pinon Pine
Pinon sawfly	Neodiprion edulicolus	Discoloration	Moderate	Pinon Pine
Pinyon needle scale	Matsucoccus acalyptus	Defoliation	Moderate	Pinon Pine
Red turpentine beetle	Dendroctonus valens	Mortality	Low	Conifer
Scale insect	Various	Defoliation	Low	Multiple
Spruce aphid	Elatobium abietinum	Discoloration	Low	Spruce
Twig beetles	Pityophthorus spp.	Mortality / Branch Flagging	Low	Pine
Western cedar bark beetle	Phloeosinus punctatus	Mortality	Low	Incense Cedar
Western pine beetle	Dendroctonus brevicomis	Mortality	High	Pine
EXOTIC INSECTS				
Goldspotted oak borer	Agrilius auroguttatus	Mortality	High	Oak
Kuroshio shot hole borer	Euwallacea spp.	Mortality	High	Multiple
Polyphagus Shot Hole Borer	Euwallacea spp.	Mortality	High	Multiple
Satin moth	Leucoma salicis	Defoliation	Low	Hardwood
Willow leafblotch miner	Lithocolletis spp.	Defoliation	Low	Hardwood

Data Source: [12] Forest Pest Council, 1955-2016.

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Chapter 6: Population Growth and Development Impacts

This chapter provides a synthesis of indicators, issues, and opportunities related to population growth and development impacts.

SUMMARY

With 39.5 million current residents, California's population has been growing at just under 1% annually on average since the year 2000. This annual rate of growth is projected to continue or decrease slightly over the next few decades (ⓘ6.1). Approximately 354,000 new residents are anticipated in California yearly [2, 3].

Urban lands currently comprise 5.3 million acres, or about 5% of the total area of the state [4]. Nearly 85% of urbanized land was converted from what was originally rangeland (although most had first been converted to intensive agriculture prior to urbanization). Population growth leads to increases in housing density and urbanized area, with new residential developments arising because of: 1) densification of existing housing in urbanized areas (in-fill) and urban housing redevelopment projects; 2) development of land currently under cultivation; and 3) development of forest or range characterized as open space (primarily near existing urban areas). While all three processes are at work in the state, only the last is addressed in this chapter.

For decades, there have been efforts to reduce the kind of development called "urban sprawl" in the state's agricultural, forest and rangeland. Agricultural lands under California Land Conservation Act (Williamson Act, or WA) contracts offer lower property tax assessments in return for an annually renewed 10-year agreement not to subdivide or develop. About 9.4 million acres of forest and rangeland (excluding croplands) were under WA contracts in 2015 (ⓘ6.2). That is down from about 10.5 million acres enrolled in 2005. It should be noted that in some counties, reporting of acreage under WA contracts has been sporadic since 2008.

More recently, forest and range landowners have been selling conservation easements (which restrict development) on their holdings [5]. Some owners have sold or donated land title directly to conservation organizations and resource conservation districts. Since the early 1990s, rangeland acreage in these categories has increased from under 400,000 to more than 1.4 million acres statewide (ⓘ6.3).

Overall, the 37 California counties designated as "metro" by the federal Census Bureau and the Office of Management and Budget (i.e. those with urban centers of 50,000 or more population) [6] account for almost 98% of the state's residents. This makes California the most urbanized state in the Union [7]. Nearly all population growth in the past ten years has occurred in these metro counties, and particularly around major urban centers such as the Bay Area, greater Sacramento area, and southern California. Consequently, forest and

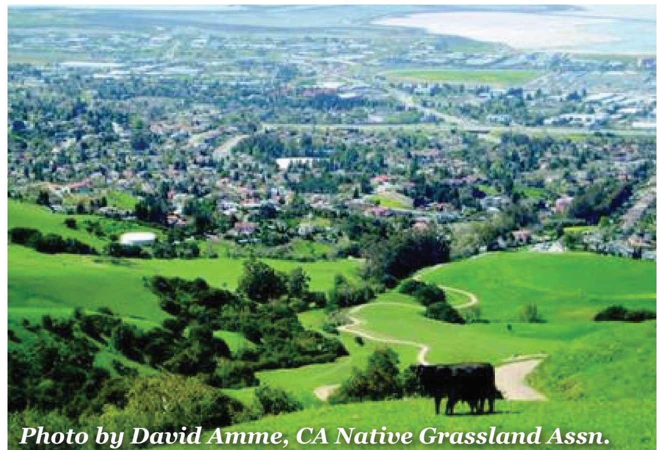


Photo by David Amme, CA Native Grassland Assn.

INDICATORS

ⓘ6.1 Population trends

ⓘ6.2 Rangeland under Williamson Act

ⓘ6.3 Protected Private Wildlands

rangelands most at-risk of development in California are in these regions.

Metro counties account for about 72% (13.5 million acres) of private rangelands and 33% (2.9 million acres) of all private forestlands (including industrial timberlands) statewide. Historically, private rangelands have been much more prone to development than private forestland, due to their desirable climate, lower elevations and access.

Since joining the Union in 1850, about 98,000 acres of California forest and rangeland per year on average has been converted to agriculture, housing development and other uses. However, most acreage conversions, such as reclamation projects in the Central Valley for intensive agriculture, occurred during the first century of American statehood (1850–1950).

More recent rates have been much lower than the long term historical average, with permanent forest and rangeland conversion to development estimated at around 25,000 acres per year. Statewide annual rates of forestland conversions *per se* are quite low - on the order of a few hundred acres per year. These are concentrated mainly in a few developed areas in forested lands (such as the I-80 and highway 50 corridors, greater Lake Tahoe, and mountainous areas of southern California around Lake Arrowhead and Big Bear).

To gauge the potential impact of population growth on the development of forest and rangelands we used California Department of Finance projections and other data to parameterize the U.S. Environmental Protection Agency's Spatially Explicit Regional Growth housing allocation model (SERGoM v3), and estimated the amount of acreage that would be parcelized into housing densities greater than or equal to 1 unit per 20 acres by the years 2040 and 2060. The result: nearly all such future development (excluding that on cropland) is projected to occur on rangeland (84%), with much less development on forestland (16%). Due to low amounts of available land, by 2060 the Bay Area and San Joaquin Valley regions emerge as those most likely to be impacted by new development, with on average nearly 63% of countywide forest and rangeland acres converted for development. Southern California counties would absorb about 22% of the total newly developed forest and rangelands, and the remaining development (~15% of the total) is shown as spread across the other regions of the state.

Although the pressure of development on forest and rangelands has eased somewhat, there are regions where extensive conversion has occurred, and remaining undeveloped lands have become scarcer–with a risk of losing valued ecosystem services. Opportunities to protect the remaining forest and rangelands include:

- Resumption of state government subvention payments to counties participating in the Williamson Act.
- Continued plans and implementation by cities and counties of "smart growth" type high-density development.
- County consultation with CAL FIRE Pre-Fire Engineers (PFEs) assigned to assist planning of new fire-wise development to be located within wildland areas (forests and rangeland WUI).
- Continued funding for acquisition of conservation easements and fee titles by natural resources agencies and conservation organizations.
- Additional Habitat Conservation Plans (federal) and Natural Communities Conservation Plans (state) as needed; as more species are listed as threatened or endangered.

KEY FINDINGS

General and Regional Population Trends in California

ⓘ6.1 Indicator: Recent and Projected Population Trends

- California's population of 39.5 million has been growing at about 0.9% per year in the past decade. This amounts to about 354,000 additional residents per year. The same annual rate of growth, or slightly lower, is projected to continue over the next decades.
- About 98% of people live in California's 37 metropolitan counties, with the remaining two percent in the 21 rural counties. More than 99% of all new residents are projected to live in the metro counties in the coming decades.
- Metropolitan counties also contain about 72% of private rangelands, and 33% of private forestlands, and those within or close to urban areas are the most at-risk of new development.
- With stable or declining populations, very little rural county forest and rangelands have recently been converted to development. Thus, these are considered at low risk. Projections suggest this is likely to continue

Forest and Rangeland Protections from Development Threat

- Statewide, acreage in the decade-long process of WA contract non-renewal (being withdrawn from the program) has apparently been increasing since 2002. Likewise, program participation appears to be decreasing in recent years, and at least one county (Imperial) has withdrawn from the program entirely. Since 2008, with the cessation of subvention payments from the state to county governments in lieu of WA contract land property taxes, some WA counties have not been diligent in submitting their WA records. Recent trends are more difficult to discern from sporadically incomplete data.
- The number of land trust organizations active in protecting forest and rangelands in California has grown substantially in recent years. In 2017, the California Council of Land Trusts had nine statewide (or nationwide) member organizations, and 83 regional member organizations. The Council states that more than 220 organizations in total currently self-identify as land trusts in California.
- Demand for conservation easements by owners of working rangelands currently exceeds the supply of willing and able purchasers. The USDA Natural Resources Conservation Service has acquired major acreage of forest and rangeland easements in California, but the trends and unmet demand signals that significantly more acreage is likely to be under such easements within the next decade.
- Acreage within state-designated Timber Production Zones (TPZ), approximately 5.3 million acres of forestland where development options are extremely limited, has been very stable through recent years. This is due in part to the level of difficulty required to rezone such areas at the county level.

ⓘ6.2 Indicator: Rangeland Under California Land Conservation Act ("Williamson Act", or "WA") Contracts

- About 9.36 million acres of forest and rangeland were under WA contracts in California in 2015. This is an apparent net decrease of about 870,000 WA acres in these types since 2008 (average of -124,000 acres per year).
- WA-enrolled rangeland engaged in the 10-year process of non-renewal totaled about 245,000 acres in 2015, about 17% fewer than the previous 4-year average. In recent years, about 25,000 acres of rangeland is losing its WA contract status per year on average.
- Since the 2009 cessation of state government subvention payments to counties, both current and future WA contracts on rangeland

statewide may be at-risk. Resumption of subvention payments to counties, and WA tax benefits, are important to keeping larger livestock operations in business.

ⓘ6.3 Indicator: Private Forest and Rangeland Under Conservation Easements, or Conservation Organization Owned

ⓘ 🔑 In 2016, lands owned by conservation organizations included about 457,000 acres of rangeland and 154,000 acres of forestland. In the same year, lands with conservation easements comprised about 1.25 million acres of rangeland, and 452,000 acres of forestland.

ⓘ 🔑 The amount of land managed for conservation of rangeland has been increasing for the past 2 decades. Acreage of similarly managed forest lands has increased sharply in the past decade.

ⓘ 🔑 In the past two decades, nearly 600,000 acres of desert rangelands and 8,300 acres of forest have been acquired by non-profits, and subsequently re-conveyed to government agencies permanently for management purposes.

DISCUSSION

This chapter summarizes historical and recent trends in population, and consequent land use conversions, with an emphasis on permanent changes from forest and rangelands to urban development. Population growth in general stimulates new development, and the manifestations of new development may be categorized into three general types: land that is already mostly urbanized within metropolitan areas (redevelopment or infill), lands that are near urban margins, and lands either under irrigated cultivation, or comprised of mostly forests and rangeland with very low housing density.

We examine past patterns and trends, and projections for the future. Historically, most wildland conversions have been to agricultural uses. When irrigation ceases, fallow lands can often revert to natural vegetation such as grassland, especially areas of orchards and vineyards planted at the margins of the Central Valley [8]. Conversions to urban land uses through residential and commercial development, however, are usually permanent. Forests and rangelands located at the periphery of large growing urban areas are particularly at-risk of such development.

Recent and Projected Population Trends in California

California's population of 39.5 million residents in 2016 remains by far the largest of any state in the Union. Increasing on average at about 0.9% per year in recent decades, its growth is projected to continue to 2060 at a rate that will decrease slightly over time (ⓘ6.1). Natural increase (births minus deaths) and foreign immigration have both been strongly positive in recent years, but this is offset by a substantial net domestic out-migration to other states [9]. Ninety-eight percent of residents live in the 37 metro counties, making it proportionately the most urbanized state in the country. Conversely, only 2% of people reside in the 21 rural counties, predominantly located in more remote parts of the northern and eastern state (Figure 6.1).

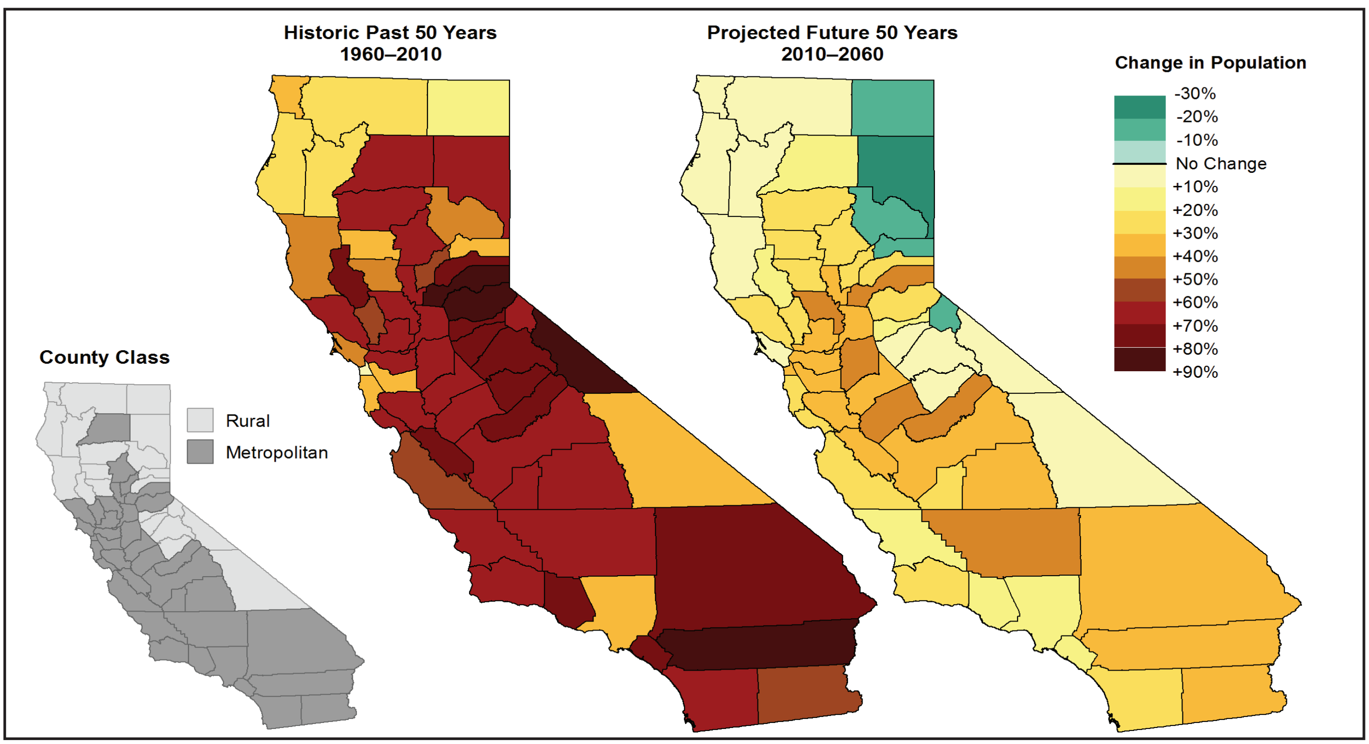


Figure 6.1: California's 21 Rural and 37 Urban Counties, as determined by the U S Office of Management and Budget (OMB); population growth rates over 50 years from 1960 – 2010 (high for most counties, and fairly evenly distributed across the state); and population growth rates projected over 50 years (until 2060). Overall projected rates are much lower than for the previous half century, and remote rural counties are on track for stable or declining populations.

Data Sources: [3] Demographic Research Unit, 2017; [10] Demographic Research Unit, 2017; [13] Office of Management and Budget, 2010.

Overall the rate of population growth in the state is projected to be much less over the next 50 years when compared to the preceding half-century [10]. From 1960–2010, the number of residents in the state grew by nearly 58%, whereas in the 2010–2060 timeframe the increase is projected to be less than half that rate (about 27%) (Figure 6.1). More notably, while the growth of rural counties largely kept pace with metropolitan counties in the past, rates of the former from 2010 onward are projected to stagnate or plummet over the next decades. Some remote rural counties, such as Lassen and Modoc, have been losing people and are projected to continue with a net loss until 2060.

Main Processes at Work

The state's current and future population growth, and consequent pressure for new residential development, is being fueled largely by regional employment opportunities stimulated by strong economic growth. In 2016, California's gross state product (GSP) of $2.5 trillion was 36% more than the second largest state economy (Texas), and real GDP grew at a healthy 2.9% [11]. Much of the recent growth is coming from foreign immigration in response to recruitment for jobs in the information technology sector, for example in the south and east Bay Area, where GDP grew at an annual rate of 5.2% in 2016 [11]. High housing costs are likely spurring sprawl at the margins of areas of such strong growth, where land is significantly less expensive. Another driver of population growth is from the natural increase from in-state births, particularly in the Los Angeles, Imperial Valley and San Joaquin Valley regions. The former more than make up for the recent net loss of about 138,000 residents annually who left for other states in 2016–2017.

In contrast, in many rural areas the population trends are flat or continue downward, as deaths and out-migration to other counties and states exceed in-migration and natural increase. The cause of rural stagnation is slow economic growth and few new job opportunities [12]. Because of this, there is a low overall threat from future development to forest and rangelands in the 21 non-metro counties.

Land Use Changes from Population Growth

The landscapes of California have undergone immense changes since colonization by Euro-Americans in the mid-1800s. Expanses of what were once rangeland and forestland have been converted, mostly permanently, to intensive agricultural and urban uses. While many conversions to agricultural land uses occurred early-on, the large growth in urban areas is more recent, and has happened largely since the WWII era [14]. The desirability of the state as a place to grow food, work, and to live, has caused a steady influx of people from the world over who are choosing California as their home.

The history of land use regulation in California is quite complex, and beyond the scope of this Assessment. The timeline shown in Figure 6.2, from a recent publication by the California Department of Housing and Community Development, shows a number of the most important legislative milestones that have impacted housing developments and land use for the past century.

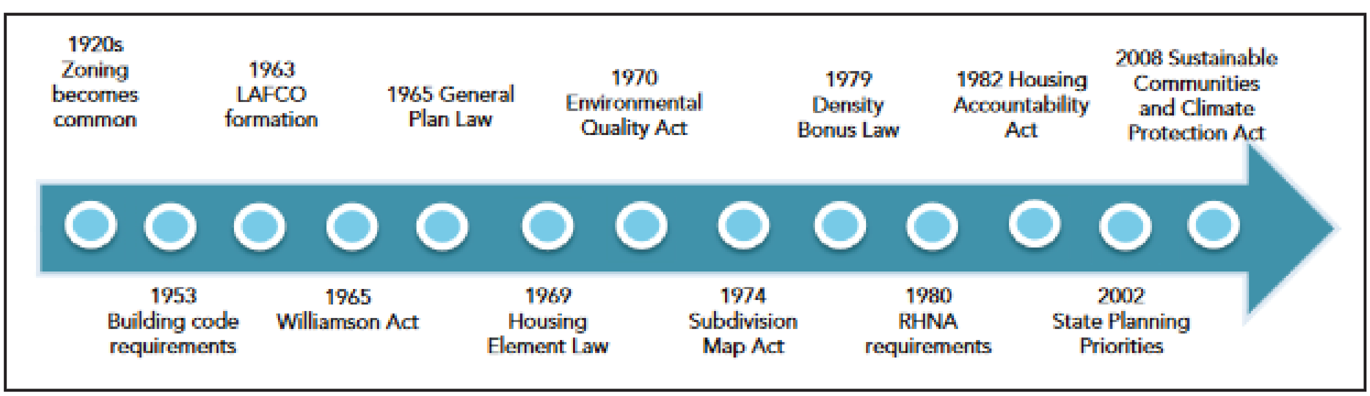


Figure 6.2: Timeline of important California land use and housing laws impacting development over the last century

Data Source: [1] California Department of Housing and Community Development, 2018.

Land Conversions Since World War II

The post-war period brought a large wave of in-migration from other states, along with the natural increase with the arrival of the baby boomer generation. Many former military personnel who had been deployed to the Pacific Theater from bases in California relocated here permanently when they were discharged. In the 20 years from 1940–1960, the population of the state increased by 35% (1.75% growth per year), from 6.5 million to 8.8 million residents [10]. In the Bay Area alone, the population grew by almost 110% over that same period.

This influx of new residents resulted in a tremendous demand for new housing and other support services and infrastructure, and with it came new development across large tracts of land formerly used for agriculture and range. Much of the new housing came in the form of single family residences. Large tracts of land were converted to urban and suburban areas in Los Angeles and Orange counties, the greater Bay Area, and elsewhere. Figure 6.3 shows the number of new residential units built per year statewide since 1955 [1]. In 1986, production peaked at about 315,000, nearly 50% more than any year since 1990. Some of the fastest-growing areas such as Los Angeles, which had no regional planning at that time, have been used as prime examples of what later became known as “urban sprawl.”

Negative impacts of “urban sprawl” (the uncontrolled expansion of urban areas) on surrounding lands were widely recognized by the 1960s. The California Land Conservation Act (“Williamson Act” or WA) was signed into law in 1965 to help conserve prime agricultural land and natural parks and open spaces close to urban core areas. The effect of these 10+ year contracts is to reduce the assessed value of qualifying lands, thus lowering a landowner’s property tax liability and increasing incentives for keeping the land in agricultural use. About 16 million acres of land (including irrigated cropland) are now under WA contracts, lowering the pressure of development interests upon the farm and rangeland owners (ⓘ6.2) [15].

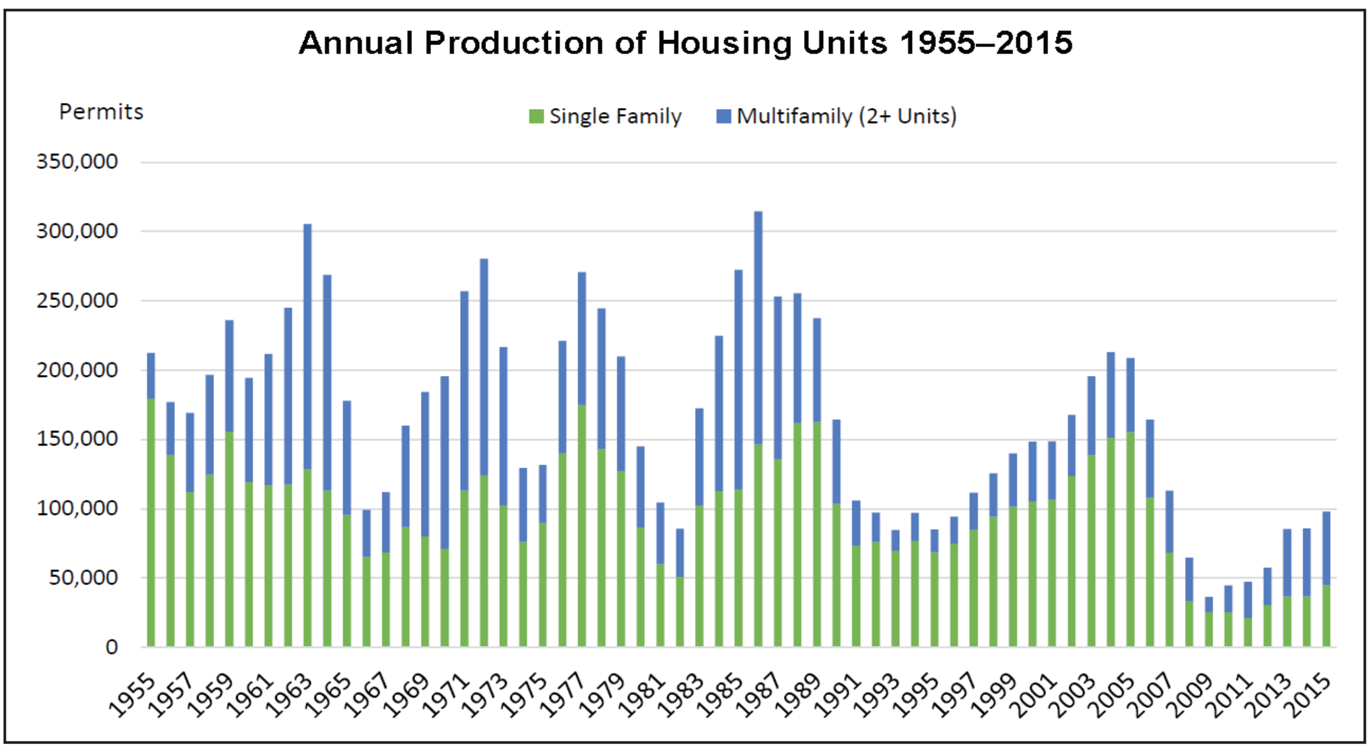


Figure 6.3: Annual Production of Housing Units, 1955–2015. In the 1960’s, 70’s and 80’s totals exceeded 250,000 nine times (which it did not do since). The three lowest years (2009–2011), precipitated by the economic recession, were the first in this period that did not exceed 50,000. The data suggest this cyclical pattern may be facing a downward trend.

Data Source: [1] California Department of Housing and Community Development, 2018.

A similar program for the protection of private timber lands was enacted in the Forest Taxation Reform Act of 1976. Under the Act, lands were zoned as Timber Production Zones (TPZ), with strong constraints on conversion of land to development or other uses. About 5.3 million acres is currently in this designation, and relatively few acres have moved into or out of TPZ over the past decades. In return for lowered rates of taxation, land owners forego certain land use options.

Development Spurred by Population Growth – Recent Trends and Future Projection

Recent and Current Anti-Sprawl Efforts

Agencies in multiple levels of government have been working to discourage urban sprawl in the state. City spheres of influence (SOI), which function as development boundaries and are established under state law by county Local Area Formation Commissions (LAFCOs), demarcate the expected limits of future development for each municipality. County general plans include zoning ordinances that regulate where development can occur. Across the state, 25 Councils of Government (COGs) such as the Association of Bay Area Governments (ABAG) coordinate planning activities among local governments. ABAG and the Metropolitan Transit Commission (MTC) recently released a comprehensive environmental impact report on the Plan Bay Area 2040, addressing the need for rational location of future housing in the region.

Similar recent public and private collaborative efforts to avoid urban sprawl can be grouped under the term “smart growth.” The Governor’s Office of Planning and Research produced a guidebook for communities based upon these principles [16]. Agencies and private organizations are addressing patterns of traffic volume and flow, greenhouse gas emissions, availability of transportation, and quality of life issues throughout the state. Urban sprawl remains an issue in many parts of the state, particularly in southern California counties such as Orange, San Bernardino, and Riverside (the “Inland Empire”).

To counter the destructive effects of development on wildlife habitat, the California Department of Fish and Wildlife in partnership with federal agencies and counties has either implemented or planned 34 Regional Conservation Plans across the state [17]. Some qualify as federal Habitat Conservation Plans (HCPs), state-based Natural Community Conservation Plans (NCCPs), or both. Several plans are in important areas where the growth of development has been particularly rapid, such as southern California, Kern County and the Sacramento metropolitan area. While most plans do not stem new development directly, they aim to reduce impacts by establishing permanent reserves of similar habitat in rough proportion to (or sometimes multiple times the size of) the area slated for development.

Recent and Current Land Use Conversion

Estimates of acreage totals of recent land conversions from non-urban (forests, rangeland, agriculture) to urban uses in California have varied due to differences in data sources and methodology. By far, most conversions to urban uses have been from rangeland, not forestland. This has been due primarily to rangeland being the dominant land cover type at the lower elevations of the state where nearly all development has occurred. In 2003, the FRAP Assessment reported that in the 1980s and 1990s, 42,000 to 90,000 acres per year of rangeland was converted to other uses [18].

Sleeter, et al. (2011) reported that in California during the 27-year period from 1973–2000, an average of 43,500 acres per year of mainly rangeland and agriculture statewide had been converted to urban [19]. About 20,000 acres of that total were estimated to have been formerly grass and shrub dominated rangelands, with roughly half of that total conversions occurring in the Mojave Desert ecoregion. In the study, the Central Valley and Chaparral and Oak Woodlands ecoregions comprised approximately 46% of the total rangelands converted to urban (9,300 acres per year average). Moreover, they estimated that 47% of new development came from rangeland, versus 42% from irrigated agricultural lands, and that the development on irrigated lands has further pushed the conversion of rangeland into croplands.

A 2014 study by the Nature Conservancy and the California Rangeland Conservation Coalition (CRCC) included 33.4 million acres in, and surrounding, the Central Valley (comprising about one third of the state), and estimated rates of land use conversion using a combination of California Department of Conservation's Farmland Mapping and Monitoring Program (FMMP) data and National Agricultural Imagery Program (NAIP). They reported that within that region from 1984–2008, an average of 9,800 acres of rangeland per year had been converted to urban uses [20]. The latter figure excludes conversions that occurred in southern California counties of the South Coast and Desert bioregions.

An examination of statewide FMMP land use data by FRAP showed that between 1992–2010, about 25,000 acres per year of dryland farming and grazing lands was converted to urban. Although significant areas of rangeland are still at risk, the amount of rangeland conversion to urban uses has been at its lowest level in the years of most recent data (2010–2012), when compared with the past quarter of a century.

Shifts in Threats from Development Within the Past Decade

In the past decade, several important shifts have taken place that influence the current pressure of development on forest and rangelands. Most importantly, the economic recession beginning in 2007–2008 severely reduced the demand for new housing construction. In addition, state legislation stemming from AB 32, including SB 375, mandates that counties estimate the number and type of new residences planned in areas of new development, and assign a high priority to the use of major transportation routes, the reduction of greenhouse gas emissions, and the provision for low income housing. Lifestyle preferences of the younger generation may be reflected in less demand for land-consuming suburban single-family homes and a preference for higher density multi-unit housing within already urbanized areas.

There was a large inventory of new, unoccupied housing for several years after 2008 due to overbuilding during the preceding housing bubble. The lack of housing demand resulted in a lull in construction across the state and the nation that bottomed out in 2009 (Figure 6.2) [21] but lasted for several more years. Consequently, new development of all types (forests and rangelands included) was brought nearly to a standstill. The 21 rural counties in California, especially those in remote regions, have not experienced much economic recovery since 2008, a trend that is projected to continue [12]. The continuing lack of demand for new housing in these counties has resulted in a low level of impact to forests and rangelands from development.

In the Bay Area and other metropolitan regions, new housing construction has recently rebounded (although not yet to the levels of the late 1990s and early 2000s) (Figure 6.4) [12]. Several metropolitan counties have extensive areas of private forests and rangelands, and such areas–particularly at the margins of urbanized lands–are most likely to be affected by new development in the coming years. Large, new subdivisions are already in the works on the rangelands in Sacramento, El Dorado and Placer counties, and elsewhere.

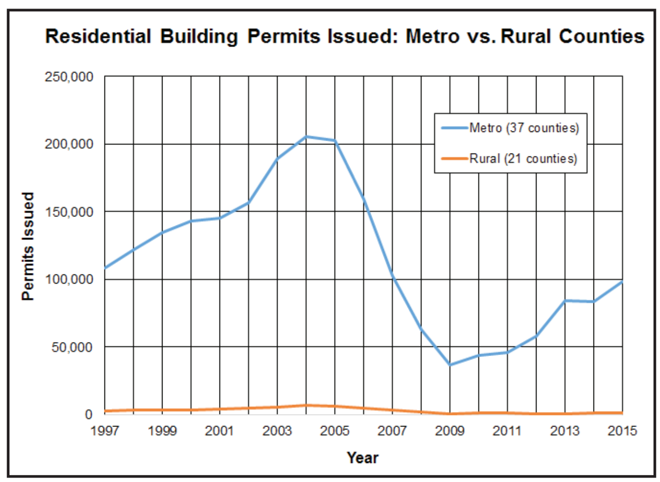


Figure 6.4: Residential Building Permits Issued: Metro vs. Rural Counties. The number of residential housing unit permits shows the effect of the housing bubble, and the subsequent collapse from the recession that began around 2007. Its rebound since 2009 has been focused in metropolitan areas, but there are very few permits being issued in rural counties.

Data Source: [11] California Economic Forecast, 2017.

Although recent and projected trends point to continued growth in much of California (both in population and new land area developed) throughout the 2060 timeframe, the net impact of these future new residents on the state's working landscapes is difficult to predict [22-24]. Massive housing losses from recent wildfires may affect future rates of redevelopment in those areas, and possibly discourage others from building in and moving to similar fire-prone landscapes. Recent reports of insurance companies refusing to issue fire insurance policies in some fire-prone areas of the state may also change development patterns in the Wildland Urban Interface (WUI). In addition, several initiatives and movements are underway that seek to avoid the spread of new development in areas that are more removed and disconnected from urban centers, and focus it within the existing urban footprint. If successful, new housing units would, *per capita*, have an overall smaller impact on working landscapes than in years past.

Senate Bill 375 (2008) and the County-Based Regional Housing Need Allocation (RHNA) Process

State Senate Bill 375 (SB 375) was enacted in 2008 as a part of the state's overall approach to mitigating greenhouse gas pollution that threatens to worsen climate change [25]. The law encourages county planning departments to take travel time to work, and the locations of major transportation networks, into account when considering the approval of new residential construction. By concentrating new residences in areas close to existing transportation routes, pollution from commuting to work may be lessened.

A part of the legislation calls for each county's planning department to estimate the number of housing units that will be required to accommodate projected future populations. This is called the Regional Housing Need Allocation (RHNA) process. The RHNA is tracked by the California Department of Housing and Community Development [26]. Housing projections are targeted for five to eight years into the future. The allocations provide specific information about where planners anticipate future housing development will occur. Allocations are reported by individual municipalities and for unincorporated areas. Since most working forest and rangelands are in the unincorporated areas of counties, the RHNA numbers reflect the level of development anticipated by the planning departments on these lands (by county) generally, in the next 5 or so years. The most current county housing need allocation reports are for the 5th cycle (planning timeframe), which extends to the year 2022.

Table 6.1 shows the most current RHNA allocations for the top twenty counties in order of descending numbers of housing units in unincorporated areas. While the numbers are not directly comparable (they vary by planning date horizon) they provide a good indication of what county planners anticipate to meet future demand. Based upon recent projections from the RHNA process for all counties, about 82% of all new housing is expected to be located within incorporated municipalities statewide. The remaining 18% are planned for unincorporated areas. The top twenty reflect this proportion closely (21% for unincorporated areas), however, this percentage varies considerably by individual county (from 4% in Alameda County to 89% in Yuba County). This is due in part to the difficulty of building high-density, low-income housing in rural areas without water and sewer districts.

In metropolitan counties, most private rangeland is in unincorporated areas. In the five-year timeframe, the most development pressure on rangeland will be in unincorporated parts of southern California. The top four counties–Riverside, Los Angeles, San Diego and Kern–comprise about 52% of the state total number of residential units planned for lands outside of municipalities. Imperial and Orange counties also are in the top ten. Most of these counties have limited agricultural lands available for urban or residential expansion. Most of the other counties in Table 6.1 with large unincorporated regional housing allocations are in the Central Valley, or have significant populated areas within the unincorporated area. Given the expanses and availability of agricultural lands surrounding urban areas in these counties, it is likely that new development on unincorporated lands will occur on agricultural lands, rather than on forestland or rangeland.

Table 6.1: Regional Housing Needs Allocation (RHNA) Projections (5th cycle) for the 20 Counties with the Largest Number of Residential Units Planned for their Unincorporated Areas

County	Population 2010	Allocated Housing Units			Planned by Year
		Unincorporated	Incorporated	County Total	
Riverside	2,189,641	30,303	60,579	90,882	2021
Los Angeles	9,818,605	30,145	149,736	179,881	2021
San Diego	3,095,313	22,412	139,568	161,980	2020
Kern	839,631	21,583	46,092	67,675	2023
Sacramento	1,418,788	13,844	44,542	58,386	2021
San Joaquin	685,306	10,167	30,193	40,360	2023
Imperial	174,528	6,474	10,077	16,551	2021
Madera	150,865	5,682	7,213	12,895	2023
Butte	220,000	5,515	13,620	19,135	2025
Orange	3,010,232	5,272	32,694	37,966	2021
Placer	348,432	4,703	16,922	21,625	2021
Yuba	72,155	4,676	555	5,231	2021
Merced	255,793	4,445	11,405	15,850	2023
El Dorado	181,058	3,948	1,188	5,136	2021
Tulare	442,179	3,370	8,095	11,465	2023
Fresno	930,450	2,722	38,748	41,470	2023
Stanislaus	514,453	2,241	19,089	21,330	2023
Yolo	200,849	1,890	9,239	11,129	2021
Alameda	1,510,271	1,769	42,267	44,036	2022
Monterey	415,057	1,551	5,835	7,386	2023

Data Source: [26] California Department of Housing and Community Development, 2017.

Easements and Outright Title Purchase by Government Agencies and Conservation Organizations

The acquisition of forest and rangeland by government agencies for conservation and preservation against development has long been a part of the American landscape. The U.S.D.A Forest Service, National Park Service, Bureau of Land Management, and U. S. Fish and Wildlife Service have been managing millions of acres of forest and rangelands across the state for many decades. The majority of these acres are in more remote mountainous forests and in high plains and desert regions. These lands are managed as either working landscapes or wilderness areas–while being made available to the public for hunting, grazing, and (in the case of the former) timber production. The agencies hold title to the land, and residential and commercial development are explicitly forbidden except in certain limited instances.

Private organizations have also formed to promote the additional conservation of natural landscapes that are at-risk given their proximity to urbanized areas. Founded early in the 20th century, the Save the Redwoods League has worked to conserve old growth redwood stands [14]. Since 1951, the Nature Conservancy has been acquiring fee title to high ecological value lands primarily for the purposes of conservation and management. Because of the high price of real estate in California, the amount of land they can obtain title to has been limited.

Since about 1980, government agencies and private land conservation organizations have pursued a fresh approach to help stem the tide of development on forests and rangelands. The advent of conservation easements on farms and ranches has allowed development rights to be purchased for forest and rangeland for considerably less money than it would otherwise take to purchase the fee title to the same property. The practice of conservation organizations and some governmental agencies acquiring conservation easements accelerated in the 1990s (ⓘ6.3).

The Department of Agriculture Natural Resources Conservation Service (NRCS) now holds numerous conservation easements on rangeland in the state. Private land trusts and other organizations working on land conservation have formed across the state, operating at local, regional and national scales. The California Council of Land Trusts lists 66 member organizations, and estimates that a total of 220 groups self-describe as land trusts [27]. The trend of increasing numbers of easement acquisitions on working forest and rangelands (particularly since 2000) shows no signs of abating. However, according to the California Rangeland Conservation Coalition and the California Rangeland Trust [28], a number of ranches totaling more than 400,000 acres of land are still awaiting funding for the purchase of permanent conservation easements.

Current Levels of Landscape Parcelization

Housing density is often used in the analysis of human impact on landscapes that are otherwise dominated by wildland vegetation. A useful metric is the average density (i.e., size) of privately owned developed and undeveloped land parcels. Housing and parcel density within a wildland fuel matrix can be used to delineate wildland urban intermix and interface, collectively known as WUI (defined as an area where houses meet or intermingle with undeveloped wildland vegetation). Currently in California there are about 17.7 million acres in WUI, with more than 2.2 million housing units (see Chapter 11).

The challenges of fire prevention and suppression in the WUI is a focus of wildfire agencies at all levels of government. Because most lands protected by CAL FIRE are in private ownership, WUI considerations are prominent in documents such as the California Fire Plan [29]. Fire Safe regulations (PRC 4290, PRC 4291, Title 14) and building codes (Chapter 7A, Chapter 47, Title 24) address the need to remove flammable materials from around structures and use fire resistant materials in construction, etc. Fire Hazard Severity Zones designate areas at risk from fire hazards. County planners are encouraged to include fire safe considerations in county general plan safety elements. The need for wildfire prevention and protection escalates with the concentration of assets such as structures located in otherwise wild landscapes. Chapter 11 explores the status of trends in wildfire protection of such areas in ⓘ11.3.

The process by which large tracts of land are divided into smaller is often referred to as "parcelization" [18]. Soon after parcelization, land development (such as home building) often follows. The organization GreenInfo Network has published maps of California showing the distribution of parcelized landscapes – i.e. areas dominated by parcels smaller than can typically function as working landscapes [30].

FRAP conducted a similar exercise, with the assumption that housing development begins to appreciably impact values such as wildlife habitat and other wildland ecosystem services at or above densities of one unit per 20 acres. Such land is no longer considered by FRAP to be "rural." Figure 6.5 shows the extent of two levels of parcelization: 1) landscapes converted to urban/suburban use (including incorporated lands); and 2) those classed as exurban, along with the matrix of the surrounding general land cover (forestland, rangeland, or cropland/barren). The exurban parcelized areas are the private parcels, both developed and undeveloped, with an average size from one parcel per 20 acres to one parcel per acre. Exurban areas typically retain some wildland values, and are particularly vulnerable to impact from further development density that can drive them into suburban and urban classes.

A look at Figure 6.5 reveals substantial parcelization across several areas of the State. Notable regions (with substantial exurban areas within predominantly forest and rangelands) include the western Mojave Desert of San Bernardino, Los Angeles and Kern counties; western Riverside and San Diego counties; and the Sierra Nevada foothills of Nevada, Placer and El Dorado counties. Smaller areas of exurban densities appear on the north and south ends of the Bay Area (Sonoma, Santa Cruz, and Santa Clara counties) greater Redding (Shasta County), and are distributed along the forest-rangeland transitional areas of the western slope Sierra Nevada (southward through Fresno County). Some cropland in the Central Valley has been parcelized, but these areas are not central to this Assessment because they are not primarily forest or rangelands.

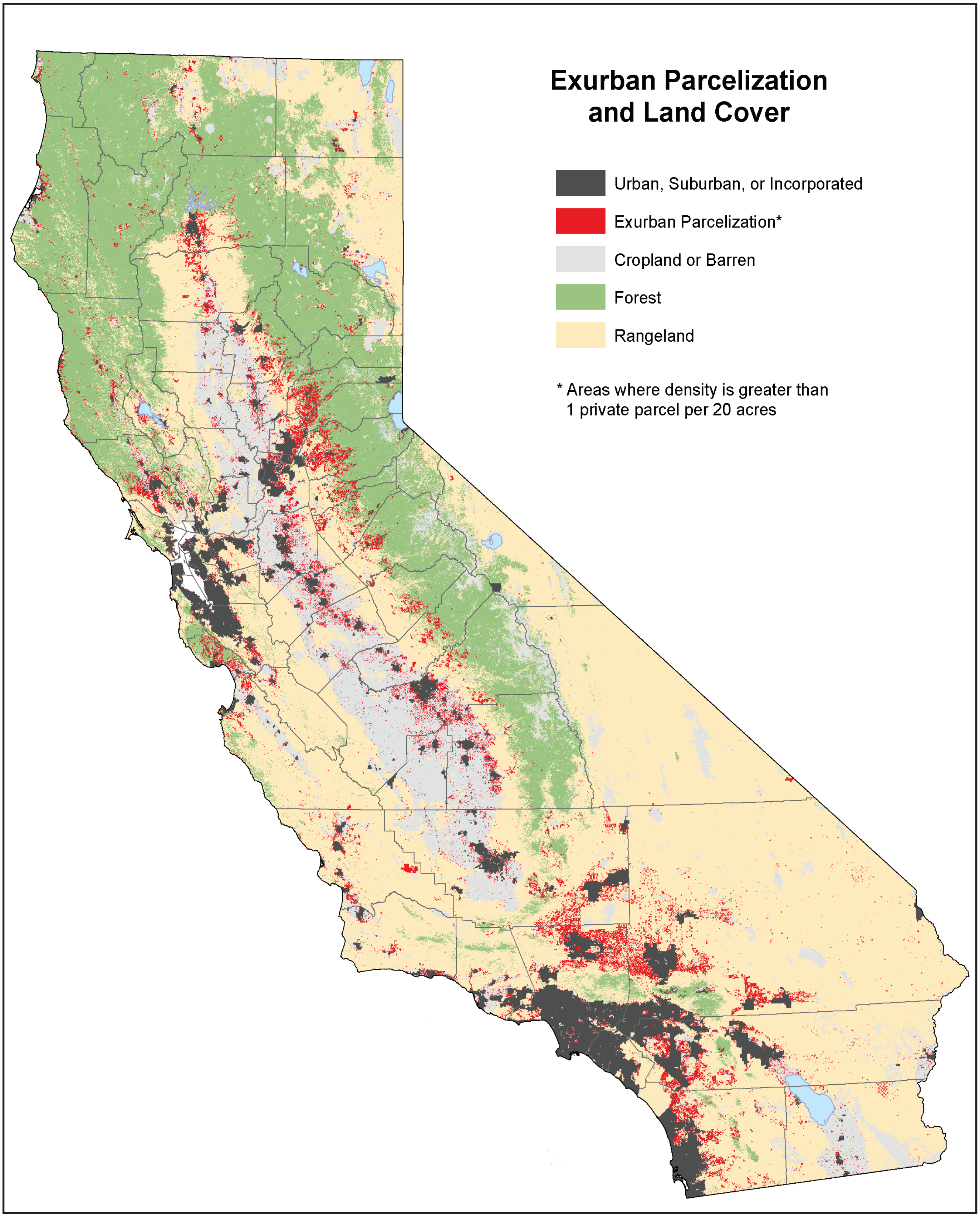


Figure 6.5: Exurban Parcelization and Land Cover. Includes converted (>=1 parcel per acre) and exurban (< 1 parcel per acre and >1 parcel per 20 acres) parcelization of private lands, within a generalized surrounding land cover matrix.

Data Source: [32] Digital Map Products Inc., 2017.

Not all such concentrations of smaller parcels are equally at risk of future dense development. Some unincorporated communities such as California Pines (Modoc County), California City (Kern County), and California Valley (eastern San Luis Obispo County) have substantial acreage of forests and rangelands characterized by dense networks of mainly primitive roads and small, individually-owned parcels. Situated in remote locations, these communities will probably remain largely undeveloped into the foreseeable future due to building constraints and water and sewage requirements.

The Future

Modeling of Future New Housing with Spatially Explicit Regional Growth Model (SERGoM)

FRAP developed reference baseline housing density data for 2000 and 2010, and used them with land development constraints and county population projections to create relatively fine-grained spatial maps of future housing density for 2040 and 2060. These housing density maps help in the identification of working forests and rangelands that will experience significant development.

The Demographic Research Unit of the California Department of Finance (DOF) provides population estimates and projections. Most recent county projections extend to the year 2060 by 5-year increments [3]. Countywide population projections are converted to housing units and allocated at sub-county scales using the Spatially Explicit Regional Growth Model (SERGoMv3) [31], that was originally designed for the Integrated Climate and Land Use Scenarios (ICLUS) project (but freely available and implemented by other agencies, including the National Park Service).

Results

We used two related metrics to rank the projected amount of parcelization to forest and rangelands by county to the year 2060. The first is the total number of acres within the county that the model projected to be parcelized. The second is the proportion of available developable land within that county that those acreage totals represent. These were then combined, given equal weight, into a composite risk factor rating.

Table 6.2 shows the results, in order of composite threat to forest and rangelands (in descending order). San Diego and Los Angeles Counties emerged as being the most at-risk of future forest and rangeland parcelization in the next 40+ years. These two counties rank at or near the top in both the absolute and relative measures of threat. Other counties near the top tier, given the criteria, are Kern, Riverside, Sonoma, Yuba and Sacramento. Other related land use projections based on the Department of Finance (DOF) population projections to the year 2100 show similar regional results for urban expansion [24].

Table 6.2: Top 10 Counties with Forest and Rangeland Most Threatened by Projected Development (to 2060), Ranked by Total Area and Percentage of Remaining Developable Land

County	Overall Rank	Acres Per Year	Percent of Available
San Diego	1	5,782	13.5%
Los Angeles	2	5,648	17.3%
Kern	3	7,472	9.8%
Riverside	4	6,455	8.9%
Sonoma	5	2,628	16.0%
Yuba	6	1,114	20.3%
Sacramento	7	1,029	25.5%
San Bernardino	8	9,472	3.9%
Placer	9	1,637	10.9%
Contra Costa	10	1,115	20.6%

Data Source: [33] Spero, J. and R.E. Walker, 2017.

By total number of parcelized acres, three of the top five counties (San Diego, Los Angeles, and Riverside) are in southern California. If nearby Kern County is included, the four counties together with San Bernardino contain well over half of all parcelization-threatened forest and rangelands in the state. It should be noted that much of the at-risk acreage in San Bernardino and Riverside counties is desert rangeland.

In relative terms, four counties emerge from northern California as having forest and rangelands highly threatened by parcelization: Sacramento, Contra Costa, Yuba, Placer, and Sonoma. Sacramento and Yuba contain relatively small areas of forest and rangeland, and for each of these just over 1,000 acres is projected to be newly parcelized per year on the average. However, Sonoma County is projected to lose more than 2,600 acres annually until 2060.

The results are most robust when tallied at the county or multi-county regional scale. Because these results do not consider other factors that can influence the spread of parcelization on forest and rangeland (such as zoning restrictions) they may differ from locally generated, fine scale planning maps.

Opportunities

Opportunities to continue the conservation of California's working forest and rangeland landscapes include:

- Resumption of state government subvention payments as soon as possible to counties participating in the Williamson Act, to compensate for loss in property tax revenue. Because of the lapse since 2008, some counties have not been honoring new WA contract applications, and one county has withdrawn its half million acres of farmland from the progra-m. Without state payments, more participating counties–particularly those with tight budgets–are likely to withdraw from the program, exposing substantial areas of rangeland which are currently protected by the WA to development pressure.

- Continued plans by cities and counties for high-density "smart growth" type development patterns.

    - Enacted in 2008, SB 375 requires counties to plan for new housing to minimize greenhouse gas pollution from transportation systems. Through its Regional Housing Need Assessment process, the State has been pushing counties to explicitly state where they expect their new housing units to be built. Allocations are made to municipalities and unincorporated areas. The most recent (5th cycle) county reports show that most new units will occur within cities (some with annexations) and not on intact working rangelands or forests.

- Continued public and private funding from agencies such as the USDA Natural Resources Conservation Service (NRCS) for acquisition of conservation easements, and for easement and title acquisitions by conservation organizations.

- Other mechanisms to make them more resistant to development and maintain their status as working forest and rangelands.

    - As additional species become listed as threatened or endangered, new Natural Communities Conservation Plans and/or Habitat Conservation Plans created to mitigate impacts on them will help conserve their ecosystems.

Indicator: Recent and Projected Population Trends ⓘ6.1

Which Montreal Protocol Criteria does the indicator evaluate?

MPC1: Conservation of biological diversity

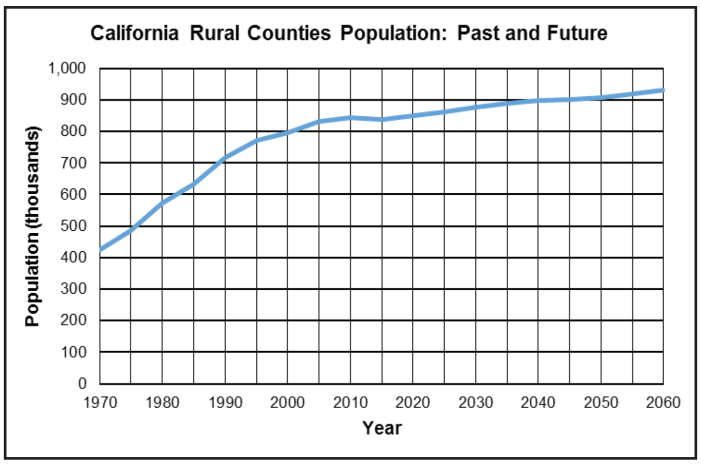
MPC2: Maintenance of productive capacity of forest ecosystems

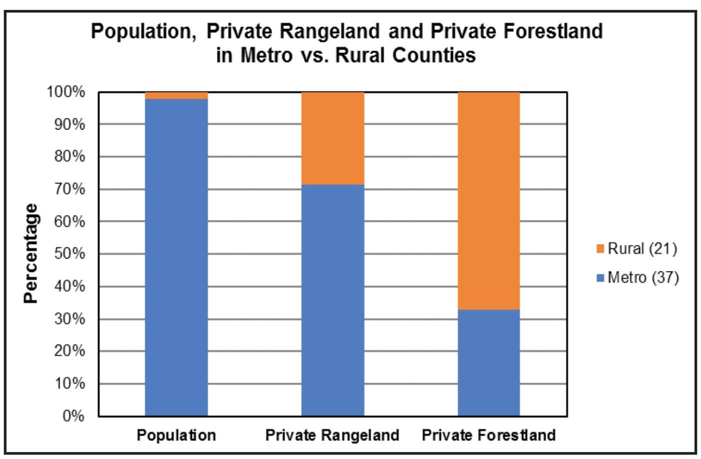
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

Population increase is a primary driver of regional growth and development growth, and consequent permanent conversions from cropland, rangeland and forestland to commercial and residential buildings.

What does the indicator show?





Key Findings:

ⓘ California's population is about 39.5 million, and has been growing at 0.9% per year over the past decade. This amounts to about 354,000 additional residents per year. This annual rate of growth, or slightly lower, is projected to continue over the next decades.

ⓘ About 98% of people live in California's 37 metropolitan counties, with the remaining two percent in the 21 rural counties. More than 99% of all new residents are projected to live in the metro counties in the coming decades.

ⓘ Metropolitan counties also contain about 72% of private rangelands, and 33% of private forestlands, and those within or close to urban areas are the most at-risk of new development.

ⓘ With stable or declining populations, very little rural county forest and rangelands have recently been converted to development. Thus, these are considered at low risk. Projections suggest this is likely to continue.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Metro and Rural counties of the US	[13] Office of Management and Budget, 2010.	****
WHR vegetation types	[34] Fire and Resource Assessment Program, 2015.	****
County population projections	[3] Demographic Research Unit, 2017.	****

Indicator: Rangeland Under California Land Conservation Act ("Williamson Act") Contracts ⓘ6.2

Which Montreal Protocol Criteria does the indicator evaluate?

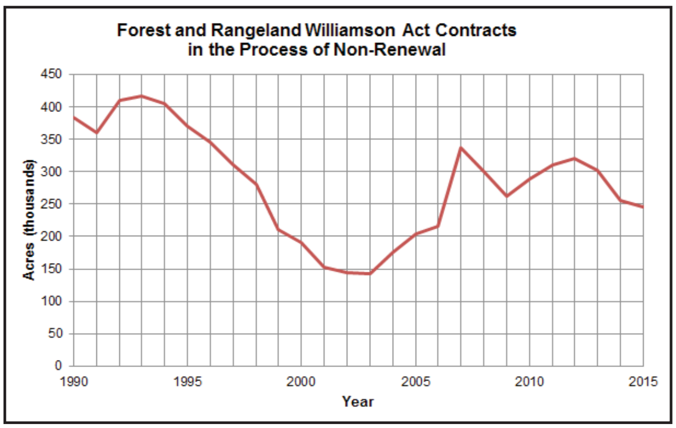
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

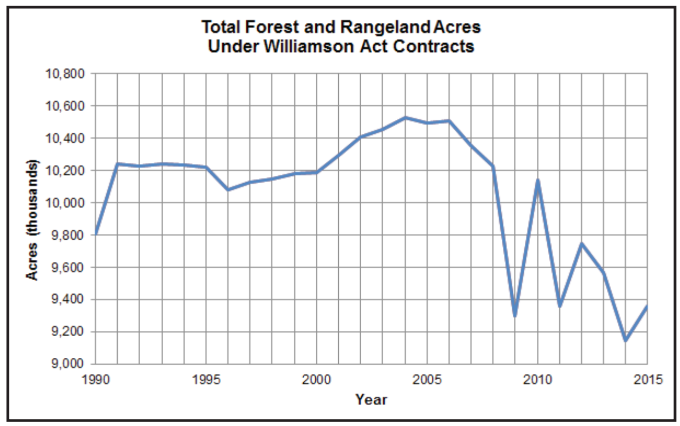
MPC7: Legal, institutional and economic framework for forest conservation and sustainable management

Why is the indicator important?

Rangeland enrolled under the Williamson Act (WA) is comprised of "non-prime" agricultural lands, which totals approximately 62% of all WA contract acres. These lands receive property tax breaks in exchange for the owners giving up development rights for at least 10 subsequent years. Without action by the landowners, contracts are automatically renewed each year for another 10-year term.

What does the indicator show?





Key Findings:

- ⓘ About 9.36 million acres of forest and rangeland were under WA contracts in California in 2015. This is an apparent net decrease of about 870,000 WA acres in these types since 2008* (average of -124,000 acres per year).

- ⓘ WA-enrolled rangeland engaged in the 10-year process of non-renewal totaled about 245,000 acres in 2015, about 17% fewer than the previous 4-year average. In recent years, about 25,000 acres of rangeland is losing its WA contract status per year on average.

- ⓘ Since the 2009 cessation of state government subvention payments to counties, both current and future WA contracts on rangeland statewide may be at-risk. Resumption of subvention payments to counties, and the WA tax benefits, are important to keeping larger livestock operations in business.

**Cessation of state government WA payments to counties after 2008 has resulted in inconsistent reporting on the part of multiple participating counties, and in some cases missing data for those counties since that year.*

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Williamson Act Contract Lands	[35] Land Conservation (Williamson) Act Program, 2016.	***

Indicator: Private Forest and Rangeland Under Conservation Easements, or Conservation Organization Owned

ⓘ6.3

Which Montreal Protocol Criteria does the indicator evaluate?

MPC1: Conservation of biological diversity

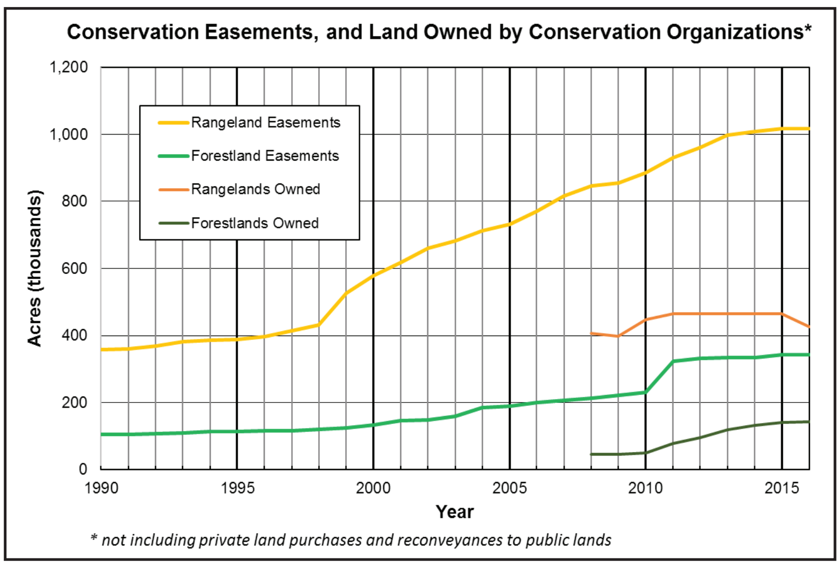
MPC2: Maintenance of productive capacity of forest ecosystems

MPC6: Maintenance and enhancement of long-term multiple socioeconomic benefits

Why is the indicator important?

Forest and rangeland managed under conservation easements or owned by conservation organizations is off-limits to major development. Conservation easements maintain working landscapes with or without some amount of management to enhance non-commodity values. In some areas with high or unique biological values, easements are used to create private ecological reserves where commodity production is no longer permitted.

What does the indicator show?



Key Findings:

ⓘ In 2016, lands owned by conservation organizations included about 457,000 acres of rangeland and 154,000 acres of forestland. In the same year, lands with conservation easements comprised about 1.25 million acres of rangeland, and 452,000 acres of forestland.

ⓘ The amount of lands managed for conservation of rangeland has been increasing for the past 2 decades. Acreage of similarly managed forest lands has increased sharply in the past decade.

ⓘ In the past two decades, nearly 600,000 acres of desert rangelands and 8,300 acres of forest have been acquired by non-profits, and subsequently re-conveyed to government agencies permanently for management purposes.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Conservation Easements	[36, 37] Ducks Unlimited and The Trust for Public Land, 2015.	***
Conservation Protected Areas	[38] GreenInfo Network, 2017.	****
WHR vegetation	[34] Fire and Resource Assessment Program, 2015.	****

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Chapter 7: Climate Change

This chapter provides a synthesis of climate change indicators, key findings, and discussion of opportunities for climate change mitigation and adaptation in forest management.

INDICATORS

ⓘ7.1 Temperature

ⓘ7.2 Precipitation

ⓘ7.3 Carbon Storage - Forests

ⓘ7.4 Carbon Sequestration

SUMMARY

Climate greatly influences forest and range ecosystem dynamics and the environmental services that they produce, as well as the type, composition and productivity of vegetation. Future climate change scenarios predict increases in temperature (ⓘ7.1), changes in the amount and distribution of precipitation (ⓘ7.2), changes in spring runoff (ⓘ9.3), and increases in climatic water deficit (ⓘ9.4) - a measure of water stress. Altering these fundamental components of climate can result in changes in tree growth, range and distribution of species, and disturbance regimes. These include changes in the timing, frequency and extents of wildfires, pest infestations, and other agents of disturbance.

In California, climate change is leading to longer, hotter and drier summers, with more pronounced fire activity and increased tree mortality from pest outbreaks. Extreme weather events, hotter droughts and severe flooding are expected to occur more frequently with global warming. While California's forests currently have high carbon stocks (ⓘ7.3) and are functioning overall as a net sink (ⓘ7.4), in some forest types current conditions combined with these increases in wide-scale disturbances have the potential to reduce carbon storage and affect the capacity of forests to continue operating as a net sink.

Management practices, including fire suppression policies, also influence the balance of carbon stored in forests and wood products, and involve trade-offs between carbon sequestration, carbon storage in live trees versus wood products, and risk of loss from wildfire and pests. The Sustainable Working Forests chapter (Chapter 1) described a range of observed timber management emphases, each with unique implications for carbon:

- High timber emphasis: Emphasize high tree growth and sequestration rates in live trees, set harvest rotations to avoid risk of loss, and increase carbon stored long-term in wood products.
- Medium timber emphasis: Longer rotations, uneven-aged management, higher ecosystem services, and accept potentially higher risk of forest carbon loss for gains in ecosystem benefits.
- Low/no timber emphasis: Allow forests to grow and store carbon naturally, emphasize ecosystem services, but accept potentially higher risk of loss and lower carbon stocks in wood products.

Scientific uncertainty exists in terms of how climate will change, and how natural systems will respond. Under an uncertain future, it is possible that forest management fifty years from now could be quite different than it is now, in part to place a higher emphasis on managing for carbon. The role of research will be critical to explore new management paradigms, which could include changes in the use of genetic stock, planting a combination of species for different purposes (e.g. for wood products and for carbon storage), and innovative ways to reduce risk.

CAL FIRE has several programs to mitigate Greenhouse Gas (GHG) emissions and improve forest health including: reforestation, forestland conservation, fuels reduction, urban forestry, and forest pest management. Collectively, these programs support the state goals described in the Forest Carbon Plan to create healthy and resilient forests.

KEY FINDINGS

ⓘ7.1 Indicator: Average Annual Temperature

ⓘ Air temperatures have been increasing across California for decades.

ⓘ Statewide increases in air temperature are consistent with global trends (1–2°F).

ⓘ Minimum air temperatures are increasing faster than maximum air temperatures.

ⓘ7.2 Indicator: Annual Precipitation

ⓘ There is high interannual variability and no strong trend across the data record that covers more than 100 years of observational data.

ⓘ Wet years are commonly associated with El Niño events.

ⓘ Climate change is likely to create more extreme drought and flood events.

ⓘ Global Climate Models (GCM) have markedly different predictions for precipitation in future decades that vary with GCM and emissions scenarios.

ⓘ7.3 Indicator: Carbon Storage - Forests

ⓘ In 2015, total carbon storage in above and belowground living and dead plant materials in California's forests is just over 2 billion metric tons.

ⓘ Two-thirds of carbon storage is on federal, state, and other public lands.

ⓘ Total carbon storage is greatest across the Sierra/Cascades (0.95 billion metric tons), Klamath/Interior Coast Ranges (0.57 billion metric tons), and North Coast regions (0.27 billion metric tons).

ⓘ Carbon density varies by region and is greatest across the North Coast region.

ⓘ7.4 Indicator: Carbon Sequestration – Live Trees

ⓘ Based on changes in the aboveground live tree pool in 2015, California forests remaining forests sequester 0.79 metric tons (MT) CO2e/acre/year, equating to 23.9 MMT CO2e/year. For perspective, this would be equivalent to sequestering 5% of the total greenhouse gas emissions reported in the state for 2015.

ⓘ Federally-owned U.S. Forest Service (USFS) timberlands experience lower harvest rates than private timberlands, have higher growth rates than USFS reserve lands, and sequester 0.90 MT CO2e/acre/year.

ⓘ Mortality outpaces growth on USFS reserve forestlands at the rate of -0.20 MT CO2e/acre/year.

ⓘ On private corporate timberlands growth is high and exceeds removal from harvest and mortality, reflecting sustained yield. These lands sequester 0.78 MT CO2e/acre/year and contribute the most to additional carbon storage in harvested wood products.

ⓘ On private non-corporate timberlands timber harvest is not the primary objective. These lands show increasing inventories with the highest growth rates and net sequestration (2.77 MT CO2e/acre/year).

ⓘ When flux from all forest pools are accounted for, including soils, as well as non-CO2 emissions from fire and flux from forest land-use conversions, net sequestration is 32.8 MMT CO2e/year.

DISCUSSION

Climate can greatly influence the health of forest and range ecosystems. Climate influences the type, mix and productivity of species. Global Climate Change models incorporate emissions scenarios that predict future conditions in temperature, changes in the amount and distribution of precipitation, and other climatological variables [1]. Altering these fundamental components of climate can result in changes in tree growth, changes in the range and distribution of species and alteration to disturbance regimes (e.g. wildfires, outbreaks of pests, invasive species). While disturbances occur regularly in nature, large changes in the extent and intensity of disturbance could make forests less resilient and possibly lead to shifts from forests to other vegetation types. Forest types or species with restricted ranges may be more vulnerable than others, as well as areas that are already under stress from land use (i.e. expanding wildland urban interface) and management.

The influence that climate has on disturbance regimes may already be affecting forests and rangelands. In California, extended drought and earlier snowmelt are leading to longer and drier summers with more pronounced fire activity. Relatively small changes in temperature and precipitation can affect reforestation success, growth and forest productivity. Summarized below are changes in climate and their effects that have already been detected and those that are expected under future climate scenarios.

Global Warming

Carbon Dioxide (CO2) is a naturally occurring gas in the Earth's atmosphere and is used by green plants to make carbohydrates for growth. CO2 and other greenhouse gases trap energy radiated from the Earth into the atmosphere, where some of the energy is absorbed and redirected back to the Earth's surface. CO2 is released to the atmosphere through natural processes, but rates of CO2 release and accumulation to the atmosphere have sharply increased through human activities. Increased use of fossil fuels over time has resulted in a steady increase in atmospheric CO2 concentration that is particularly pronounced in recent decades [2] (Figure 7.1). Increases in CO2 and other greenhouse gases change the overall energy balance for the planet, a process known as radiative forcing.

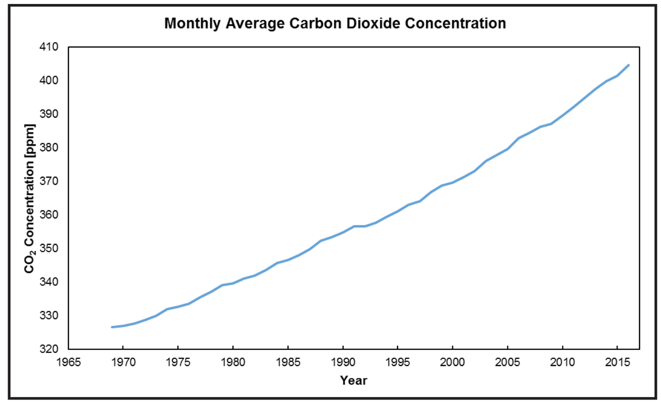


Figure 7.1: Carbon Dioxide Concentrations Measured from Scripps CO2 Program in La Jolla, CA.

Data Source: [2] Keeling et al., 2017.

Air Temperatures

California's climate, along with the global climate, is warming. Globally, average surface temperatures (combined land and ocean) have shown an increase of 1.53°F over the period 1880–2012 [3, 4]. In addition, each of the last three decades have been successively warmer and the last three consecutive years have been the warmest on record. Temperature increases in California are similar to the global trend. In the past 100 years, California's average annual air temperature has increased by 1–2°F (ⓘ7.1) (Table 7.1). Both minimum and maximum air temperatures have increased, though minimum air temperatures are increasing at a faster rate [5, 6]. For example, minimum air temperatures in some locations have increased by as much as 4°F over the past 100 years. There is some variation in the rate of warming among ecological regions in California. Warming in maximum air temperature has been greatest for ecological units including: Sierra Nevada, Mono and Southeastern Great Basin (Eastside), Modoc Plateau, and Southern California Mountain and Valleys.

Future climate conditions were represented using two global climate models (GCM); a warmer and wetter GCM (CNRM CM5) and a hotter and drier GCM

Table 7.1: Average Maximum Air Temperature Changes by Ecological Unit						
Ecoregion	Name	Mean Historical Maximum Temperature (°F)				Temperature Increase (1921–2015)
		1920–1950	1951–1980	1981–2010	2011–2015	
M262B	Southern California Mountains and Valleys	73	73	73	75	2
261B	Southern California Coast	74	73	74	74	1
M261F	Sierra Nevada Foothills	74	73	74	74	1
261A	Central California Coast	68	68	69	69	1
M262A	Central California Coast Ranges	74	73	74	75	1
M261E	Sierra Nevada	58	58	58	60	2
341DF	Mono and Southeastern Great Basin	66	65	66	68	2
263A	Northern California Coast	67	66	67	67	0
M261ABC	Northern California Coast Ranges	67	67	67	68	1
342B	Northwestern Basin and Range	62	62	62	64	2
M261D	Southern Cascades	61	60	61	62	1
M261G	Modoc Plateau	60	59	59	61	1

Data Source: [23] Thorne, et al., 2017.

(MIROC ESM). Both GCMs predict continued warming, but the amount of warming varies among GCM and Representative Concentration Pathway (RCP) emissions scenarios (RCP 4.5 and RCP 8.5). Based on the two GCMs shown in Figure 7.2, annual maximum air temperatures are predicted to increase by 3–14°F by 2099, depending on GCM and ecological unit.

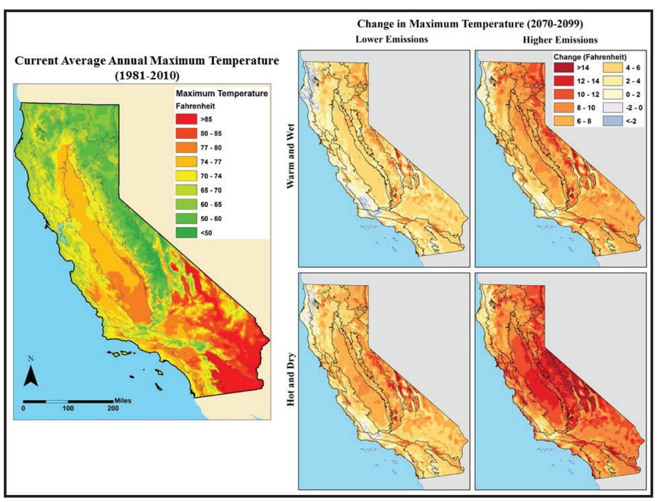


Figure 7.2: Current Average Annual Maximum Temperature and Change in Maximum Temperature by 2070–2099 Under Four Climate Scenarios. Maximum daily air temperatures are predicted to increase substantially under estimated future climate conditions. The current temperature is represented as the 30-year average (1981–2010) and compared to predictions from Global Climate Models (MIROC ESM, CNRM CM5) under RCP 4.5 and RCP 8.5 emissions scenarios.

Data Source: [23] Thorne, et al., 2017.

Precipitation

Precipitation in California is characterized by high interannual variability. Analysis of precipitation data from over 100 years showed no statistically significant trend [5] (ⓘ7.2). The precipitation data shows periodic fluctuations between wet and dry years (Table 7.2). In addition, during the latest drought all ecoregions showed a significant decline in precipitation compared to the 30-year average (1981–2010), and forests experience substantial water stress [7].

Under a warmer climate, researchers suggest that severe droughts may occur more frequently and intensify [8]. In addition, as temperatures warm, more precipitation will fall as rain. Thus, snowpack will continue to decline and peak runoff from snowmelt will occur earlier in the year leaving less water available to vegetation during the growing season. Future patterns and amount of precipitation are much more difficult to predict and Global Climate Model estimates are highly variable (Figure 7.3). An analysis of predicted precipitation from GCMs showed a slight tendency towards wetter conditions and increased extremes in precipitation from year to year [9].

Hydrology

Recent winters have been warmer and snowmelt has begun sooner [10] (ⓘ9.2). The timing of snowmelt and spring runoff can lead to longer dry periods in the summer months which can reduce soil moisture available for forest plants. With warming temperatures, the peak in spring runoff is now occurring sooner [11, 12] (ⓘ9.3). Regionally, it has been estimated that spring runoff (April–July) has declined over the last 100 years by 9% on the Sacramento River and by 6% on the San

Table 7.2: Average Annual Precipitation by Ecological Unit						
Ecoregion	Name	Historical Mean Precipitation (inches)				"Change in Mean Precipitation 1981–2010 to 2011–2015"
		1920–1950	1951–1980	1981–2010	2011–2015	
M262B	Southern California Mountains and Valleys	19	19	19	13	-6
261B	Southern California Coast	23	24	25	19	-5
M261F	Sierra Nevada Foothills	24	26	27	21	-6
261A	Central California Coast	26	28	29	21	-8
M262A	Central California Coast Ranges	15	16	17	12	-5
M261E	Sierra Nevada	35	38	39	30	-9
341DF	Mono and So. Great Basin	9	9	10	8	-2
263A	Northern California Coast	52	57	56	48	-8
M261ABC	Northern California Coast Ranges	48	54	54	44	-10
342B	Northwestern Basin and Range	11	12	12	11	-1
M261D	Southern Cascades	32	37	37	30	-7
M261G	Modoc Plateau	16	18	18	16	-3

Data Source: [23] Thorne, et al., 2017.

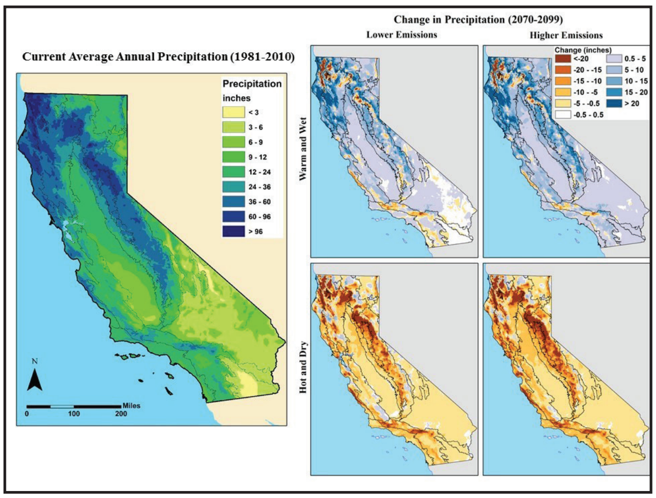


Figure 7.3: Current Average Annual Precipitation and Change in Precipitation by 2070–2099 Under Four Climate Scenarios. Future precipitation patterns are uncertain and difficult to predict. Global Climate Models predict both increases and decreases based on the model and the emissions scenario. The current precipitation is represented as the 30-year average (1981–2010) and compared to predictions from Global Climate Models (MIROC ESM, CNRM CM5) under RCP 4.5 and RCP 8.5 emissions scenarios.

Data Source: [23] Thorne, et al., 2017.

Joaquin River [5]. The recent drought years have also caused a substantial decline in spring runoff [13] (Figure 7.4). Climate models forecast this trend to continue. In addition to warmer temperatures, climate models predict decreases in snow accumulation and a greater percentage of precipitation from rainfall [14]. Climate model simulations suggest that snow pack losses are likely to occur more quickly in milder climates and at lower elevations. Slower losses are expected at higher elevations and particularly in the mountainous regions in the southern Sierra [15]. This has been shown through predictive models to affect the timing of river flows in the Sierra that are supported by snowmelt [16]. Research has speculated that a change resulting in earlier and shorter spring runoff from snowmelt will likely affect water supply [17]. See the Water Resources chapter (Chapter 9) for additional information on climate change impacts to water resources.

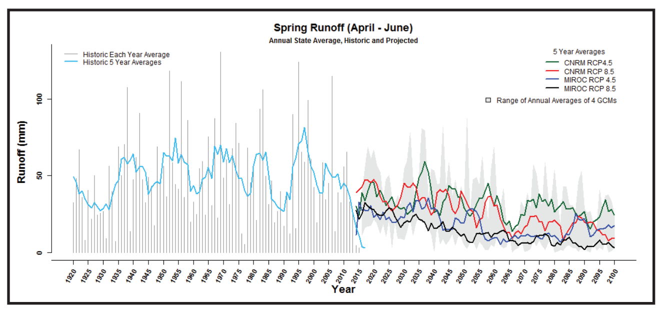


Figure 7.4: Spring Runoff (April–June). Spring runoff showed a steady decline during the recent drought period (ⓘ9.3). The recent drought is shown in blue line, at the end of the current record, and four modeled future climates are portrayed in colored lines on the right.

Data Source: [23] Thorne, et al., 2017.

Wildfire

The size, severity, duration, and frequency of wildfires are greatly influenced by climate. While fires are a natural part of the California landscape, the fire season in California and elsewhere seems to be starting sooner and lasting longer, with climate change being suspected as a key mechanism in this trend [18, 19]. An increase in wildfires has been attributed in part to warmer spring and summer temperatures, reduced snowpack and earlier spring snowmelt [15, 19]. Warmer and drier conditions may also lead to increased moisture stress that can result in an earlier and thus longer fire season. An increase in wildfire frequency may mean an increase in GHG and other pollutant emissions and a corresponding increase in the number of days exhibiting poor air quality.

The length of fire season is also estimated to have increased by 75 days across the Sierra and seems to correspond with an increase in the extent of forest fires across the state [19]. California wildfires have burned an average of roughly 500,000 acres annually over the last two decades (1996–2015), and eight of the ten largest fire years occurred during that same time frame. This represents an increase of 179% in average annual acres burned from the current time frame (1996–2015) to the previous 20-year period (1976–1995).

Wildfire risk will continue to be highly variable across the state. Research suggests that large fires and burned acreage will increase by as much as 100% or more throughout the century [20, 21] with some declines after mid-century due to vegetative-type conversions.

Impacts on Tree Species

With warmer temperatures, tree species in California are likely to respond by migrating both northward and to higher altitudes [22]. As the rate of climate change increases some tree species may not be able to adapt to changed conditions. Species with currently restricted ranges will be most vulnerable, while species with broader climate tolerances may be able to adapt more easily. Sub-alpine forests and related plant species are particularly vulnerable. While initial warming may increase moisture in spring due to earlier melting of snowpack coinciding with springtime growth conditions, the mid- and end-century expectation is for these trees to become more drought stressed, and their habitat range is likely to be compressed with little room to expand. Lack of adequate soil depth and geologic barriers at higher elevations may also be factors that would constrain their uphill expansion.

The simulated effect of climate on the distribution of vegetation types has been analyzed for several different climate change scenarios [23]. The results show that 15 of 31 tree species are projected to lose 75% of their current suitable range by 2099. See the Wildlife chapter (Chapter 10) for a discussion of impacts on individual tree species. In addition, Thorne et al. [23] evaluated the climate exposure to California Wildlife Habitat Relationship (CWHR) vegetation types (Figure 7.5). This analysis provides a measure of stress to vegetation from changing climatic conditions. Under future climate conditions, the South Sierra shows substantial vulnerability to vegetation from changing climate conditions. This is particularly shown under predictions leading to a hot and dry climate with higher emissions.

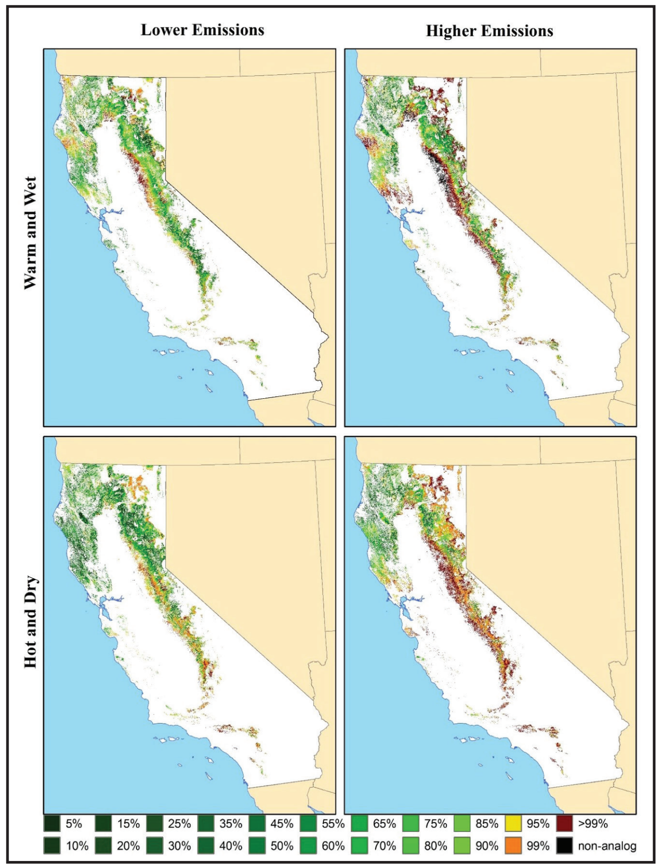


Figure 7.5: Vegetation-Climate Exposure Map of 6 WHR Types to the End of the Century (2070–2099). The darkest green colors are the locations at the center of the climate conditions for each type, while the orange and red colors are considered climatically marginal. The black color refers to areas where the vegetation will experience climate conditions by the end of century that currently do not occur. The lower emissions scenario is represented by RCP 4.5 and RCP 8.5 represents the higher emissions scenario.

Data Source: [23] Thorne, et al., 2017.

Carbon Storage - Forests

A 10-year rolling average of data collected for the U.S. Forest Service Forest Inventory and Analysis (FIA) program between 2006–2015 demonstrates that in 2015 California forests are storing 1.30 billion metric tons (MT) of carbon in aboveground biomass and 734 million metric tons (MMT) of carbon below ground, including soil organic carbon [24] (Figure 7.6) (ⓘ7.3). This amounts to an approximate total of 2 billion MT of carbon. Over 66% of carbon storage is on federal, state, and other public lands. Total carbon storage is greatest across the Sierra/Cascades, Klamath/Interior Coast Ranges, and North Coast regions. Carbon density varies by region and forest type (Figure 7.7, Figure 7.8).

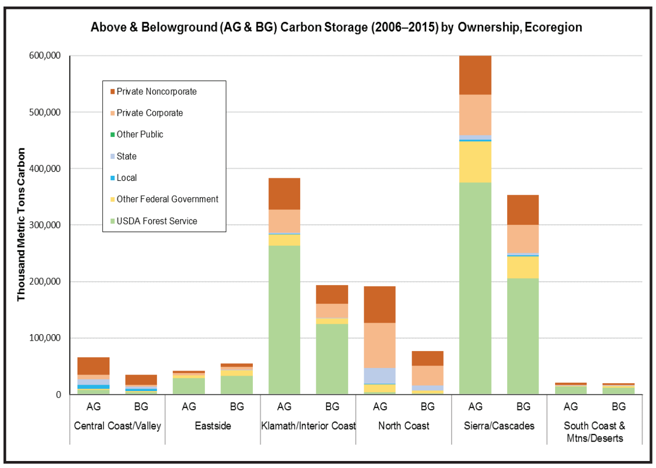


Figure 7.6: Above and Belowground Forest Carbon Storage by Ecoregion. Statewide a total of 2 billion metric tons of carbon on Forestland (ⓘ7.3).

Data Source: Derived from [24] Christensen, et al., 2017.

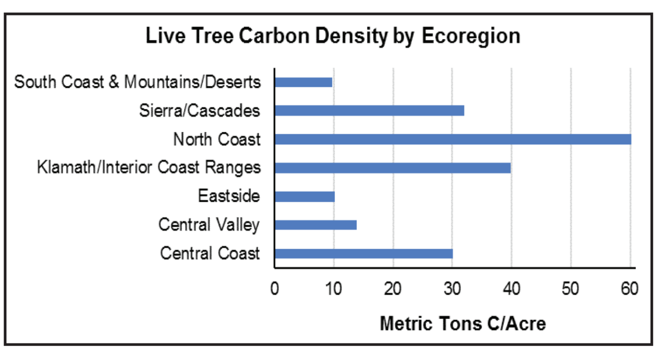


Figure 7.7: Live Tree Carbon Density by Ecoregions. Note the density is estimated for just forested lands within each ecoregion.

Data Source: Derived from [24] Christensen, et al., 2017.

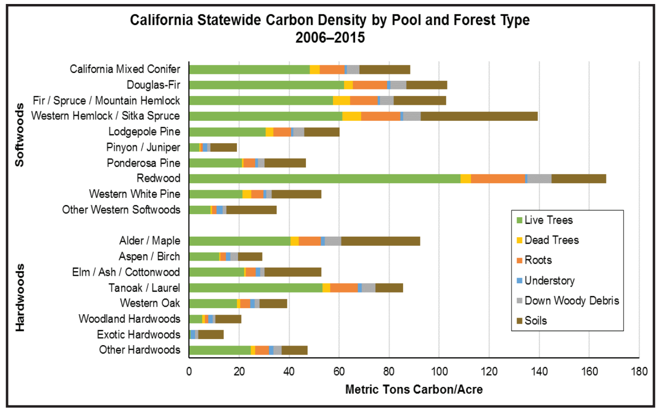


Figure 7.8: Estimates of Carbon Density by Forest Type in California for all Stocking Levels, 2006–2015.

Data Source: [24] Christensen, et al., 2017.

Forest Carbon Sequestration – Live tree

Data from the FIA program was also used to evaluate changes in growth, mortality, and removals in the aboveground live (AGL) tree carbon pool on all ownerships on plots first measured between 2001–2005 and re-measured between 2011–2015 [24]. This analysis shows variation in forest carbon trends for different ownerships on a per acre basis (Figure 7.9) (ⓘ7.4). Factors contributing to these differences include the relatively higher growing capacity of much of the private timberlands and the different management behavior of public and private forests. For clarification, forest is considered timberland if it is growing on ground that is capable of significant annual tree volume growth and considered available for timber management, even if it isn't managed for that objective. Reserve forestland is non-timberland and is permanently reserved from harvest through statute or administrative designation, such as designated wilderness.

Federally-owned USFS timberlands are less productive and experience much lower harvest rates than private corporate timberlands. They also have higher per-acre growth than reserve forestlands. These forests are sequestering carbon at a rate of 0.90 metric tons carbon dioxide equivalent (CO_2e)/acre/year. On USFS reserve forestlands tree mortality outpaces growth, resulting in a net loss in live tree carbon of -0.20 metric tons CO_2e/acre/year. Gross growth is highest on private timberlands. On private corporate timberlands growth exceeds removal from harvest and mortality, reflecting sustained yield and a carbon sequestration rate of 0.78 metric tons CO2e/acre/year. On private non-corporate timberlands, timber production is not the primary objective. These lands show increasing inventories with moderate levels of tree mortality and the highest rates of growth and net sequestration (2.77 metric tons CO2e/acre/year). Private corporate timberlands contributed 70% of the 2012 timber harvest while private non-corporate timberlands contributed 13% [25]; private lands are therefore successful at maintaining positive sequestration rates in standing forest carbon stocks and are an important contributor to carbon storage in harvested wood products (HWP). Other carbon benefits may be associated with avoided fossil fuel emissions from burning wood for energy and using wood in place of more energy-intensive building products.

Overall, in 2015 aboveground live trees in California forests are sequestering carbon at a rate of 0.79 metric tons CO2e/acre/year. This equates to a net gain of 23.9 MMT CO2e/year (Table 7.3), and for perspective would be equivalent to sequestering 5% of the total greenhouse gas emissions reported in the state for 2015 [26]. When flux from all forest pools are accounted for, including soils, as well as non-CO2 emissions from fire, and flux from forest land-use conversions, net sequestration is 32.8 MMT CO2e/year [24]. Based on this information, the state is currently meeting the AB 1504 goal of sequestering 5 MMT CO2e/year, assuming that carbon flows associated with HWP do not significantly counteract sequestration exhibited in the forest carbon pools. Due to differences in the amount of forestland in each owner and reserve class, the total impact to net changes in carbon stocks varies. Although private non-corporate timberlands have the highest rate of sequestration and contributed slightly more carbon per year than USFS timber and reserve lands, they cover only a quarter of the forestland base compared to USFS timber and reserve lands. Nevertheless, USFS timber/reserve lands store the highest amount of carbon due to their greater areal extent.

Some studies suggest certain forest types, such as mixed conifer forests of the Sierra Nevada, have changed when compared to historic conditions, with more of the current carbon stock in higher densities of small, fire-prone trees [27-30]. These forests are thought to be vulnerable to fire, pest outbreaks, and other disturbance, especially

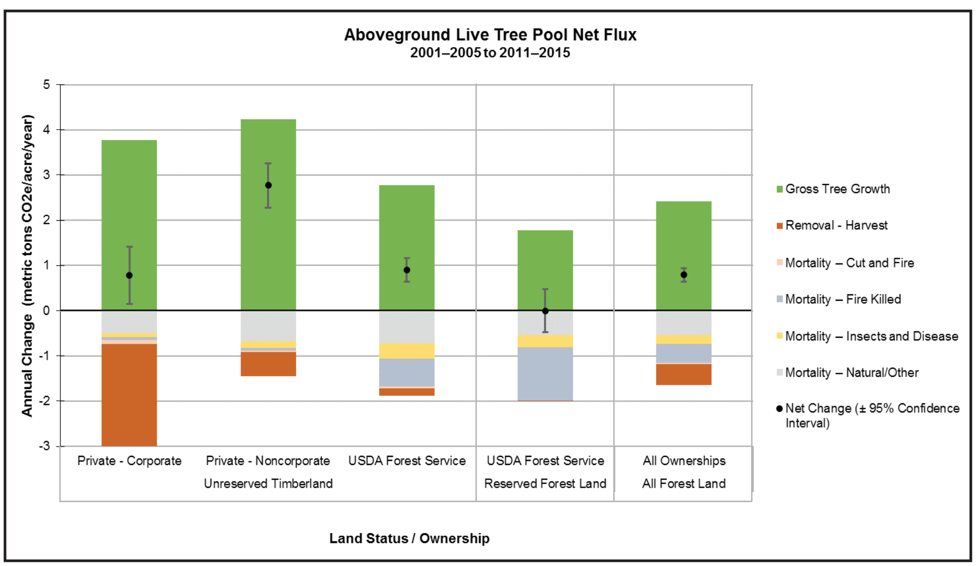


Figure 7.9: California Forest Carbon: Growth, Mortality, Removals and Net Change by Owner. Analysis of FIA re-measurement plots (2001–2005; 2011–2015) shows growth, removals, mortality and net change in the aboveground live tree pool for different ownerships (ⓘ7.4). When looking at all forestlands combined, California forests are performing as a net sink, sequestering carbon at a rate of 0.79 ± 0.15 metric tons CO2e/acre/year. When results are parsed out by smaller categories, trends are apparent but uncertainty increases. The estimate for USFS reserve forestland carries a large degree of variability, particularly when viewed in context with the very small mean value -- the 95% confidence interval spans the zero-net change value. However, the data supports confidence that while modest, these lands are likely serving as atmospheric sources of carbon.

Data Source: [24] Christensen et al., 2017.

Table 7.3: Growth, Mortality, and Removals on Private and Federal U.S. Forest Service Timberlands and USFS Reserved Forestland (thousand metric tons per year)										
	Unreserved Timberland						Reserved Forestland		All Forests[2]	
	Private Corporate		Private Non-Corporate		USFS		USFS			
	C	CO_2e	C	CO_2e	C	CO_2e	C	CO_2e	C	CO_2e
Gross Growth	4,797	17,589	2,827	10,368	6,755	24,770	1,946	7,135	19,962	73,199
Removal - harvest	-2,871	-10,527	-362	-1,327	-399	-1,464	-6	-22	-3,721	-13,645
Mortality – fire killed	-59	-217	-43	-157	-1,500	-5,499	-1,279	-4,689	-3,427	-12,566
Mortality – cut and fire[1]	-127	-466	-13	-49	-89	-326	0	0	-230	-842
Mortality – insects and disease	-115	-421	-100	-367	-836	-3064	-283	-1039	-1,562	-5,728
Mortality – natural/other	-634	-2,325	-454	-1664	-1,743	-6392	-601	-2203	-4,511	-16,543
Net Change	991	3,633	1,855	6,804	2,188	8,025	-223	-818	6,511	23,875
95% confidence interval +/-									1,248	4,575

[1]Mortality – Cut and fire: plots where tree mortality has occurred due to both harvest and fire.

[2]Total includes other private and public forestland not highlighted in the table (i.e., private and USFS unreserved “other forest,” other public reserved and unreserved forestland).

Data Source: [24] Christensen et al., 2017.

as changes in climate continue to affect the timing, frequency, intensity and extent of some disturbances. The ingrowth of small trees under the main canopy increases the likelihood of fire reaching the overstory canopy, where it can result in higher overall severity and the death of large trees. Historically, the low to mid-elevation dry mixed and coniferous forests in California were highly variable, but in general were largely comprised of fewer, very large trees [28, 31]. These historical forest structures were considered to provide more stable carbon storage than contemporary forest given the overall resilience of historical forests to disturbance [32-35]. Consequently, much of the current stocks of aboveground live carbon are not stable and are likely to show significant losses over a 50 to 100-year horizon, especially as changes in climate continue to affect the timing, frequency, intensity and extent of disturbances such as wildfire and pest outbreaks. As shown in the results described above, USFS reserve forestlands are already exhibiting this trend.

Forest Carbon Accounting – Other Studies

Estimates of carbon sequestration for California forests have also been conducted using remote sensing methods in combination with FIA data developed for the California Air Resources Board. Using these methods, Gonzalez et al. [36] reported a carbon stock of 840 ± 210 MMT C in 2010 and a net loss in AGL carbon of -29 ± 10 MMT C in California forests remaining forests for 2001–2010. There is an approximate error of 25% associated with the C stock estimate and a 35% associated with the flux estimate. However, the authors noted that the remote sensing based methods employed in the study exhibited sensitivity to disturbance, and less sensitivity to tree growth. Working from re-measurement data reported in FIA database version 6.0 of plots first measured between 2001–2002 and re-measured between 2011–2012, the authors posited a decadal statewide average tree growth rate of approximately 6% or +47 ± 8 MMT C, representing tree growth undetected by remote sensing. By including this estimated undetected growth, the 2001–2010 AGL stock-change in forestland remaining forestland evaluates to +18 MMT C and would put the 2010 carbon stock at 888 MMT C. When annualized, the AGL stock-change rate evaluates to +2 MMT C/year or +7.3 MMT CO2e/year. These figures are less than the 2010 AGL stock value reported directly by the FIA program of 1,025 ± 28 MMT C stock and a 2015 annual gain of 23.9 ± 4.6 MMT CO2e sequestration per year [24]. There is an approximate 3% error associated with the stock estimate and 19% associated with the flux estimate. Some of the differences may be attributed to the different time periods of analysis, land category definitions such as inclusion of shrub-dominated land in the definition of forestland in the Gonzalez estimate but not in the FIA estimate, slight differences in the carbon fraction of biomass used in the calculations for each estimate, and trade-offs associated with sources and methods. Opportunities to further understand processes occurring in California’s forests will accrue with advances in both remote sensing techniques and as the FIA program continues to refine methods to calculate carbon pools and to account for disturbance processes. For a more detailed comparison between forest carbon stocks and sequestration values reported in Christensen et al., [24] and those reported for the California Air Resources Board, refer to Christensen et al., [24].

Carbon Storage - Harvested Wood Products

In the short-term, some forest management activities remove carbon from forests in the form of harvested woody material. These activities include thinning, timber harvest, and mechanical methods of fuels treatment. Under some circumstances, the removed carbon may be utilized in ways that can have net positive GHG benefits [37-39]. For example, the carbon contained in a long-lived wood product can persist in storage for long periods, while the forest regrows and stores more carbon. Substituting wood products may reduce demand for more fossil fuel energy or GHG-intensive building materials, such as concrete or steel. Wood burned for bioenergy may result in overall reductions in GHG emissions through avoided fossil fuel emissions.

The primary products of commercial timber operations in California are lumber, other wood products, and biomass energy (bioenergy) [25]. These primary products are converted into secondary products (e.g., buildings and landscaping products) where they can reside for a period of time. The various uses of wood products follow different life-cycle pathways and have different rates of disposal. Once disposed, discarded wood products decay over time back to the atmosphere, the process of which is dependent on the manner of disposal. In anaerobic environments, wood decay ceases after several decades, leaving a carbon fraction that persists in solid form indefinitely.

Timber harvesting activities in California have been on the decline since the mid-1980s (ⓘ1.4). Timber harvesting in California was 1.425 billion board feet in 2012 [25], representing a decline of 18% from 2006 (1.733 billion board feet) and of 36% from 2000 (2.250 billion board feet). However, since reaching a low of about 750 million board feet in 2009, harvest has picked up somewhat to approximately 1.591 billion board feet in 2015 [40].

Using 2012 timber harvest volumes for the state of California [25], it was determined for the California Forest Carbon Plan that 1.1 million metric tons of carbon was processed into finished lumber and other products, while 1.2 million metric tons of carbon was burned for bioenergy [41]. These calculations include additional utilization of harvest byproducts such as slash and bark. In the case of slash, more remains in the forest that transfers carbon to dead wood pools and eventually decomposes, or is disposed of through open pile-burning and is not accounted for in the carbon calculations. The amount of slash associated with the 2012 harvest is approximately 108 million cubic feet [42], representing 0.59 MMT C. This does not include sub-merchantable material cut for forest health and fuels reduction. If increased utilization of logging residuals and sub-merchantable material were economically and logistically possible, greater carbon benefits could be incurred.

Further analysis using national and state mill efficien¬cies, wood product lifetimes and factors governing the fate of discarded wood products as reported by Smith et al. [43] and by Stewart and Nakamura [39] demonstrates how much carbon remains stored in harvested wood products 100 years after harvest [41]. The ten-year average wood products in storage from harvests between 2001–2010 [40] (excludes additional utilization of slash or bark) range between 541,604 and 599,940 metric tons of carbon per year (Table 7.4). Long-term storage estimates from harvest activities on public lands ranges from 53,394 to 59,146 metric tons of carbon per year, while estimates range from 488,208 to 540,796 metric tons of carbon per year from harvest on private lands.

Table 7.4: California Ten-Year Average Harvested Wood Products (2001–2010)

	Carbon Storage After 100 years (metric tons)		
Method	Public Ownership	Private Ownership	Total
Smith et al., 2010, 2006	53,394	488,208	541,604
Stewart and Nakamura, 2012	59,146	540,796	599,940

Data Sources: Revised from [44] Saah et al., 2016 for [41] FCAT, 2017.

If the same analysis is applied to the 2012 timber harvest volumes, carbon values remaining in storage after 100 years are similar to those based on the 2001–2010 harvests (Table 7.5). When converting volumes in board feet to cubic feet, it is not appropriate to use the mathematical board foot to cubic foot ratio as it does not reflect losses (such as from trim or saw kerfs), diameter variations, nor the estimated recovery of lumber per board feet [45, 46]. Board foot to cubic foot conversions can also vary over time [47]. The 2012 California timber harvest volumes associated with various primary products are already converted from board feet to cubic feet using mill data corresponding to the same year, so resulting carbon calculations are likely more accurate than the calculations completed for Table 7.5. These calculations do not address additional emissions from utilization of slash and bark for bioenergy in year 1 or additional storage benefits from utilization of bark for wood products.

Table 7.5: Carbon Remaining in Storage 100 Years After 2012 CA Timber Harvest (metric tons)

Method	Total
Smith et al. (2006)	483,075
Stewart and Nakamura (2012)	553,057

Data Sources: Revised from [44] Saah et al., 2016 for [41] FCAT, 2017.

This analysis does not address the allocation of primary products (i.e. lumber, veneer, etc.) to specific end-uses (i.e. construction, manufacturing, etc.), the associated wood product lifetimes, carbon storage and emissions from products harvested in previous years, wood removed from the forest for commercial or personal-use fuelwood, or avoided emissions from wood product substitution of more energy intensive materials or from burning wood instead of fossil fuels for energy. In 2018, a more comprehensive inventory will occur in the second AB 1504 Forest and Harvested Wood Product Carbon Inventory report for the Board of Forestry and Fire Protection and will build off the work completed for the California Forest Carbon Plan.

Opportunities

Forests provide a broad range of environmental services, carbon storage being just one of these provisioning services. However, forests in California are already feeling the effects of a changing climate. The composition of forests and associated ecosystem services that we see today may not be present in coming decades. Forests that have been impacted or are most vulnerable from wildfire and drought impacts need stand management and restoration treatments. Delaying this investment in our forests reduces their resilience to impacts associated with climate change. Given the diversity of California's forestlands, the management of forests for carbon and related climate benefits will vary. Forests along the North Coast may be capable of sustaining increased carbon sequestration rates without incurring higher risks of loss. Alternatively, forests in the Sierra may need a strategy that is focused more on creating forests with lower stand density that are more resilient to disturbance from wildfire, pests, and other forest health issues. The California Forest Carbon Plan [41] outlines a range of management options that include:

- Increased use of easements to retain forested ecosystems.
- Increased use of forest carbon offsets to provide financial incentives for forest landowners.
- Forest Health Treatments – Increased use of thinning and prescribed burning to reduce wildfire risk and to restore forest health.
- Restoration – Replanting of forests that have been impacted from wildfire and mortality from pest outbreaks using climate-smart forestry practices.
- Increased use of wood products to improve carbon storage from working forests.
- Emphasis on forest management treatments that protect headwater forests, including restoration of mountain meadows.

Indicator: Average Annual Air Temperature

ⓘ7.1

Which Montreal Protocol Criteria does the indicator evaluate?

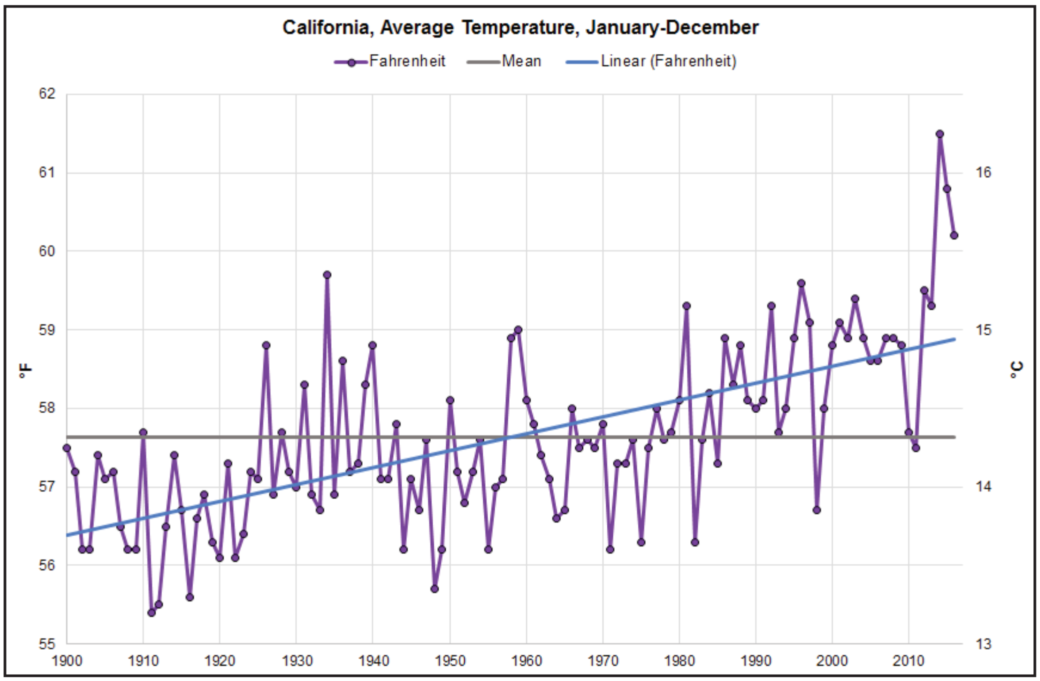
MPC5: Maintenance of forest contribution to global carbon cycles

Why is the indicator important?

Increases in air temperature are predicted because of climate change. Statewide air temperatures have been warming and this is consistent with global trends. Increases in air temperature have a broad range of environmental effects relating to forest health, distribution of forest vegetation, wildfire regimes, and public health issues.

What does the indicator show?

The indicator shows trends in average annual air temperature across decades.



Key Findings:

ⓘ Air temperatures have been increasing across California for decades.

ⓘ Statewide increase in air temperature are consistent with global trends (1–2°F).

ⓘ Minimum air temperatures are increasing faster than maximum air temperatures.

Data Sources and Quality

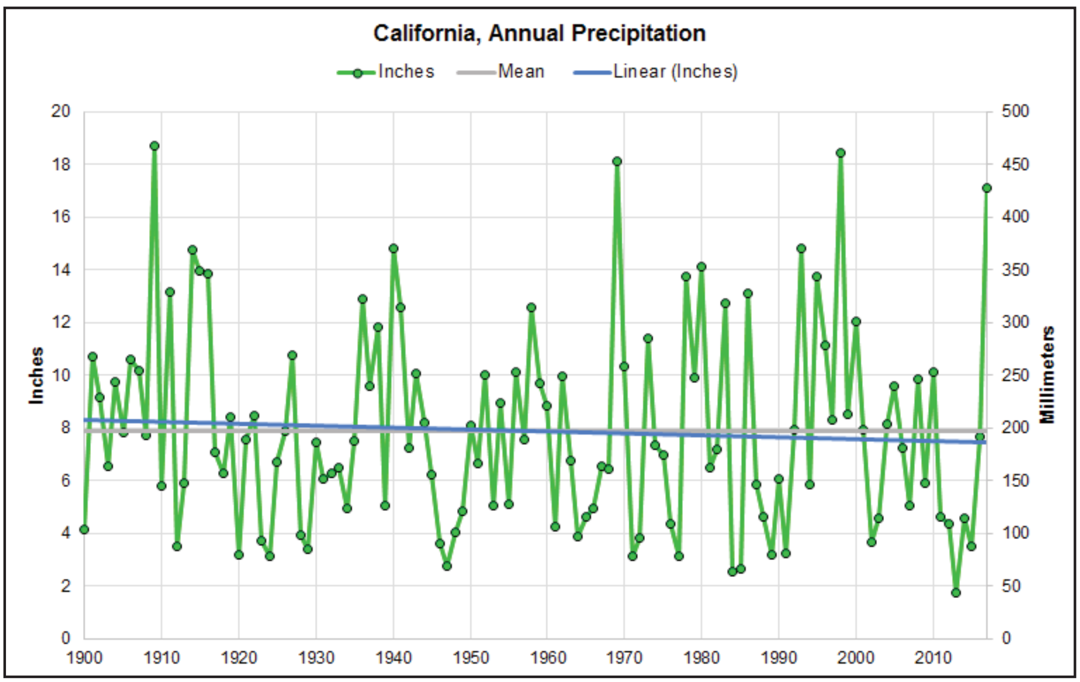
Data Theme	Source	Quality (5 star max)
Average Annual Air Temperature	Climate at a Glance: U.S. Time Series, NOAA, 2017.	****

Indicator: Annual Precipitation ⓘ7.2

Which Montreal Protocol Criteria does the indicator evaluate?
MPC5: Maintenance of forest contribution to global carbon cycles

Why is the indicator important?
Precipitation patterns have great influence on the composition of forest vegetation and influence seasonal moisture levels for fuel conditions. Wet years are often associated with El Niño events.

What does the indicator show?
The indicator shows trends in annual precipitation in California.



Key Findings:

ⓘ There is high interannual variability and no strong trend across the data record.

ⓘ Wet years are commonly associated with El Niño events.

ⓘ Climate change is likely to create more extreme drought and flood events.

ⓘ Global Climate Models (GCM) have markedly different predictions for precipitation in future decades that vary with GCM and emissions scenarios.

Data Sources and Quality

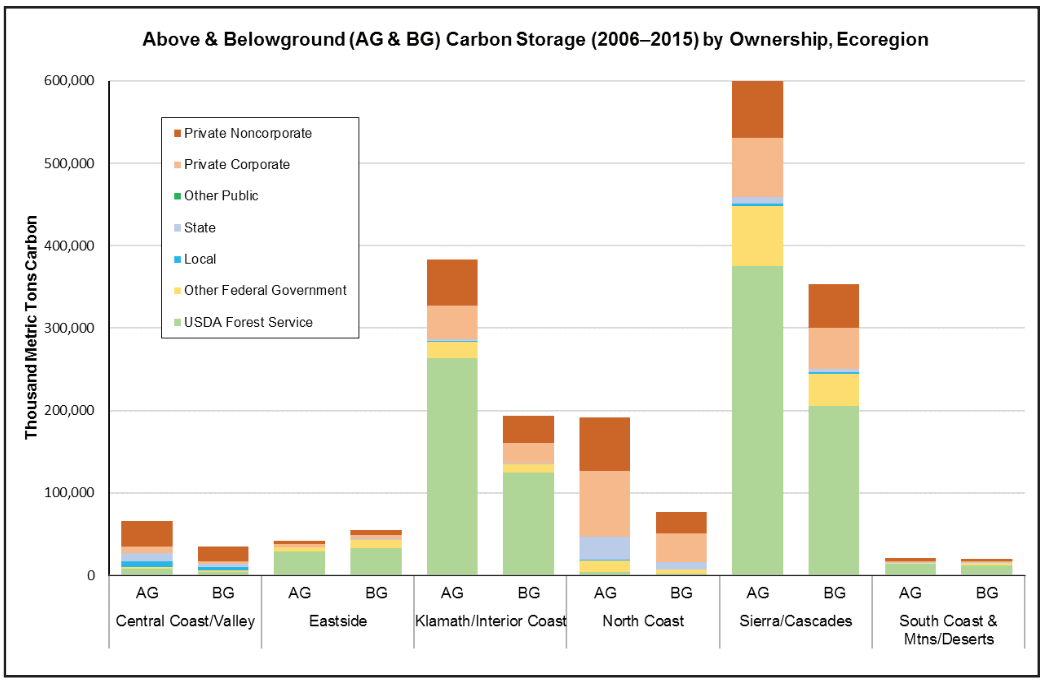
Data Theme	Source	Quality (5 star max)
Annual Precipitation	Climate at a Glance: U.S. Time Series, NOAA, 2017.	****

Indicator: Total Ecosystem Carbon Pools by Ownership, Ecoregion ⓘ7.3

Which Montreal Process Criterion does the indicator evaluate?
MPC5: Maintenance of forest contribution to global carbon cycles

Why is this indicator important?
Promoting storage of carbon in forests is recognized as one of the most important tools for offsetting emissions of greenhouse gases.

What does the indicator show?
The indicator shows above/belowground forest carbon stocks by ownership and ecoregion, 2006-2015.



Key Findings:

ⓘ 🔑 In 2015, total carbon storage in above and belowground living and dead plant materials in California's forests is just over 2 billion metric tons.

ⓘ 🔑 Two-thirds of carbon storage is on federal, state, and other public lands.

ⓘ 🔑 Total carbon storage is greatest across the Sierra/Cascades (0.95 billion metric tons), Klamath/Interior Coast Ranges (0.57 billion metric tons), and North Coast regions (0.27 billion metric tons).

ⓘ 🔑 Carbon density varies by region and is greatest across the North Coast region.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Forest Inventory Data	[24] Christensen et al., 2017	****

Indicator: Change in Ecosystem Carbon Pools by Ownership Group ⓘ7.4

Which Montreal Process Criterion does the indicator evaluate?

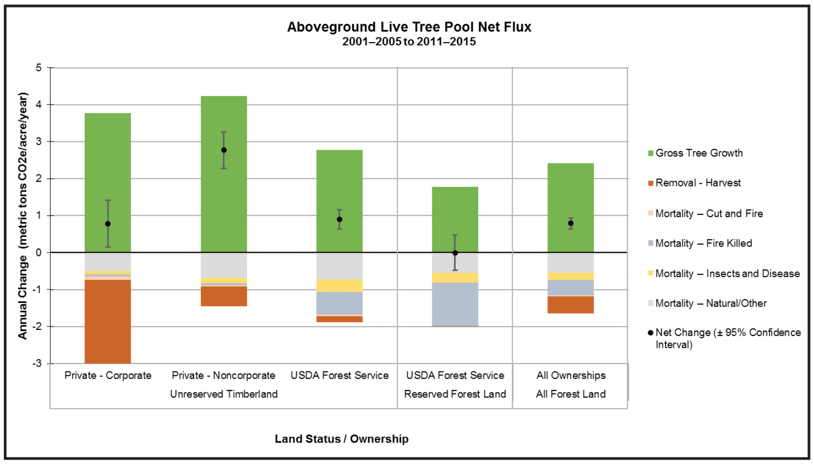
MPC5: Maintenance of forest contribution to global carbon cycles

Why is this indicator important?

Promoting storage of carbon in forests is recognized as one of the most important tools for offsetting emissions of greenhouse gases.

What does the indicator show?

The indicator shows net change in aboveground live tree forest carbon by owner/reserve classes.



Key Findings:

- ⓘ Based on changes in the aboveground live tree pool in 2015, California forests remaining forests sequester 0.79 metric tons (MT) CO2e/acre/year, equating to 23.9 MMT CO2e/year. For perspective, this is equivalent to sequestering 5% of the total 2015 greenhouse gas emissions reported.
- ⓘ Federally-owned U.S. Forest Service (USFS) timberlands experience lower harvest rates than private timberlands, have higher growth rates than USFS reserve lands, and sequester 0.90 MT CO2e/acre/year.
- ⓘ Mortality outpaces growth on USFS reserve forestlands at the rate of -0.20 MT CO2e/acre/year.
- ⓘ On private corporate timberlands growth is high and exceeds removal from harvest and mortality, reflecting sustained yield. These lands sequester 0.78 MT CO2e/acre/year and contribute the most to additional carbon storage in harvested wood products.
- ⓘ On private non-corporate timberlands timber harvest is not the primary objective. These lands show increasing inventories with the highest growth rates and net sequestration (2.77 MT CO2e/acre/year).
- ⓘ When flux from all forest pools are accounted for, including soils, as well as non-CO2 emissions from fire and flux from forest land-use conversions, net sequestration is 32.8 MMT CO2e/year.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Forest Inventory Data	[24] Christensen et al., 2017	****

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Chapter 8: California's Non-Metro Regional Economy

This chapter documents and compares the economic outcomes across the state and describes how California's rural performance compares with the rest of the nation's rural areas.


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INDICATORS

ⓘ8.1 Relative Performance

ⓘ8.2 Trends

ⓘ8.3 Prosperity

ⓘ8.4 Stress

ⓘ8.5 Structure

For nearly two decades non-metro California has outperformed U.S. non-metro in terms of employment, population percent change, and changes in personal income (ⓘ8.1). The 46-year span of history (1970–2016) trends upward for California's non-metropolitan economy (ⓘ8.2). Compared to the rest of the nation's non-metro regions, California has demonstrated remarkable signs of health and prosperity (ⓘ8.1). This does not trivialize the plight of many rural communities and families; the economy does not seem to work well for some white male Americans in midlife [1], or for some tribal communities [2]. Short and long-term unemployment has certainly been an overpowering and adverse force in the lives of many (ⓘ8.4), and environmental degradation has inflicted havoc on us all. But the region is not well characterized by crisis (ⓘ8.1). Still, there is too much inequality [3], and not enough upward mobility [4-9]. In addition, the lingering effects of the Great Recession are still felt. However, the structural makeup of the region indicates several years of consecutive job growth, and nationally the financial sector has stabilized (ⓘ8.5). In short, the story of the region is one of progress, moving towards full recovery from the Great Recession (ⓘ8.1).

Economists agree, we cannot freeze the structure of the employment opportunities to some past level [10-15]. The shift from natural-resource-based livelihoods to service-based industries has been underway for over 200 years [16-19]. Well into the twentieth century, rural industries such as ranching, farming, mineral extraction and logging contributed significantly to California's Gross Domestic Product (GDP). Today those mature industries provide an increasingly smaller fraction of employment and income opportunities in those areas (ⓘ8.5). This decline has been alarming to many rural residents ushering a feeling that something vital is being lost because of this transition [20-22]. That transition is characterized by a 'New West' where most employment is services-related (ⓘ8.5). The New West is characterized by an 'amenity gold rush' that attracts people in search of high quality living environments, which "has replaced the 'Old West' based on commodity extraction" [23].

Given these stark changes, many are concerned about the cultural fabric as they contemplate a changing way of life. This chapter will document and explore the structural shift and cultural concerns that contribute to the understanding of ourselves and our communities. The purpose of this chapter is to foster an understanding of what the economy is all about in rural areas, which in turn may provide a healthy place to start discussing important policy options that have historically been cloaked in brittle and divisive political discourse.

The chapter is organized as follows. First, we define the geographic scope of the region. We then look at the importance of land in terms of jobs, income and ecosystem services. Next up is a discussion of demographics and some political concerns. Then we turn to a focused discussion of people—the challenges they face, populations at risk and why some are thriving. We conclude with a short list of opportunities to address those challenges.

KEY FINDINGS

ⓘ8.1 Indicator: Relative Economic Performance

- Based on economic data from 2000–2016, non-metro California surpasses U.S. non-metro in terms of employment, population percent change, and increases in personal income.

ⓘ8.2 Indicator: Economic Trends

- From 1970–2016, population grew from 425,424 to 832,574 people, a 96% increase.
- From 1970–2016, employment grew from 171,829 to 406,789, a 137% increase.
- From 1970–2016, personal income grew from $10,833.9 million to $37,193.9 million (2016 dollars), a 243% increase.
- From 2000–2016, migration (intra-national and international) contributed to 57% of population growth.

ⓘ8.3 Indicator: Economic Prosperity

- From 1970–2016, average annual earnings per job grew from $46,331 to $47,790 (2016 dollars), a 3% increase.
- From 1970–2016, per capita income grew from $25,466 to $44,673 (2016 dollars), a 75% increase.

ⓘ8.4 Indicator: Economic Stress

- Since 1990, the annual unemployment rate ranged from a low of 6.2% in 2000 to a high of 16.3% in 1982. As of July 2017, the monthly unemployment rate for the region was 5.8%.
- In 2016, people with disabilities accounted for 18 % of non-institutionalized civilian population compared to 15.1% for the nation as a whole.
- In 2016, people without health insurance accounted for 11.6% of non-institutionalized civilian population.

ⓘ8.5 Indicator: Economic Structure

- In 1970, proprietors (the self-employed) represented 23% of total employment (full & part-time jobs). By 2016, proprietors represented 31% of total employment.
- From 1970–2016, proprietors grew from 39,099 to 124,201, a 218% increase.
- In 1970, proprietors represented 23% of total labor earnings. By 2016, proprietors represented 31% of total labor earnings.
- From 1970–2016, dividends, interest and rent grew from $3,328.8 million to $17,954.5 million, an increase of 439%.
- From 1970–2016, age-related transfer payments grew from $641 million to $5,187 million, an increase of 708%.
- From 1970–2016, income maintenance transfer payments grew from $507 million to $3,446 million, an increase of 580%.
- In 2016, total non-government service-related employment accounted for approximately 77% of the total share of jobs.
- From 2001–2015, the three industry sectors that added the most new jobs were health care and social assistance (12,480 new jobs), real estate, and rental and leasing (2,797 new jobs), and other services, except public administration (2,430 new jobs).
- From 2001–2015, earnings in services-related industries grew from $6,127.3 million to $8,854.6 million, a 45% increase.
- From 1998–2015, timber employment shrank by 5,927 jobs, a 50% decrease.
- From 1998–2015, industries associated with travel and tourism in the region grew by 8%, non-travel and tourism industries shrank by 4%.

DISCUSSION

California's non-metro region (shown in Figure 8.1) provides ecosystem services to the rest of the state, nation and world. Those services include provisioning services such as food, fuel, fiber, water and medicinal products. In addition, the region plays a critical role in regulating the climate, providing cultural services and supporting services that help support all other life on earth [24, 25]. The region is endowed with an appealing climate for agriculture, recreation and residence, which has fostered growth rates in employment, population and personal income that have outpaced similar rural geographies in the rest of the nation. For this chapter, rural areas are synonymous with non-metro counties as defined by the Office of Management and Budgets and the U. S. Department of Agriculture's Economic Research Service.

A structural change has been underway since the last quarter of the twentieth century; rural can no longer be synonymous with forestry and farming [17]. With nearly 98% of California's population living in metropolitan areas [26] the region's ability to integrate into national and international markets through exports influences sustained growth through a pattern of diversified economic activity [27]. Rural economies are constantly being shaped and reshaped by the centralizing and decentralizing forces of cities and metropolitan areas. The economic dominance of these national and international forces influences the spatial distribution of economic activities in the region [28].

Where is Economic Activity Concentrated?

Jobs are concentrated where people are—the location of people is the best predictor of their income [29, 30]. With 98% of California's population living in urban areas this makes California more urban than the West (defined here as Arizona, Colorado, California, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming), which has 89% of the population living in metropolitan areas. The nation as whole has 85% of the population living in metropolitan areas.

But the distinction between urban and rural began to blur during the 20th century because of increased agriculture productivity and transportation access. The simple dichotomy of "Rural vs. Urban" is misleading; there is an interdependence between dense urban places and remote rural settings that produces a continuum, where neither one is entirely separate from the other. This interdependence is characterized by the concept of "Three Wests" (shown in Figure 8.1), which classifies counties to reflect the importance of access between cities and towns via transportation networks including airports [31, 32].

- **Metro:** While there are no metropolitan counties in rural California, it is useful to describe what characteristics contribute to its success and comparative advantage. These metropolitan counties are industrially diverse which leads to stable income levels. More professional jobs cause higher earnings per job. Metro areas offer more high wage service jobs for managers, scientists, and other professionals. Labor shortages and unemployment are less likely when firms exist in a single location [33].

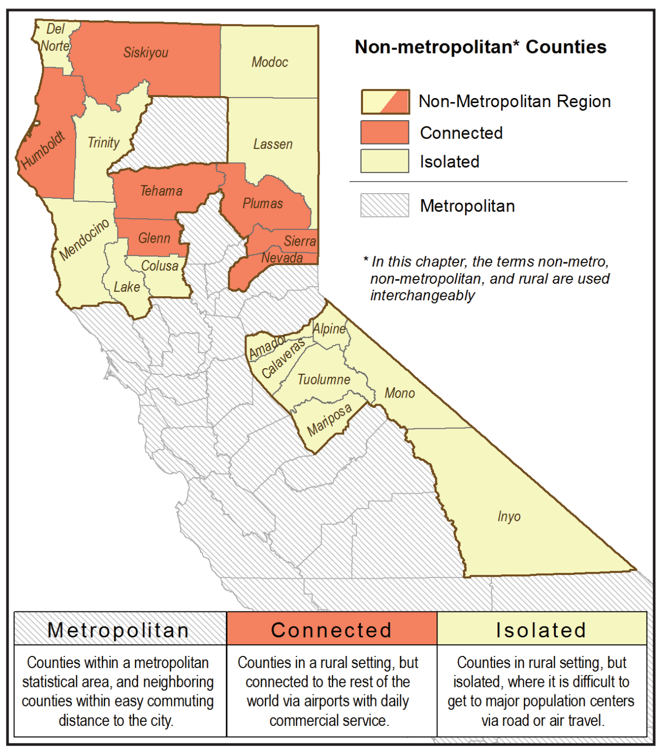


Figure 8.1: Three Wests.

Data Source: [34] Rasker, 2009.

- **Connected:** Seven counties in Non-Metro California are considered "Connected" to the rest of the word via airports with daily commercial service. Connected areas have relatively low income volatility due to industry diversification. Increased earnings are in part a reflection of the transition to a knowledge-based economy. Growth in high wage service jobs is enabled by expanded access to markets and IT infrastructure. Connected counties are better situated for economic development via transportation infrastructure than isolated counties.

- **Isolated:** Fourteen counties in Non-Metro California are considered "Isolated" where it is difficult to get to major population centers via road or travel. These counties have more volatile income levels that result from a higher dependence on farming and energy sectors. There are fewer professional and managerial jobs which contribute to lower job earnings. Isolated counties have fewer high wage service jobs. Demographic data for these counties also suggest slower population growth due to aging and little in-migration, increases in median age, and low education and skill levels.

Connection to urban centers drives economic development. Access to markets create avenues for businesses to expand [35, 36] into new areas as highways and airports expand [32]. Internet access in connected and isolated counties can improve communication infrastructure, which in turn provides increased access to jobs, educational resources, healthcare and government services.

Land: Provisioning Services, Recreation and Residence

Food, timber and energy are important commodities in the region. Forested watersheds support the state's water supply and other beneficial uses. In addition, the outdoor recreation economy is a significant driver in rural California. Employment in those use sectors is shown in Table 8.1. Here, "use sectors" refers to components of the economy that have the potential for being associated with the use of public land, including timber, mining and agriculture, and industries that include travel and tourism.

People living in rural areas have long made productive use of natural resources as material inputs. In terms of employment, the once very important natural resource industries have been declining, bringing with it fear and uncertainty into the cultural fabric of those who live in those areas. The traditional extractive industries continue to play an important role, but they are no longer the source of new jobs and higher incomes. Figure 8.2 shows jobs in the timber sector (including growing and harvesting, sawmills and papermills, and wood products manufacturing) from 1998–2015. Jobs in growing and harvesting shrank from 2,783 to 1,428, a 48.3% decrease. During that same time jobs in the mills shrank from 6,721 to 2,181, a 67.5% decrease, while wood products manufacturing shrank from 2,203 to 2,151 jobs, a 2.4% decrease.

Table 8.1: Employment in Use Sectors

	Non-Metro CA	Non-Metro U.S.
Timber % of Total Private Employment, 2015	~3.2%	~2.4%
Mining % of Total Private Employment, 2015	~0.3%	~2%
Fossil Fuels (Oil, Gas, & Coal), 2015	~0.03%	~1.54%
Other Mining, 2015	~0.24%	~0.89%
Agriculture % of Total Employment, 2015	4.4%	5.6%
Travel & Tourism % of Total Private Employment, 2015	~26.2%	~16.4%

~Estimates for data that were not disclosed.
**Data for timber, mining, and travel and tourism-related are from County Business Patterns which excludes proprietors. Data for agriculture are from Bureau of Economic Analysis which includes proprietors.*

Data Source: [37] U.S. Department of Commerce, Bureau of Economic Analysis, Census Bureau, Reported by Headwaters Economics, 2016–2017.

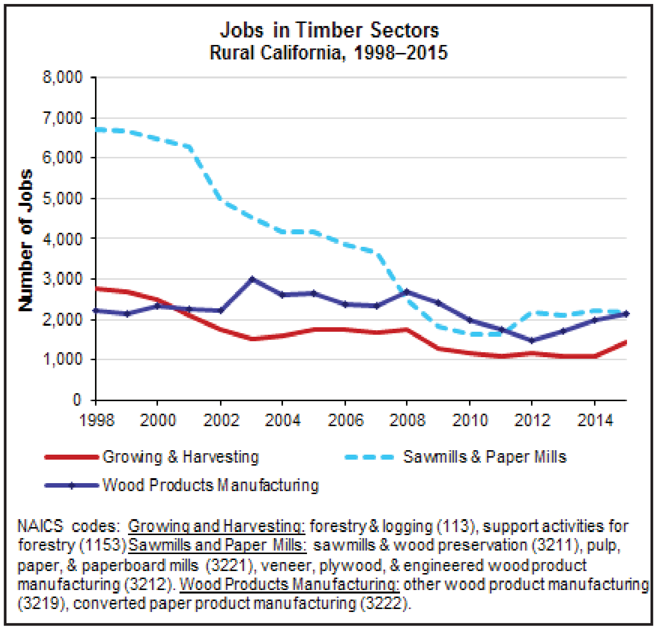


Figure 8.2: Jobs in Timber Sectors, Rural California, 1998–2015.

Data Source: [38] U. S. Department of Commerce, Census Bureau, reported by Headwaters Economics, 2017.

Rural labor markets have shifted from a heavy dependence on agriculture and other natural resources to a greater diversity of economic activities [39]. Even though the countryside is largely covered by fields and forests, most people living in rural areas earn a living in service industries (Figure 8.3).

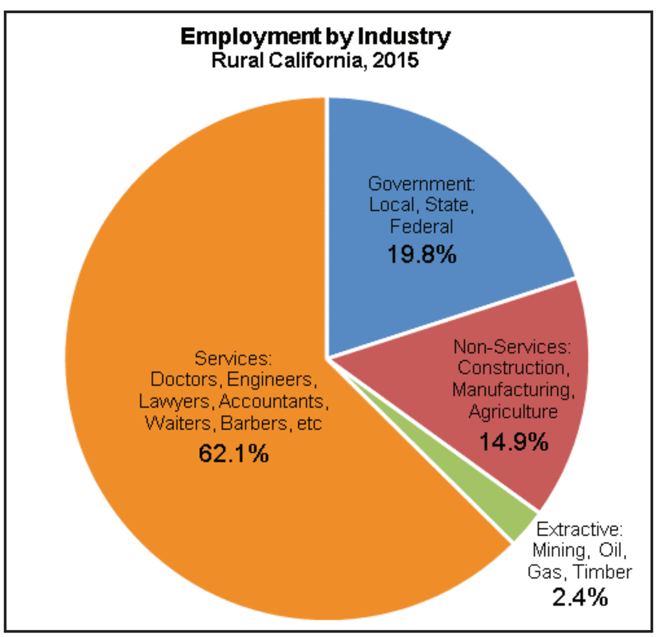


Figure 8.3: Employment by Industry, 2015.

Data Source: [40] U.S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

These signs of economic vitality (Figure 8.4) (ⓘ8.1) despite a decline in traditional natural resource industries (Figure 8.2) have not set well with many rural communities [41, 42]. The changes in economic structure (Figure 8.4) (ⓘ8.5) have left some people cash-strapped and jobless, ushering in a deep sense of anxiety and concern over the fate of their livelihoods. This concern is in part a reflection of culture, custom and historical heritage since the United States was originally a nation of farmers and other natural resource workers steeped in American Jeffersonian values that honored a rural way of life.

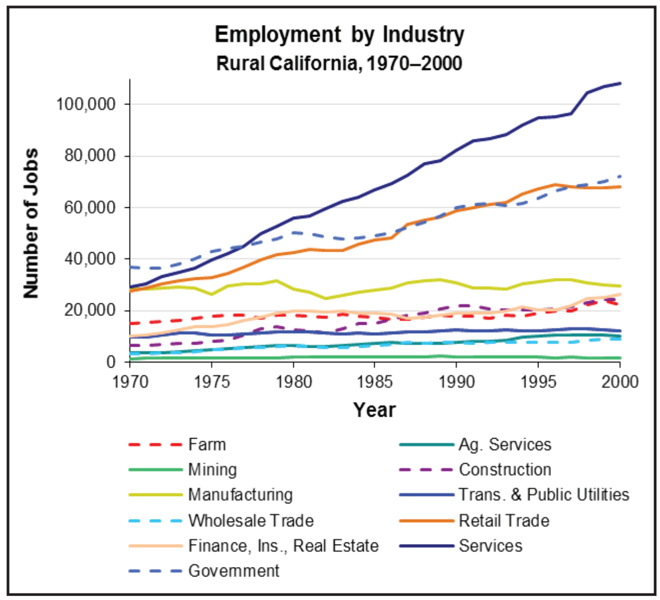


Figure 8.4: Employment by Industry, Rural California, 1970–2000.

Data Source: [40] U.S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

There has been concern that all the good jobs left the region when the jobs in the timber sector declined. But as Figures 8.4 and 8.5 demonstrate, the rise in the service sector economy has not limited the region's economy.

Rising per capita real income (i.e. inflation adjusted) (Figure 8.5) provides individuals more choices to consume the products and services they desire. In rural California, it has been on the rise for forty years. Per capita real income (2016 dollars) grew from $25,466 in 1970 to $44,673 in 2016, a 75% increase. Using this measure, a family of four's real purchasing power rose by $76,828. For many families, this is a welcomed improvement in economic well-being.

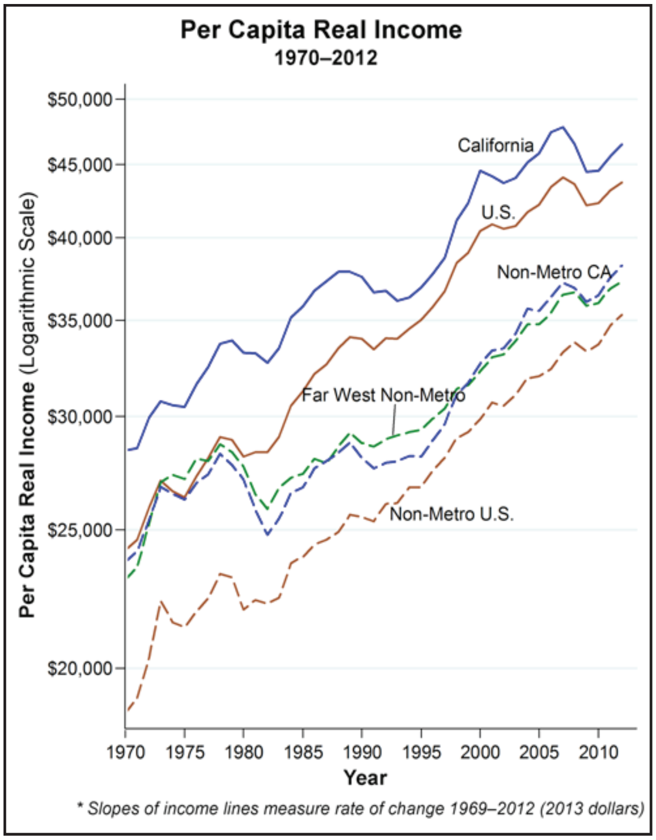


Figure 8.5: Per Capita Real Income, 1970–2012.

Data Source: [43] Bureau of Economic Analysis, 2014.

However, there are forces at work that are depressing wages in both non-services (e.g. resource extraction industries) and the services sector. Even if there was not a shift from goods to services wages would be falling. It is incorrect to blame the shift from manufacturing to service-based sectors for stagnant or declining wages. In fact, the shift to services is responsible for only a sixth of the decline in average real wages [15, 19]. In addition, after adjusting for occupational risk, gender and seasonality, non-services jobs are not significantly higher paying than other industries [18].

Over the last half century, the economic role of our natural landscapes has changed, but the cultural heritage and identity is still firmly rooted in rural land-based livelihoods [21]. The natural environment functions not only as a warehouse of commercial resources waiting to be extracted, but also provides valuable non-commercial environmental services that flow from those landscapes and could support environmental stability and a high quality of life. Many early economists focused almost exclusively on commercial export oriented economic activities [44]; while there are many extractive industries concentrated in regions where the particular resources are abundant, none of these regions in California are dependent on extractive industries (based on the USDA Economic Resource Service (ERS) definition of dependent found in Irwin, Isserman, Kilkenny and Partridge, 2010, p. 531 [17]).

The attractiveness of a region as a place to live, work and do business is central to attracting and holding economic activity [18, 46, 47]. Accessibility to urban markets rather than the commodity productivity of land has become a key factor in the prosperity of rural regions [17]. As a result, the focus of most economic analyses has shifted to the transformation processes such as markets, technology, and entrepreneurial innovation as worker's skills became increasingly more important for prosperity. These trends have resulted in expanded rural labor markets and we have seen increased employment in service industries.

Figure 8.6 shows that in 2016, total non-government service related employment have been steadily on the rise, while non-service related jobs have declined.

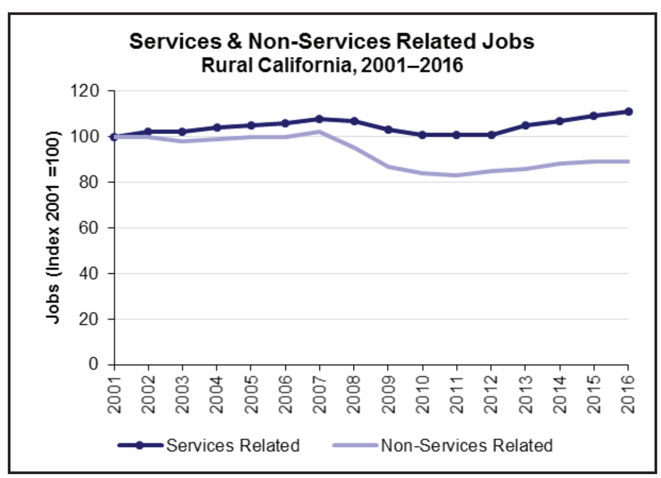


Figure 8.6: Services & Non-Services-Related Jobs, Rural California, 2001–2016.

Data Source: [45] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

Note that the terms "non-services-related" and "services-related" are not terms used by the U.S. Department of Commerce. They are used here to help organize the information into easy-to-understand categories. See ⓘ8.5 Metric "Employment by Industry" for a breakdown by sector.

Qualities of the environment that make a region an attractive place to live, recreate, and work are known as amenities, and can represent an important pulling factor of migration movements. Amenity driven migration [48-50] often corresponds with above average growth in the service occupations. For instance, amenity migration and jobs in tourism and recreation often go together. From 2000–2016, migration contributed to 57% of population growth in rural California. This could be an indication that some people care about where they live and work and will act on their preferences for a high-quality living environment [18, 51-53]. A proxy indicator of this may be that approximately 26% of jobs in rural California are associated with recreation and tourism. In short, economic activity has continued to increase while timber employment has stagnated or dropped. This trend reflects the fact that people are attracted to environmental amenities and a rural lifestyle [18, 47].

Demography and Politics

Population information provided in Tables 8.2–8.4 may help in identifying the values, attitudes and beliefs of rural Californians that may place different demands on public agencies. For instance, each age bracket has a characteristic mobility level, spending pattern and demand for recreation that is different from the other. This has relevance since some land management decisions will impact some groups more than others.

There are approximately 22,000 more males in rural California than females. In addition, rural California has less ethnic diversity than the state but more ethnic diversity than the rest of rural America (Table 8.4). In fact, from 1980–2015 total population has increased because of minorities in five of the counties in rural California while 15 counties gained population including minorities, and one county lost population but minorities increased.

The ethnic composition and age categories may tell us something meaningful about the different views, experiences, and expectations regarding land management. In addition, the flow of people in and out of the region shape how the local economies within them function. Different people consume and demand a variety of resources; understanding population growth trends is increasingly important for the current and future needs of citizens. Land managers should consider how a proposed management action could disproportionally affect minority populations, resulting in environmental justice concerns.

Table 8.2: Age Distribution in Rural California, 2010–2015

	Population		Percent of Total	
	2010	2015	2010	2015
Total Population	842,283	834,035		
Under 18	178,873	165,915	21.24%	19.89%
18-34	165,517	169,399	19.65%	20.31%
35-44	102,226	92,187	12.14%	11.05%
45-64	260,142	248,303	30.89%	29.77%
65 and Over	135,525	158,231	16.09%	18.97%

Note: American Community Survey 5-year estimates used. 2015 represents average characteristics from 2011–2015; 2010 represents 2006–2010.

Data Source: [54] U. S. Department of Commerce, Census Bureau, reported by Headwaters Economics, 2016.

Table 8.3: American Indian and Native Population, 2016

	Rural California	U.S. Non-Metro
Total Population	831,617	60,353,314
Total Native American	26,851	990,346
American Indian Tribes: Specified	22,181	828,308
American Indian; Not Specified	791	13,734
Alaska Native Tribes; Specified	284	57,450
Alaska Native; Not Specified	2,613	68,382
American Indian or Alaska Native; Not Specified	3,404	82,116
International Indian Tribe	606	12,617

Note: The data in this table are calculated by the American Community Survey using annual surveys conducted during 2010–2014 and are representative of average characteristic during this period.

Data Source: [55] U. S. Department of Commerce, Census Bureau, reported by Headwaters Economics, 2016.

Table 8.4: Estimated Ethnic Population in Rural California								
	Population				Percent of Total			
	California	California Non-Metro	United States	United States Non-Metro	California	California Non-Metro	United States	U.S. Non-Metro
Total Population	38,654,206	831,617	318,558,162	60,353,314				
Hispanic or Latino (of Any Race)	14,903,982	141,325	55,199,107	3,719,481	38.6%	17.0%	17.3%	6.2%
Not Hispanic or Latino	23,750,224	690,292	263,359,055	56,633,833	61.4%	83.0%	82.7%	93.8%
White Alone	14,837,242	612,217	197,362,672	50,556,716	38.4%	73.6%	62.0%	83.8%
Black or African American Alone	2,158,363	11,376	39,098,319	3,562,692	5.6%	1.4%	12.3%	5.9%
American Indian Alone	136,582	22,949	2,084,326	932,048	0.4%	2.8%	0.7%	1.5%
Asian Alone	5,280,818	13,821	16,425,317	503,961	13.7%	1.7%	5.2%	0.8%
Native Hawaiian & Oth. Pacific Is. Alone	138,956	1,861	508,924	38,921	0.4%	0.2%	0.2%	0.1%
Some Other Race	90,413	1,057	676,003	49,134	0.2%	0.1%	0.2%	0.1%
Two or More Races	1,107,850	27,011	7,203,494	990,361	2.9%	3.2%	2.3%	1.6%
Note: The data in this table are calculated by American Community Survey using annual surveys conducted during 2011–2015 and are representative of average characteristics during this period.								

Data Source: [56] U. S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

Inequalities are often expressed along racial and ethnic lines [12]. For example, Native Americans often experience unemployment rates near 80%, which feed a spiral of despair, hopelessness and isolation that too often leads to suicide [2]. In addition, increased death rates from the opioid crisis amongst white middle-aged men [1, 9, 57] is an indication that the economy is not working very well for them.

Rural Californians vote reliably Republican. The 2016 presidential election highlighted a growing disconnect between cities and small towns [58]. For example, the things that contribute to Silicon Valley's success (including globalization, foreign trade and immigration) are exactly what concerns many rural voters [58, 59]. A recent pew report found that "the divisions between Republicans and Democrats on fundamental political values – on government, race, immigration, national security, environmental protection and other areas – reached record levels during Barack Obama's presidency. In Donald Trump's first year as president, these gaps have grown even larger" [60]. In short, the findings from the report show that partisanship has intensified and political values have grown wider ushering in an intense time of political polarization [61]. The net effect is a stark difference in voting patterns between urban and rural people [62].

People: What are the challenges facing rural people and why are some thriving?

The economic geography of rural California is characterized by limited access to markets, a dispersed though mobile labor pool and a systemic economy-wide division of labor that discriminates based on gender and minority status [63-65]. The region faces persistent challenges deeply rooted in inequality of opportunity, wealth and income [5, 30, 66-69].

However, people don't usually move to and remain in places they don't like. For a half century economists and economic geographers have observed migration to California in search of climatic, social and geographic characteristics [17, 32, 48, 49, 51, 71-74]. That is, people are often compensated (as defined by McCloskey [75]) by amenities outside the labor market, although higher wages also increase migration [76]. This is supported by the general indicators of economic well-being (population, employment, and real personal income) measured over time (Figures 8.7–8.9). Long-term steady growth of population, employment, and real personal income generally indicates of a healthy, prosperous economy.

From 1970–2016, population grew from 425,424 to 832,574 people, a 96% increase (Figure 8.7). However, from 2000–2016 population grew by 35,511 people, only a 4% increase. An aging population and decreased fertility rates reflects a slower growth in population in recent decades. From 2000–2016, natural change contributed to 28% of the increase while migration contributed to 57% of population growth.

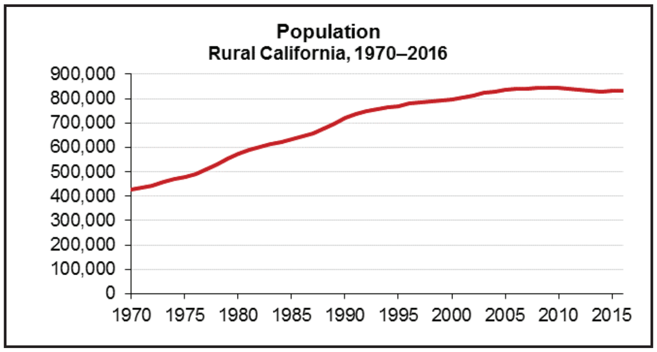


Figure 8.7: Population, Rural California, 1970–2016.

Data Source: [70] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

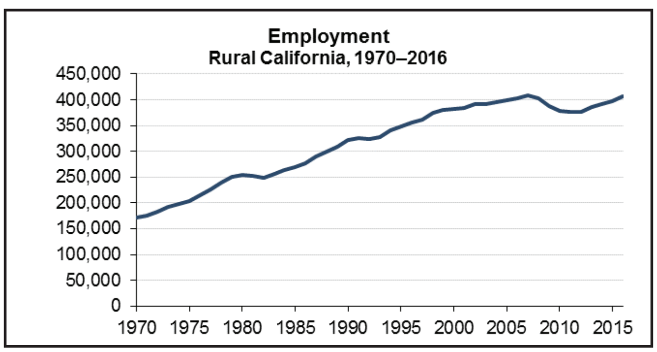


Figure 8.8: Employment, Rural California, 1970–2016.

Data Source: [70] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

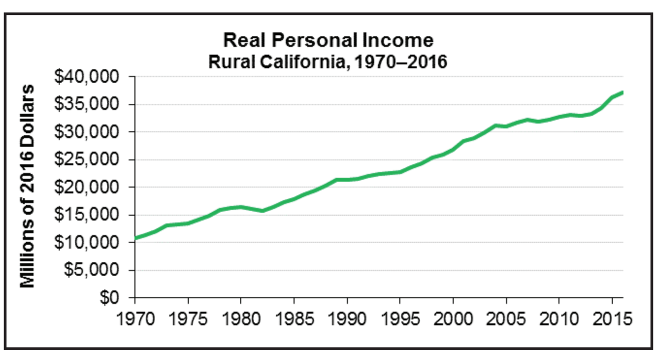


Figure 8.9: Real Personal Income, Rural California, 1970–2016.

Data Source: [70] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

Over the same period, employment grew from 171,829 to 406,789, a 137% increase (Figure 8.8). Similarly, personal income grew from $10,698.9 million to $37,193.9 million (2016 dollars), a 243% increase (Figure 8.9). Together these three metrics indicate that rural California has outperformed the rest of the rural United States in terms of population growth, employment and personal income (ⓘ8.1).

Two popular ways of characterizing the relative performance of regional economies are annual earnings per job and per capita personal income, shown in Figure 8.10. Average earnings per job is a common way to measure the quality of local employment, with higher average earnings per job indicating that there are relatively more high-wage occupations. It is a measure of the compensation of the average job. Note that it's useful to consider earnings against local cost of living indicators.

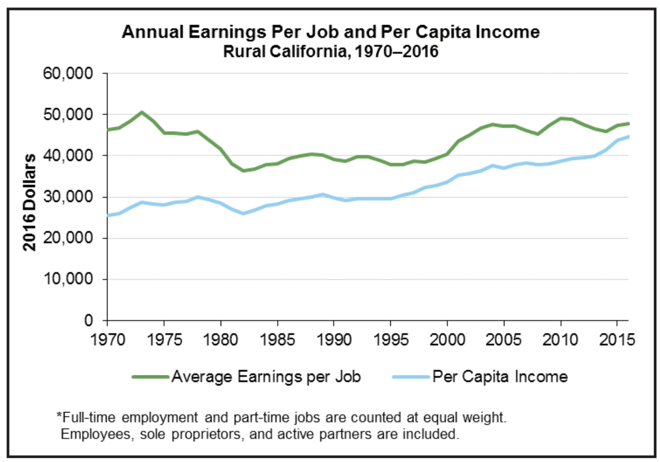


Figure 8.10: Annual Earnings per Job and Per Capita Income, Rural California, 1970–2016.

Data Source: [80] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

In real terms (2016 dollars) average annual earnings per job in rural California grew from $46,331 to $47,790 from 1970–2016, a 3% increase. The 3% increase (near zero growth) in average earnings per job reflects reduced hourly wages and a concentration of economic power that has resulted in the wealthiest 1% owing 42% of the nation's private assets [4, 5, 77]. That is, record concentration levels of wealth and income have kept wages low [5, 78]. In terms of a household's perception of well-being, however, the relative standing of their incomes determines the tolerance for inequality [66, 79]. However, compared to the rest of the rural U.S., rural California's annual earnings per job has grown 8 percentage points from 2000–2016.

Rising per capita personal income provides individuals more choices to consume the products and services they desire. In rural California, it has been on the rise for over forty years (Figure 8.10). But the interpretation of this popular indicator of economic well-being needs to be understood in the proper context; namely because it includes non-labor forms of income and because it is calculated using the total population—which includes those who do not work—children, for example, and stay at home adults, retirees and, disabled persons. Consideration also needs to be given to how the income is distributed [7]. Most of the fruits of economic growth going to asset holders rather than workers is reflected in slow wage growth.

Since a small wealthy segment of the population can skew the distribution, it's not clear exactly what percentage of the population experienced their real incomes (2016 dollars) rise from $46,331 to $47,790 from 1970–2016. However, we do know that national data from administrative tax records shows that the top 1% of tax units received 19.3% of total income, the largest since 1928 [67, 81]. This means that there is a disconnect between the productivity of economy and a typical worker's income.

Furthermore, annual earnings reflect the compensation of the average job. However, individuals and families frequently receive additional income that is not from a paycheck. This "non-labor income" includes income from assets such as savings accounts, stocks, bonds, retirement pensions, dividends, interest, capital gains and rent (money earned from investments). Also included are transfer payments, which includes government retirement and disability insurance benefits, social security, medical payments such as Medicare and Medicaid, income maintenance benefits, unemployment insurance benefits, etc.

From 1970–2016 labor earnings grew by 156%; however, during the same time period non-labor income increased by 439%. Combined, these forms of income have leveraged per-capita income upward. Figure 8.11 illustrates these trends and shows that dividends, interest and rent make up the largest share of non-labor income. Across the country as a whole non-labor income is significant and has represented approximately one-third of Americans' income for nearly three decades. For instance, in rural California in 1970, non-labor income represented 31% of total personal income. In 2016, non-labor income accounted for 48% of total personal income in rural California. In rural California, from 1970–2016 non-labor income grew from $3,328.8 million to $17,954.5 million (2016 dollars), a 439% increase.

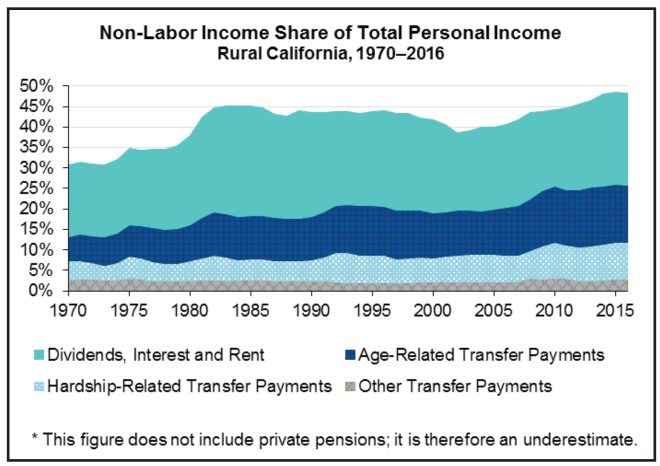


Figure 8.11: Non-Labor Income Share of Total Personal Income, Rural California, 1970–2016.

Data Source: [82] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.

Hourly wages are an important representation of pay per unit of effort. Jobs throughout various sectors of the economy require different levels of work. As a result, it is possible for jobs that pay the same hourly wage to have different levels of total pay on an annual basis. Much of the previous discussion on wages focused on "pay per job" which is not "pay per person" or "pay per household" because people can hold more than one job and households may have more than one wage earner. For instance, across the non-metro U.S. people tend to have a high rate of multiple job holdings [83]; assuming rural California does not deviate from that trend, it has important implications. Lower levels of annual earnings per job in rural California can be explained in part by the fact that a larger portion of rural Californians' work part-time or hold seasonal jobs than is true in the rest of the State, region and nation.

Hourly wages in combination with the length of the workweek can tell us if workers are working longer hours for less pay. Table 8.5 summarizes the percent of weeks worked per year and hours worked per week, which may signify worker preference for leisure over income, or it may indicate that the region is suffering from underemployment.

For instance, part-time jobs maybe ideal for those taking care of children, dependents or for students. But the extent to which a decline in the total hours worked per week is an indication of economic hardship depends on how income is distributed and the age and sex of the population. Some workers will prefer to work less and accept the tradeoff in a decline in earnings. To put this in perspective, consider that since the latter half of the nineteenth century the workweek has been declining; in 1860 the industrial workweek was 64 hours [49]. In 2014, that number is closer to 33 hours per week for private service providing jobs, and closer to 40 hours per week for private goods providing jobs.

The rate of unemployment (Figure 8.12) is an important indicator of economic stress and economic well-being. It fluctuates with recessions, local economic downturns and seasonal variations in unemployment. During some periods of the year unemployment is higher as a result of the winter months interfering with the construction industry, tourism and other forms of seasonal employment.

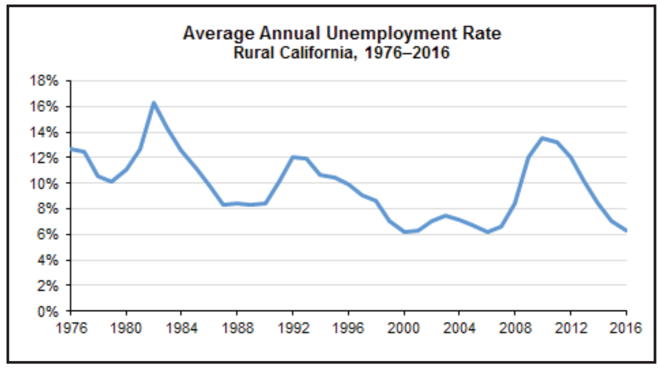


Figure 8.12: Average Annual Unemployment Rate, Rural California, 1976–2016.

Data Source: [85] U.S. Department of Labor, Bureau of Labor Statistics, reported by Headwaters Economics, 2017.

As the economy of a place diversifies, it often becomes more resilient and less affected by downturns and rising unemployment rates. This is particularly true of places that attract in-migration, retain manufacturing, and support a high-tech economy. In addition, public land agencies sometimes provide seasonal employment and

Table 8.5: Labor Participation Characteristics

Percent of Total	California	California Non-Metro	United States	U.S. Non-Metro
Weeks Worked Per Year				
Worked 50 to 52 Weeks	53.62%	44.76%	56.43%	55.11%
Worked 27 to 49 Weeks	10.41%	11.60%	10.17%	9.65%
Worked 1 to 26 Weeks	8.41%	10.54%	8.73%	8.36%
Did Not Work	27.56%	33.10%	24.68%	26.88%
Hours Worked Per Year				
Worked 35 or More Hours Per Week	54.10%	46.10%	57.61%	56.90%
Worked 15 to 34 Hours Per Week	14.83%	16.42%	14.22%	12.91%
Worked 1 to 14 Hours Per Week	3.51%	4.38%	3.49%	3.30%
Did Not Work	27.56%	33.10%	24.68%	26.88%

Note: The data in this table are calculated by American Community Survey using annual surveys conducted during 2012–2016 and are representative of average characteristics during this period.

Data Source: [84] U. S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

may affect the local rate of unemployment. Figure 8.12 shows that since 1976, the annual unemployment rate ranged from a low of 6.2% in 2000 to a high of 16.3% in 1982.

The unemployment rate for people with disabilities is more than double than for those without [86]. In addition, those with autism face staggering unemployment rates ranging from 70–90%, and extended unemployment complicates an already extremely challenging job hunt. Furthermore, people with disabilities were 26% less likely to get expressions of interest from employers. Fear of the unknown and social stigma contribute to this outcome, which can further alienate this population and negatively impact their well-being. People with disabilities face unique challenges when evacuating during a natural disaster [87] and medical care may be harder for them to obtain during such an event. Furthermore, women veterans who have served since 2001 are more likely than men to have a service-related disability [88], which could result in difficulties in accomplishing tasks, social isolation and diminished options and opportunities [89]. Table 8.6 shows that disabled people are less likely to have health insurance compared to the non-disabled population [90].

People who lack health insurance are vulnerable to sickness, disease and other health problems and are unlikely to get the diagnoses, treatment and medication they need thereby exacerbating their poor health. Nationwide poverty contributes to the uninsured status of households, with a quarter of those living in poverty without health insurance [92]. Low income minority communities face cost-related barriers to care [93]. While large disparities remain, the Affordable Care Act (ACA) has reduced racial/ethnic disparities and increased insurance coverage [94]. Nationwide the ACA has nearly halved the share of Americans without coverage [95].

Households associated with increased hardship include the elderly living alone, single female households, single female households with children and households without a car. Elderly people are less able to overcome disease. People living alone have exacerbated health risks, which are made worse by social isolation. Social isolation is associated with poor health status [96] and presents a risk to the well-being of individuals. Specifically, it's associated with premature death, heart attack, depression, and greater levels of disability from chronic diseases [97]. Age is a factor related to the vulnerability of heat-related illness or death; especially at risk are those 65 years and older [98] living alone. Del Norte County has the largest share of households with people over 65 living alone (14.2%). Table 8.7 shows these potentially vulnerable households.

Del Norte county also has the largest share of single female households (14.2%) and the largest share of single female households with children (9.9%). This is important since female-headed households face challenges related to income, education and food security, which make it more difficult to respond to climate, health and environmental risks. These households typically have poverty rates twice the national average [100], which are most prevalent amongst minority communities [101]. Single mothers collectively raise one in five children and are more likely to experience extreme poverty

Table 8.6: Potentially Vulnerable People

	Population		Percent of Total	
	California Non-Metro	U.S. Non-Metro	California Non-Metro	U.S. Non-Metro
Noninstitutionalized Civilian Total	804,986	59,313,425		
People With Disabilities	145,061	8,957,264	18.02%	15.10%
People Without Health Insurance	95,179	6,558,134	11.82%	11.06%

Note: The data in this table are calculated by American Community Survey using annual surveys conducted during 2012–2016 and are representative of average characteristics during this period.

Data Source: [91] U.S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

Table 8.7: Potentially Vulnerable Households

	Population			Percent of Total		
	California	California Non-Metro	United States Non-Metro	California	California Non-Metro	United States Non-Metro
Total Occupied Households	12,807,387	326,743	22,668,939			
People > 65 Years & Living Alone	451,227	12,423	433,463	3.52%	3.80%	1.91%
Single Female Households	1,724,502	33,749	2,079,722	13.46%	10.33%	9.17%
With Children < 18 Years	1,056,652	21,834	1,287,771	8.25%	6.68%	5.68%
Households With No Car	974,500	20,742	935,808	7.61%	6.35%	4.13%

Note: American Community Survey 5-year estimates used. 2016 represents average characteristics from 2012–2016; 2010 represents 2006–2010.

Data Source: [99] U.S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

than married coupled families or single father families [102]. Single mothers tend to be poorer and less educated than the general population, which places them at greater risk during a natural disaster [103]. Finally, children of single mothers are less upwardly mobile than their counterparts [30].

Children living apart from their biological father are associated with greater risk of adverse outcomes [104]. Single fatherhood poses unique challenges [105], especially for those widowed fathers adjusting to the demands of becoming breadwinner and caregiver against the backdrop of grief and conflicting gender norms [106]. Instability in the household is linked to adverse child outcomes; and cohabitating unions are less stable than marriages at all education levels [107]. That is a reflection of the underlying social and economic forces that have transformed American families. Specifically, the instability of family arrangements has paralleled rising inequality in wages and income [107]. Easing this instability and inequality is the flexibility of gender roles, which provides families with the tools needed to navigate changing circumstances while reducing stress on both individuals and families [65].

Households that have a car are more likely to have higher wages and financial stability. Not having a car has a dramatic impact on labor market outcomes [108]. Car ownership enables households to find and maintain employment [109]. People who own cars can reach more jobs per unit of time allowing them to work longer hours [108, 109]. In addition, those who have a car are more likely to leave welfare and get higher paying jobs [110]. During a natural disaster those who have cars are more likely to evacuate and have access to emergency response centers [98].

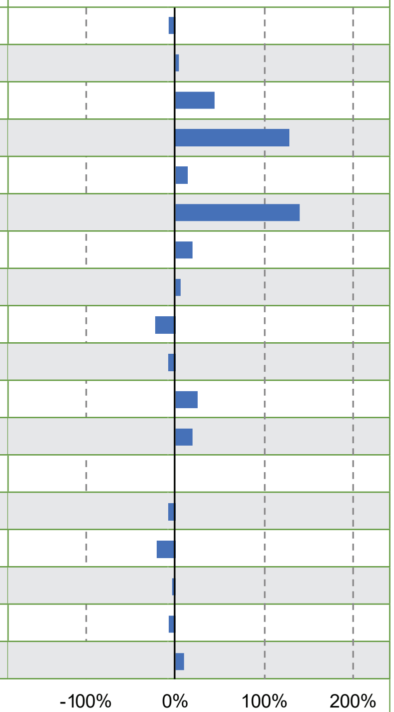
Table 8.8 provides a quick comparison of indicators that help inform which populations are more likely to experience adverse outcomes from extreme events, climate change, pollution and limited healthcare access. Exceptionally high percentages in any of these indicators might indicate populations that are in need of outreach from disaster planning, public health, or social service organizations.

Of particular importance is education [112], which is a strong indication of potential economic success [3, 9, 30, 113]. Lack of education is closely linked to low income [114] and poverty. Hundreds of studies spanning multiple geographies show that with a higher than average educated workforce incomes are higher and suffer less during economic downturns than other geographies [113, 115]. Table 8.9 shows the educational attainment for California and the United States rural population ages 25 and older.

Compared to the rest of nation's rural population, rural California graduates more high school and college education students. In the 2010–2014 time period, Mono County had the highest number of people who were 25 years and older with a bachelor's degree or higher

Table 8.8: Populations at Risk

Indicators 2015*	California Non-Metro	U.S. Non-Metro	Percent Difference: California Non-Metro vs. United States Metro
Population Under 5	5.0%	5.4%	
Population Over 65	17.9%	17.0%	
Population Non-White (All Other Races)	17.9%	11.5%	
Population Hispanic	24.9%	5.4%	
Population Without a High School Diploma	15.4%	13.4%	
Population That Speak English "Not Well"	5.6%	1.0%	
Population in "Deep Poverty"	6.7%	5.5%	
Families Below Poverty	10.1%	9.5%	
Families That Are Single Mother Households and Below Poverty	2.7%	3.4%	
Households Receiving Food Stamps (SNAP)	7.8%	11.7%	
Population That "Did Not Work"	34.6%	26.9%	
Rentals Where Gross Rent Exceeds 30% of Household Income	42.6%	35.3%	
Housing That Are Mobile Homes	13.1%	16.4%	
Households That Are Single Female With Children Under 18	4.8%	5.8%	
Households With No Car	3.4%	4.2%	
Population Over 65 and Living Alone	38.3%	39.4%	
Population With Disabilities	14.0%	15.1%	
Population Without Health Insurance	13.6%	12.2%	



** American Community Survey 5-year estimates: 2015 represents average characteristics from 2011–2015; 2010 represents 2006–2010.*

Data Source: [111] U.S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

Table 8.9: Educational Attainment

	Population		Percent of Total	
	California Non-Metro	U.S. Non-Metro	California Non-Metro	U.S. Non-Metro
Total Population 25 Years or Older	595,011	42,348,189		
No High School Degree	75,964	5,501,774	12.77%	12.99%
High School Graduate	519,047	36,846,415	87.23%	87.01%
Associates Degree	56,275	3,752,655	9.46%	8.86%
Bachelor's Degree or Higher	133,804	9,100,673	22.49%	21.49%
Bachelor's Degree	88,421	5,833,457	14.86%	13.77%
Graduate or Professional	45,383	3,267,216	7.63%	7.72%

Note: The data in this table are calculated by American Community Survey using annual surveys conducted during 2009–2014 and are representative of average characteristics during this period.

Data Source: [116] U. S. Department of Commerce, Census Bureau, American Community Survey Office, reported by Headwaters Economics, 2016.

(33.3%), and Lassen County had the lowest (12.9%). Similarly, Colusa County had the highest percentage of people who were 25 and older without a high school degree (31.1%), and Nevada County had the lowest (5.7%).

Conclusion

We tried to show the importance of the land in terms of jobs, income, provisioning services, recreation and residence. We demonstrated that rural labor markets have shifted away from a heavy dependence on agriculture and other natural resources to a greater diversity of economic activities. It is not that natural resources are becoming less important; rather, the role of natural resources in our lives is changing. Next, the attention we gave to demographics may illuminate the different needs, values, and concerns that different races and ethnicities have, which are then translated in votes on election day. Particularly noteworthy is the extent to which minority populations are driving growth in the region and the systematic institutional challenges faced by this population.

In the final section of this chapter we looked at why some people are thriving and other are not. In the aggregate, there are positive trends in population, employment and personal income (ⓘ8.2). However, average earning per job have grown only 3% in 46 years. Record concentration levels of wealth and income have kept wages low [5, 78]. In the past few decades the share of economic output each worker receives has fallen [117]. Other signs of vulnerability include people with disabilities and those without health insurance, whose numbers in 2014 were higher in rural California when compared to the rest of the state. Other notable populations at risk include people over 65 and living alone and those without a car who may find following evacuation orders during fire events difficult. Finally, the economy is not working well for white males in mid-life suffering from the opioid crisis. For them death rates are on the rise; however, it is not necessarily a rural or urban problem—it effects both.

Closing the gap between the rich and the poor will mean increased educational attainment, and a labor force capable of adapting to a rapidly changing economy driven by innovation [118]. Some communities are doing better than others because of the following characteristics [7]:

- Low rates of violent crime.
- Better performing schools. For example, higher student test scores, lower student dropout rates, smaller class sizes, and more expenditures per student.
- Stronger social networks.
- Higher share of middle-income households. Places that produce greater mobility tend to have larger shares of middle-income households, and they have smaller income differences between the highest-income and lowest-income households.
- Larger share of two-parent households.

Achieving those characteristics requires understanding the land, the politics that govern it and the people who define the region's customs and culture. This chapter has tried to show the importance of rural California, how it is growing, and the stresses the region faces.

Opportunities

Local and state governments cannot guide and steer the economy in a preferred direction [119, 120]; without permission, open economies move people, workers, capital, goods and services between towns and cities. But governments can do the following to enhance our well-being:

- Focus on people by supporting education, training, health, nutrition and other human development programs.
- Rebuild and maintain road and bridge infrastructure.
- Encourage Forest Stewardship Council (FSC) certified sustainable forest products.
- Increase rural broadband connectivity and bring rural communities out of the "dark side of the digital divide."
- Build on the progress of the Affordable Care Act.

Indicator: Relative Economic Performance

8.1

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

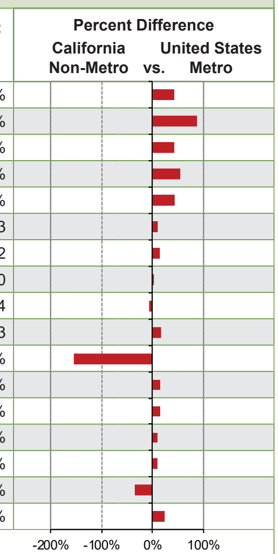
These indicators can be analyzed to get a comprehensive view of the economy. When considering the benefits of growth, it is important to distinguish between standard of living (such as earnings per job and per capita income) and quality of life (such as leisure time, crime rate, and sense of well-being).

What does the indicator show?

These indicators of economic performance highlight how the region differs from similar regional economies. The ratio of the region to the benchmark geography is a percentage calculated by dividing the figure from the region by the figure from the benchmark.

Relative Economic Performance

		California Non-Metro	Benchmark: U.S. Non-Metro
Trends	Population (Change, 2000–2016)	4.5%	2.9%
	Employment (Change, 2000–2016)	6.4%	2.5%
	Personal Income (Change, 2000–2016)	38.5%	24.8%
	Average Earnings Per Job (Change, 2000–2016)	18.5%	10.5%
	Per Capita Income (Change, 2000–2016)	32.6%	21.3%
Prosperity	Average Earnings Per Job	$47,790	$42,983
	Per Capita Income	$44,673	$38,222
	Average Annual Wages - Services Related	$34,051	$33,230
	Average Annual Wages - Non-Services Related	$44,635	$48,314
	Average Annual Wages - Government Related	$47,372	$40,343
Stress	Unemployment Rate (Change 2000–2016)	0.1%	0.8%
	Unemployment Rate	6.3%	5.4%
Structure	Percent of Employment in Proprietors	30.5%	26.3%
	Percent of Personal Income in Non-Labor	48.3%	44.0%
	Percent of Services Related Jobs	62.1%	56.7%
	Percent of Non-Services Related Jobs	17.3%	24.5%
	Percent of Government Jobs	19.8%	15.7%



Trends refers to general indicators of economic well-being (population, employment, and real personal income) measured over time. Prosperity refers to common indicators of individual well-being or hardship (unemployment, average earnings per job, and per capita income). Stress refers to the unemployment rate; which is the number of people who are jobless, looking for jobs, and available for work divided by the labor force. Structure refers to how the economy is arranged. Economy refers to three significant areas of the economy: non-labor income (e.g., government transfer payments, and investment and retirement income), and services and government employment. Use Sectors refers to components of the economy (commodity sectors including timber, mining and agriculture, and industries that include travel and tourism) that have the potential for being associated with the use of public land.

Key Findings:

- Non-metro California surpasses U.S. non-metro in terms of employment, population percent change, and increases in personal income.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Performance	[121] U.S. Department of Commerce, Bureau of Economic Analysis, Department of Labor, Bureau of Labor Statistics, reported by Headwaters Economics, 2016.	*****

Indicator: Economic Trends

ⓘ8.2

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

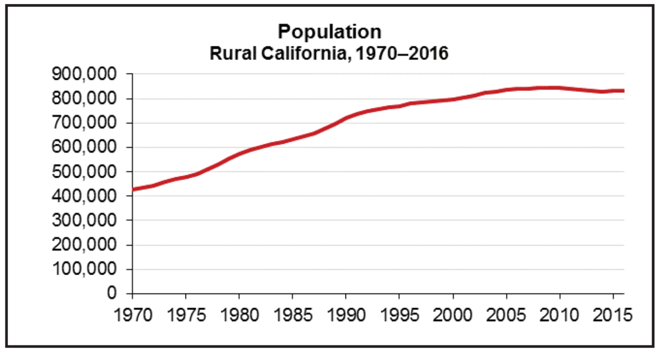
These indicators can be analyzed to get a comprehensive view of the economy. When considering the benefits of growth, it is important to distinguish between standard of living (such as earnings per job and per capita income) and quality of life (such as leisure time, crime rate, and sense of well-being).

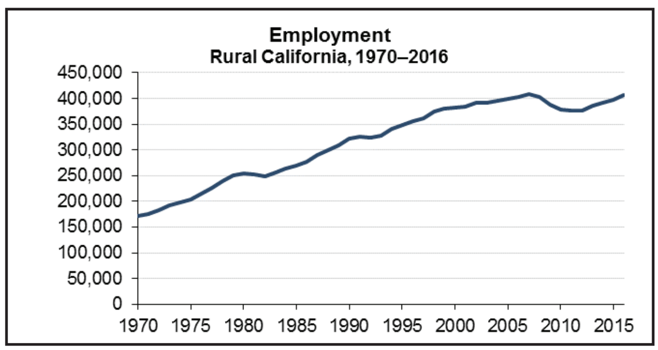
What does the indicator show?

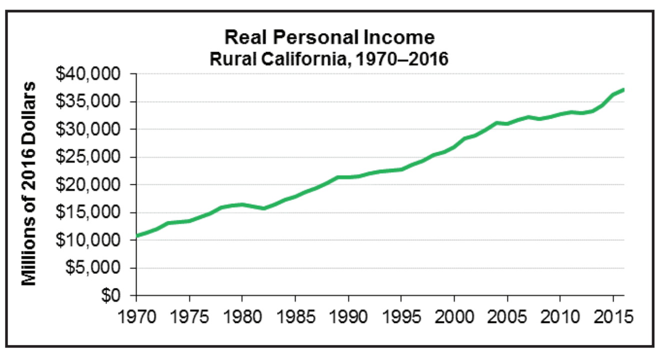
Long-term steady growth of population, employment, and real personal income is generally an indication of a healthy, prosperous economy. Erratic growth, no-growth, or long-term decline in these indicators are generally an indication of a struggling economy.

Key Findings:

- From 1970–2016, population grew from 425,424 to 832,574 people, a 96% increase.
- From 1970–2016, employment grew from 171,829 to 406,789, a 137% increase.
- From 1970–2016, personal income grew from $10,833.9 million to $37,193.9 million (2016 dollars), a 243% increase.
- From 2000–2016, migration (intra-national and international) contributed to 57% of population growth.







Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Socioeconomic Trends	[70] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.	*****

Indicator: Economic Prosperity

ⓘ8.3

Which Montreal Protocol Criteria does the indicator evaluate?

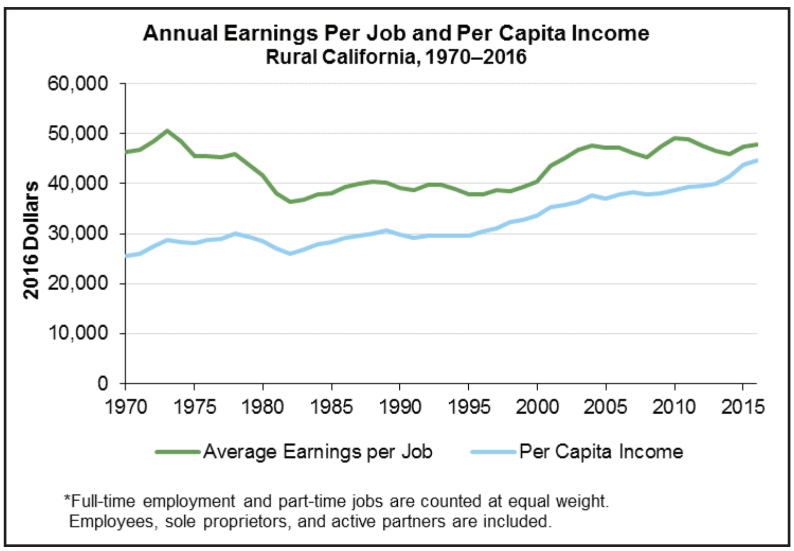
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

Average earnings per job is an indicator of the quality of local employment. A higher average earnings per job indicates that there are relatively more high-wage occupations. It can be useful to consider earnings against local cost of living indicators.

Per capita income is considered one of the most important measures of economic well-being. However, this measure can be misleading. Per capita income is total personal income divided by population. Because total personal income includes non-labor income sources (dividends, interest, rent and transfer payments), it is possible for per capita income to be relatively high due to the presence of retirees and people with investment income. And because per capita income is calculated using total population and not the labor force as in average earnings per job, it is possible for per capita income to be relatively low when there are a disproportionate number of children and/or elderly people in the population.

What does the indicator show?



Key Findings

ⓘ From 1970–2016, average earnings per job grew from $46,311 to $47,790 (2016 dollars), a 3% increase.

ⓘ From 1970–2016, per capita income grew from $25,466 to $44,673 (2016 dollars), a 75% increase.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Performance	[80] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.	*****

Indicator: Economic Stress ⓘ8.4

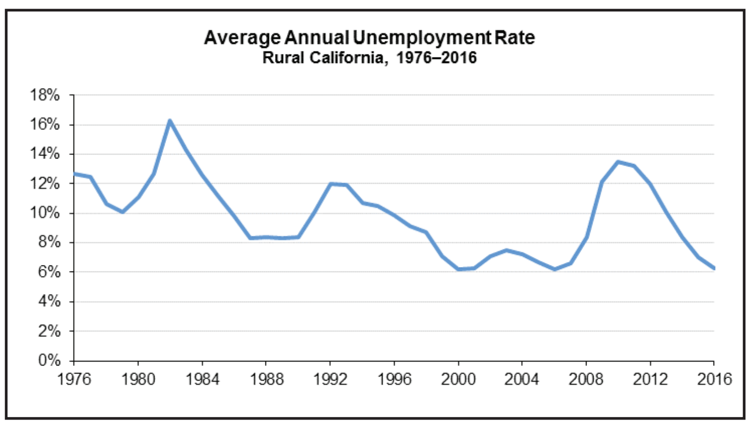
Which Montreal Protocol Criteria does the indicator evaluate?
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?
The rate of unemployment is an important indicator of economic well-being. This figure can go up during national recessions and/or when more localized economies are affected by area downturns. There can also be significant seasonal variations in unemployment.

It is important to know how the unemployment rate has changed over time, whether there are periods of the year where the rate is higher or lower, and if this seasonality of unemployment has changed over time. Geographies that are heavily dependent on the tourism industry, for example, may show higher rates of unemployment during spring and fall "shoulder seasons." Places that rely heavily on the construction industry, for example, may have lower unemployment rates during the non-winter months.

As the economy of a place diversifies, it can become more resilient and less affected by downturns and rising unemployment rates. This is particularly true of places that are able to attract in-migration, retain manufacturing, and support a high-tech economy. Public land agencies sometimes provide seasonal employment and may have an effect on the local rate of unemployment.

What does the indicator show?



Key Findings:

ⓘ Since 1990, the annual unemployment rate ranged from a low of 6.2% in 2000 to a high of 16.3% in 1982. As of July 2017, the monthly unemployment rate for the region was 5.8%.

ⓘ In 2016, people with disabilities accounted for 18% of non-institutionalized civilian population compared to 15.1% for the nation as a whole.

ⓘ In 2016, people without health insurance accounted for 11.6% of non-institutionalized civilian population.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Performance	[85] U.S. Department of Labor, Bureau of Labor Statistics, reported by Headwaters Economics, 2017.	*****

Indicator: Economic Structure ⓘ8.5

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits

Why is the indicator important?

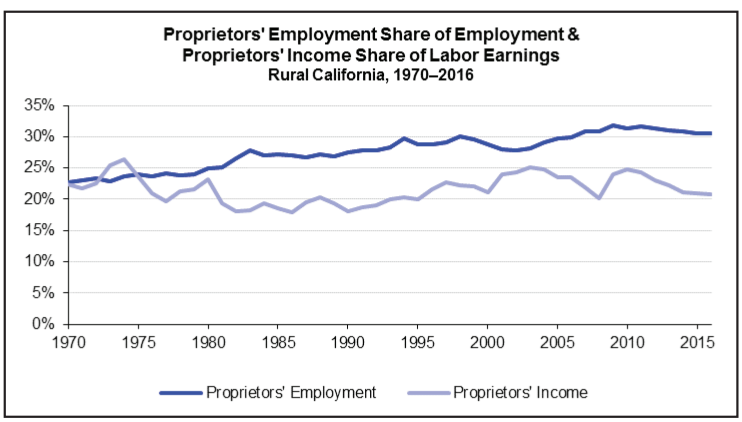
The structure of the economy tells us how the economy is arranged. Structure tells the story about livelihoods—just what is it that people do for a living. It tells us the source of employment and income. It is measured here using *proprietors' percent of jobs, non-labor income, services related employment* and *employment by industry*. The importance of each of these metrics are described below.

Metric: Proprietors

Proprietors includes the self-employed in nonfarm and farm sectors. Nonfarm self-employment consists of the number of sole proprietorships and the number of individual business partners not assumed to be limited partners. Farm self-employment is defined as the number of non-corporate farm operators, consisting of sole proprietors and partners.

Rapid growth and/or high proportions of proprietors' employment and income can be a sign of a healthy economy that is attracting entrepreneurs and stimulating business development. Correlating this growth here with patterns of population growth (such as high levels of in-migration) and unemployment rates (robust business development activity tends to be associated with lower rates of unemployment) support this finding. High levels of proprietors in an economy can also indicate a weak labor force and a lack of opportunity. This may be the case if proprietors' employment is increasing and labor earnings as a whole are flat or declining.

What does this metric show?



Key Findings

- ⓘ In 1970, proprietors (the self-employed) represented 23% of total employment (full & part-time jobs). By 2016, proprietors represented 31% of total employment.

- ⓘ From 1970–2016, proprietors grew from 39,099 to 124,201 a 218% increase.

- ⓘ In 1970, proprietors represented 23% of total labor earnings. By 2016, proprietors represented 31% of total labor earnings.

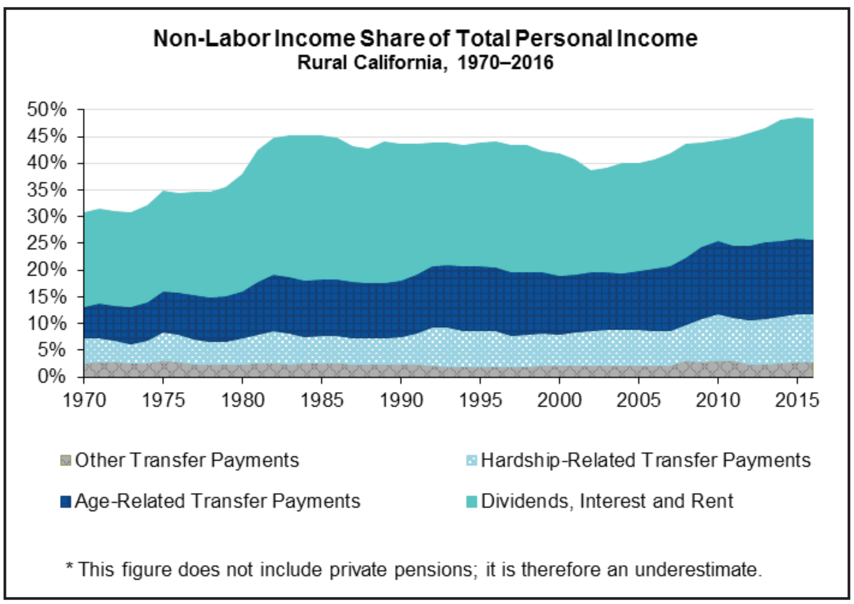
Metric: Non-Labor Income

In some geographies, non-labor income has grown rapidly over the last three decades, while in others it has not. Also, some geographies are more dependent on non-labor sources of income than others.

Because non-labor income is often so significant, it is important to understand component details [122]. Some places may rely more on investment income, others on retirement benefits, and still others on welfare-related income streams. Some important metrics include the largest components of non-labor income, whether non-labor income is growing, which components are growing the fastest, whether investment earnings are significant and growing, and whether age-related components of transfer payments are significant and growing. Also worth considering is whether the growth in non-labor income stems from new investment and age-related income and whether poverty-related components of transfer payments are significant and growing.

If age-related transfer payments are significant and growing, it may be important to consider whether public lands resources are meeting the needs of an aging population. If poverty-related transfer payments are significant and growing, it may be important to consider whether there are environmental justice issues related to public lands management.

What does this metric show?



Key Findings:

- From 1970–2016, dividends, interest and rent grew from $3,328.8 million to $17,954.5 million (in real terms), an increase of 439%.
- From 1970–2016, age-related transfer payments grew from $641 million to $5,187 million, an increase of 708%.
- From 1970–2016, income maintenance transfer payments grew from $507 million to $3,446 million, an increase of 580%.

Metric: Services

In most geographies, the majority of new job growth in recent years has taken place in services related industries. This consists of the following sectors:

- Utilities;
- Wholesale Trade;
- Retail Trade;
- Transportation & Warehousing Information;
- Finance & Insurance;
- Real Estate, Rental & Leasing;
- Professional, Scientific, & Tech., Mgmt. of Companies & Enterprises;
- Administrative & Support Services;
- Educational Services;
- Health Care & Social Assistance;
- Arts, Entertainment, & Recreation;
- Accommodation & Food Services; and
- Other Services.

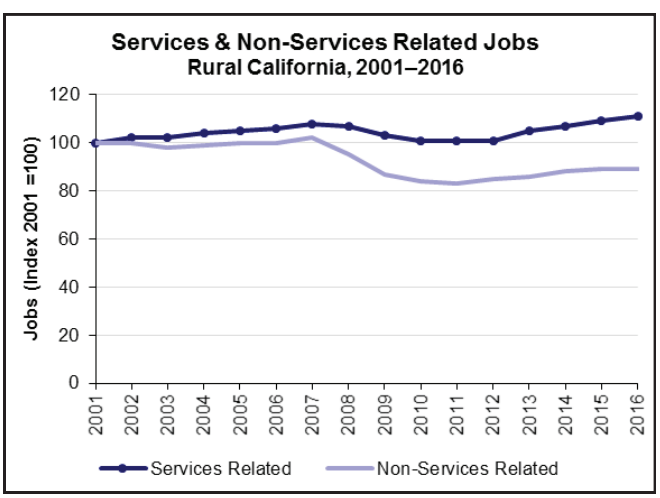
Amenity-driven migration [48-50] often corresponds with above-average growth in the service occupations. Some of those jobs are associated with recreation and tourism. People care about where they live and work and will act on their preferences for a high-quality living environment [18, 51-53].

What does this metric show?

Services Related Employment, 2015

	Non-Government Employment		Percent of Total	
	Rural California	United States Non-Metro	Rural California	United States Non-Metro
Total Non-Government Employment	322,800	20,330,005		
Services Related	~248,028	13,546,964	~76.8%	66.6%
Non-Services Related	~70,881	6,000,135	~22.8%	29.5%

Note: Estimates for data that were not disclosed are indicated with tildes (~).



Key Findings:

In 2016, total non-government service related employment accounted for approximately 77% of the total share of jobs.

Metric: Employment by Industry

Services related industries encompass a wide variety of high and low-wage occupations ranging from jobs in accommodation and food services to professional and technical services.

It can be useful to ask what factors are driving a shift in industry makeup and competitive position. The economic role and contribution of working lands has changed along with broader economic shifts in many geographies.

Note that the terms "non-services-related" and "services-related" are not terms used by the U.S. Department of Commerce. They are used here to help organize the information into easy-to-understand categories.

What does the indicator show?
Key Findings:

- From 2001–2015, the three industry sectors that added the most jobs were health care and social assistance (12,480 new jobs), real estate and rental and leasing (2,797 jobs), and other services except public administration (2,430 jobs).

- From 2001–2015, earnings in services related industries grew from $6,127.3 million to $8,854.6 million, a 45% increase.

- From 1998–2014, timber employment shrank by 6,369 jobs, a 54.5% decrease.

Employment by Industry

	% of Total				% Change
	2001	2005	2010	2015	2010–2015
Total Employment					5.58%
Non-Services Related	˜20.2%	˜19.4%	˜17.1%	˜17.7%	˜9.1%
Farm	5.13%	4.18%	4.43%	4.37%	4.12%
Forestry, Fishing, & Ag. Services	˜1.5%	˜1.6%	˜1.7%	˜2.2%	˜38.1%
Mining (Including Fossil Fuels)	˜0.2%	˜0.2%	˜0.3%	˜0.3%	˜5.3%
Construction	˜7.1%	8.07%	˜6.4%	˜6.2%	˜3.3%
Manufacturing	˜6.2%	5.24%	˜4.3%	˜4.6%	˜12.0%
Services Related	˜59.0%	˜59.4%	˜60.4%	˜62.0%	˜8.4%
Utilities	˜0.4%	˜0.5%	˜0.5%	˜0.5%	˜0.8%
Wholesale Trade	˜1.6%	˜1.7%	˜1.7%	˜1.8%	˜18.2%
Retail Trade	11.94%	˜11.7%	10.88%	10.95%	6.24%
Transportation and Warehousing	˜2.4%	˜2.2%	˜2.0%	˜2.2%	˜12.7%
Information	˜1.2%	˜1.2%	˜1.0%	˜0.9%	-˜7.7%
Finance and Insurance	˜2.5%	˜2.3%	˜2.7%	˜2.3%	-˜11.8%
Real Estate and Rental and Leasing	˜3.7%	˜4.4%	˜4.4%	4.23%	˜1.8%
Professional and Technical Services	˜4.7%	˜4.9%	˜5.4%	˜4.9%	-˜5.3%
Management of Companies and Enterprises	˜0.5%	˜0.3%	˜0.4%	˜0.3%	-˜13.6%
Administrative and Waste Services	˜3.8%	˜3.5%	˜3.7%	˜3.8%	˜6.9%
Educational Services	˜0.7%	˜0.8%	˜0.9%	˜1.0%	˜16.3%
Health Care and Social Assistance	˜8.0%	˜8.1%	˜9.1%	˜10.9%	˜26.5%
Arts, Entertainment, and Recreation	˜2.3%	˜2.4%	˜2.7%	˜2.7%	˜3.2%
Accommodation and Food Services	˜8.8%	˜8.5%	˜8.5%	˜8.8%	˜8.8%
Other Services, Except Public Administration	˜6.5%	˜6.6%	˜6.4%	˜6.8%	˜13.0%
Government	19.59%	19.92%	21.20%	19.32%	-3.81%

Note: All employment data are reported by place of work. Estimates for data that were not disclosed are indicated with tildes (~).

- From 1998–2014, industries associated with travel and tourism in the region grew by 4%. Over the same period, non-travel and tourism industries shrank by 7%.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Components	[123] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016; [82] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.	*****
Economic Sectors	[45] U. S. Department of Commerce, Bureau of Economic Analysis, reported by Headwaters Economics, 2016.	*****
Industry Sectors	[40] U.S. Department of Commerce, Bureau of Economic Analysis, Reported by Headwaters Economics, 2016.	*****

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Chapter 9: Water Resources

This chapter provides a synthesis of water resource indicators, key findings, and discussion of opportunities for watershed protection in forested watersheds and headwater areas.

SUMMARY

Forested watersheds and headwater areas are the origin of much of California's water supply and are a critical part of the natural infrastructure. Healthy forests play an important role in the hydrologic cycle, promoting infiltration and maintaining the delivery of high quality water to streams and downstream uses. While headwater forests play a pivotal role in maintaining the delivery of high quality water, these resources have been undervalued. Water quality is generally good on forested streams (ⓘ9.1), but there are many threats. In many watersheds, the type of management and fire exclusion has resulted in forests that are either at risk from fire and pests, or have already been impacted. Forested watersheds are also at risk from drought (ⓘ9.4), warming climate (ⓘ7.1), and declining snowpack (ⓘ9.2). Post-fire erosion from large wildfires and other disturbances can negatively impact water quality, downstream water storage, and other critical water infrastructure. The impact of grazing on water quality has mixed findings, but water quality indicators (ⓘ9.1) on rangelands show a higher level of impairment.

INDICATORS

- ⓘ9.1 Water Quality
- ⓘ9.2 Snowpack
- ⓘ9.3 Spring Runoff
- ⓘ9.4 Climatic Water Deficit

Indicators and key findings suggest that California's climate and hydrology is changing, resulting in warmer annual temperatures, with increases in both maximum and minimum temperatures (ⓘ7.1). In turn, warmer temperatures are causing declining snowpack (ⓘ9.2) and altering the timing of spring runoff (ⓘ9.3). As snowmelt begins to occur early in the spring we are likely to see longer dry periods and more frequent severe fire weather (ⓘ4.5). In addition, as evapotranspiration from forest vegetation increases under warmer temperatures, vegetation becomes further stressed by prolonged drought conditions [1]. When these climatic factors are combined with high risk stands, forests face increased threat from both pests and severe wildfires. Changes in the frequency and severity of large scale disturbance can influence the timing and delivery of water downstream, which may necessitate changes in water storage, increased storage capacity, and altered flood management practices.

Opportunities for improved management and protection of forested watersheds and headwater areas include:

- Prioritize funding for restoration in headwater areas to protect against severe wildfire, insect and disease.
- Support restoration of mountain meadows and related measures from the State Water Plan.
- Develop coordinated landscape-level forest health projects to focus investments.
- Coordinate forest health treatments to support local Integrated Regional Water Plan (IRWMP) objectives.
- Support frameworks like the Sierra Nevada Watershed Improvement Program to promote large-scale watershed restoration.
- Target fuel reduction in headwater areas that provide significant water supply.
- Support reforestation of areas subjected to severe wildfire.

KEY FINDINGS

ⓘ9.1 Indicator: California Stream Condition Index

- Forest streams are mostly in a good biological condition. There are a higher percentage of forest streams in good condition (62%) compared to rangelands (34%).
- California Stream Condition Index scores show some interannual variability across the monitoring period (2000–2012), but forest streams consistently show that 50% or more streams are in good condition in the more recent sampling period.
- Rangeland streams show a greater percentage of streams in poor (21%) and very poor (21%) condition.

ⓘ9.2 Indicator: April 1st Snow Pack

- The data shows high interannual variability, but no strong historic trend.
- Snowpack has declined substantially under the current drought conditions (2012–2015), but rebounded in 2016.

ⓘ9.3 Indicator: Spring Runoff

- Spring runoff shows a steady decline from 1997–2015.
- Trends show a decreased water availability in summer months for downstream uses.
- Decreased water availability likely increases moisture stress for vegetation, and drier vegetation can lead to more extreme wildfire behavior, and greater insect mortality.

ⓘ9.4 Indicator: Climatic Water Deficit (CWD)

- The increasing trend in CWD since 1980 suggests drier conditions and increased moisture stress.
- Climatic Watershed Deficit for the recent drought (2012–2015) has created moisture deficits that are as or more severe than the drought of the 1970s.
- Many forested watersheds that provide water supply for the state have experienced high CWD.
- There appears to be a relationship between CWD and elevated levels of tree mortality.

DISCUSSION

Watersheds across California are immensely diverse, from the wet coastal watersheds on the North Coast to the arid desert landscapes in portions of southern California. This biophysical diversity creates a broad range of environmental services supported by California's watersheds and a considerable resource management challenge within each watershed. A substantial portion of runoff that supports the state's water supply, and other beneficial uses, is generated from forested watersheds. These tend to be higher elevation headwater locations. For example, approximately 60% of the state's water is derived from the Sierra Nevada region [2]. The management of these lands can greatly influence the quantity and quality of water, along with timing and distribution of water for downstream uses. In addition, the current drought and warming climate are creating additional changes in forest hydrology and watershed conditions.

Water Resources – Forest Management

Water quality impacts from forest management and other land management activities can affect a broad range of environmental processes that include hillslope erosion, stream sedimentation, the amount of large wood in streams, increases in water temperature and nutrient loading, and changes in peak and low flows (Table 9.1). The California State Water Resources Control Board (SWRCB) has primary responsibility for addressing water pollution and addressing water quality issues. Reporting on the conditions of water quality is mandated under section 305(b) of the federal Clean Water Act and the listing of impaired waterbodies under section 303(d). To evaluate stream health, survey data on macro-invertebrates was used to develop an index of stream health relative to a reference condition [3, 4]. These datasets were used for a water quality indicator. While water quality impairments do arise from forest management, forested streams are predominately considered in good (62%) or fair (17%) condition; 15% of streams are listed as poor and 7% as very poor. The monitoring data exhibit some interannual variability, but with the exception of one reporting period the majority of forested streams surveyed were found to be in good condition.

The impact of forest management on water yield is more variable. Forest thinning can influence base and peak flow, and water yields; however, without repeated treatments the increase is temporary and eventually returns to pretreatment levels [5]. Other research has shown that prescribed burning and managed wildfire can increase charcoal in soils, which should increase water holding capacity of forest soils [6]. In addition

Table 9.1: Water Quality Stressors

Stressor	Cause(s)	Primary Response	Secondary Response	Type
Sediment	Hillslope erosion; land disturbance (timber harvest, agriculture, mining, grazing, etc.); road erosion	Delivery of fine sediment to streams from surface erosion processes; delivery of sediment from mass wasting associated with roads and hillslopes	Effect spawning gravels; channel morphology; effect stream turbidity, reservoir storage capacity	Chronic and Episodic
Stream Temperature	Forest management; agriculture and other land uses	Stream shading reduced	Changes in temperature affecting coldwater fish; change in aquatic habitat	Chronic and Episodic
Nutrients	Land management; wildfires	Increase concentration of nitrogen and phosphorus, as well as other nutrients	Raise nutrient loadings in lakes and rivers	Chronic and Episodic
Contaminants	Land management; marijuana cultivation	Water contamination from application of herbicides, pesticides, rodenticides, or fuel spills	Effects on riparian habitat and aquatic organisms	Episodic

Data Source: FRAP, 2010.

to changes in water yield, other hydrologic responses to reductions in forest canopy from forest management include decrease in interception of precipitation by forests, reduced transpiration (i.e., water lost from trees and plants), and increased soil moisture. In higher elevation snow dominated forests, research suggests that forest thinning can increase snow accumulation and affect timing of snowmelt [7, 8]. This research estimated that forest thinning with target canopy cover levels of 30% and 60% could increase water yield by 16% and 8%, respectively, as well as extend snow storage by two weeks. In another study, researchers found increases in the ratio of annual runoff to precipitation associated with watersheds where managed wildfire had been introduced over the last 40 years [9]. This was largely attributed to the recovery and expansion of mountain meadows in the watershed.

Changes in water quantity as a result of forest management using thinning to reduce fuel loading and wildfire risk was modeled as part of the Sierra Nevada Adaptive Management Project (SNAMP). Results from decreasing vegetation by 8% led to an increase in runoff of 12% at the Last Chance study site in the central Sierra. With predicted vegetation growth, the water yield was expected to decrease to pretreatment levels after 10 years [7]. Smaller increases in water yield (<3%) were predicted from a second study site in the southern Sierra Nevada (i.e., Sugar Pine), but with a similar return in water yields after 10 years. Maintaining water yield increases would require maintenance treatments or more intensive treatments. The SNAMP study also measured several water quality variables (stream temperature, turbidity, dissolved oxygen, etc.) before and after treatment implementation. Given that the intensity of the treatments were relatively light and occurred during a relatively dry period, no significant changes in water quality were detected. Overall, non-commercial thinning to reduce wildfire risk has minimal hydrologic impacts [10, 11].

Post-Fire Erosion

While wildfires are a natural process in forested watersheds, the size and severity of wildfires in recent years have shown an increasing trend (ⓘ4.1, ⓘ4.2). After decades of fire suppression, many forests have a high buildup of fuels. With an increasing number of large wildfires in conifer forests in recent years, and a higher amount of watershed area burned at high severity, there are concerns regarding whether watersheds can deliver high quality water to support beneficial uses. Post-fire erosion can contribute to downstream sediment impacts to water quality, aquatic habitat, and water storage. Researchers have estimated that almost 200 reservoirs have lost more than half of their initial storage capacity to sedimentation [12]. Wildfires can increase sediment delivery, but reservoir sedimentation is influenced by other factors as well (natural sedimentation rate, age of reservoir, trap efficiency, etc.). The potential impacts from increased sediment from severe fires in the Sierra Nevada region is greatest in the small and moderate-sized reservoirs (3,000–50,000 acre feet) at the middle and lower elevations (2,000–6,500 feet).

Rangelands and Water Quality

Water quality issues on rangelands revolve around impacts from cattle grazing (Table 9.2). Livestock seek out water, succulent forage, and shade in riparian areas, leading to trampling and overgrazing of streambanks, soil erosion, loss of streambank stability, declining water quality, and drier, hotter conditions [13]. Microbial and nutrient pollution are the most common factors that degrade water quality on rangelands. Research studies have reported mixed results in terms of the impact of grazing on water quality. In the central Sierra Nevada, a study that collected water quality samples before and after cattle grazing began found that the introduction of cattle was associated with substantial increases in bacteria (E. coli, total coliform, and fecal coliform) concentrations [14]. In contrast, a more comprehensive study of grazing on national forest lands in California found that nutrient concentrations on grazed lands were under Environmental Protection Agency (EPA) designated benchmarks and at least one order of magnitude below levels of ecological concern [15].

Water quality on rangelands was evaluated using the same stream survey data on macro-invertebrates that was used to develop the indicator on forestlands. These datasets were used for the rangelands water quality

Table 9.2: Potential Impacts to Water Quality from Grazing	
Factor	**Impact**
Nutrient Concentrations	Reduced dissolved oxygen and possible water salinization in isolated pools and downstream lakes; alteration of instream species composition
Bacteria	Higher human and wildlife disease-producing potential from pathogens; human health endangered by swimming and other contact
Sediment - Turbidity	Increased turbidity; pool filling; degraded aquatic habitat
Water Temperature	Reduced shade from riparian vegetation can increase water temperature and associated impacts on aquatic habitat and cold-water species
Dissolved Oxygen	Reduced oxygen in spawning gravels
Channel Morphology	Potential changes in channel width, depth, bank stability, etc.
Hydrologic Change	Reduced water infiltration due to soil compaction; changes in peak flows resulting from increased overland flow
Soil Properties	Increased bare soil; increased soil compaction; loss of top soil

Data Source: [13] Belsky et.al., 1999.

indicator (ⓘ9.1). In comparison to forests, rangelands show a higher level of impairment. Based on stream survey data, less than half of streams surveyed are listed in good (34%) or fair (16%) condition; 29% are in poor and 21% very poor condition. Similar to forestlands, the data exhibits interannual variability, but only one reporting period showed the majority of surveyed streams in good condition.

Climate and Drought

Prolonged drought conditions over multiple years combined with a series of long and active fire seasons and massive tree mortality from insect attack has renewed interest in forest health and watershed protection. California has had several distinct periods of drought since 2000 (Figure 9.1). Consecutive dry winters in the most recent drought were associated with ocean conditions that maintained a stable ridge of high pressure that prevented winter storms from reaching California. Precipitation during this period of severe drought conditions was the second lowest since 1895 [16]. During the same period, potential evapotranspiration (PET) was estimated to have increased along with warming temperatures: 9–12% above average for water year 2014 [17]. The return of wet conditions in the most recent winter (2016/17) brought much needed rain and snow, but the effects of severe drought conditions still persist in parts of the state (e.g., extensive tree mortality, depleted groundwater, etc.).

Trends in precipitation are highly variable across the state. The North Coast region has the highest annual precipitation, while the Colorado dessert region has the lowest. Precipitation declined markedly across all ecoregions during the most recent drought period (Figure 9.1). Precipitation predicted by future climate models is also highly variable. Climate models show an expected change in precipitation (2010–2039 to 2070–2099) across ecological units that varies from -28% to +15%.

Temperature data show interannual variability, but an overall increasing trend (ⓘ7.1). Long-term monitoring

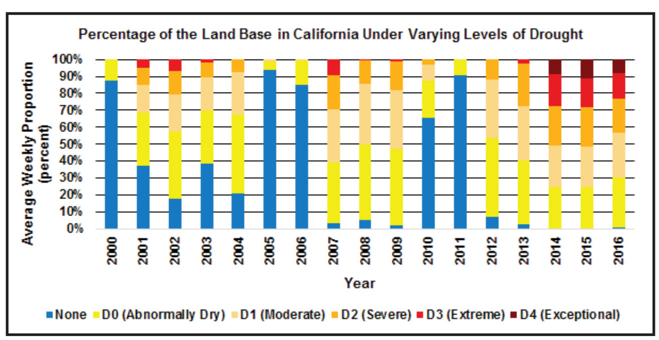


Figure 9.1: Percentage of the Land Base in California under Varying Levels of Drought

Data Source: NOAA, U.S. Drought Monitor, Palmer Drought Severity Index, 2016.

reveals that statewide temperatures have experienced an increase of 1.2–2°F in mean temperatures during the last century [18]. An increasing trend is present in minimum, average, and maximum temperatures, but minimum temperatures appear to be increasing at a faster rate. Under the recent drought conditions (2011–2014) average temperatures have been estimated to have increased 2–4°F compared to the 20th century average [19]. Geographically, studies have found warming trends to be greatest in southern California and in the Central Valley [20]. These findings are consistent with data reported in this study. Concerns about future drought conditions for California are further heightened by predictions from climate models. Global Climate Models (GCMs) show substantial variation in future conditions, but consistently project warmer conditions.

Recent research has suggested that warmer temperatures are producing "hotter droughts" that increase evaporative demand and make forest trees more susceptible to mortality [21]. This assumption is supported by documented increases in rates of tree mortality, though the response is quite variable among tree species and stand characteristics [22, 23]. Temperature increases alone can have a great effect on forest hydrology.

Snowpack and Spring Runoff

Warming temperatures influence the amount of precipitation falling as snow. This is supported by monitoring data that has shown declining snowpack in recent decades across the Sierra and western states [24]. The Sierra snowpack has high interannual variability, but overall declines appear greatest in the southern Sierra (ⓘ9.2). With warming temperatures in future decades, snowpack is expected to experience sharp declines by 2100 (Figure 9.2).

Climate model predictions suggest that there will be a shift in precipitation that results in more rainfall and less snowfall at mid-elevations in the Sierra Nevada, and more rapid spring snowmelt in the Sierra Nevada is already occurring [25]. If snow is replaced by rain at mid-elevations, then winter flood peaks are likely to become larger and more frequent. Correspondingly,

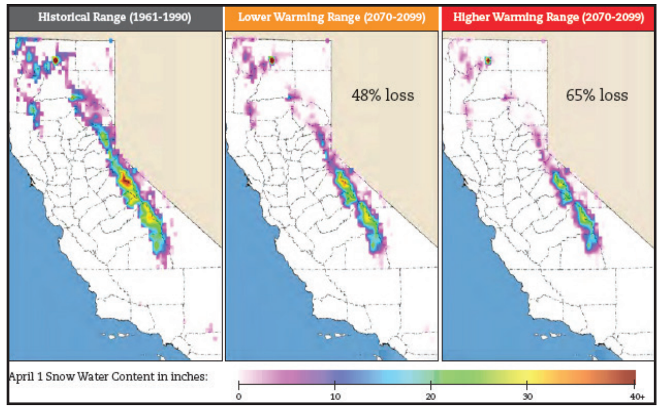


Figure 9.2: Declining Snowpack: Historic and Projected Future Conditions

Data Source: [18] Department of Water Resources (DWR), 2015.

summer stream base flows will be lower in dry months, limiting water availability for forest vegetation and extending the dry season. In addition, research has also shown the potential for upslope vegetation migration and expansion to increase evapotranspiration, resulting in reduced runoff and streamflow [26]. Warming temperatures and declining snowpack have already resulted in declining spring runoff in Sierra rivers. Spring runoff from the Sacramento River has shown a 9% decline since 1906 (Figure 9.3). Declines in spring runoff have also been reported on other river systems throughout the Sierra Nevada [27]. Statewide, there is interannual variability, but spring runoff shows a steady decline since 1995 (ⓘ9.3).

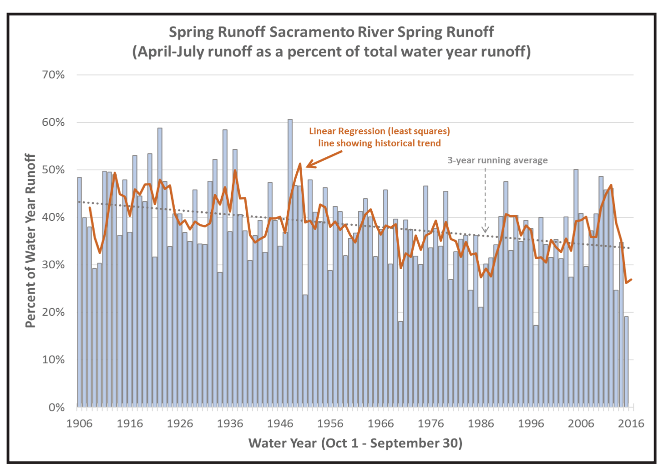


Figure 9.3: Trend in Spring Runoff for the Sacramento River

Data Source: [18] Department of Water Resources (DWR), 2015.

Water Stress – Climatic Water Deficit

Climate change also directly affects forests through increased drought stress, which makes trees more vulnerable to insect attack, with the resulting increased rates of tree mortality influencing wildfire frequency, size, and severity [28-30]. These stresses on forests will affect their capacity to naturally regulate streamflow and buffer water quality. Many streams that are now perennial may become intermittent with the resulting loss of riparian zones, aquatic habitats, and other beneficial uses of water that depend on perennial flows. With increasing temperatures, researchers are beginning to document hotter droughts that may lead to increased tree mortality [21].

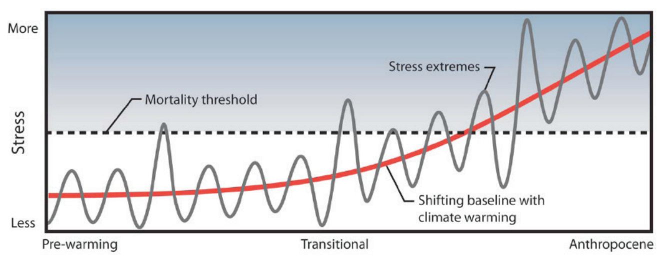


Figure 9.4: Forest Stress with Warming Climate

Data Source: [21] Allen et.al., 2015.

Water stress from drought conditions can be evaluated using Climatic Water Deficit (CWD). CWD is an index that is evaluated as actual evapotranspiration minus potential evapotranspiration. It provides an important measure of moisture stress that affects the health and resilience of forest vegetation, particularly under prolonged drought conditions. The CWD indicator shows an increasing trend historically since 1920 and a sharper increase corresponding with the severe drought conditions in recent years (ⓘ9.4). Recently, researchers have examined the relationship between tree mortality and CWD. In the Sierra Nevada, they found northern aspects and lower elevations had higher probabilities of tree mortality and higher climate water deficit [31].

Opportunities

Forested watersheds in California are the origin of much of the water supply in the state and support a broad range of beneficial uses. Currently, the majority of forested watersheds demonstrate good water quality as measured by the California Stream Condition Index [3]. However, watersheds do experience impacts from forest management and other land use practices. The combined stressors from management and changing climate conditions threatens the ability of forested watersheds to provide clean and abundant water that supports downstream uses. Actions are needed to protect forested watersheds and increase their resilience to climate change impacts. Suggested measures include:

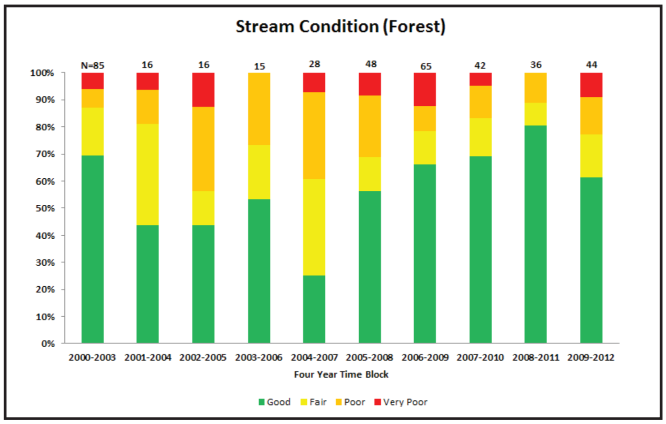
- Prioritize restoration funding and water bond funding in headwaters to reduce risk from severe wildfire, insect and disease.
- Support restoration of mountain meadows and related measures from the State Water Plan [11].
- Develop coordinated landscape level forest health projects to focus investments.
- Coordinate forest health treatments to support local Integrated Regional Water Plan objectives.
- Support frameworks like the Sierra Nevada Watershed Improvement Program to promote large-scale watershed restoration (www.restoresierra.org).
- Target fuel reduction in headwater areas that provide significant water supply.
- Support reforestation of areas subjected to severe wildfire.

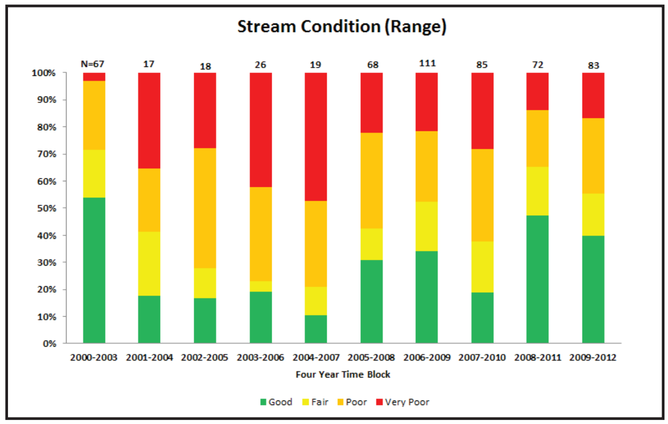
Indicator: California Stream Condition Index ⓘ9.1

Which Montreal Protocol Criteria does the indicator evaluate?
MPC 4: Conservation and Maintenance of Soil and Water Resources

Why is the indicator important?
The California Stream Condition Index (CSCI) translates data about individual benthic macro invertebrates (BMI) found living in a stream into an overall measure of stream health. The indicator evaluates the environmental health of a stream against reference sites.

What does the indicator show?
The indicator evaluates trends in stream health. A value of 1 represents good stream health; values approaching 0 show departure from reference conditions. Scores are then placed into categories: Class 1 (good), Class 2 (fair), Class 3 (poor), and Class 4 (very poor).





Key Findings:

- Forest streams are mostly in a good biological condition. There are a higher percentage of forest streams in good condition (62%) compared to rangelands (34%).

- California Stream Condition Index (CSCI) scores show some interannual variability across the monitoring period (2000–2012), but forest streams consistently show that 50% or more streams are in good condition in the more recent sampling period.

- Rangeland streams show a greater percentage of streams in poor (21%) and very poor (21%) condition.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
CA Stream Condition Index	State Water Resources Control Board, Ca Stream Condition Index, 2015.	****

Indicator: Snow Pack (April 1st)

ⓘ9.2

Which Montreal Protocol Criteria does the indicator evaluate?

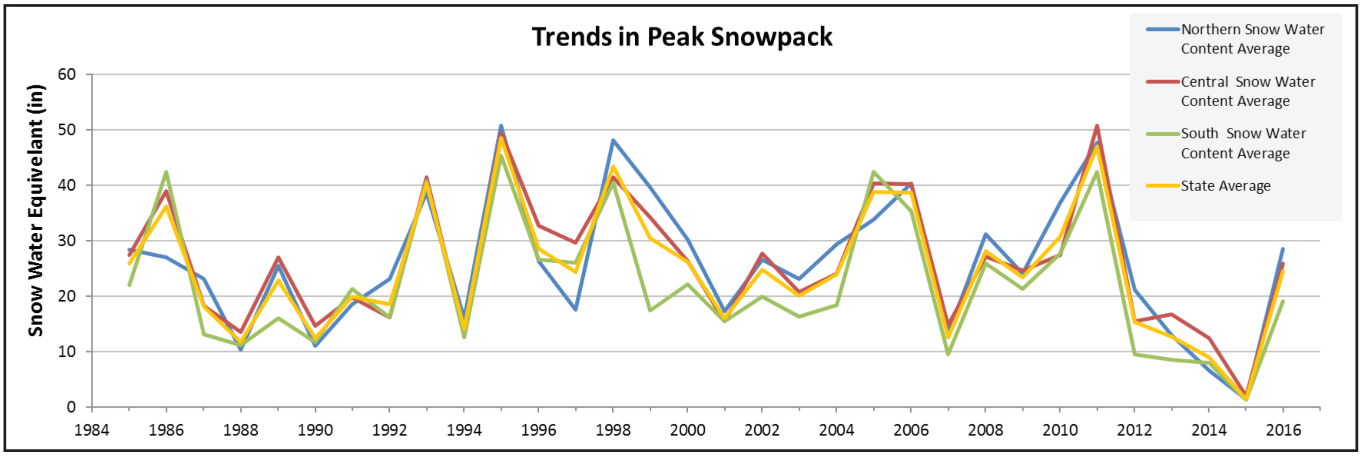
MPC 4: Conservation and Maintenance of Soil and Water Resources

Why is the indicator important?

The amount of water held in the snowpack is a measure of how much water is stored above ground in snow at a given point in time. Under a warming climate, the amount of precipitation falling as snow is expected to decline. The amount of water stored in the snowpack, particularly across the Sierra, is important to California's water supply. The amount and timing of snowmelt can influence water availability for forest vegetation.

What does the indicator show?

The indicator shows trends in peak snowpack. This includes historic and predicted trends.



Key Findings:

ⓘ The data shows high interannual variability, but no strong historic trend.

ⓘ Snowpack has declined substantially under the recent drought conditions (2012–2015), but rebounded in 2016.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Snow Water Equivalent	[18] Department of Water Resources (DWR), 2015.	****

Indicator: Spring Runoff

ⓘ9.3

Which Montreal Protocol Criteria does the indicator evaluate?

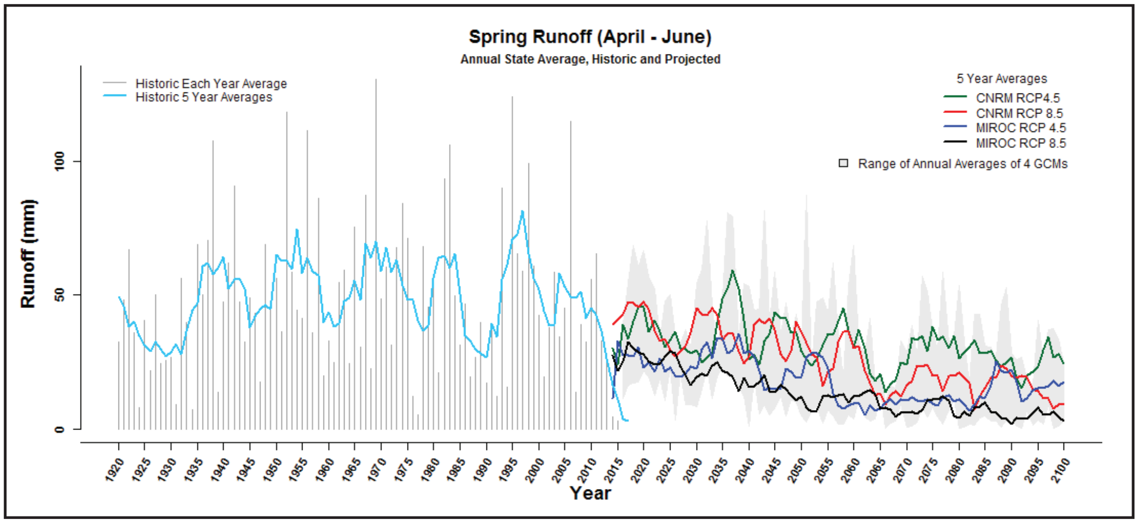
MPC 4: Conservation and Maintenance of Soil and Water Resources

Why is the indicator important?

The fraction of runoff that occurs in the spring months (April–July) is influenced by snowmelt at higher elevations. Under warmer temperatures there is less precipitation stored in snowpack and water moves more directly into streams and as a result spring runoff is diminished.

What does the indicator show?

The indicator shows trends in spring runoff.



Key Findings:

ⓘ 🔑 Spring runoff shows a steady decline from 1997–2015.

ⓘ 🔑 Trends show a decreased water availability in summer months for downstream uses during this period.

ⓘ 🔑 Decreased water availability likely increases moisture stress for vegetation, and drier vegetation can lead to more extreme wildfire behavior, and greater insect mortality.

Data Sources and Quality

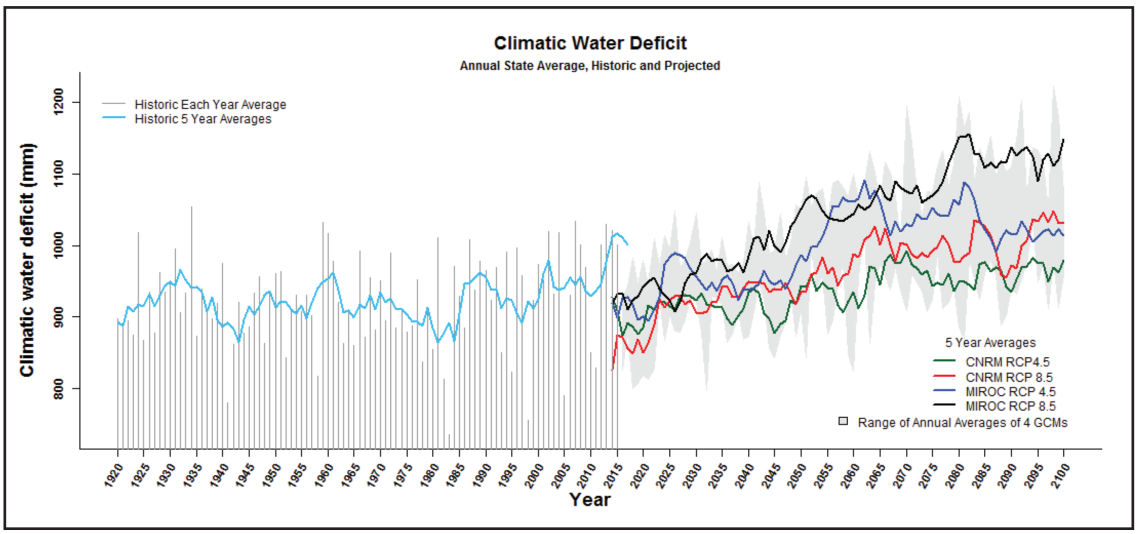
Data Theme	Source	Quality (5 star max)
Spring Runoff	USGS, Flint L., Basin Characterization Model, 2016.	****

Indicator: Climatic Water Deficit ⓘ9.4

Which Montreal Protocol Criteria does the indicator evaluate?
MPC 4: Conservation and Maintenance of Soil and Water Resources

Why is the indicator important?
Climatic Water Deficit (CWD) is an index that is evaluated as actual evapotranspiration minus potential evapotranspiration. It provides an important measure of moisture stress that affects the health and resilience of forest vegetation, particularly under prolonged drought conditions. The indicator can also be used to infer trends in moisture conditions over time.

What does the indicator show?
The indicator shows trends in CWD across decades and for the current drought.



Key Findings:

- The increasing trend in CWD since 1980 suggests drier conditions and increased moisture stress.
- Climatic Watershed Deficit for the recent drought (2012–2015) has created moisture deficits that are as or more severe than the drought of the 1970s.
- Many forested watersheds that provide water supply for the state have experienced high CWD.
- There appears to be a relationship between CWD and elevated levels of tree mortality.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Climatic Water Deficit	USGS, Flint L., Basin Characterization Model, 2016.	****

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Chapter 10: Wildlife Habitat

This chapter provides a synthesis of indicators, issues and opportunities related to wildlife habitat.

SUMMARY

Indicators and key findings suggest that California's plant and animal species are experiencing increasing pressure. Of the approximately 7,500 native plants and animals found in California, 252 are listed as threatened or endangered under the California and 320 under the Federal Endangered Species Act (CESA and ESA respectively), 408 total listed (ⓘ10.1). A more comprehensive account of at-risk species in the state is provided by the California Department of Fish and Wildlife (CDFW) under the Species of Greatest Conservation Need (SGCN) [1], which consists of 1,153 species (264 invertebrates, 414 fish and wildlife and 475 plants). Most of the SGCN are identified as threatened, endangered, rare, endemic or vulnerable under ESA, CESA or other dependable species status ranking systems by NatureServe, California Native Plant Society and CDFW.

The extent, structure and quality of forest and rangeland have significantly changed due to human activities such as development, road construction, exotic species introduction and invasion, and land management (see Chapter 6 - Population Growth and Development Impacts). Currently only around 13% of California conifer forests are over 200 years old (ⓘ10.2), and are mostly high elevation types such as western white pine and Lodgepole pine, as defined in the California Wildlife Habitat Relationships (CWHR). Vegetation that have gone through extensive human disturbances (low intactness) are primarily coastal, foothill and riparian types, and include Valley Foothill Riparian (71% low intactness), Desert Riparian (49%), Valley Oak Woodland (43%), Coastal Scrub (33%), Montane Riparian (26%), Coastal Oak Woodland (26%), and Redwood (21%) (ⓘ10.3). Those habitat alterations have inevitably influenced the livelihood of many forest and rangeland obligate species.

Climate change imposes an additional threat to wildlife habitats. Modelling efforts under different climate scenarios show that the quantity, quality and spatial distribution of habitat types will likely change. For example, red fir is projected to be severely impacted in its extent under the hotter and dryer climate model. Within the Sierra regions, oak woodlands show the highest potential loss in the southern counties both under the hotter and dryer and the warmer and wetter models (ⓘ10.4). In drier regions, Joshua Tree is projected to be severely impacted in its extent under the two climate models, and impacts are already being observed presently.

INDICATORS

ⓘ10.1 Species at risk

ⓘ10.2 Habitat Structure

ⓘ10.3 Habitat Degradation

ⓘ10.4 Habitat Vulnerability to Climate Change

ⓘ10.5 Protected Habitat

Total extent of forest and rangeland have consistently been around 80 million acres since CAL FIRE's Fire Resource and Assessment Program started reporting in 1979. Just under 58% of these habitats are protected from conversion through acquiring fee title by public or conservation organizations, or more recently by a growing trend of purchasing conservation easements on private lands (ⓘ6.3). The least protected habitat types under CWHR are Blue Oak and Valley Oak Woodland (17% each), Annual Grassland (20%), Blue Oak Foothill Pine (24%) and Valley Foothill Riparian (36%) and within the conifer forests, they are Redwood (30%), Ponderosa Pine (49%) and Montane Hardwood Conifer (49%) (ⓘ10.5). There are also habitat types that have experienced major habitat losses over time, for example, Fresh Emergent Wetland (68% protected) and Coastal Scrub (42% protected). Countless native species, including SGCN, rely on those diverse ecosystems; thus, protecting what remains as an attempt to ensure their survival is a highest conservation priority of the state.

CAL FIRE supports the opportunities and conservation priorities outlined in the California Wildlife Action Plan 2015 Update. In addition, other opportunities include partnership agreements, state regulations and laws, private landowner incentives, and conservation efforts. A more detailed list of conservation opportunities is found at the end of the chapter.

KEY FINDINGS

Key findings and indicators are grouped below for the five chapter topics.

Species at Risk

Of the 32 salmonids recognized in California (21 anadromous and 11 non-anadromous), one is now extinct and 14 others are listed as threatened or endangered under ESA and/or CESA. The most threatened salmonid populations in California are the southern steelhead, the winter-run Sacramento River Chinook salmon and the Central California Coho salmon. 45% of California salmonid species are likely to be extinct in the next 50 years. In 100 years, 23 of the remaining 31 species (74%) are likely to be extinct if present conditions continue [2].

ⓘ10.1 Indicator: Number of Threatened and Endangered Species Listed Under the California (CESA) and/or Federal Endangered Species Act (ESA)

ⓘ Since 2010, 15 species have been added to the list of threatened or endangered species, mostly under ESA. The amphibian taxa saw the largest increase in listing with 7 new species added. Currently, 252 species are listed as threatened or endangered under the CESA and 320 under the ESA, with 408 total species listed (2017).

ⓘ California Department of Fish and Wildlife has compiled a list of Species of Greatest Conservation Need (SGCN) that includes threatened, endangered, rare, endemic, vulnerable and species of special concern, under ESA, CESA or other dependable species status ranking systems by NatureServe, California Native Plant Society and CDFW. Of the 1,153 species on the list, there are 264 invertebrates, 414 fish and vertebrates, and 475 plants.

Habitat Structure

ⓘ10.2 Indicator: Forest Stand Age Class by Ownership

ⓘ Late seral (201+ stand age): Nearly 32% of public reserve conifer land is late seral stage defined as being over 200 years old, and 12% of public non-reserve conifer land is late seral. Nonindustrial private conifer land is made up of less than 3% stands over 200 years old, and well under 1% on forest industry land. Western white pine (62%) and lodgepole pine (40%) currently have the largest proportion of older stands.

ⓘ Mid-late seral (161–200 stand age): Public reserve lands have the largest percent of mid-late seral tree stands between 161 and 200 years old (13% for conifer and 6% for hardwood lands). For forest industry, the percentages are 1% of conifer and 1% of hardwood.

ⓘ Early seral (<80 stand age): 67% of California's conifer stands and 73% of hardwood stands on forest industry forestland are less than 80 years old. Nonindustrial private lands are comprised of 52% conifer stands under 80 years old and 61% hardwood stands under 80 years old. 25% of the conifer stands and 49% of hardwood stands on public land are less than 80 years old.

Habitat Degradation

ⓘ10.3 Indicator: Terrestrial Intactness of California Wildlife Habitat Relationships (CWHR) Types Based on Human Impacts

ⓘ Habitat types with the lowest percentage of intactness are primarily coastal, foothill and riparian habitat types such as Valley Foothill Riparian (71% low intactness), Desert Riparian (49%), Valley Oak Woodland (43%), Coastal Scrub (33%), Montane Riparian (26%), Coastal Oak Woodland (26%), and Redwood (21%).

- By this measure, the Central Valley (65% low intactness), Central Coast (34%) and South Coast (43%) ecological regions (i.e. USFS Bailey's classification system) have the highest level of habitat degradation while the Great Basin (79% high intactness), South Sierra (75%) and South Interior (68%) have the highest level of intactness.

- Desert and high elevation habitat types (Desert Scrub, Low Sage, Joshua Tree, Pinyon-Juniper, Palm Oasis, Alpine Dwarf Shrub, Aspen, Lodgepole Pine, Red Fir and Subalpine Conifer) have the most intactness, all with over 75% of habitat extent in the high intactness class.

Habitat Vulnerability to Climate Change

We can assume that habitat, species, community composition, and spatial distribution will continue to change into the future, under a changing climate. With the understanding that there is uncertainty in climate change models, they still provide valuable information for systematic conservation planning that can be adjusted through adaptive management, incorporating future findings from monitoring and research.

10.4 Indicator: Projected Impacts of Climate Change on the Extent of California Wildlife Habitat Relationships (CWHR) Types

- Habitat types such as Joshua Tree are projected to have severe impacts under the two hotter/dryer and warmer/wetter climate scenarios.

- For habitat types such as Red Fir, the future climate scenario has major implications in terms of loss.

- Habitat types such as Coastal Scrub are projected to have minimal impact in extent under either climate scenario. However, there may be qualitative impacts, for example, changes in species composition within Coastal Scrub habitats.

- In addition to losses, changing climate provides opportunities for habitat types to "migrate" into areas that were climatically unsuitable in the past. Whether these opportunities are realized will depend on the adaptability of the habitat types to these new sites, for example, intactness, soil conditions, competition with other vegetation, and disturbance regimes found in the potential sites.

Protected Habitat

10.5 Indicator: California Wildlife Habitat Relationships (CWHR) Types Protected from Conversion

- High elevation habitat types such as Red Fir, Subalpine Conifer and Aspen are at least 85% protected in almost all regions where they are found.

- Nearly 80% of hardwood woodland habitat types are on private lands and thus have low protected status, e.g., Blue Oak Woodland (17%), Valley Oak Woodland (17%), Foothill Pine (24%)and Coastal Oak Woodland (35%). Hardwood forests are less protected than other habitat types in all regions across the state, with the exception of Aspen and Joshua Tree. The Central Coast and Central Valley regions have the lowest percentage of protected hardwood woodlands.

- Of the 65% of conifer forestlands that are protected, most are managed by the US Forest Service. Some conifer forest habitats are not as well protected, depending on the specific regions. Coastal Redwood habitat is almost exclusively found in the North Coast but only 28% is protected, and less than 50% of Ponderosa Pine habitat is protected in the North Coast, North Interior and North Sierran regions.

DISCUSSION

Species at Risk

California is home to approximately 75 amphibian, 100 reptile, 650 bird and 200 mammal species [3]. California hosts over 6,500 species, subspecies, and varieties of plants that occur naturally in the state [4], and approximately 66 native freshwater, estuarine, and anadromous fish species [5]. Species become candidates to be listed under the California (CESA) and/or Federal Endangered Species Act (ESA) as threatened or endangered when their survival and reproduction in the wild is recognized to be in immediate danger due to change or loss of habitat, over-exploitation, predation, competition, disease or other factors. Currently, 252 species are listed as threatened or endangered under the CESA and 320 under the ESA, with 408 total species listed as of October 2017 [6, 7] (ⓘ10.1).

The number of species identified under the CESA and ESA has been used in the past as an indication of the number of species that are in decline or threatened by extinction. However, getting a species on the state or federal lists can be a long, slow process that is not always a reliable method for accurately accounting for all species that are experiencing stress and dire population decline. With the ESA under critical review [8], we look for other more supported sources for tracking vulnerable species. A more comprehensive account of at-risk species in the state is provided by the California Department of Fish and Wildlife (CDFW) under the Species of Greatest Conservation Need (SGCN). As defined in the California State Wildlife Action Plan 2015 Update [1], the SGCN consist of 1,153 species (264 invertebrates, 414 fish and vertebrates, and 475 plants). Most of the SGCN are federally or state listed, ranked critically imperiled (S1) under the NatureServe Ranking System, ranked as experiencing significant decline in the last century (1B.1) under the CNPS California Rare Plant Ranking System, or identified as the Species of Special Concern or climate vulnerability by CDFW.

Many of these vulnerable species are under even more stress as a result of the recent extreme drought that started in 2012. In 2016, CDFW conducted a rapid assessment study to identify and prioritize the taxa and habitats that are most at-risk under drought conditions. Although all ecoregions throughout the state were found to contain drought sensitive taxa, the Southern California Coast, Mountain and Valley, Central California Coast, Sierra Nevada and Colorado Desert had the highest number of species most vulnerable to the drought conditions. The majority of the most vulnerable taxa identified in the study are found in freshwater marshes, riparian, and wet meadow communities, throughout temperate, mountain and desert regions [9].

Habitat Structure

Wildlife species utilize a variety of stand structures for unique habitat needs such as feeding, breeding, and cover. Healthy seral stage forests include multilayered canopies, with multi-age stands, tree canopy gaps, a wide range of tree species, snags and woody debris, though the level of variation depends on the landscape content. Uneven-aged forests enhance wildlife diversity and improve resilience from disturbance impacts [10].

Land management influences stand age structure at the landscape level, so different stand age classes tend to be associated with a specific ownership type (ⓘ10.2). Older tree stands that are generally considered late seral have declined significantly in California in the last hundred years [11], and the remaining stands are predominately on public reserve lands. Over 50% of conifer and hardwood tree stands between 160–200 years old and over 60% of stands over 200 years old are on public reserve lands (Figure 10.1). The large branches, cavities, snags and logs in these older forests offer distinctive roosting, nesting, den, cover, and habitat opportunities for species such as bats, spotted owls, marbled murrelet, fisher, pine martens and fungi, and improve soil fertility through nutrient cycling and moisture retention [12]. According to the U.S. Forest Service (USFS) 2001–2010 Forest Inventory and Analysis report, Forest Service managed lands have the highest density of dead wood biomass, with an average of 18 snags per acre, and for conifers the maximum total biomass per acre in standing dead trees occurs in stands 161–200 years old [13].

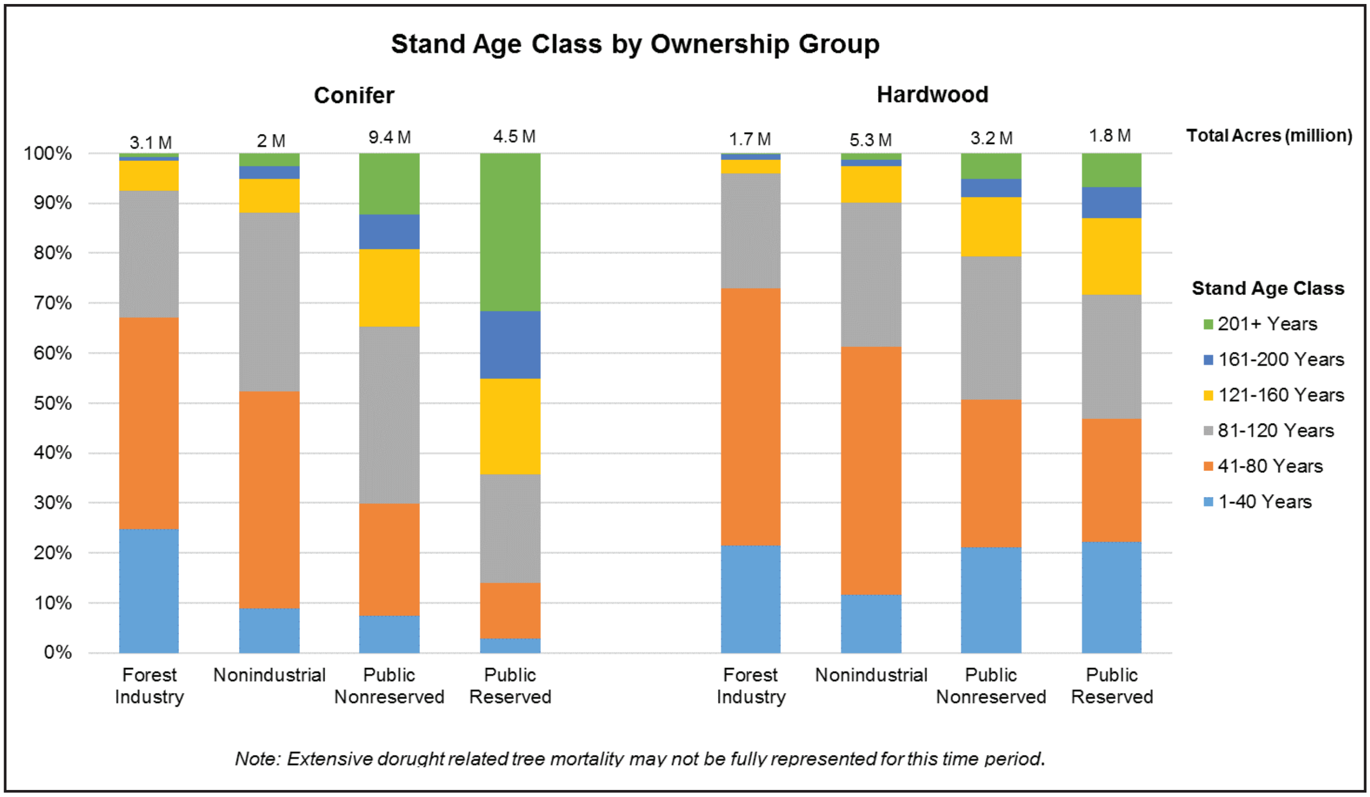


Figure 10.1: Stand Age Class by Ownership Group.

Data Source: [15] Christiansen, G., 2017.

Conversely, 7% of conifer and 4% of hardwood stands on private lands are over 160 years old, while 35% of conifer and 33% of hardwood stands on private land are under 40 years old, indicating that private lands are predominantly made up of young trees and lack diverse age stands. If management incorporates wildlife habitat needs, early seral stage forests can offer robust and diverse understories [13], with more woody debris, a higher nutrient fixation rate, increased herbaceous species and more structural complexity than mature forests, resulting in good habitat for wildlife such as song birds, small mammals and mule and blacktail deer [14]. About 30% of dead wood is on private ownership with an average of about 10 snags per acre [13].

Habitat Quality and Degradation

Wildlife species have historically adapted to recurring disturbance events such as stand-replacing fires, intense storms and floods, wind events, volcanic eruptions, snow avalanches or outbreaks of insects and diseases. The increased frequency and intensity of these events due to a changing climate, combined with the increased loss of habitat through land use alteration and habitat fragmentation, is causing species to become more vulnerable to disturbances [16].

Human activities are steadily converting large expanses of wildlands habitat into smaller, disconnected patches and degrading ecosystems at all levels, from individual populations to webs of interaction. Based on the 2015 California State Wildlife Action Plan (SWAP) [1], sources of habitat degradation affecting every ecoregion throughout the state are climate change and non-native invasive species (Table 10.1). Other extensive degradation pressures are associated with fire, development, livestock, farming and ranching.

The Conservation Biology Institute quantified terrestrial landscape intactness based on a myriad of human impacts [17]. Further analyzing their findings by specific habitats, the Central and South Coast and Central Valley regions were found to have the lowest levels of intact habitat. The habitat types under CWHR that have the lowest level of intactness throughout the state are Blue

Oak and Valley Oak Woodland (17%), Annual Grassland (20%), Blue Oak Foothill Pine (24%) and Valley Foothill Riparian (36%). The least protected conifer habitat types are Redwood (30%), Ponderosa Pine (49%) and Montane Hardwood Conifer (49%) (ⓘ10.3).

Development

Chapter 11 of this Assessment found that approximately 2.2 million housing units are in wildland urban interface and intermix across the state (ⓘ11.3). Housing developments are directly linked to increased wildlife

Table 10.1: Common Sources of Habitat Degradation by Province and Ecoregion

	North Coast and Klamath				Cascades and Modoc Plateau			Bay Delta and Central Coast		Central Valley and Sierra Nevada			South Coast		Desert
Human Induced Conservation Pressures	Northern California Coast	Northern CA Coast Ranges	Northern CA Interior Coast Ranges	Klamath	Southern Cascades	Modoc Plateau	North Western Basin and Range	Central CA Coast	Central CA Coast Range	Great Valley	Sierra Nevada Foothills	Sierra Nevada	Southern California Coast	Southern CA Mountain and Valley	Mono, Mojave, Sonoran, Colorado, Great Basin
Agricultural and Forestry Effluents	X	X						X	X	X			X		
Airborne Pollutants	X							X							X
Annual and Perennial Non-Timber Crops	X	X			X	X		X	X	X		X	X	X	X
Climate Change	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Commercial and Industrial Areas	X			X				X		X			X		X
Dams and Water Management/Use	X	X				X		X	X	X		X	X	X	X
Fire and Fire Suppression	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Garbage and Solid Waste	X												X	X	
Household Sewage and Urban Wastewater	X	X						X	X	X			X	X	
Housing and Urban Areas	X	X		X		X		X	X	X	X	X	X	X	X
Industrial and Military Effluents	X												X		X
Introduced genetic material	X														
Invasive Plants/Animals	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Livestock, Farming and Ranching	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Logging and Wood Harvesting	X			X	X					X		X			
Military Activities															X
Mining and Quarrying										X			X	X	X
Other Ecosystem Modifications							X								X
Parasites/Pathogens/Diseases				X								X			X
Recreational Activities		X	X	X		X					X	X	X	X	X
Renewable Energy					X	X		X	X	X	X	X			X
Roads and Railroads	X	X						X	X	X	X	X	X	X	X
Tourism and Recreation Areas								X					X	X	
Utility and Service Lines					X	X		X	X			X			X
Wood and Pulp Plantations	X														

Data Source: [1] California Department of Fish and Wildlife, 2015.

injuries and mortality from fences, power lines, toxic substances, proliferation of invasive species, decline in pollinators, and a decreased ability to move and disperse (including plant seeds), find food, and reproduce [18]. Housing developments also bring domestic pets, which increase predation and spread diseases to native wildlife [19], and create wildlife depredation issues from wildlife predators mistaking pets for prey. Roads cause direct habitat alteration and loss, create barriers for wildlife movement causing genetic isolation leading to loss of variability and genetic extinctions, contribute to wildlife injury or death by vehicle collisions [20], and can change an area's species composition based on species sensitivities and tolerances [21]. Roads are a contributing factor to most of the types of degradation listed in Table 10.1.

Non-native Species

Non-native invasive species have dramatic ecological effects that heavily impact both plant and animal communities. They decrease desirable plant biodiversity by, for example, out-competing the native plant community, changing soil fertility, increasing soil erosion and altering fire frequency intervals. Of the approximately 1800 non-native plants growing wild in California, about 200 of those are considered invasive [22]. It is well known now that non-native insects and diseases are causing extreme tree mortality. Chapter 5 of this Assessment found that detected occurrences of forest pest species have tripled since the 1950's, and one third to one half are exotic, including sudden oak death, pitch canker, goldspotted oak borer, and the polyphagous shot hole borer (ⓘ5.2). In addition, the recent drought has resulted in a dramatic increase in tree mortality, largely due to drought-stressed trees providing a nexus for an increase in the native bark beetle population, which is causing a major die-off in the Sierras.

Livestock, Agriculture and Ranching

Livestock, farming and ranching pressures are a concern throughout all ecoregions of the state. Much of what was once shrubland, wooodland, forest, meadow, riparian, wetland, and grassland habitat has been converted to farmland throughout all ecoregions. Agricultural water use, pesticide runoff and grazing are negatively impacting California's river and stream habitat.

Cannabis is a crop of particular concern. Its cultivation has been rapidly expanding and getting more attention since its quasi-legalization for medical use in 1996 and now full legalization under California law in 2016. Legal and illegal grow operations in natural areas across the state continue to multiply, and are damaging wildlife habitat and wildlife species. Growers divert water from streams and springs in the summer and fall, when flows are already low, drying up seasonal streams that salmon and other wildlife depend on. Growers are notorious for removing large swaths of forest without following protective measures or guidelines, and using large quantities of unregulated pesticides, herbicides and rodenticides that degrade forest soils and water quality and kill forest wildlife [23].

Cannabis grow operation in forestland. Photo courtesy of California Department of Fish and Wildlife.

Wildfire

Land managers are increasingly recognizing that forest health and wildlife habitat are better maintained by more natural fire regimes. Low-to-moderate severity wildfire generally increase biodiversity, create nesting sites, stimulate plant growth, attract fire adapted insects and plants, and create openings and habitat patch diversity on the landscape. Wildfires create more open understories and/or early seral habitat (pre-canopy closure stage) that deer, elk, bear, some songbirds, and some small mammals prefer [14]. Many plant species are fire dependent for their life cycle, such as giant sequoia, lodgepole pine and some fungi. However, recent trends indicate that fires are becoming larger and more severe (ⓘ4.4), most likely due to fire suppression and inadequate forest management [1]. Chapter 4 of this Assessment found that seven of the ten largest wildfires in recorded state history occurred after 2000, mostly in conifer forests, and some were large enough to be considered "megafires." Unlike fires representative of historic natural regimes, these larger megafires are a major disturbance agent that can greatly alter forest and range ecosystems. Disturbance from megafires can alter habitat composition for long periods of time, lead to localized vegetation type conversions, warm streams, and alter flow and water volume. Post-fire hydrologic changes can increase sedimentation, initiate debris flows and endanger aquatic species and other terrestrial wildlife species. Megafires also kill small mammal, reptile, and amphibian species seeking shelter in burrows that survive in less intense natural historic fires. Such events could have profound effects on already compromised species that are vulnerable to stochastic population fluctuations.

The Sierra Nevada Adaptive Management Project [24], conducted by a team of university scientists, was an intensive 10 year study that looked at the affects of land management on forest health in the Sierra Nevada. The study concluded that strategically placed landscape treatments (SPLATs) are an effective way to reduce severity of wildfires, and may have a positive effect on tree growth and increase forest resilience. However, reintroduction of fire into the system is necessary for long-term reslience (see Chapter 4 – Wildfire Threat).

Habitat Vulnerability to Climate Change

Climate change has the potential to significantly alter the quantity, quality, and spatial distribution of habitat types across California, in diverse habitats ranging from deserts to high elevation forests [25]. Climate change also poses the most critical threat to California salmonids [2]. To estimate potential terrestrial habitat losses, FRAP modelled current mapped extent of habitats in comparison to areas that will be climatically unsuitable for that habitat in the future [26]. In addition, model results provide the spatial distribution of areas that are projected to become climatically suitable for a habitat type in the future. Actual future migration of the habitat types into these areas will depend on adaptability of the habitat types to factors beyond climate such as soils, competition with other vegetation, seed dispersal, and disturbance regimes.

In the study, future conditions were modeled under two emission scenarios (RCP 4.5 and RCP 8.5) and two Global Climate Models (GCMs); the results provided below were limited to the high emission scenario (RCP8.5) that best matches the current global trajectory [27, 28].

- Climate model CNRM CM5 warmer and wetter scenario: By the end of this century, the mean annual minimum temperatures increase by 3.26°C and total annual precipitation increases 35% (+ 5.8 inches) per the RCP8.5 emissions scenario [26].

- Climate model MIROC ESM hotter and dryer scenario: By the end of this century, the mean annual minimum temperatures increase by 3.95°C and total annual precipitation decreases by 26% (- 6.9 inches) per the RCP8.5 scenario [26].

Figure 10.2 shows that climate impact varies by habitat type for the hotter/dryer (MIROC ESM) and warmer/wetter (CNRM CM5) climate models, under the RCP 8.5 emission scenario. Habitat types under CWHR such as Joshua Tree are projected to be severely impacted under both climate scenarios and climate impacts are already being observed [30]. For habitat types such as Red Fir, the model predictions are mixed and dependent on the future climate scenario used. This has major implications in terms of evaluating the degree of impact. Habitat types such as Coastal Scrub are projected to incur minimal impact in extent under either climate scenario. However, qualitative impacts may occur, for example changes in species composition within Coastal Scrub habitats, which are beyond the scope of the study.

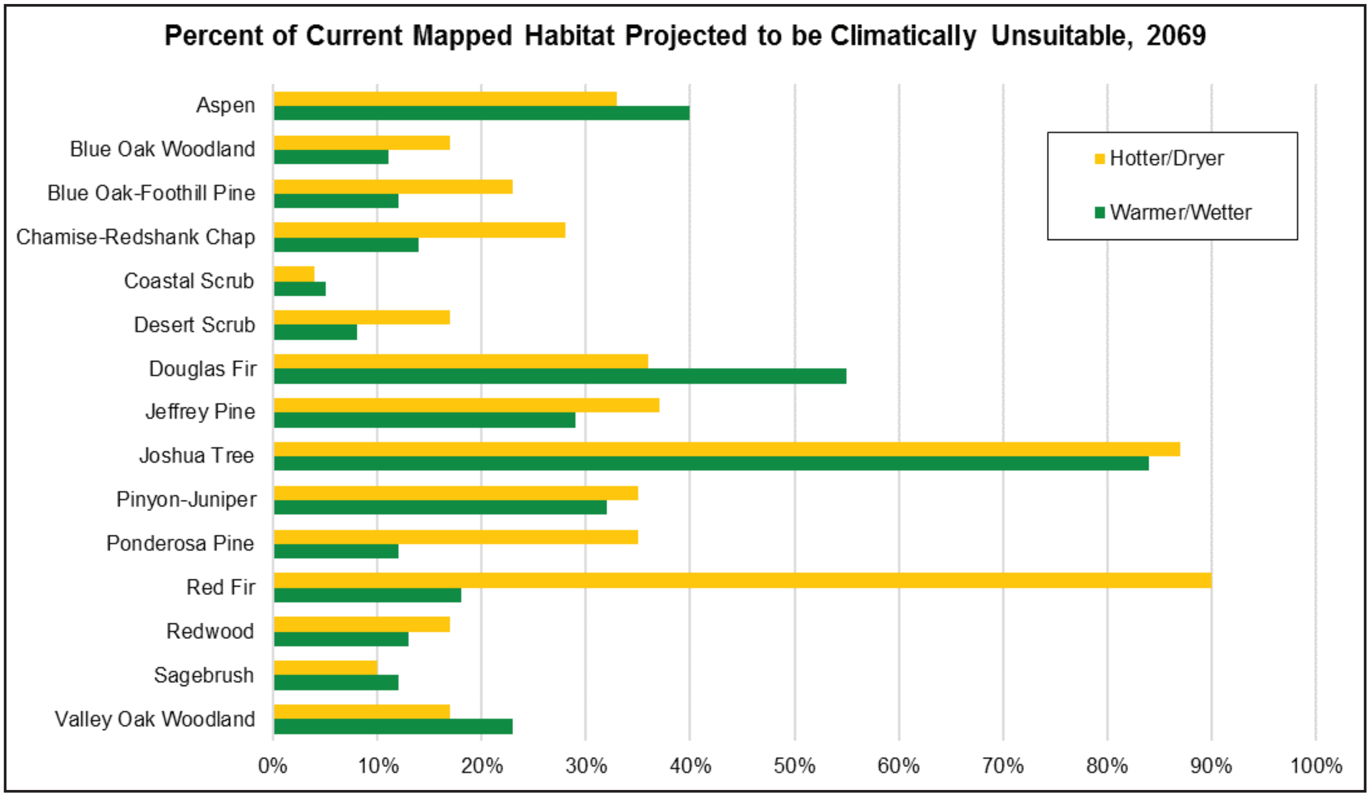


Figure 10.2: Percent of Current Mapped Habitat Projected Under the RCP 8.5 Scenario to be Climatically Unsuitable, 2069.

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

While the potential for significant impacts is obvious from the statewide results, a regional examination provides ramifications for wildlife, a few of which are provided in the following sections.

Southern Sierra Oak Woodlands

Oak Woodlands in the south Sierra are primarily associated with Blue Oak (*Quercus douglasii*), as either Blue Oak Woodland or Blue Oak Foothill Pine habitats under CWHR. These habitats are important for wildlife, with mature stages providing optimal or suitable breeding habitat for 29 species of amphibians and reptiles, 57 species of birds, and 10 species of mammals, assuming that other special habitat requirements are met [31].

Projected climate change results in potential losses in significant portions of this habitat, and the impact appears to increase from north to south (Figure 10.3). Table 10.2 shows the affected counties sorted in directional order. Potential habitat losses are greatest under both climate scenarios in southern counties such as Kern and Tulare.

While the potential losses are significant, Figure 10.2 also shows that there are substantial areas in all south Sierra counties that currently do not contain Blue Oak, but will be climatically suitable for the species in the future, and could represent areas for future migration in response to climate change. Generally, this involves an uphill migration, and requires adaptation to different soil conditions, seed dispersals, competition with other vegetation, and disturbance regimes.

Table 10.2: Percent of Mapped Oak Woodland Habitat That Will be Climatically Unsuitable in 2069 for Two Climate Scenarios, South Sierra Counties

	County	Mapped Acres (thousands)	Percent Unsuitable	
			Warm/Wet	Hot/Dry
N	Calaveras	178	1	5
▲	Tuolumne	118	1	23
	Mariposa	175	14	27
	Madera	143	10	29
	Fresno	141	17	33
▼	Tulare	162	40	45
S	Kern	169	63	58

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

Southern California Conifer Forests

Southern California conifer forests are critical for providing various ecosystem services, including wildlife habitat. These forests already occupy the higher elevation sites, so there are limited opportunities for them to migrate into new areas. Lower elevation conifer forest species such as Coulter Pine can potentially migrate upslope, but the highest elevation conifer types have nowhere to go. Thus, it could be inferred from the study that a warming climate would change both the species composition of conifer forests, as well as the overall extent.

Table 10.3 shows the projected impacts to the Southern California conifer forests by 2069 under both climate models. While the hotter/dryer scenario has extreme impacts, even the warmer/wetter scenario results in significant losses of conifer forest habitats in these counties.

Table 10.3: Percent of Mapped Conifer Forest That Will be Climatically Unsuitable in 2069 for Two Climate Scenarios, Southern California Counties

County	Mapped Acres (thousands)	Percent Unsuitable	
		Warm/Wet	Hot/Dry
Los Angeles	81	44	90
Riverside	56	35	59
San Bernardino	144	12	35
San Diego	24	44	75

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

Mojave Desert

There is already significant evidence that climate change is impacting species such as Joshua tree (Yucca brevifolia) and pinyon pine in the Mojave Desert [32]. Modeling conducted in this study found up to a 90% reduction in their current distribution due to climate stress (i.e. increase temperature and decreased precipitation). In fact, Joshua tree is currently under consideration as

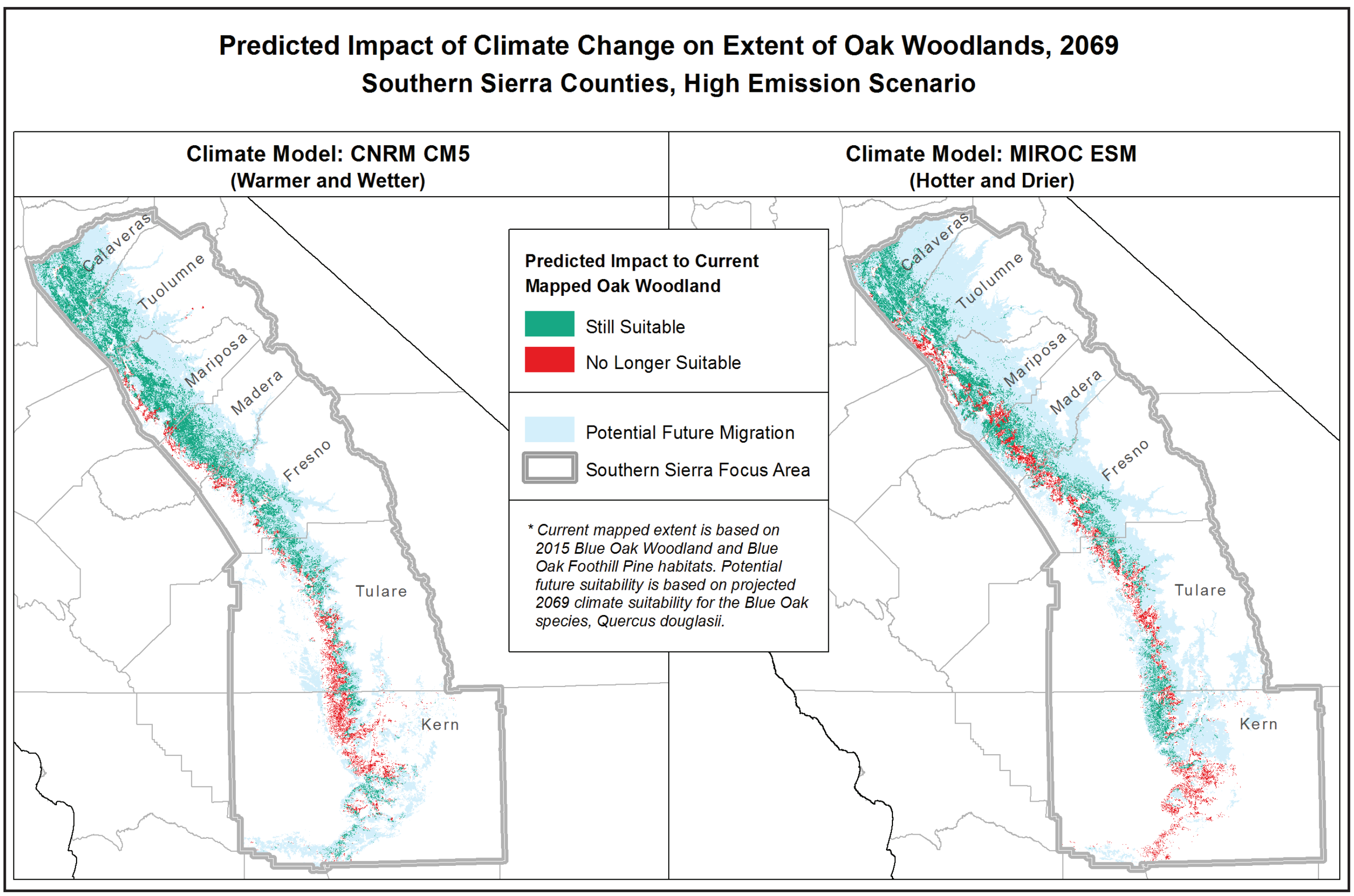


Figure 10.3: Predicted Impact of Climate Change on Extent of Oak woodlands, 2069, Southern Sierra Counties, High Emission Scenario.

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

Table 10.4: Percent of Mapped Joshua Tree and Pinyon-Juniper Habitats That Will be Climatically Unsuitable in 2069 for Two Climate Scenarios, Mojave Desert				
	Vegetation Type (WHR)	Mapped Acres (thousands)	Percent Unsuitable	
			Warm/Wet	Hot/Dry
Mojave Desert, California	Pinyon-Juniper (PJN)	323	53	87
	Joshua Tree (JST)	978	84	88
Joshua Tree National Park	Pinyon-Juniper (PJN)	32	100	100
	Joshua Tree (JST)	41	100	98
Mojave National Preserve	Pinyon-Juniper (PJN)	83	89	95
	Joshua Tree (JST)	406	91	89

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

one of the first species listed as threatened under the Federal Endangered Species Act due to climate change [33]. Joshua tree is an important species for wildlife, providing critical above ground nesting for 25 bird species [34].

Projections show extreme impacts for the Mojave Desert, as well as for two important areas established in part to protect biological diversity (Table 10.4). In response to this threat, more detailed modelling efforts are under way to study the problem [30].

Quaking Aspen

Quaking aspen (*Populus tremuloides)* provides a critical wildlife habitat in high elevations in California. Often occurring as small islands within large areas of conifer forest, aspen stands can provide forage levels equivalent to grasslands and up to ten times that of coniferous forests [35]. Quaking aspen vegetation is an important habitat for neotropical migrant bird species, cavity-nesting birds, excavating species and cavity nesters seeking aspen snags among others [36]. Currently the main impacts on northern California aspen stands are animal browsing (wildlife and cattle), conifer encroachment due to fire suppression, insect and disease agents, and drought conditions [37].

Significant impacts to the aspen communities are expected in all counties under either climate scenario (Table 10.5). Given that quaking aspen occurs on specialized sites at mid-to-high elevations, it is likely that there are limited opportunities for the species to migrate up to new sites that become climatically suitable.

The examples of climate impacts on vegetation in the preceding section are not meant to accurately predict the future, but instead point the way to potential conditions that narrow uncertainty and give resource managers another tool, combined with local knowledge, to evaluate potential outcomes [38]. We are already witnessing climate change impacts that are driving changes in wildlife habitat, such as the unprecedented tree mortality due to the 2012–2016 drought, increased

Joshua Tree. Photo courtesy of Debbie Chapman.

Table 10.5: Percent of Mapped Aspen Habitat That Will be Climatically Unsuitable in 2069 for Two Climate Scenarios, for Counties With At Least Four Thousand Aspen Acres			
County	Mapped Acres (thousands)	Percent Unsuitable	
		Warm/Wet	Hot/Dry
Alpine	4	97	54
Fresno	5	23	16
Inyo	5	28	44
Lassen	4	46	7
Modoc	5	38	30
Mono	27	31	29

Data Source: [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.

pathogen outbreaks, increased fire risk [39-41], and changes in snow pack volume and melting patterns, species migration patterns and habitat composition and structure.

Protected Habitat

Total California forest and rangeland acres have remained at approximately 80 million acres since reporting started by FRAP in 1979 [42]. A portion of these habitats are protected from conversion via public or conservation organization ownership, and more recently by a growing trend in purchasing of conservation easements on private lands (ⓘ6.3).

Oak woodlands, annual grassland and coastal redwood habitats have the least acres protected from conversion (Table 10.6) (ⓘ10.5). Of the nearly 2.8 million acres of Blue Oak Woodland in the state, less than 16% are under protection. High elevation habitat types, such as Red Fir, Subalpine Conifer, Lodgepole Pine, Aspen and Alpine Dwarf Shrub are 85% or more protected. There are also habitat types that have experienced major losses over time, for example, Fresh Emergent Wetlands (68%

Table 10.6: Percent of CWHR Type Protected by Vegetation Zone

	Conifer								Hardwood								Shrub and Rangeland					Desert Shrub and Woodland*				
Vegetation Zone	Conifer Forest Totals	Redwood	Montane Hardwood Conifer	Closed Cone Pine Cypress	Red Fir	Pinyon-Juniper	Lodgepole Pine	Subalpine Conifer	Hardwood Woodland	Valley Oak Woodland	Blue Oak Woodland	Blue Oak-Foothill Pine	Coastal Oak Woodland	Valley Foothill Riparian	Joshua Tree	Aspen	Shrub and Herbaceous	Annual Grassland	Coastal Scrub	Desert Riparian	Chamise-Redshank Chaparral	Desert Shrub and Woodland Totals	Desert Scrub	Low Sage	Desert Wash	Alpine-Dwarf Shrub
Central Coast	47	44	47	50	-	98	-	-	30	24	26	25	36	25	-	-	31	18	41	22	42	66	83	-	42	-
Central Valley	46	-	43	34	-	94	-	-	15	12	13	19	22	29	-	-	20	17	28	-	43	18	100	-	32	-
Great Basin	96	-	92	-	100	98	-	100	0	-	-	-	-	-	100	93	83	52	-	83	-	97	99	92	98	100
North Coast	59	28	45	58	92	-	98	95	31	13	16	43	32	46	-	100	47	21	39	-	61	33	-	89	-	97
North Interior	60	-	32	91	84	-	85	95	28	-	11	55	-	8	-	85	69	27	-	-	-	3	-	85	-	91
North Sierran	67	-	48	74	85	84	81	96	22	3	16	25	-	-	-	79	69	40	-	-	82	-	-	96	-	98
South Coast	88	-	84	83	-	92	100	100	37	31	31	49	34	52	74	-	63	28	43	90	74	83	85	-	61	-
South Interior	97	-	99	-	-	93	98	-	15	11	11	-	-	26	82	-	37	21	31	42	93	84	86	100	89	-
South Sierran	91	-	70	91	99	86	99	100	31	11	27	43	-	97	88	97	81	48	-	95	77	81	81	100	56	100
Total % Protected		30	49	60	92	94	95	99		17	17	24	35	36	84	93		20	42	45	59		87	87	88	100

Poor Protection (shaded columns: Redwood, Montane Hardwood Conifer, Closed Cone Pine Cypress, Valley Oak Woodland, Blue Oak Woodland, Blue Oak-Foothill Pine, Coastal Oak Woodland, Valley Foothill Riparian, Annual Grassland, Coastal Scrub, Desert Riparian, Chamise-Redshank Chaparral) — Good Protection (shaded columns: Red Fir, Pinyon-Juniper, Lodgepole Pine, Subalpine Conifer, Joshua Tree, Aspen, Desert Scrub, Low Sage, Desert Wash, Alpine-Dwarf Shrub)

* Desert Shrub and Woodland include Alkali Desert Scrub, Desert Riparian, Desert Scrub, Desert Succulent Shrub, Desert Wash, Joshua Tree, Palm Oasis.

Data Sources: Vegetation, FRAP, v15_1; Ecoregions, U.S. Forest Service, v07_4; California Protected Areas Database (CPAD), GreenInfo Network, v2016a.

protected) and Coastal Scrub (42%). Countless native species including SGCN rely on those ecosystems; thus, protecting what remains as an attempt to ensure their survival is a highest conservation priority of the state.

Lands protected from conversion, particularly those managed to function as healthy ecosystems such as preserves and reserves, play a major role in promoting habitat diversity and wildlife abundance. Historically, preserves and reserves were most often chosen based on opportunity, which overwhelmingly selected for higher elevation, steeply sloped land, and areas with low agricultural suitability and large distances to roads and cities. As a result, protected lands largely host similar habitat types, leaving out other just as important, but often more difficult to obtain, habitat types [43]. A more systematic approach to conservation planning is needed to better manage for the persistence of ecological processes and biodiversity. A systematic approach would guide decisions to conserve areas based on location, configuration, habitat linkages, and management. The selection process would include stakeholders, and aim to adequately protect a representative sample of species and habitat long term, including their processes and genetic diversity. In designing a conservation area, instead of trying to restore an area back to its historical state, many conservation planners are now focusing on restoring key ecological processes and conditions to revitalize a self-sustaining system that is adaptive to changing conditions including those due to climatic changes. Conservation planners are turning toward target-based designs that rank the landscape for conservation by selecting target species for protection and prioritizing variables such as optimal connectivity between reserves, opportunities for expanding reserves, and identifying low ecological value areas for development [44]. An ecosystem-level, large-scale landscape approach to conservation is generally a more desirable conservation approach to maintain ecological integrity and biodiversity, which in turn benefits wildlife species and societal values [1].

Government Programs to Assist Private Landowners with Habitat Conservation

There are a variety of state and federal programs that offer incentives for private landowners to improve habitat. CAL FIRE offers land owner assistance through the Forest Legacy and California Forest Improvement Programs. These programs encourage forest land owners to maintain the integrity of forest health and improve fish and wildlife habitat by funding permanent easement agreements, fuel reduction projects, research, and forestland conservation, and by avoiding conversion to other uses. California Department of Fish and Wildlife (CDFW), with support from the U.S. Fish and Wildlife Service (USFWS) administer Private Lands Incentive Programs that encourage landowners to enroll to receive technical assistance and financial incentives for enhancing riparian, wetlands, and native grass habitat, and reducing the decline of at-risk species. There are currently over 29,000 acres of land under these programs [45].

CAL FIRE regulates logging on privately-owned lands in California by enforcing the Forest Practice Act (1973), and the associated regulations under the Forest Practice Rules, which was designed to protect fish, wildlife, streams and forest ecology. Requirements include restricted activity in Watercourse and Lake Protection Zones (WLPZ), protection of snags and nest sites, erosion control, seasonal machine operation guidelines, and protection of sensitive watersheds and species. CAL FIRE has partnered with UC Cooperative Extension, Resource Conservation Districts (RCDs) and the Natural Resource Conservation Service to offer landowners technical and financial assistance through the Forest Stewardship Program with the intent of promoting good forest management that maintains habitat and clean water and air.

CDFW offers a series of conservation programs to private and public partners to help conserve wildlife habitats in response to economic development. The Natural Community Conservation Plans (NCCP) are at an ecosystem scale intended to protect biological diversity of species, habitat and landscape, and accommodate needed economic activities and development. Currently planned and approved NCCPs cover approximately 7 million acres [46]. The Lake and Streambed Alteration Program aims to protect existing fish and wildlife resources in the bed, bank, or channel of a stream or lake. CDFW reviews proposed projects that substantially alter a lake or streambed, and provides and implements agreements for activities affecting these resources. The Conservation and Mitigation Banking Program allows private and public land managers to satisfy legal requirements for development projects that adversely impact the environment by selling or transferring habitat credits of protected land to the developers. CDFW started participating in the Conservation and Mitigation Banking Program in 1993, and now oversees 79 conservation and mitigation banks across the state, making up over 52,000 acres. In 2016, new banks were created in Yolo, Fresno, San Diego and Los Angeles Counties [47]. CDFW has a new program, the Regional Conservation Investment Strategies Program, that is intended to enable the development of quicker, more effective regional conservation strategies to protect declining species, promote resiliency to climate change, and provide efficient mitigation delivery [48].

The federal government also offers a variety of incentives for private landowners to improve habitat. The Environmental Quality Incentives Program, managed by the USDA National Resource Conservation Service (NRCS), has a variety of funding pools that allows the NRCS to contract with or make direct payments to landowners to improve habitat. The Fish and Wildlife fund pool focuses on creating or improving fish and wildlife habitat on farms and ranches. Working Lands for Wildlife (WLFW) encourages partnerships among local and federal governments, tribes and private landowners and focuses on at-risk species identified by USFWS; California species are sage grouse and southwestern willow flycatcher [49]. The NRCS Regional Conservation Partnership Program (RCPP) is another vehicle that provides assistance through partnership agreements, program contracts or easement agreements under the Agricultural Conservation Easement Program (ACEP), Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP) or the Healthy Forests Reserve Program (HFRP) [50].

Anadromous Fish

Anadromous fish are an important component to terrestrial forest ecosystems in that they increase riparian and fresh water productivity and supply forage for carnivores and scavengers. Of the 32 salmonid types recognized in California (1 of which is extinct), 21 are anadromous, and 11 are non-anadromous [2]. All anadromous fish populations in California are declining due to loss of habitat, habitat degradation and alteration, and domestic and agricultural water consumption. The main contributors to the decline of anadromous fish populations, and the number of species most affected by those threats, are listed in Figure 10.4.

The implementation of the Forest Practice Act and Forest Practice Rules in 1975 created rules designed to protect streams in California by requiring an environmental review called a Timber Harvesting Plan (THP) prior to logging, limiting the size of logging units, implementing stream protection zones, specifying road drainage requirements, and implementing stream crossing

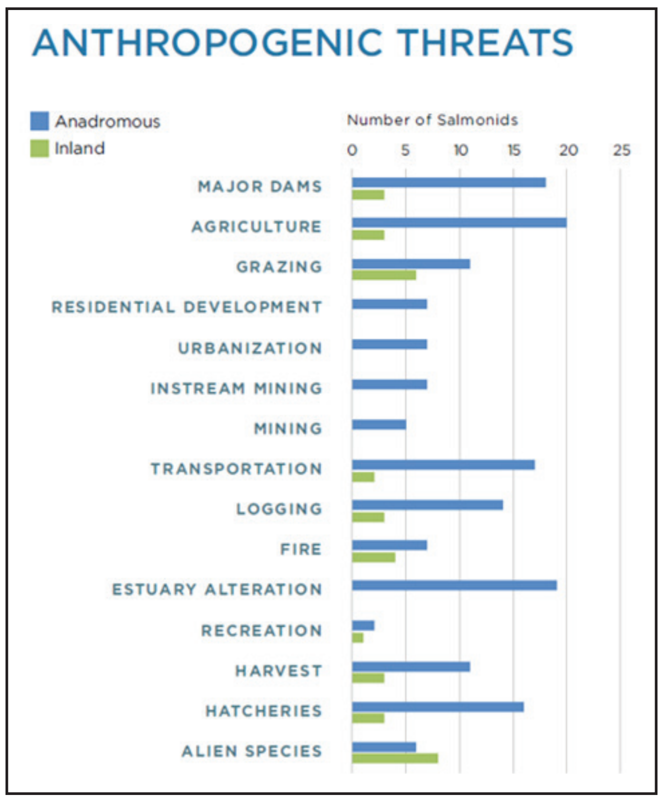


Figure 10.4: Number of Anadromous and Inland Salmonids with Critical, High and Medium Level Anthropogenic Threats.

Data Source: [2] Moyle, P.B. and R. Lusardi, 2017.

requirements for roads. The Anadromous Salmonid Protection Rules were adopted by the Board of Forestry in 2010 under the Forest Practice Rules to better protect, maintain and improve riparian and anadromous fish habitat during timber harvesting operations.

In addition to all the existing threats to salmonids, climate change has been identified as having the most devastating potential impact along with pesticides/herbicides/fertilizers in conjunction with cannabis cultivation. Of the 31 existing salmonid types in California, 26 have been identified as highly or critically threatened by climate change, and at the current rate, 45% of California salmonids are likely to be extinct in the next 50 years [2]. The UC Davis Center for Watershed Science status report [2] identifies multiple effects as being the most life-threatening for anadromous fish due to climate change, such as lack of cold water due to decreasing snow melt, low and variable stream flows due to prolonged drought and high intensity storm events, constricted habitat by water projects and food web alteration due to Pacific Ocean temperature increases, current and upwelling alterations and acidification.

Opportunities

The following is a summary of opportunities to conserve and improve wildlife habitat.

Partnership agreements

- Continue to support the state and federal grant incentive programs for private landowners to improve habitat, including the California Forest Improvement Program (CFIP), Forest Legacy Program, California Forest Stewardship Program, CDFW Private Lands Incentive Programs, the California Safe Harbor Agreement (a CDFW Program), and the USDA National Resource Conservation Service (NRCS) Environmental Quality Incentives Programs.

- Continue to support the state and federal programs that aid with partnership agreements such as the CDFW Natural Community Conservation Planning (NCCP) Program, the NRCS Environmental Quality Incentives Program (EQIP), Regional Conservation Partnership Program (RCPP), Agricultural Conservation Easement Program (ACEP), Conservation Stewardship Program (CSP) and the Healthy Forests Reserve Program (HFRP).

- Support a land management approach that uses systematic and iterative processes, includes science to develop policy at an ecosystem level, and includes flexibility in decision making to account for future uncertainties.

- Support collaborative projects that involve state and federal agencies, local communities, and other stakeholders for improving economic and environmental sustainability.

State Regulations and Laws

- Support state regulations that aim to protect wildlife and their habitat such as the CDFW Lake and Streambed Alteration Program and Conservation Mitigation Banking, the CAL FIRE Forest Practice and Anadromous Salmonid Protection Rules, California Environmental Quality Act and the California and Federal Endangered Species Acts.

- Support and coordinate with other agencies to continue and increase development, implementation and enforcement of regulatory programs to ensure that cannabis cultivation and associated activities do not adversely impact fish and wildlife. Existing programs include CDFW Watershed Enforcement Team (WET), which works to prevent, assess, and remediate cannabis cultivation related to environmental damage, and the Cannabis Restoration Grant Program that funds watershed level restoration and protection of anadromous salmonid habitat.

Conservation efforts

- Focus on conservation that prioritizes optimal connectivity among reserves and that expands reserves that adequately protect representative species, habitats and landscapes, as well as the key ecological processes and conditions that would sustain their ecological health. Encourage self-sustaining systems that can adjust to unpredictable changes including due to climatic changes.

- Work to avoid salmonid extinctions by prioritizing protection and restoration of mountain meadows, floodplains, coastal lagoons, estuaries, groundwater, springs, spring-fed rivers and the most fully functioning, intact watersheds and river ecosystems. Continue support of working landscapes, management models that integrate innovative, science-based solutions that influence statewide policy relating to salmonid conservation. Bring together stakeholders, agency partners, and diverse communities of fishery, farming and ranching, and commerce to improve fish passage in the historical and new spawning and rearing habitats by removing dams and other barriers, improving genetic management, and reducing gene flow between hatchery and wild salmonids [2].

- Utilize species distribution and climate models to help inform land management and policy decisions, and maintain insight into mechanisms and awareness of the potential magnitude of climate change effects.

- Maintain healthy forest practices for early seral stands by restoring natural fire regimes and implementing good post-fire management by deferring salvage and dense replanting across or parts of major disturbed areas. When salvaging, practice variable retention of significant structural elements such as large diameter live trees, snags, and down woody debris, while avoiding reseeding of exotic invasive plant species.

Indicator: Number of Threatened and Endangered Species Listed Under the California (CESA) and/or Federal Endangered Species Act (ESA) ⓘ10.1

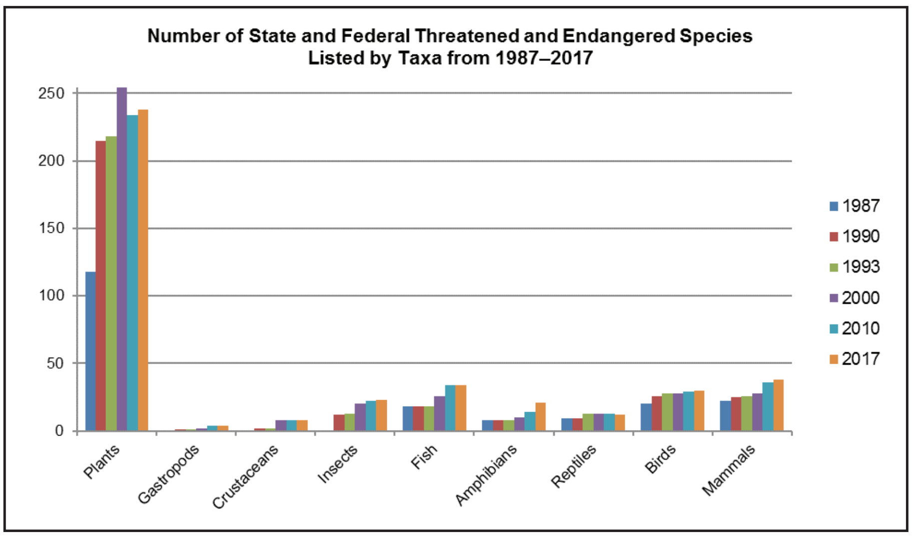
Which Montreal Process Criterion does the indicator evaluate?

MPC1: Conservation of biological diversity

Why is this indicator important?

Biological diversity is dependent on species richness and population levels, which are influenced by the ecosystems that supports the diversity. Changes in species populations and distribution can be an indication of changes in ecosystem health, productivity, and sustainability. Therefore, at-risk species, such as listed species, would likely indicate concerns around the ecological integrity.

What does the indicator show?



Key Findings:

- ⓘ Since 2010, 15 species have been added to the list of threatened or endangered species, mostly under ESA. The amphibian taxa saw the largest increase in listing with 7 new species added. Currently, 252 plant and animal species are listed as threatened or endangered under the CESA and 320 under the ESA, with 408 total species listed (2017).
- ⓘ California Department of Fish and Wildlife has compiled a list of Species of Greatest Conservation Need (SGCN) that includes threatened, endangered, rare, endemic, vulnerable and species of special concern, under ESA, CESA or other dependable species status ranking systems by NatureServe, California Native Plant Society and CDFW. Of the 1,153 species on the list, there are 264 invertebrates, 414 fish and vertebrates, and 475 plants.

Data Sources and Quality

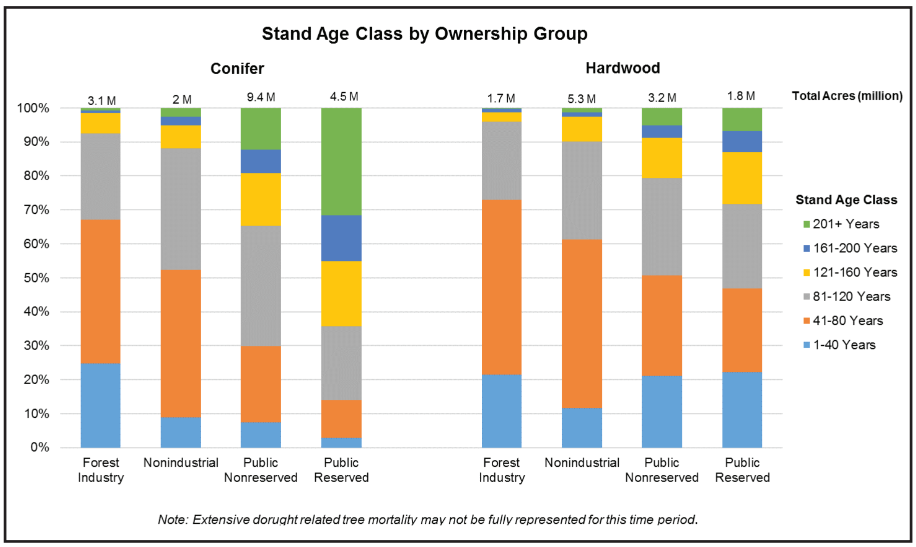
Data Theme	Source	Quality (5 star max)
T&E Species	[6] California Department of Fish and Wildlife, 2017; [7] California Department of Fish and Wildlife, 2018.	****
SCGN	[1] California Department of Fish and Wildlife, 2015.	***

Indicator: Forest Stand Age Class by Ownership ⓘ10.2

Which Montreal Process Criterion does the indicator evaluate?
MPC1: Conservation of biological diversity

Why is this indicator important?
Stand age classes are broad indicators of changes in vegetation structure and of ecosystem dynamics. Wildlife utilize different stand structures for different needs such as for feeding, breeding, and cover. Late seral habitat is especially important given its relatively limited distribution compared to historic conditions. Land management objectives have had the effect of concentrating large landscapes into groups of similar stand ages.

What does the indicator show?



Key Findings:

ⓘ Late seral (201+ stand age): Nearly 32% of public reserve conifer land is late seral stage defined as being over 200 years old, and 12% of public non-reserve conifer land is late seral. Nonindustrial private conifer land is made up of less than 3% stands over 200 years old, and well under 1% on forest industry land. Western white pine (62%) and lodgepole pine (40%) currently have the largest proportion of older stands.

ⓘ Mid-late seral (161–200 stand age): Public reserve lands have the largest percent of mid-late seral tree stands between 161 and 200 years old (13% for conifer and 6% for hardwood lands). For forest industry, the percentages are 1% of conifer and 1% of hardwood.

ⓘ Early seral (<80 stand age): 67% of conifer stands and 73% of hardwood stands on forest industry forestland are less than 80 years old. Nonindustrial private lands are comprised of 52% conifer stands under 80 years old and 61% hardwood stands under 80 years old. 25% of conifer stands and 49% of hardwood stands on public land are less than 80 years old.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
PNW-FIADB	[15] Christiansen, G., 2017.	****

Indicator: Terrestrial Intactness of California Wildlife Habitat Relationships (WHR) Types Based on Human Impacts

ⓘ10.3

Which Montreal Process Criterion does the indicator evaluate?

MPC1: Conservation of biological diversity

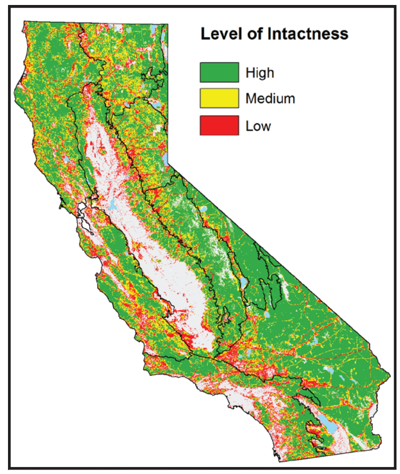
Why is this indicator important?

Habitat degradation results in spatial discontinuity or fragmentation of habitats that affect species occupancy, reproduction and survival. This indicator identifies forest and rangeland habitat types that are lacking intactness due to human disturbance (residential/commercial development, roads and other human influences).

What does the indicator show?

Percent of Vegetation Types by Intactness Class (subset of 23 types)

	Conifer							Hardwood							Herbaceous			Shrub					
	Redwood	Ponderosa Pine	Montane Hardwood-Conifer	Lodgepole Pine	Red Fir	Pinyon-Juniper	Subalpine Conifer	Valley Foothill Riparian	Desert Riparian	Valley Oak Woodland	Coastal Oak Woodland	Montane Riparian	Blue Oak-Foothill Pine	Blue Oak Woodland	Fresh Emergent Wetland	Annual Grassland	Wet Meadow	Coastal Scrub	Alkali Desert Scrub	Bitterbrush	Mixed Chaparral	Desert Wash	Desert Succulent Shrub
Low	21	20	13	4	3	2	0	71	49	43	26	26	18	14	81	33	31	33	28	17	12	12	12
Medium	40	45	30	17	16	8	5	15	30	28	26	23	27	26	17	32	25	28	23	27	21	17	17
High	38	35	56	79	81	90	95	14	20	29	48	52	54	60	3	36	44	39	48	57	67	71	71



Key Findings:

- ⓘ Habitat types with the lowest percentage of intactness are primarily coastal, foothill and riparian habitat types such as Valley Foothill Riparian (71% low intactness), Desert Riparian (49%), Valley Oak Woodland (43%), Coastal Scrub (33%), Montane Riparian (26%), Coastal Oak Woodland (26%), and Redwood (21%).
- ⓘ By this measure, the Central Valley (65% low intactness), Central Coast (34%) and South Coast (43%) ecological regions (i.e. USFS Bailey's classification system) have the highest level of habitat degradation while the Great Basin (79% high intactness), South Sierra (75%) and South Interior (68%) have the highest level of intactness.
- ⓘ Desert and high elevation habitat types (Desert Scrub, Low Sage, Joshua Tree, Pinyon-Juniper, Palm Oasis, Alpine Dwarf Shrub, Aspen, Lodgepole Pine, Red Fir and Subalpine Conifer) have the most intactness, all with over 75% of habitat extent in the high intactness class.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Terrestrial Landscape Intactness	[17] Degagne, R., J. Brice, M. Gough, T. Sheehan, and J. Strittholt, 2016.	***
Vegetation	Vegetation, FRAP, v15_1.	****

Indicator: Projected Impacts of Climate Change on the Extent of California Wildlife Habitat Relationships (CWHR) Types

ⓘ10.4

Which Montreal Process Criterion does the indicator evaluate?

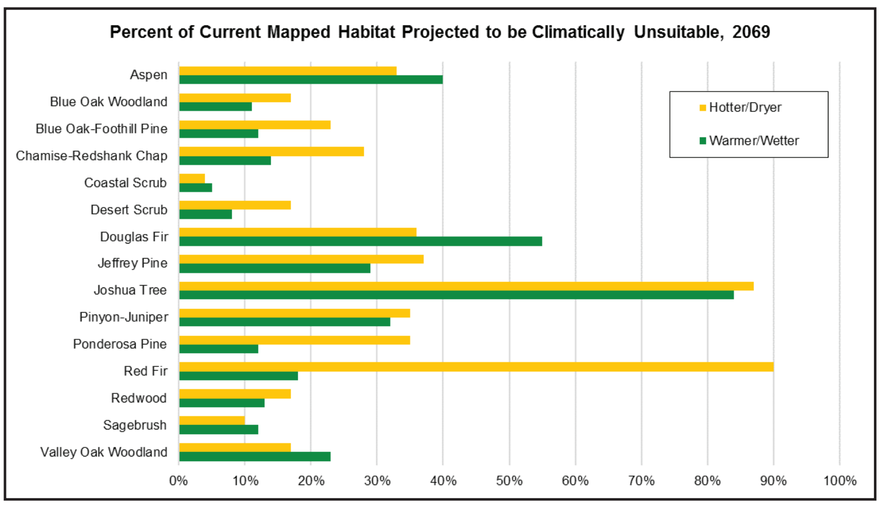
MPC1: Conservation of biological diversity

Why is this indicator important?

Climate models allow us to estimate the impact of different future climate and emission level scenarios on the extent of different habitat types.

What does the indicator show?

Climate impacts were simulated under two climate scenarios (CNRM CM5 and MIROC ESM), both assuming high carbon emissions. Impacts are estimated based on the percent of the current mapped area of a habitat type that will be climatically unsuitable by 2069.



Key findings:

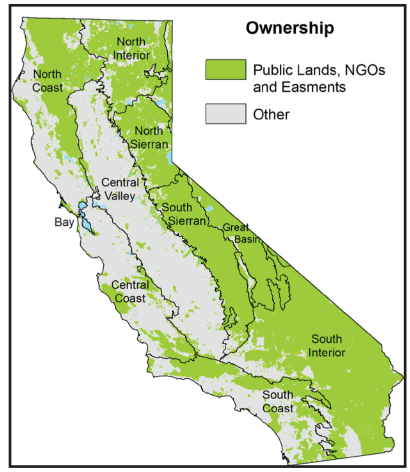
- ⓘ Habitat types such as Joshua Tree are projected to have severe impacts under the two hotter/dryer and warmer/wetter climate scenarios.
- ⓘ For habitat types such as Red Fir, the future climate scenario has major implications in terms of loss.
- ⓘ Habitat types such as Coastal Scrub are projected to have minimal impact in extent under either climate scenario. However, there may be qualitative impacts, for example, changes in species composition within Coastal Scrub habitats.
- ⓘ In addition to losses, changing climate provides opportunities for habitat types to "migrate" into areas that were climatically unsuitable in the past. Whether these opportunities are realized will depend on the adaptability of the habitat types to these new sites, for example, intactness, soil conditions, competition with other vegetation, and disturbance regimes found in the potential sites.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Vegetation	Vegetation, FRAP, v15_1; [29] Thorne, J.H., CAL FIRE Fire and Resource Assessment Program (FRAP), 2017.	****

Indicator: California Wildlife Habitat Relationships (CWHR) Types Protected from Conversion

ⓘ10.5



Which Montreal Process Criterion does the indicator evaluate?

MPC1: Conservation of biological diversity

Why is this indicator important?

Some California Wildlife Habitat Relationship (CWHR) types are more vulnerable to conversion based on the level of public ownership and easements, particularly in some vegetation zones. Public reserves, wilderness areas and private conservation easements protect CWHR types from degradation and loss.

What does the indicator show?

Table 10.6: Percent of CWHR Type Protected by Vegetation Zone

	Conifer								Hardwood								Shrub and Rangeland					Desert Shrub and Woodland*				
Vegetation Zone	Conifer Forest Totals	Redwood	Montane Hardwood Conifer	Closed Cone Pine Cypress	Red Fir	Pinyon-Juniper	Lodgepole Pine	Subalpine Conifer	Hardwood Woodland	Valley Oak Woodland	Blue Oak Woodland	Blue Oak-Foothill Pine	Coastal Oak Woodland	Valley Foothill Riparian	Joshua Tree	Aspen	Shrub and Herbaceous	Annual Grassland	Coastal Scrub	Desert Riparian	Chamise-Redshank Chaparral	Desert Shrub and Woodland Totals	Desert Scrub	Low Sage	Desert Wash	Alpine-Dwarf Shrub
Central Coast	47	44	47	50	-	98	-	-	30	24	26	25	36	25	-	-	31	18	41	22	42	66	83	-	42	-
Central Valley	46	-	43	34	-	94	-	-	15	12	13	19	22	29	-	-	20	17	28	-	43	18	100	-	32	-
Great Basin	96	-	92	-	100	98	-	100	0	-	-	-	-	-	100	93	83	52	-	83	-	97	99	92	98	100
North Coast	59	28	45	58	92	-	98	95	31	13	16	43	32	46	-	100	47	21	39	-	61	33	-	89	-	97
North Interior	60	-	32	91	84	-	85	95	28	-	11	55	-	8	-	85	69	27	-	-	-	3	-	85	-	91
North Sierran	67	-	48	74	85	84	81	96	22	3	16	25	-	-	-	79	69	40	-	-	82	-	-	96	-	98
South Coast	88	-	84	83	-	92	100	100	37	31	31	49	34	52	74	-	63	28	43	90	74	83	85	-	61	-
South Interior	97	-	99	-	-	93	98	-	15	11	11	-	-	26	82	-	37	21	31	42	93	84	86	100	89	-
South Sierran	91	-	70	91	99	86	99	100	31	11	27	43	-	97	88	97	81	48	-	95	77	81	81	100	56	100
Total % Protected		30	49	60	92	94	95	99		17	17	24	35	36	84	93		20	42	45	59		87	87	88	100

Poor Protection   Good Protection

* Desert Shrub and Woodland include Alkali Desert Scrub, Desert Riparian, Desert Scrub, Desert Succulent Shrub, Desert Wash, Joshua Tree, Palm Oasis.

Key Findings:

High elevations CWHR types such as Red Fir, Subalpine Conifer and Aspen are at least 85% protected in almost all regions where they are found.

Nearly 80% of hardwood woodland habitat types are on private land and thus have low protected status, e.g., Blue Oak Woodland (17%), Valley Oak Woodland (17%), Foothill Pine (24%) and Coastal Oak Woodland (35%). Hardwood forest habitat types are less protected than other habitat types in all regions across the state, with the exception of Aspen and Joshua Tree. The Central Coast and Central Valley regions have the lowest percentage of protected hardwood woodlands.

Of the 65% of conifer forest habitat types that are protected, most are managed by the US Forest Service. Some conifer habitat types are not as well protected, depending on the specific regions. Coastal Redwood habitat type is almost exclusively found in the North Coast but only 28% is protected, and less than 50% of Ponderosa Pine habitat type is protected in the North Coast, North Interior and North Sierran regions.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Wildlife Habitat	Vegetation, FRAP, v15_1.	****
Ecoregions	Ecoregions, U.S. Forest Service, v07_4.	****
Protected Areas	California Protected Areas Database (CPAD), GreenInfo Network, v2016a.	*****

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Chapter 11: Reducing Community Wildfire Risk

This chapter provides a synthesis of indicators, issues, and opportunities for reducing wildfire risk to communities.

INDICATORS

- ⓘ11.1 Structure Loss
- ⓘ11.2 Housing Units by Hazard Class
- ⓘ11.3 Housing Units in WUI
- ⓘ11.4 Community Planning

SUMMARY

In California, severe fire years can potentially lead to the loss of thousands of structures, and the historical trend shows the problem is getting worse (ⓘ11.1). This is consistent with trends from the wildfire chapter (Chapter 4) - increasing wildfire activity (ⓘ4.3) and severity (ⓘ4.4).

Development patterns have created a fire environment where about 3 million housing units are within Fire Hazard Severity Zones (FHSZ) and are potentially at risk (ⓘ11.2). This includes 2.2 million housing units within the Wildland Urban Interface (WUI), 83% of which are in dense Interface, and 17% of which are in more sparsely populated Intermix (ⓘ11.3). In addition, 67% of Interface and 73% of Intermix housing units are within High or Very High FHSZ.

The National Cohesive Wildland Fire Management Strategy includes a goal of creating Fire Adapted Communities, which recognizes the importance of various programs and actions such as community planning, land use planning, education programs, and homeowner responsibility. Communities are encouraged to take collective action to analyze their unique fire environment, identify appropriate solutions, and commit resources to mitigate risk and raise community awareness. Two ways this can be accomplished are by creating a Community Wildfire Protection Plan (CWPP), or by becoming a Firewise community. Currently, of 1,338 communities identified as Communities at Risk (CAR), 66% (881) are covered by a CWPP (individual, regional or countywide) and/or are recognized by the Firewise program (ⓘ11.4). Numerous other communities are at various stages of CWPP development.

The CAL FIRE Land Use Planning program works with local government to address wildfire risk as part of the safety element in city and county general plans, as required in government code 65302. Land use planning includes considering wildfire risk in the location, arrangement, and composition of new development. There are opportunities to reduce overall fire risk through new development that meets current code and standards for fire resistive construction, infrastructure upgrades such as increased roadway and water flow standards, and fuel modification requirements.

Additional components of community safety are education programs such as Ready, Set, Go!, and homeowners taking responsibility to reduce their risk. A recent sample of almost 19,000 CAL FIRE defensible space home inspections indicates that 76% passed on the first visit; within Firewise communities the pass rate increased to 84%.

KEY FINDINGS

ⓘ11.1 Indicator: Number of Structures Destroyed by Wildfire Annually

- Since 1989, there were seven years in which a loss of more than 1000 structures (residences, commercial properties, outbuildings) occurred in CAL FIRE/Contract County Direct Protection Areas (DPA), including 2015, 2016, and 2017. In bad fire years, this number can exceed 5,000, as in 2003 and 2017.

- In all jurisdictions, the top 20 most damaging fires on record destroyed 25,913 structures. About half of these losses occurred in 2015, 2016, or 2017.

- The National Fire Information Reporting System has complex requirements for reporting structure loss due to wildfire. Structure losses on lands protected by local agencies are not always reported.

ⓘ11.2 Indicator: Housing Units by Fire Hazard Severity Zone (FHSZ) Class

- In 2010, in all counties, about 3 million housing units (HU) were in FHSZ and potentially at risk from wildfire. This includes about 1.2 million HU (41%) in the Very High class.

- Over 460,000 HUs were added within FHSZ between 2000 and 2010. This includes 144,000 HU added to the Very High class.

- A large proportion of the HU within FHSZ are in the southern portion of the state. The top five counties for FHSZ HU, all in southern California, contain about half of all statewide HU in FHSZ, and 62% of the HU in the Very High class. However, this is clearly a statewide problem – 37 counties have at least 10,000 HU in FHSZ.

ⓘ11.3 Indicator: Housing Units and Wildfire Threat within the Wildland Urban Interface (WUI)

- In 2010, in all counties, about 2.2 million housing units (HU) were in WUI, with 17% in Intermix and 83% in Interface.

- County development patterns create unique fire risk environments. Urban counties like Los Angeles and Orange tend to have areas of dense development next to unpopulated open space, and HU are primarily in the Interface (97% and 99%). Conversely, numerous counties provide a rural lifestyle that includes low density Intermix dispersed within wildland fuels, where about half of HU are in Intermix (e.g. Butte, Eldorado, Santa Cruz, and Sonoma).

- The difficulty in protecting HU from wildfire in California is demonstrated by the fact that 67% of Interface HU and 73% of Intermix HU are in High or Very High fire hazard classes.

- Statewide, the 2010 WUI footprint is 17.7 million acres, including 1 million acres of Interface, 1.3 million of Intermix, and a 15.3 million acre influence zone.

ⓘ11.4 Indicator: Number and Percent of Communities at Risk (CAR) that are Firewise Communities or Covered by a Community Wildfire Protection Plan (CWPP)

- There are 1,338 individual communities represented by the Communities at Risk (CAR) list. Of these communities, 66% (881) are covered by a CWPP (individual, regional or countywide) and/or are recognized by the Firewise program. Numerous other communities are at various stages of CWPP development.

- Of the CARs communities, 16% (213) are covered by individual CWPPs or the Firewise program. Individual CWPPs typically provide the finest detail for project-level planning; however, many county-level plans are very detailed, while others serve more generally as an umbrella for individual CWPPs.

DISCUSSION

This chapter uses indicators to examine development patterns and the resulting risk to housing from wildfire in terms of houses in Fire Hazard Severity Zones (FHSZ) and in the Wildland Urban Interface (WUI). It then examines opportunities to mitigate risk through community planning efforts and land use planning.

Historical Structure Loss

Figure 11.1 shows the historical trend in structures (residences, commercial properties, outbuildings) destroyed by wildfire in California (ⓘ11.1). Since 1989, there were seven years in which a loss of more than 1000 structures occurred in CAL FIRE/Contract County Direct Protection Areas (DPA), including 2015, 2016, and 2017. This is consistent with trends from the wildfire chapter (Chapter 4) – increasing wildfire activity (ⓘ4.3) and severity (ⓘ4.4).

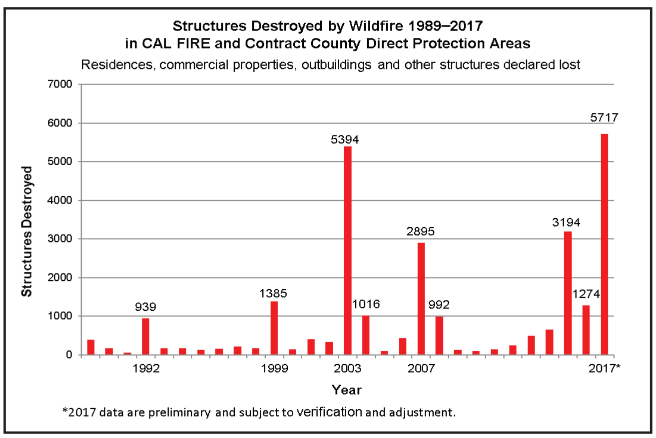


Figure 11.1: Structures Destroyed by Wildfire in CAL FIRE and Contract County District Protection Areas, 1989–2017.

Data Source: Wildfire Activity Statistics (Redbooks), CAL FIRE, 1989-2017.

Development Patterns and Wildfire Hazard

As of 2010, there were about 3 million housing units (HU) in FHSZ and potentially at risk from wildfire (ⓘ11.2). Figure 11.2 shows how these HU are distributed among California counties. A large proportion of the HU within FHSZ are in the southern portion of the state. The top five counties for FHSZ HU, all in southern California, contain about half of all statewide HU in FHSZ. However, this is clearly a statewide problem – 37 counties have at least 10,000 HU in FHSZ.

Figure 11.3 shows the distribution of HU by hazard class for counties with at least 100,000 HU in FHSZ, for 2000 and 2010 (Appendix 11.1 provides 2010 numbers for all counties). Counties with the highest numbers of HU tend to be in densely populated southern California,

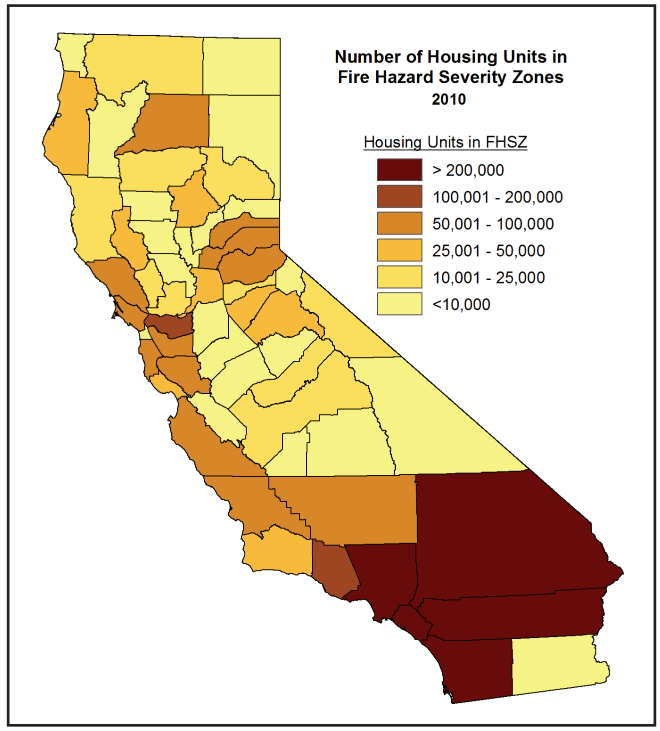


Figure 11.2: Number of Housing Units in Fire Hazard Severity Zones, 2010.

Data Sources: Fire Hazard Severity Zones, FRAP, v11; Census block data, U.S. Census Bureau, 2010.

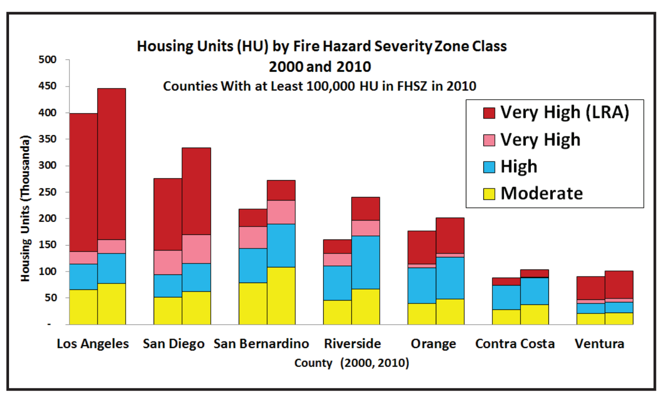


Figure 11.3: Census Housing Units by Fire Hazard Severity Zone Class, 2000 and 2010 (Counties with at least 100,000 HU in FHSZ in 2010).

Data Sources: Housing Density, LandScan, v12_2; Census block data, U.S. Census Bureau, 2000 and 2010; Fire Hazard Severity Zones, FRAP, v11_1.

where hazard tends to be the highest. The top five counties for FHSZ HU, all in southern California, contain 62% of all the statewide HU in the Very High class. Over 460,000 HU were added within FHSZ between 2000 and 2010. This includes 144,000 HU added to the Very High class.

Development can be classified into two Wildland Urban Interface (WUI) classes, each presenting unique fire protection problems and opportunities for risk mitigation. Interface represents dense urban development adjacent to wildland. The definable boundary between houses and wildland provides a line of defense, and focuses mitigation efforts along this boundary.

Intermix represents sparse development interspersed within a landscape that maintains much of the wildland characteristics. Intermix areas often require fire agencies to devote resources to protect individual houses. Mitigation includes actions such as prevention efforts, fire resistant building materials, and defensible space clearance around structures.

For the Assessment, FRAP focused on mapping WUI as the Interface and Intermix areas at risk from fire, and a 1.5 mile "influence zone" into adjacent fuels around those areas. Statewide, the 2010 WUI footprint is 17.7 million acres, including 1 million acres of Interface, 1.3 million of Intermix, and a 15.3 million acre influence zone.

Development patterns have created a fire environment where in 2010 about 2.2 million housing units were within Wildland Urban Interface (WUI) (Table 11.1), 83% of which are in Interface, and 17% of which are in Intermix (ⓘ11.3) (Appendix 11.2 provides WUI class numbers by county). The difficulty in protecting houses from wildfire in California is demonstrated by the fact that 67% of HU in Interface are in High or Very High FHSZ classes. The same applies to 73% of HU in Intermix.

County development patterns create unique fire risk environments. Urban counties like Los Angeles and Orange tend to have areas of dense development next to

Table 11.1: Housing Units (HU) by Wildland Urban Interface (WUI) Class, and Within High or Very High Fire Severity Zones (FHSZ), for Counties with at Least 25,000 HU in FHSZ

	Housing Units (HU)	Percent of HU		Percent of HU in High/Very High FHSZ	
County	All WUI	Intermix	Interface	Intermix	Interface
Los Angeles	375,411	3%	97%	93%	82%
San Diego	264,272	8%	92%	76%	80%
San Bernardino	207,795	20%	80%	81%	58%
Riverside	185,363	6%	94%	84%	68%
Orange	177,546	1%	99%	93%	74%
Ventura	84,642	5%	95%	71%	77%
Contra Costa	80,207	12%	88%	87%	59%
Alameda	75,901	6%	94%	85%	69%
San Luis Obispo	62,346	25%	75%	81%	37%
Marin	54,341	36%	64%	75%	67%
El Dorado	52,079	48%	52%	76%	58%
Placer	47,008	36%	64%	61%	15%
San Mateo	43,923	13%	87%	71%	66%
Santa Clara	39,987	18%	82%	88%	67%
Monterey	34,512	38%	62%	94%	69%
Kern	33,956	22%	78%	71%	34%
Santa Cruz	33,518	50%	50%	33%	37%
Nevada	33,315	49%	51%	94%	85%
Sonoma	31,488	52%	48%	35%	23%
Santa Barbara	30,679	13%	87%	77%	59%
Butte	28,741	51%	49%	95%	54%
Shasta	27,900	37%	63%	90%	66%
Counties (>25K)	2,004,930	15%	85%	73%	69%
Statewide	**2,213,881**	**17%**	**83%**	**73%**	**67%**

Data Sources: Housing Density, LandScan, v12_2; Fire Hazard Severity Zones, FRAP, v11_1; Census block data, U.S. Census Bureau, 2000 and 2010; Vegetation (for urban areas), FRAP, v11_1.

unpopulated open space, and HU are primarily in the Interface (97% and 99%). Conversely, numerous counties provide a rural lifestyle that includes low-density Intermix dispersed within wildland fuels, where about half of HU are in Intermix (e.g. Butte, Eldorado, Santa Cruz, and Sonoma).

Figure 11.4 shows examples of two patterns of WUI typical in California. The highway 50 corridor in Eldorado County has Interface areas in the most densely populated areas such as Placerville and Camino, which are surrounded by widespread Intermix areas in more sparsely populated areas. This pattern of development is common in other rural Sierra and northern counties.

In the Los Angeles County example, an extended Interface zone is present where densely populated urban areas are immediately adjacent to wildlands. Here, the wildlands are not populated since they are primarily in public ownership (Angeles National Forest), and thus there is little Intermix. This pattern is commonly found in portions of other southern counties and the San Francisco Bay Area.

National Cohesive Wildland Fire Management Strategy

A national vision for wildfire management is expressed by the National Cohesive Wildland Fire Management Strategy. This represents a "strategic push to work collaboratively among all stakeholders and across all landscapes, using best science, to make meaningful progress towards the three goals:

1. Resilient Landscapes
2. Fire Adapted Communities
3. Safe and Effective Wildfire Response" [1]

The second goal, Fire Adapted Communities, recognizes the importance of various programs and actions such as community planning, land use planning, education programs, and homeowner responsibility.

Community Planning

Community Wildfire Protection Plans (CWPPs)

Communities are encouraged to take collective action to analyze their unique fire environment, identify appropriate solutions, and commit resources to mitigate risk and raise community awareness. Two ways this can

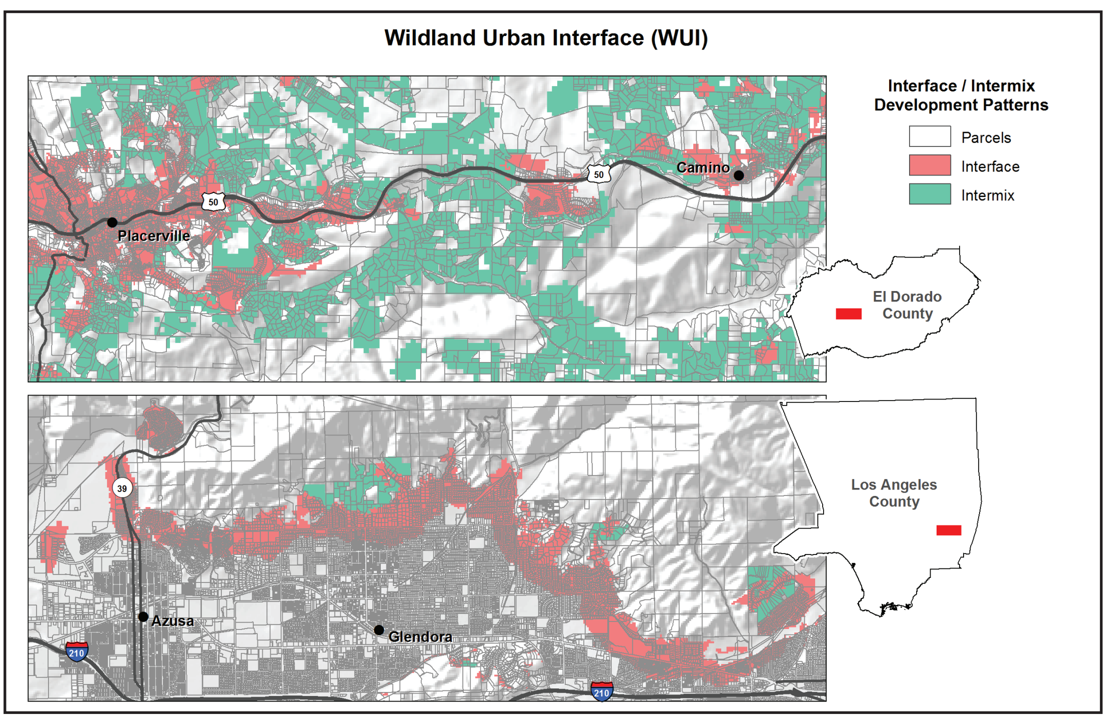


Figure 11.4: Wildland Urban Interface (Interface and Intermix), Highway 50 Corridor in Eldorado County (Top) and Glendora Area in Los Angeles County (Bottom).

Data Sources: Housing Density, LandScan, v12_2; Vegetation (for urban areas), FRAP, v11_1; Fire Hazard Severity Zones, FRAP, v11_1.

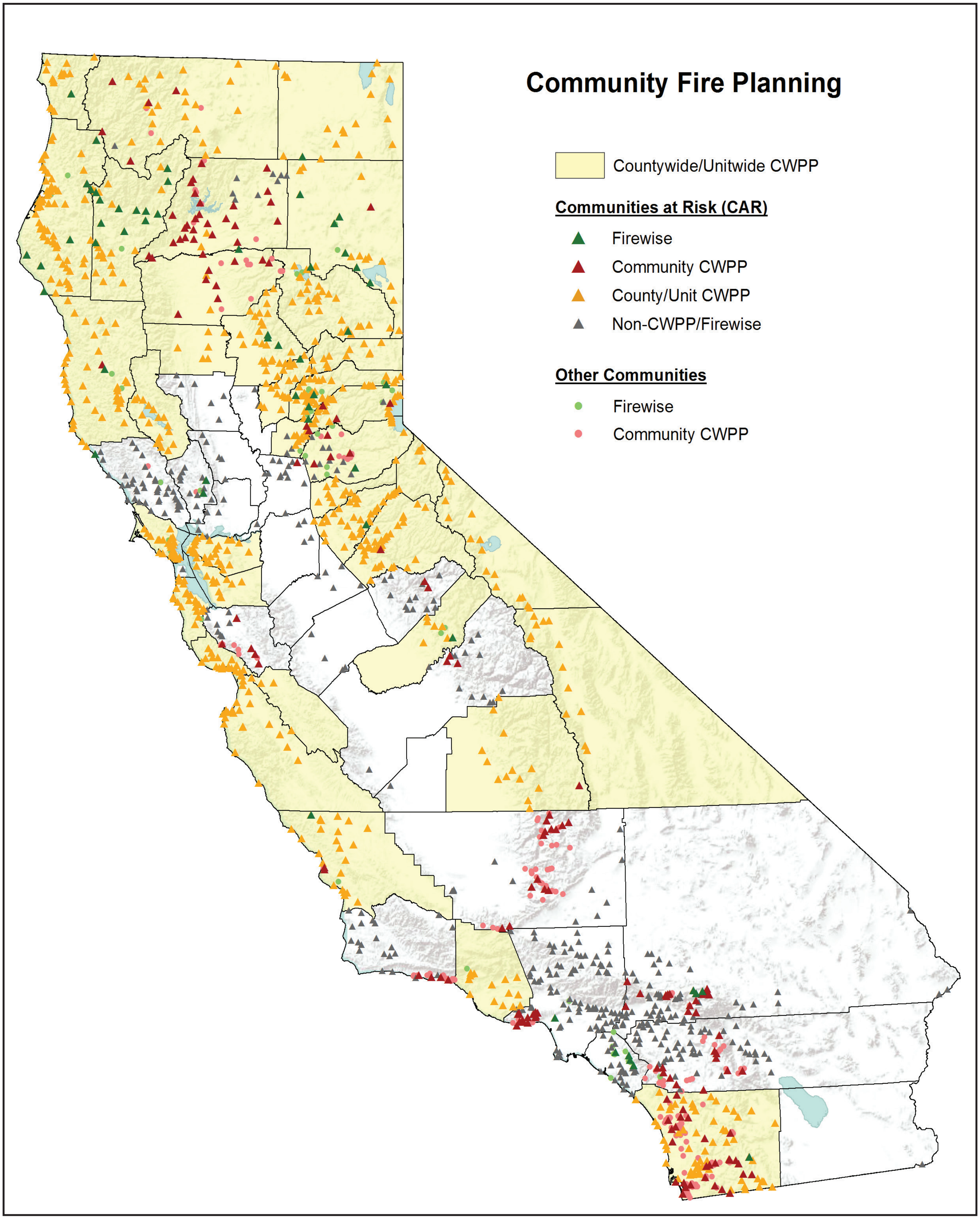


Figure 11.5: Communities at Risk (CAR) and Other Communities with a Signed Community Wildfire Protection Plan or Identified as Firewise.

Data Sources: Communities at Risk, CAL FIRE, v15_2; CWPP/Firewise community data, local sources, 2015.

be accomplished are by creating a Community Wildfire Protection Plan (CWPP), or by becoming a Firewise community.

One of the goals of the Healthy Forests Restoration Act of 2003 (HFRA) was to incentivize community fire planning through development of a Community Wildfire Protection Plan. "An approved CWPP can influence and prioritize future funding for hazardous fuel reduction projects, including where and how federal agencies implement fuel reduction projects on federal lands"[2]. Creating and maintaining a CWPP is a collaborative process that can include participation by local government, fire safe councils, fire protection districts, resource conservation districts, residents, and appropriate state and federal agencies. One primary purpose of CWPPs is to provide a guiding document for future actions by local Fire Safe Councils, land management agencies, private landowners, and local emergency service providers [3]. CWPPs can be developed for an individual community, an entire county, or a unique multi-community portion of a county.

The National Fire Protection Association's (NFPA) Firewise Communities program "… encourages local solutions for safety by involving homeowners in taking individual responsibility for preparing their homes from the risk of wildfire"[4]. Firewise communities are required to demonstrate an ongoing commitment to reducing fire risk, for example by developing a community wildfire hazard assessment, conducting an annual Firewise Day event, and demonstrating a level of effort of at least $2 per capita in the community.

Currently, of 1,338 communities identified as Communities at Risk (CAR) [5], 66% (881) are covered by a CWPP (individual, regional or countywide) and/or are recognized by the Firewise program (ⓘ11.4). Numerous other communities are at various stages of CWPP development. Of the CARs, 16% (213) are covered by individual CWPPs or the Firewise program. Individual CWPPs typically provide the finest detail for project-level planning, however, many county-level plans are very detailed, while others serve more generally as an umbrella for individual CWPPs. Figure 11.5 shows the distribution of communities involved in these efforts.

Fire Safe Councils

The California Fire Safe Council [6] is a statewide non-profit organization that supports various grassroots fire-related movements, as the state liaison for the Firewise program, operating the innovative online Grants Clearinghouse, and encouraging the formation of local fire safe councils (Figure 11.6). Local fire safe councils are typically groups of volunteers that conduct a variety of activities to reduce fire risk that are beyond the capacity of fire services [7]. In California, there are 34 countywide fire safe councils, and over 125 community councils (Figure 11.6).

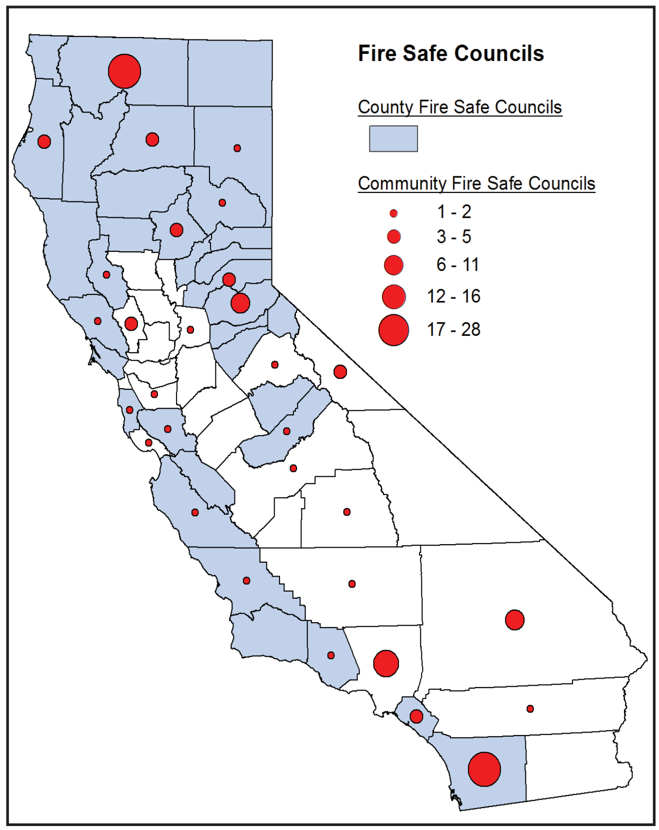


Figure 11.6: County and Community Fire Safe Councils in California.

Data Sources: [6] California Fire Safe Council, 2017; CAL FIRE Unit and Contract County staff.

Land Use Planning

In addition to community planning, a second opportunity to mitigate fire risk involves land use planning. The CAL FIRE Land Use Planning program works with local government to address wildfire risk as part of the safety element in city and county general plans, as required in government code 65302. Land use planning includes considering wildfire risk in the location, arrangement, and composition of new development. The location of new development should include a consideration of fire hazard, for example favoring infill development over patterns that create additional Interface or Intermix. There are opportunities to reduce overall fire risk through new development that meets current code and standards for fire resistive construction (California Building Code (CBC), Chapter 7A, Office of the State Fire Marshal, 2013), infrastructure upgrades such as increased roadway and water flow standards, and fuel modification requirements (14 CCR § 1270).

For example, the photos at the right show two very different types of Interface. In the top photo, wildland extends directly to the edge of development, and elements of the natural landscape are maintained even within the developed area. While creating a desirable living environment, under the wrong conditions this has the potential to carry fire up to and even through a community.

The bottom photo shows an area where the slopes that surround a community have been converted to terraces where fuel modification is maintained. This includes a minimum 20 foot level irrigated zone immediately adjacent to housing [8], which creates a defensible space buffer around the community. This is a good example of how the county general planning process and local ordinances and guidelines can result in development patterns that seek to minimize community wildfire risk.

Education Programs

Educating the public about the importance of wildfire preparedness is vital. For example, CAL FIRE participates in "Ready, Set, Go!" [9, 10], a worldwide communication and education program to assist the public in being better prepared for wildfire. Topics covered include:

- Fire safe landscaping
- Creating a defensible space
- Safe use of equipment to prevent ignitions
- "Hardening" your home from fire (roofs, vents, windows, gutters, etc.)
- Evacuation preparedness
- Safe evacuation procedures

Homeowner Responsibility

A significant component of community safety is homeowners acting to reduce their individual risk. CAL FIRE provides education and assistance to homeowners in this effort through defensible space home inspections that verify homeowners comply with regulations related to establishing a defensible space and reduced fuel zone, clearance around propane tanks, adequate display of address numbers, and proper configuration of chimney and stove openings. A recent sample of almost 19,000 CAL FIRE home inspections indicates that 76% passed on the first visit. Within Firewise communities, for a

much smaller sample of 396 inspections in six communities, the pass rate increased to 84%. Collecting inspection data within the CAL FIRE enterprise Geographic Information System (GIS) is a recent development; once statewide data for multiple years are available we can generate more definitive numbers to examine the value of education programs such as Firewise for raising homeowner awareness.

Opportunities

The following is a summary of opportunities discussed in the chapter to reduce costs and losses from wildfire.

Community Planning

- Continue to support community involvement in developing Community Wildfire Protection Plans (CWPPS), and becoming Firewise and/or Fire-Adapted Communities.

Land Use Planning

- Continue the CAL FIRE Land Use Planning program to work with local government to address wildfire risk as part of the safety element in city and county general plans, as required in government code 65302.
- Reduce overall fire risk through new development that meets current code and standards for fire resistive construction, infrastructure upgrades such as increased roadway and water flow standards, and fuel modification requirements.

Education Programs

- Continue to support programs such as "Ready, Set, Go!" to educate landowners in wildfire preparedness, and encourage them to take responsibility for their home and community.

Homeowner Responsibility

- Continue and improve the CAL FIRE defensible space inspection program to assist homeowners in correcting problems that could put them at risk from wildfire.

Indicator: Number of Structures Destroyed by Wildfire Annually ⓘ11.1

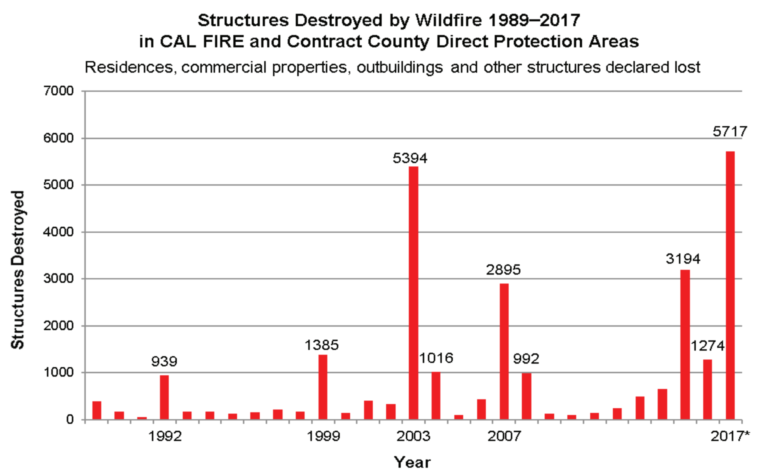
Which Montreal Process Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is the indicator important?

Structure loss over time is a reflection of factors such as development patterns, land management activities, fire suppression and pre-fire operations, and changes in climate. Tracking trends can signify when program or policy changes are needed to modify one or more of these factors.

What does the indicator show?



*2017 data are preliminary and subject to verification and adjustment.

Top 20 Most Damaging California Wildfires (Any Direct Protection Area)		
Fire	**Year**	**Structures**
Tubbs	2017	5,643
Tunnel	1991	2,900
Cedar	2003	2,820
Valley	2015	1,955
Witch	2007	1,650
Nuns	2017	1,355
Thomas	2017	1,063
Old	2003	1,003
Jones	1999	954
Butte	2015	921
Atlas	2017	781
Paint	1990	641
Fountain	1992	636
Sayre	2008	604
City of Berkeley	1923	584
Harris	2007	548
Redwood Valley	2017	544
Bel Air	1961	484
Laguna	1993	441
Erskine	2016	386
Total	**ALL**	**25,913**

Key Findings:

- Since 1989, there were seven years in which a loss of more than 1000 structures (residences, commercial properties, outbuildings) occurred in CAL FIRE/Contract County Direct Protection Areas (DPA), including 2015, 2016, and 2017. In bad fire years, this number can exceed 5,000, as in 2003 and 2017.

- In all jurisdictions, the top 20 most damaging fires on record destroyed 25,913 structures. About half of these losses occurred in 2015, 2016, or 2017.

- The National Fire Information Reporting System has complex requirements for reporting structure loss due to wildfire. Structure losses on lands protected by local agencies are not always reported.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Structures Destroyed	Wildfire Activity Statistics (Redbooks), CAL FIRE, 1989-2017.	***

Indicator: Housing Units by Fire Hazard Severity Zone (FHSZ) Class ⓘ11.2

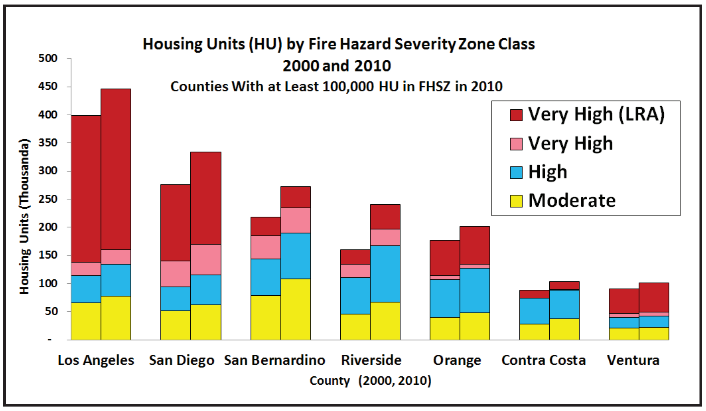
Which Montreal Process Criteria does the indicator evaluate?

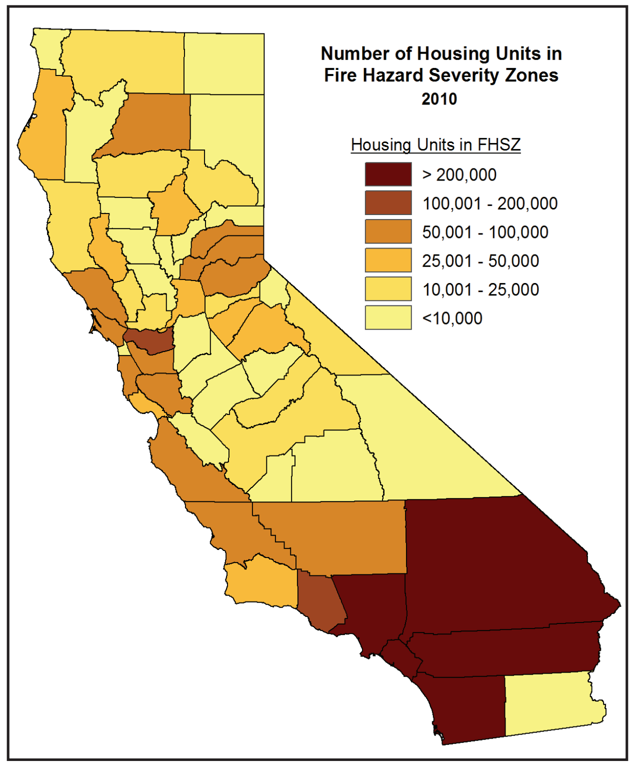
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is the indicator important?

Number of housing units (HU) by hazard class provides one measure of the pre-fire planning and overall fire protection problem. It also provides a measure to track and evaluate county growth patterns in terms of mitigating potential losses from wildfire.

What does the indicator show?





Key Findings:

- In 2010, in all counties, about 3 million housing units (HU) were in FHSZ and potentially at risk from wildfire. This includes about 1.2 million HU (41%) in the Very High class.

- Over 460,000 HU were added within FHSZ between 2000 and 2010. This includes 144,000 HU added to the Very High class.

- A large proportion of the HU within FHSZ are in the southern portion of the state. The top five counties for FHSZ HU, all in southern California, contain about half of all statewide HU in FHSZ, and 62% of the HU in the Very High class. However, this is clearly a statewide problem – 37 counties have at least 10,000 HU in FHSZ.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Housing Units	Census block data, U.S. Census Bureau, 2000 and 2010.	****
Fire Hazard	Fire Hazard Severity Zones, FRAP, v11_1.	****

Indicator: Housing Units and Wildfire Threat Within the Wildland Urban Interface (WUI)

ⓘ11.3

Which Montreal Process Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is the indicator important?

For the Assessment, FRAP focused on capturing WUI as the Interface and Intermix areas at risk from fire, and a 1.5 mile buffer area into adjacent fuels. WUI Interface is defined as high-density development adjacent to wildland fuels. Intermix is defined as lower-density housing mingled within wildland fuels. These classes pose unique problems for fire protection and pre-fire strategies. These classes combined with Fire Hazard Severity Zones provide a way to quantify the structure protection problem by county. Tracking this indicator over time will provide a measure of the effectiveness of county growth strategies.

What does the indicator show?

The table shows statistics for counties with at least 25,000 housing units (HU) in WUI, and the totals for all counties. (Appendix 11.2 provides details for all counties).

Housing Units (HU) by Wildland Urban Interface (WUI) Class, and Within High or Very High Fire Severity Zones (FHSZ), for Counties with at Least 25,000 HU in FHSZ

	Housing Units (HU)	Percent of HU		Percent of HU in High/Very High FHSZ	
County	All WUI	Intermix	Interface	Intermix	Interface
Los Angeles	375,411	3%	97%	93%	82%
San Diego	264,272	8%	92%	76%	80%
San Bernardino	207,795	20%	80%	81%	58%
Riverside	185,363	6%	94%	84%	68%
Orange	177,546	1%	99%	93%	74%
Ventura	84,642	5%	95%	71%	77%
Contra Costa	80,207	12%	88%	87%	59%
Alameda	75,901	6%	94%	85%	69%
San Luis Obispo	62,346	25%	75%	81%	37%
Marin	54,341	36%	64%	75%	67%
El Dorado	52,079	48%	52%	76%	58%
Placer	47,008	36%	64%	61%	15%
San Mateo	43,923	13%	87%	71%	66%
Santa Clara	39,987	18%	82%	88%	67%
Monterey	34,512	38%	62%	94%	69%
Kern	33,956	22%	78%	71%	34%
Santa Cruz	33,518	50%	50%	33%	37%
Nevada	33,315	49%	51%	94%	85%
Sonoma	31,488	52%	48%	35%	23%
Santa Barbara	30,679	13%	87%	77%	59%
Butte	28,741	51%	49%	95%	54%
Shasta	27,900	37%	63%	90%	66%
Counties (>25K)	2,004,930	15%	85%	73%	69%
Statewide	**2,213,881**	**17%**	**83%**	**73%**	**67%**

Key Findings:

- ⓘ 🔑 In 2010, in all counties, about 2.2 million housing units (HU) were in WUI, with 17% in Intermix and 83% in Interface.
- ⓘ 🔑 County development patterns create unique fire risk environments. Urban counties like Los Angeles and Orange tend to have areas of dense development next to unpopulated open space, and HU are primarily in the Interface (97% and 99%). Conversely, numerous counties provide a rural lifestyle that includes low-density Intermix dispersed within wildland fuels, where about half of HU are in Intermix (e.g. Butte, Eldorado, Santa Cruz, and Sonoma).
- ⓘ 🔑 The difficulty in protecting HU from wildfire in California is demonstrated by the fact that 67% of Interface HU and 73% of Intermix are in High or Very High fire hazard classes.
- ⓘ 🔑 Statewide, the 2010 WUI footprint is 17.7 million acres, including 1 million acres of Interface, 1.3 million of Intermix, and a 15.3 million acre influence zone.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Fire Hazard	Fire Hazard Severity Zones, FRAP, v11_1.	****
Housing Density	Housing Density, LandScan, v12_2.	****
Housing Counts	Census block data, U.S. Census Bureau, 2010.	****
Urban Areas	Vegetation (for urban areas), FRAP, v11_1.	****

Indicator: Number and Percent of Communities at Risk (CAR) that are Firewise Communities or Covered by a Community Wildfire Protection Plan (CWPP)

11.4

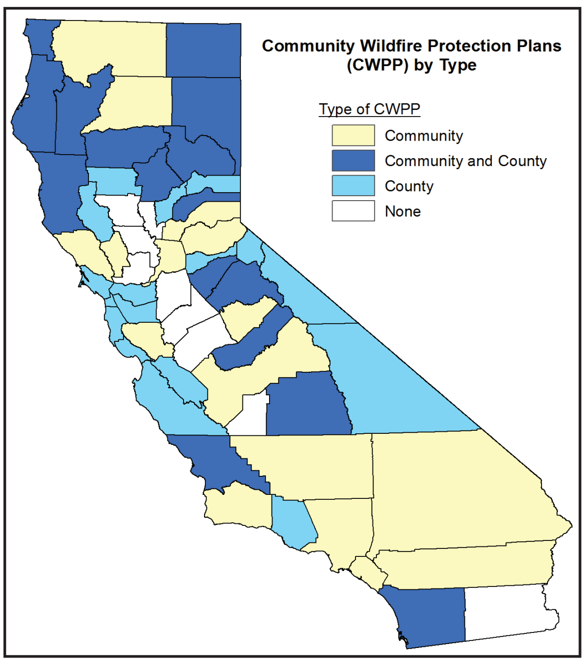
Which Montreal Process Criteria does the indicator evaluate?

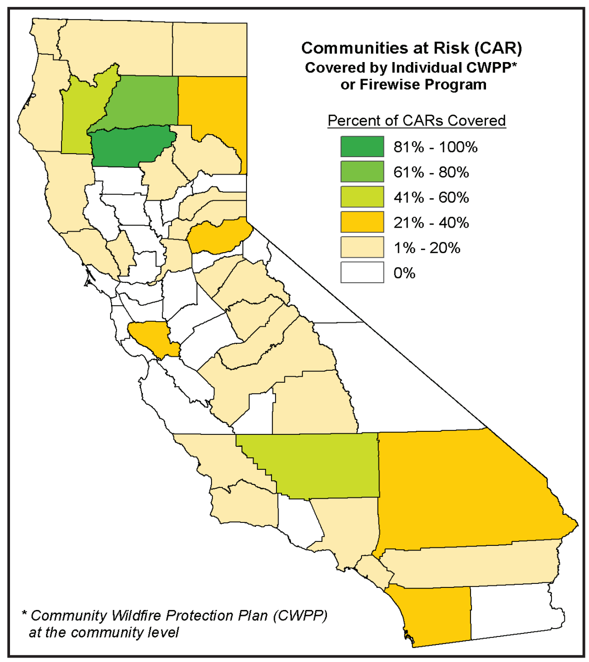
MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Why is the indicator important?

Community planning efforts, and associated pre-fire actions, have the potential to reduce wildfire frequency, severity, and damage. This is especially important in communities identified as having elevated wildfire risk.

What does the indicator show?





Key Findings:

- There are 1,338 individual communities represented by the Communities at Risk (CAR) list. Of these communities, 66% (881) are covered by a CWPP (individual, regional or countywide) and/or are recognized by the Firewise program. Numerous other communities are at various stages of CWPP development.

- Of the CARs, 16% (213) are covered by individual CWPPs or the Firewise program. Individual CWPPs typically provide the finest detail for project-level planning; however, many county-level plans are very detailed, while others serve more generally as an umbrella for individual CWPPs.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Community Planning Points	Community Wildfire Planning, FRAP, 2016.	****

Appendix 11.1

Table 11.2: Number of Housing Units by Fire Hazard Severity Zone (FHSZ) Class, 2010							
	FHSZ Class				Percent by FHSZ Class		
County	Very High	High	Moderate	Total	Very High	High	Moderate
Alameda	27,090	38,090	25,610	90,790	30%	42%	28%
Alpine	710	290	660	1,660	43%	17%	40%
Amador	6,250	2,510	7,560	16,320	38%	15%	46%
Butte	22,560	11,070	10,200	43,830	51%	25%	23%
Calaveras	15,330	9,450	2,910	27,690	55%	34%	11%
Colusa	50	260	500	820	6%	32%	61%
Contra Costa	15,370	50,590	37,490	103,450	15%	49%	36%
Del Norte	1,010	360	5,980	7,340	14%	5%	81%
El Dorado	44,260	14,990	24,340	83,590	53%	18%	29%
Fresno	4,120	5,790	4,300	14,210	29%	41%	30%
Glenn	140	120	500	760	18%	16%	66%
Humboldt	3,450	13,560	17,720	34,730	10%	39%	51%
Imperial	-	20	7,800	7,820	0%	0%	100%
Inyo	-	6,670	1,700	8,360	0%	80%	20%
Kern	12,840	13,720	29,010	55,570	23%	25%	52%
Kings	-	380	500	890	0%	43%	56%
Lake	12,700	6,570	7,070	26,350	48%	25%	27%
Lassen	2,420	2,290	4,140	8,850	27%	26%	47%
Los Angeles	311,370	56,380	77,840	445,590	70%	13%	17%
Madera	3,080	2,000	12,410	17,480	18%	11%	71%
Marin	6,460	39,220	22,030	67,710	10%	58%	33%
Mariposa	2,800	2,460	4,100	9,360	30%	26%	44%
Mendocino	2,250	11,930	10,470	24,650	9%	48%	42%
Merced	-	-	2,090	2,090	0%	0%	100%
Modoc	210	1,440	1,120	2,770	8%	52%	40%
Mono	960	5,160	5,980	12,110	8%	43%	49%
Monterey	15,640	25,130	9,490	50,250	31%	50%	19%
Napa	3,620	2,530	8,100	14,250	25%	18%	57%
Nevada	28,460	19,170	4,790	52,420	54%	37%	9%
Orange	73,610	78,880	48,420	200,910	37%	39%	24%
Placer	26,760	4,520	42,990	74,270	36%	6%	58%
Plumas	8,040	5,240	1,810	15,080	53%	35%	12%
Riverside	73,620	100,230	66,610	240,450	31%	42%	28%
Sacramento	100	2,300	27,100	29,500	0%	8%	92%
San Benito	530	1,210	1,130	2,870	18%	42%	39%
San Bernardino	83,490	81,310	108,050	272,850	31%	30%	40%
San Diego	218,750	53,820	61,460	334,020	65%	16%	18%
San Francisco	-	410	2,410	2,820	0%	15%	85%
San Joaquin	-	-	3,250	3,250	0%	0%	100%
San Luis Obispo	9,980	36,210	38,120	84,310	12%	43%	45%
San Mateo	13,760	23,830	17,190	54,780	25%	44%	31%
Santa Barbara	11,580	13,370	13,410	38,350	30%	35%	35%
Santa Clara	10,560	27,590	13,030	51,180	21%	54%	25%
Santa Cruz	360	17,580	29,530	47,470	1%	37%	62%
Shasta	31,110	10,720	8,610	50,440	62%	21%	17%
Sierra	1,300	460	340	2,110	62%	22%	16%
Siskiyou	11,130	4,150	6,410	21,690	51%	19%	30%
Solano	40	4,320	15,310	19,670	0%	22%	78%
Sonoma	3,370	18,500	38,200	60,070	6%	31%	64%
Stanislaus	-	260	2,060	2,330	0%	11%	88%
Sutter	-	-	410	410	0%	0%	100%
Tehama	5,400	2,010	4,630	12,040	45%	17%	38%
Trinity	7,140	1,220	60	8,420	85%	14%	1%
Tulare	2,580	3,010	2,320	7,910	33%	38%	29%
Tuolumne	24,010	5,620	1,330	30,960	78%	18%	4%
Ventura	59,680	20,460	21,350	101,490	59%	20%	21%
Yolo	70	580	1,690	2,340	3%	25%	72%
Yuba	4,170	840	2,810	7,820	53%	11%	36%
Statewide	**1,224,280**	**860,840**	**926,410**	**3,011,530**	**41%**	**29%**	**31%**

Data Sources: Census Block Data, U.S. Census Bureau, 2010; Fire Hazard Severity Zones, FRAP, v11_1.

Appendix 11.2

Table 11.3: Housing Units and Wildfire Threat within the Wildland Urban Interface (WUI), by County					
	Housing Units (HU)	Percent of HU		Percent of HU in High and Very High FHSZ	
County	All WUI	Intermix	Interface	Intermix	Interface
Alameda	75,900	6%	94%	85%	69%
Alpine	250	40%	60%	98%	43%
Amador	7,710	54%	46%	76%	31%
Butte	28,740	51%	49%	95%	54%
Calaveras	12,550	56%	44%	94%	88%
Colusa	370	10%	90%	81%	2%
Contra Costa	80,210	12%	88%	87%	59%
Del Norte	3,960	60%	40%	7%	27%
El Dorado	52,080	48%	52%	76%	58%
Fresno	5,010	59%	41%	80%	19%
Glenn	300	11%	89%	1%	21%
Humboldt	19,190	59%	41%	41%	28%
Imperial	4,880	8%	92%	0%	0%
Inyo	5,720	4%	96%	82%	87%
Kern	33,960	22%	78%	71%	34%
Kings	770	9%	91%	80%	38%
Lake	16,490	35%	65%	73%	74%
Lassen	3,660	43%	57%	47%	68%
Los Angeles	375,410	3%	97%	93%	82%
Madera	7,820	76%	24%	31%	12%
Marin	54,340	36%	64%	75%	67%
Mariposa	3,060	81%	19%	43%	83%
Mendocino	8,920	70%	30%	45%	18%
Merced	1,080	9%	91%	0%	0%
Modoc	440	50%	50%	71%	31%
Mono	6,960	37%	63%	66%	45%
Monterey	34,510	38%	62%	94%	69%
Napa	8,670	24%	76%	42%	34%
Nevada	33,320	49%	51%	94%	85%
Orange	177,550	1%	99%	93%	74%
Placer	47,010	36%	64%	61%	15%
Plumas	5,600	38%	62%	96%	74%
Riverside	185,360	6%	94%	84%	68%
Sacramento	23,650	10%	90%	3%	10%
San Benito	1,090	71%	29%	48%	53%
San Bernardino	207,800	20%	80%	81%	58%
San Diego	264,270	8%	92%	76%	80%
San Francisco	2,360	0%	100%	0%	17%
San Joaquin	1,810	36%	64%	0%	0%
San Luis Obispo	62,350	25%	75%	81%	37%
San Mateo	43,920	13%	87%	71%	66%
Santa Barbara	30,680	13%	87%	77%	59%
Santa Clara	39,990	18%	82%	88%	67%
Santa Cruz	33,520	50%	50%	33%	37%
Shasta	27,900	37%	63%	90%	66%
Sierra	1,130	44%	56%	98%	60%
Siskiyou	9,710	36%	64%	87%	46%
Solano	14,700	11%	89%	8%	20%
Sonoma	31,490	52%	48%	35%	23%
Stanislaus	1,110	46%	54%	19%	8%
Sutter	160	18%	82%	0%	0%
Tehama	3,710	44%	56%	68%	32%
Trinity	2,590	66%	34%	100%	99%
Tulare	2,180	70%	30%	71%	16%
Tuolumne	16,590	70%	30%	99%	81%
Ventura	84,640	5%	95%	71%	77%
Yolo	1,470	8%	92%	8%	40%
Yuba	3,290	41%	59%	87%	9%
Statewide	**2,213,880**	**17%**	**83%**	**73%**	**67%**

Data Sources: Housing Density, LandScan, v12_2; Fire Hazard Severity Zones, FRAP, v11_1; Census block data, U.S. Census Bureau, 2010; Vegetation (for urban areas), FRAP, v11_1.

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Chapter 12: Renewable Energy

This chapter provides a synthesis of renewable energy indicators, issues, and opportunities, and how they relate to sustainable output of forest and rangeland products and ecosystem services.

INDICATORS

ⓘ12.1 Renewable Energy

ⓘ12.2 Biomass Energy

SUMMARY

Based on current trends (ⓘ12.1), meeting the Governor's Renewables Portfolio Standard (RPS) mandate (SB350) that utilities procure 50% of their electricity from renewables by 2030 will require a continuing major expansion of solar and wind energy production. Where additional facilities are located, and how they are configured and maintained, will determine the level and type of impacts on forest and range operations and ecosystems [1, 2].

Public policies can affect the balance of large solar and wind facilities versus small-scale use for homes and businesses, and whether large projects are sited on leased public lands or private lands with lower ecological values (e.g. marginal agricultural lands).

Current trends (ⓘ12.2) also suggest that biomass energy will not be a significant contributor to renewable energy expansion. Biomass has become less competitive, due to declining natural gas prices, and decreasing production costs and higher public financial incentives for solar and wind [3,4], leading to a decline in the number of biomass facilities and total megawatts produced (ⓘ12.2). As of April 2017, there were 21 industrial biomass facilities operating in California, with at least 15 idle due primarily to uneconomic power purchase agreements. However, at least 9 small biomass plants [5] are in various stages of development because of SB1122 (2012), known as Bioenergy Market Adjusting Tariff (BioMAT). BioMAT rules provide procurement support for plants that supply 3 MW or less to the grid, using at least 80% feedstock from sustainable forest management, fire threat reduction, or defensible space clearance activities. If the maximum 50 MW capacity from small plants is ever realized, the total will only be equivalent to a single large biomass plant. However, the smaller facilities could be important in rural areas to improve forest health, reduce fire risk, and support rural economies.

Biomass energy has been an important factor for maintaining healthy forests, reducing fire risk, supporting rural economies, and reducing greenhouse gas and black carbon emissions [6]. The future of forest biomass in the energy sector depends in part on federal and state policy and legislation that considers the non-monetary benefits of biomass power, continued technological improvements to improve cost competitiveness versus other energy sources, and emerging potential uses such as advanced biofuels [7] (e.g. renewable diesel) that could be part of the state's Low Carbon Fuel Standard program [8].

KEY FINDINGS

ⓘ12.1 Indicator: Contribution of Renewable Energy Sources to California Electricity Generation

ⓘ 🔑 California appears to be on schedule to meet 2020 RPS targets, mainly due to increases in the contributions of wind and solar. Over the recent period 2010-2015, the contribution to state total system power from wind power has increased 78%, and solar has increased over 1700%.

ⓘ 🔑 Based on current trends, meeting RPS targets in the longer term will require a continued major expansion of wind and solar energy. Where additional facilities are located, and how they are configured and maintained, will determine the level and type of impacts on forest and range operations and ecosystems.

ⓘ12.2 Indicator: Contribution of Forest Biomass to California Electricity Generation

ⓘ 🔑 There is a downward trend for electricity generation (17% decline) as well as number of facilities that primarily utilize forest biomass (24 to 17) over the 2001-2015 period.

DISCUSSION

California's Renewables Portfolio Standard (RPS), established in 2002 under Senate Bill 1078, requires all electricity retailers in the state to procure a portion of retail sales from renewable energy sources. California's RPS establishes increasingly progressive renewable energy targets for the state's load serving entities, requiring both retail sellers and local publicly owned utilities to increase their procurement of eligible renewable energy resources to 50% of retail sales by 2030 (SB350).

To meet the mandate of 50% by 2030, California will need to continue its current trajectory of increasing reliance on renewable energy (Figure 12.1) (ⓘ12.1). If current trends continue, most of the increase will come from a continued expansion of both solar and wind power (Figure 12.2) (ⓘ12.1).

The Solutions Project [9] has charted one possible future course for meeting the state's electricity demand using 100% renewable sources by 2050 [10]. Under this scenario, new solar plants would need to occupy an additional 900,000 acres of land. A rough estimate that one-third of this expansion would be required to get from the current 25% level to the 50% RPS target translates to about 300,000 acres, a significant portion of which would likely occur on rangelands, especially in the desert. The numbers are of course estimates, but clearly underscore the importance of proper siting of facilities to minimize impacts.

Photo courtesy of BrightSource Energy.

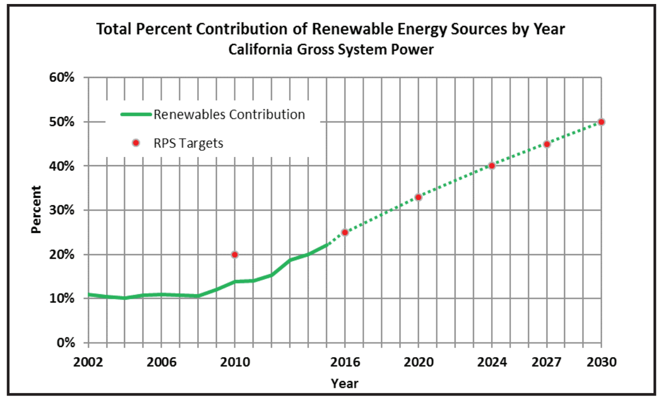


Figure 12.1: Total Percent Contribution of Renewable Energy Sources by Year to California Gross System Power.

Data source: Total System Electric Generation reports, California Energy Commission, 2002-2015.

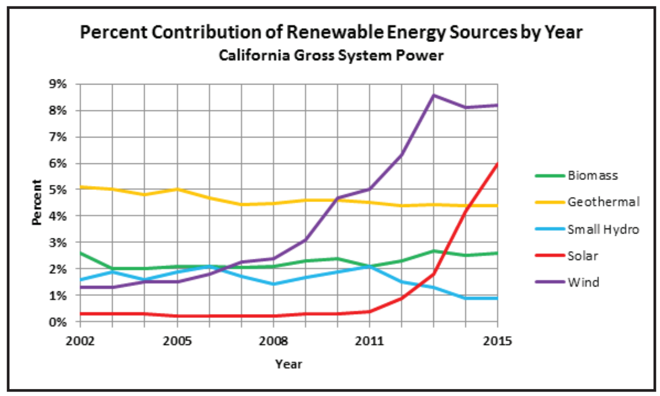


Figure 12.2: Percent Contribution of Renewable Energy Sources by Year to California Gross System Power.

Data source: Total System Electric Generation reports, California Energy Commission, 2002-2015.

Solar

A 2015 study shows that utility scale solar energy projects (over 1 MW) occupy just over 110,000 acres of rangeland in California [11]. This includes about 27,000 acres of leased Bureau of Land Management (BLM) desert land with operational or under construction solar projects [12]. This represents a complete land use conversion with associated impacts on alternative uses and ecosystem values, along with the additional impact of added human infrastructure associated with the site [13]. For these reasons, these projects are often opposed by environmental groups, despite their general support for solar to reduce carbon emissions.

Conversely, there are cases where these groups have supported large projects on previously disturbed private lands with low ecosystem values [14]. Proper site selection and use of private lands can lower costs and delays due to government regulations. However, investors have driven up prices for suitable sites for new projects on private lands [15].

The Desert Renewable Energy Conservation Plan (DRECP) is a collaborative planning process with a goal to identify appropriate locations (Development Focus Areas) for renewable energy development, while providing for conservation of resources across 22.5 million acres of the Mojave and Sonoran deserts in California [16]. In these areas, projects benefit from a streamlined permitting process and simplified mitigation measures. Phase I of the DRECP covering 10.8 million acres of public lands managed by the BLM was approved by the Secretary of the Interior in September, 2016. The lands specifically identified for renewable energy development by the plan have the potential to generate up to 27,000 megawatts of renewable energy (solar, wind, and geothermal) – enough to power over eight million homes. Phase I of the DRECP also set aside millions of acres for conservation and outdoor recreation.

Government policies such as the current 30% federal tax credit, energy pricing policies from the California Public Utilities Commission, and other incentives available under various state and local programs in California are critical for the future of solar in California, and for the relative contributions of rooftop versus large solar projects [17].

Wind

Large scale wind farms currently exist on about 27,000 acres of leased BLM lands [12, 18]. There are also numerous testing sites on BLM lands that could be developed in the future in Lassen, Lake, Kern, San Bernardino, and Imperial counties. In California, wind farms have also been developed on state-owned lands [19], tribal lands [20], city-owned lands [21], private farms and ranches [22], and even on industrial timberland [23]. On private lands, the Union of Concerned Scientists estimates that landowners with good wind resources can increase the economic yield of their land by 30-100%, while continuing current ranch or farm operations [24].

Photo by Dennis Schwartz, courtesy of U.S. Forest Service.

There are numerous environmental concerns over the expansion of wind farms [1], including mortality of birds and bats directly related to turbines. The U.S. Fish and Wildlife Service published Land-Based Wind Energy Guidelines [25] in 2012 in an effort to reduce bird and bat mortality rates. In California, efforts to replace older technology and microsite the replacement turbines should reduce mortality rates significantly. For example, Vasco Wind Energy Center replaced its 432 small turbines with 34 new turbines resulting in tripled energy production and a 70% reduction in avian mortality [26].

Biomass

Forest biomass energy production has been promoted as a way to improve forest health, reduce wildfire risk, reduce greenhouse gas emissions and black carbon [6], and supply continuous base-load power to the grid (unlike wind and solar). The Placer County Air Pollution Control District (PCAPCD) has developed a protocol [27] for quantifying the implications of forest biomass utilization that has been adopted by the California Air Pollution Control Officers' Association as part of their Greenhouse Gas Credit Exchange program [6]. Research sponsored by PCAPCD has quantified the benefits of forest biomass utilization for greenhouse gas reduction as well as air quality, when compared to the "business as usual" process of open pile burning residues from forest operations [28, 29]. Numerous studies in California provide additional evidence for the various benefits of forest biomass utilization for energy production [30, 31].

Photo courtesy of California Biomass Collaborative.

Biomass plants can also provide much needed employment opportunities in rural communities, and are often an important component of integrated wood processing facilities [32]. Providing an efficient way to dispose of residuals can be essential for economic viability of the entire facility.

On the other hand, emissions from using biomass to generate electricity can contribute to the formation of ozone and particulate matter in the Central Valley, which already exceeds air quality standards [33]. Forest biomass resources must also be shipped relatively long distances by truck, causing additional air quality emissions. The Energy Commission plans to begin a study in 2017 on the net atmospheric greenhouse gas emissions from forest biomass utilization for bioenergy, considering land use effects and other factors.

The number of biomass facilities in the state that utilize forest biomass (including residues from wood processing operations) has been declining, from 24 in 2001 to 14 in 2015, with a corresponding decline of about 17% in net electricity generation (Figure 12.3) (ⓘ12.2). There may be additional facilities (some of which rely on forest biomass) idled in 2020 when their power purchase agreements are set to expire [3]. Biomass power has become less competitive due to declining production costs and higher public financial incentives for solar and wind, and lower natural gas prices [3, 4].

Recent actions to support biomass energy may change the current trend line:

- SB1122 (2012) established a feed-in tariff to new bioenergy facilities that are 3 MW and less. This program, called the Bioenergy Market Adjusting Tariff or BioMAT program, tasks the three largest Investor-Owned Utilities (IOUs) to procure their share of 250 MW of bioenergy, with 50 MW allocated to facilities that use forest material from sustainable forest management activities.

- AB1923 (2016) adjusted the BioMAT size limits to allow electric generators to have a nameplate capacity of 5 MW while maintaining the export limit of 3 MW.

- SB859 (2016) requires that electrical corporations and the larger local publicly owned utilities purchase their proportionate share of 125 megawatts of electricity from existing bioenergy facilities that use fuel from High Hazard Zones in California.

In support of the Governor's Emergency Proclamation [34] to address public safety and property from falling dead trees and wildfire, the Public Utilities Commission issued decision E-4770 (March, 2016) requiring investor-owned utilities to purchase at least 50 MW of generating capacity collectively from biomass

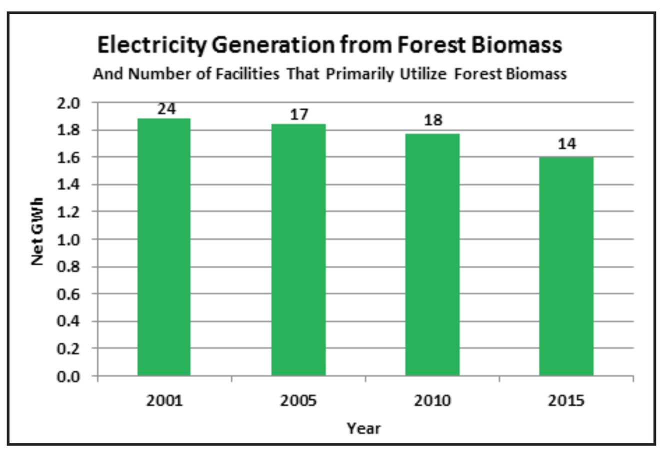


Figure 12.3: Electricity Generation from Forest Biomass and Number of Facilities that Primarily Utilize Forest Biomass.

Data source: Biomass & Waste-to-Energy Electricity Production, California Energy Commission, 2001-2015.

generation facilities that use minimum prescribed levels of feedstock from High Hazard Zones and to use the Renewable Auction Mechanism (RAM) solicitation procedures to procure the contracts.

Recent large fire and tree mortality events in the state demonstrate the importance of maintaining healthy forests, and California's biomass plants have played an important role in facilitating forest treatments to improve resiliency and reduce fire and pest risk. Studies have shown the various benefits including greenhouse gas reduction for more active harvest and prescribed burning regimes that could improve forest health and reduce fire risk [35, 36].

Figure 12.4 shows the location of operational biomass plants that primarily utilize forest biomass in relation to conifer forestlands in the state, including BioMAT plants in various stages of development. For a significant portion of conifer forestland, transport costs preclude biomass energy being a viable option for disposal of unmerchantable material from treatments. If treatments are performed, pile-and-burn or leaving materials on site are the most likely options.

Biomass energy could also be an important component of an integrated strategy to address the current tree mortality crisis, and for restoring areas damaged by large wildfires [37]. The Tree Mortality Task Force [38] has identified priority areas for treatment to address public safety and forest health. Without sufficient biomass energy capacity, strategies to treat these priority areas and effectively dispose of the resulting material become far more difficult.

The future of forest biomass in the energy sector depends in part on federal and state policy and legislation that considers the non-monetary benefits of biomass power, continued technological improvements to improve competetiveness versus other energy sources, and emerging potential uses such as advanced biofuels [7] (e.g. renewable diesel) that could be part of the state's Low Carbon Fuel Standard program [8]. The federal Biomass Research and Development (R&D) Board [39] has promoted the "Billion Ton Bioeconomy Vision" [40]. Part of the Vision is "...to rapidly expand emerging biofuels and bioproducts industries, targeting a potential 30% penetration of biomass carbon into the U.S. transportation market by 2030 in a sustainable and cost-effective manner to create jobs, reduce greenhouse gas impacts, and enhance national security." It remains to be seen what the role of forest biomass will be in this larger overall strategy.

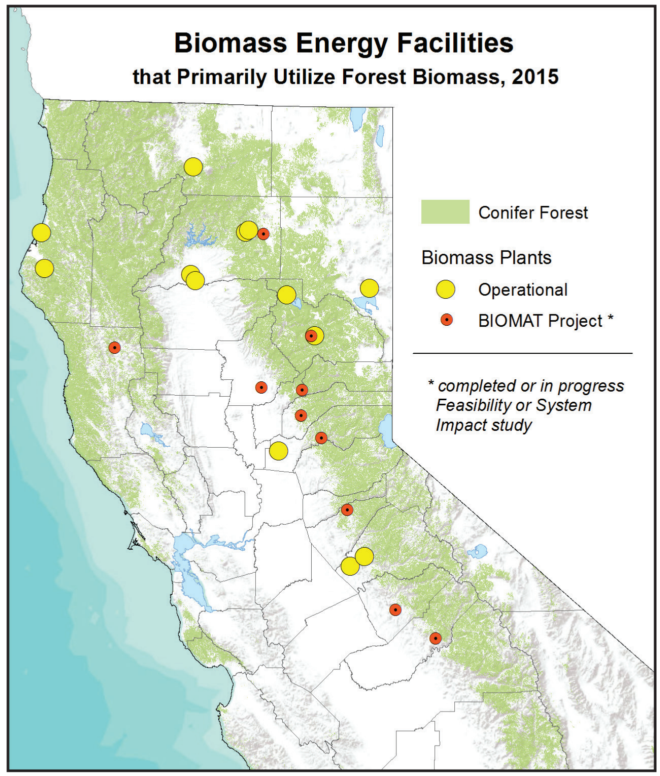


Figure 12.4: Biomass Energy Facilities that Primarily Utilize Forest Biomass, 2015.

Data Sources: Forest Products and Biomass Power Plant, UC Division of Agriculture and Natural Resources, 2017.

Opportunities

Opportunities to reduce the demand for energy production from forest and rangelands include:

- Continue to develop and support policies and programs that increase energy conservation. This includes numerous opportunities provided in the Assessment chapter related to urban forests (Chapter 3).

- Continue to develop and support policies and programs that facilitate small-scale renewable energy for homeowners, businesses, and public agencies.

Opportunities to minimize impacts from new renewable energy projects include:

- Consider the full range of impacts on forest and rangeland economic and ecosystem services when siting new renewable energy facilities, and where possible consider siting options on marginal agricultural lands or within developed areas.

- Continue to support research that improves the efficiency of renewable energy facilities, requiring less acreage per unit of energy produced.

- Continue to support research and implementation of improved technology that reduces the impact of renewable energy production on important ecosystem services.

Opportunities specific to energy production from forest biomass include:

- Continue to support research to fully account for and better quantify both the positive and negative aspects of energy production from forest biomass.

- Continue to develop and support policies that recognize the potential of forest biomass energy projects to improve forest health, reduce fire threat, contribute to rural economies, and provide other benefits.

- Explore opportunities for forest biomass to contribute towards the state's Low Carbon Fuel Standard program.

Indicator: Contribution of Renewable Energy Sources to California Electricity Generation ⓘ12.1

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies.

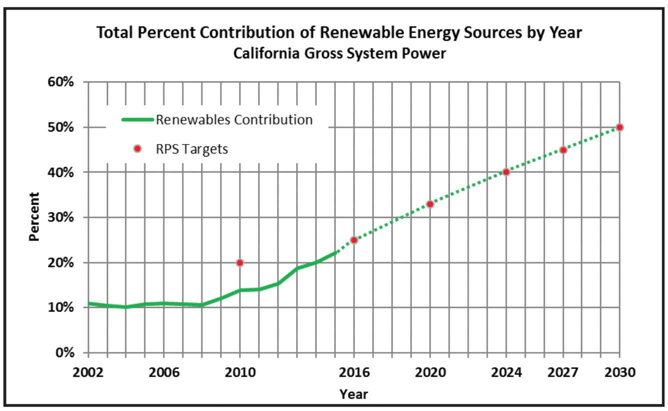
Why is the indicator important?

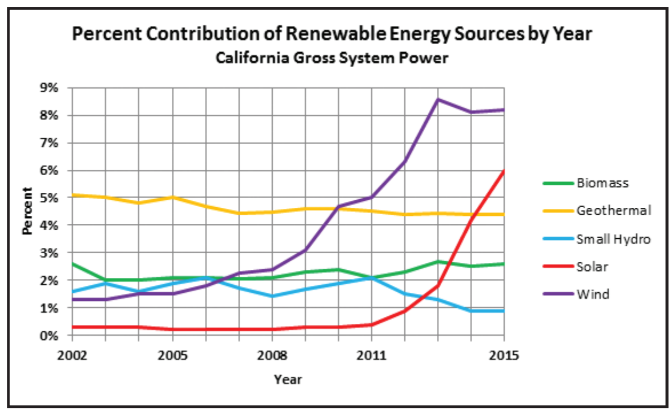
Increased use of renewable energy sources reduces our carbon emissions and reliance on fossil fuels, and provides various economic benefits. However, renewable energy does represent a significant new demand on our forest and rangelands that can have a negative impact on other ecosystem services.

Are there known targets or policy goals?

A series of legislation and executive orders, most recently SB350 (2015), sets Renewables Portfolio Standards (RPF) targets for the percent contribution of eligible renewable energy resources to electricity generated and sold to retail customers per year at 33% by 2020 and 50% by 2030.

What does the indicator show?





Key Findings:

ⓘ California appears to be on schedule to meet 2020 RPS targets, mainly due to increases in the contributions of wind and solar. Over the recent period 2010-2015, the contribution to state total system power from wind power has increased 78%, and solar has increased over 1700%.

ⓘ Based on current trends, meeting RPS targets in the longer term will require a continued major expansion of wind and solar energy. Where additional facilities are located, and how they are configured and maintained, will determine the level and type of impacts on forest and range operations and ecosystems.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Total Electricity System Power	Total System Electric Generation reports, California Energy Commission, 2002-2015.	****

Indicator: Contribution of Forest Biomass to California Electricity Generation

ⓘ12.2

Which Montreal Protocol Criteria does the indicator evaluate?

MPC6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies.

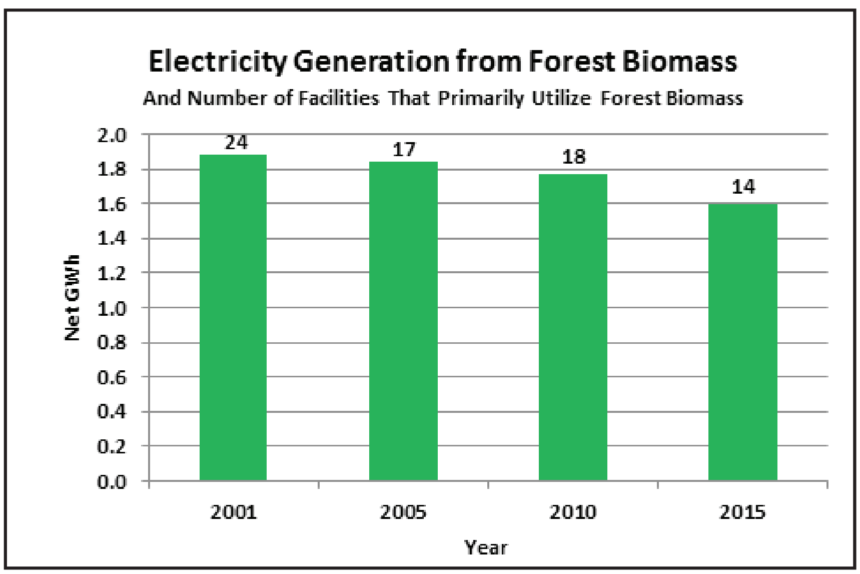
Why is the indicator important?

Forest biomass energy production has been promoted as a way to improve forest health, reduce wildfire risk, reduce greenhouse gas emissions and black carbon, provide employment in rural communities, and supply continuous base-load power to the grid (unlike wind and solar).

Are there known targets or policy goals?

A series of legislation and executive orders, most recently SB350 (2015), sets Renewables Portfolio Standards (RPS) targets for the percent contribution of eligible renewable energy resources to electricity generated and sold to retail customers per year at 33% by 2020 and 50% by 2030.

What does the indicator show?



Key Findings:

ⓘ There is a downward trend for electricity generation (17% decline) as well as number of facilities that primarily utilize forest biomass (24 to 17) over the 2001-2015 period.

Data Sources and Quality

Data Theme	Source	Quality (5 star max)
Electricity from forest biomass	Biomass & Waste-to-Energy Electricity Production, California Energy Commission, 2001-2015.	****

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Glossary

Aboveground Carbon Stocks: Carbon stocks refer to a distinct pool or reservoir capable of accumulating and releasing carbon. Aboveground carbon stocks are the amount of carbon stored in the living biomass of forest trees and plants, and dead wood and litter.

Acquisition: Parcels of land changing ownership through title transfer.

Afforestation: The establishment of a forest in an area where preceding vegetation or land was not forest.

Age Class: An interval into which a tree is classified based on its age, often in ten-year increments.

Air Pollution: The introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damage the natural environment, into the atmosphere.

Animal Unit Month (AUM): The amount of forage needed to sustain one cow and her calf, one horse, or five sheep or goats for a month (U.S. Forest Service/BLM definition).

Belowground Carbon Stocks: This includes living and dead roots, soil mesofauna, and the microbial community. In addition to this is the larger pool of soil organic carbon (see Soil Organic Carbon, SOC).

Biological Diversity: The variety of life over some spatial unit, used to describe all aspects of the broadly diverse forms into which organisms have evolved especially including species richness, ecosystem complexity and genetic variation.

Biomass Energy: Renewable organic materials including wood, agricultural crops or wastes, and municipal wastes, that can be used as a source of fuel or energy.

Bioregion: An area that includes a rational ecological community with characteristic physical (climate, geology), biological (vegetation, animal), and environmental conditions.

Bioswales: Landscape elements designed to remove pollution from surface run-off water. Commonly placed in parking lots where substantial automotive pollution is collected by the paving and then flushed by rain.

California Stream Condition Index: Translates data about individual benthic macro invertebrates (BMI) found living in a stream into an overall measure of stream health. The indicator evaluates the environmental health of a stream against reference sites.

California Wildlife Habitat Relationship System (CWHR): A classification system for California's wildlife, containing life history, management, and habitat relationships information on 675 species of amphibians, reptiles, birds, and mammals known to occur in the state. The classification system is identified by vegetation attributes that define wildlife habitat types and are used as predictors for where wildlife can be found.

Carbon Dioxide: A colorless, odorless, non-combustible gas, present in low concentrations in the atmosphere (about three hundredths of one percent by volume). Carbon dioxide is produced when any substance containing carbon is burned. It is also a product of breathing and fermentation. Plants absorb carbon dioxide through photosynthesis.

Carbon Sequestration: The process of capturing and storing atmospheric carbon dioxide that would otherwise be emitted into the atmosphere. Through photosynthesis, forests (trees, shrubs, grass, and other plants) store carbon as biomass (i.e. trunks, branches, foliage, roots) and soils, thereby preventing it from collecting in the atmosphere as carbon dioxide.

Carbon Sink: A carbon pool that has more carbon flowing into it than flowing out. Forests are good sinks because they are the most efficient means of taking carbon out of the atmosphere and storing it for long periods of time.

Carbon Storage: The process of storing carbon in leaves, woody tissue, roots, and soil nutrients.

Climate Change: Any long-term significant change in the “average weather” that a given region experiences. Average weather may include average temperature, precipitation and wind patterns.

Climatic Water Deficit: The amount of water by which potential evapotranspiration (PET) exceeds actual evapotranspiration (AET). This term effectively integrates the combined effects of solar radiation, evapotranspiration, and air temperature on watershed conditions given available soil moisture derived from precipitation.

CNRM CM5: Under this warmer and wetter climate scenario, by the end of this century mean annual minimum temperatures increase by 3.26°C and total annual precipitation increases 35% (+ 5.8 inches) under the RCP8.5 emissions scenario.

Compliance Carbon Offset Project: Projects that have been verified by ARB as meeting the requirements of California’s Cap-and-Trade Regulation, and have been issued ARB offset credits.

Community Wildfire Protection Plan (CWPP): Authorized and defined in Title I of the Healthy Forests Restoration Act of 2003, the CWPP must be collaboratively developed (with agreement among local government, local fire departments and the state agency responsible for forest management), identify and prioritize areas for hazardous fuel reduction treatments, and recommend measures that homeowners and communities can take to reduce the ignitability of structures.

Condition Class: A measurement of the degree to which a vegetation community has departed from its historical fire regime resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, and canopy closure.

Conifer Forest: A forest that consists of mostly evergreen, cone-bearing trees, generally located in higher elevation mountainous areas. California Wildlife Habitat Relationships (CWHR) types include Douglas fir, red fir, lodgepole pine, Sierran and Klamath mixed conifer and redwood.

Conifer Woodland: A woodland of low density, small, brushy conifer-dominated tree species. California Wildlife Habitat Relationships (CWHR) types include pinyon-juniper and juniper.

Conifer: Trees belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones and have needle-shaped or scale-like leaves. In the wood products industry, the term “softwoods” refers to conifers.

Conservation Easement: A restriction deeded to a qualified third party that permanently limits certain activities on real property to protect conservation values such as biodiversity, water quality, wildlife habitat, or carbon sequestration. The restriction stays with the property through successive owners, and reduces the “highest and best” economic use of the property so that the property’s value reflects only the allowed uses.

Contract County: In most cases State Responsibility Areas (SRA) is protected directly by CAL FIRE, however, in Kern, Los Angeles, Marin, Orange, Santa Barbara and Ventura counties, SRA fire protection is provided by the counties under contract with CAL FIRE.

Corridors: Any space that improves the ability of a species to move among patches of their habitat.

Defensible Space: CAL FIRE defines defensible space as a property’s front line defense against wildfire. Creating and maintaining defensible space around a home can dramatically increase the home’s chance of surviving a wildfire and improves the safety of firefighters defending the property. One hundred feet of defensible space is required by law.

Desert Shrub: Shrubland that is dominated by desert shrub and chaparral types. California Wildlife Habitat Relationships (CWHR) types include desert scrub, alkali desert scrub, desert succulent shrub and desert wash.

Developed Land: A Natural Resource Inventory definition comprising large urban and small built-up areas, as well as roads and railroads not included in urban/built-up areas.

Development: A human settlement pattern measured by housing density. Includes “conversion”, where natural landscapes are assumed to lose virtually all their ecological processes, and “parcelization”, where ecosystem processes are impacted but not completely lost. It is assumed that conversion occurs at an average housing density of five housing units per acre, and parcelization at 20 per acre.

Direct Protection Area (DPA): DPA refers to the lands that are assigned wildland fire protection by each State, Federal, and Local agency. The Cooperative Fire Management Agreement (CFMA) between the federal agencies and CAL FIRE is the primary mechanism that provides the framework for wildland fire protection responsibilities statewide. This framework allows agencies to negotiate exchanges of areas where they have legal protection responsibility, in order to consolidate DPA protection into more efficient blocks of contiguous lands.

Disturbance Regime: The characteristic pattern of natural- or human-caused events that disrupt the current physical and biological conditions of an area, such as floods, fires, storms, pest outbreaks, and human activity that shape vegetative composition and seral stage.

Drought: A protracted deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought occurs in most climatic zones, but its characteristics can vary from one region to another.

Early Action Carbon Offset Project: Projects that are being issued voluntary offsets must be listed with ARB to become early action projects. Early action projects may be issued ARB offset credits if specific requirements in the Cap-and-Trade Regulation are met.

Easement: A right to make limited use of another's real property, such as a right of way. Legal title to the underlying land is retained by the original owner for all other purposes. Easements are a tool for protecting lands against threats such as development, without the costs of acquiring and managing the land.

Ecological Integrity: The degree to which the components (types of species, soil etc.), structure (arrangement of components), and processes (flows of energy and nutrients) of an ecosystem, or natural community are present and functioning intact. Lands with high ecological integrity generally have not been subjected to significant human influences or disruption of natural processes, such as fire, floods, and nutrient and hydrological cycling.

Ecological Restoration: The process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed (U.S. Forest Service).

Ecosystem Function: The operational role of ecosystem components, structure, and processes.

Ecosystem Health: The degree to which a biological community and its nonliving environmental surroundings function within a normal range of variability; the capacity to maintain ecosystems structures, functions and capabilities to provide for human need.

Ecosystem Processes: The flow or cycling of energy, materials, and nutrients through space and time.

Ecosystem Services: The beneficial outcomes, for the natural environment, or for people, that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, clean water, or scenic views.

Ecosystem Structure: Spatial distribution or pattern of ecosystem components.

Ecosystem: The interacting system of a biological community and its nonliving environmental surroundings.

Emission Scenario: Based on the Representative Concentration Pathways (RPCs) used by the 5th IPCC (2014) Assessment Reports to model a range of future greenhouse gas emission scenarios through 2100, for projecting the effects of climate change. The RCP8.5 emissions scenario was selected for Assessment climate analysis since it appears to best match the current global trajectory of emissions, which of course could be altered through future actions.

Endemic: Found only in a specified geographic region.

Exotic Invasive Species: Plants, animals, and microbes not native to a region which, when introduced either accidentally or intentionally, out-compete native species for available resources, reproduce prolifically, and dominate regions and ecosystems.

Fire Adapted Community: A community of informed and prepared citizens collaboratively planning and acting to safely coexist with wildland fire. In these communities, the actions of residents and agencies in relation to infrastructure, buildings, landscaping and the surrounding ecosystem lessen the need for extensive protection actions and enable the communities to safely accept fire as part of the surrounding landscape (National Wildfire Coordinating Group).

Fire Frequency: A broad measure of the rate of fire occurrence in a particular area. For historical analyses, fire frequency is often expressed using the fire return interval calculation. For modern-era analysis, where data on timing and size of fires are recorded, fire frequency is often best expressed using fire rotation.

Fire Hazard Severity Zone (FHSZ): A mapped area that designates zones (based on factors such as fuel, slope, and fire weather) with varying degrees of fire hazard (i.e., moderate, high, and very high). While FHSZ zones do not predict when or where a wildfire will occur, they do identify areas where wildfire hazards could be more severe and therefore are of greater concern.

Fire Prevention: This includes various precautions that are taken to prevent or reduce the likelihood of a fire. Specific fire prevention tools include education, law enforcement, inspections, etc.

Fire Regime: A measure of the general pattern of fire frequency and severity typical to a particular area or type of landscape: The regime can include other metrics of the fire, including seasonality and typical fire size, as well as a measure of the pattern of variability in characteristics.

Fire Rotation: An area-based average estimate of fire frequency, calculated as the length of time necessary for an area equal to the total area of interest to burn. Fire rotation is often applied to regionally stratified land groupings where individual fire-return intervals across the variability of the strata (i.e., the fine scale pattern of variation in timing of fires) is unknown, but detailed information on fire size is known. Hence, fire rotation is a common estimate of fire frequency during periods of recorded fire sizes.

Fire Suppression: The act of extinguishing destructive fires. In areas that burn too frequently, fire suppression infrastructure (engines, personnel, etc.) may be augmented to increase the effectiveness of extinguishing ignitions before they can spread.

Fire Threat: An index of expected fire frequency and physical ability to cause impacts. Components include surface fuels, topography, fire history, and weather conditions.

Forage: Browse and herbage that is available and acceptable to grazing animals.

Forb: A broad-leafed herb other than a grass, especially one growing in a field, prairie, or meadow.

Forest Health: The capacity of a forest for renewal, for recovery from a wide range of disturbances, and for retention of ecological function, while meeting the current and future needs of people for desired levels of values, uses, products, and services.

Forest Inventory and Analysis (FIA) Program: U.S. Forest Service program that conducts a plot-based survey and statistical analysis of all forest lands.

Forest Management: The processes of planning and implementing practices for the stewardship and use of forests and other woodlands aimed at achieving specific environmental, economic, social and /or cultural objectives.

Forest Management (Climate Change): In the context of climate change, forest management refers to management actions that are taken to either reduce the potential loss of carbon from wildfire and associated emissions, or actions that are taken to increase carbon sequestration. This can cover a broad range of actions that includes: forest thinning, fuel reduction, reforestation and afforestation.

Forest Meadows: Wet and dry grassland vegetation in montane areas. Impacts to meadow systems from forest encroachment, grazing, and other land management practices can degrade montane meadows.

Forest Pests: Organisms (insects and diseases) capable of causing injury or damage to forests (particularly trees).

Forest Structure: The horizontal and vertical distribution of components of a forest stand including height, diameter, crown layers, and stems of trees, shrubs, herbaceous understory, and down woody debris (Dictionary of Forestry).

Forest/Forests: A biological community of plants and animals that is dominated by trees and other woody plants; by definition in the Assessment, all lands with greater than 10 percent tree canopy cover and including all CWHR types in the Conifer Forest, Conifer Woodland, Hardwood Forest and Hardwood Woodland land cover classes.

Forests and Rangelands: All CWHR types in the Conifer Forest, Conifer Woodland, Hardwood Forest, Hardwood Woodland, Shrub, Grassland, Desert Shrub, and Desert Woodland land cover classes plus the Wetland CWHR type Wet Meadow; excludes Urban, Agriculture, Barren, and Water.

Forest Industry: An ownership class of private lands owned by a company or individual(s) operating a primary wood-processing plant (USFS-FIA definition).

Fragmentation: The process by which a contiguous land cover, vegetative community, or habitat is broken into smaller patches within a mosaic of other forms of land use/land cover, e.g., islands of an older forest age class immersed within areas of younger aged forest (Dictionary of Forestry), or patches of oak woodlands surrounded by housing development.

Fuels Reduction Projects: The harvest of live and dead vegetation to reduce potential fire threat, and often resulting in improved timber growth and/or forage production. Some projects create revenue through the sale of wood products or biomass for energy.

Geographic Information System (GIS): A computer-based system used to store and manipulate geographical (spatial) information.

Geothermal: Natural heat from within the earth, captured for production of electric power, space heating, or industrial steam.

Global Climate Models: Computer-driven models for weather forecasting, understanding climate, and projecting climate change.

Grassland: Land on which the vegetation is dominated by grasses, grasslike plants, or forbs (The Dictionary of Forestry). California Wildlife Habitat Relationships (CWHR) types include annual and perennial grasslands.

Grazing Allotment: An area of land where one or more lessees or permittees graze their livestock. The number of livestock and period of use are stipulated for each allotment (BLM definition).

Greenhouse Gases: Any of the atmospheric gases, including carbon dioxide (CO_2), that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the Earth's surface.

Gross State Product: Gross economic output (sales, receipts and other operating income, commodity taxes, and inventory changes) minus intermediate inputs (consumption of goods and services purchased from other U.S. industries or other nations).

Groundwater Basins: A groundwater basin is defined as an area underlain by permeable materials capable of furnishing a significant supply of groundwater to wells or storing a significant amount of water. Groundwater basins in California have been delineated by the Department of Water Resources (Bulletin 118).

Habitat: The living place of an organism, natural or otherwise, characterized by its physical or biological properties; a specific classification of vegetation in the California Wildlife Habitat Relationships System.

Hardwood Forest: A forest that is made up of 50% or more hardwoods, and is usually located in the mountainous elevations above the Hardwood Woodlands and are often associated with Conifer Forest tree species. California Wildlife Habitat Relationships (CWHR) types include montane riparian and montane hardwood.

Hardwood Woodland: A land cover class with greater than 10% total tree cover and of which 50% or more are hardwoods (70% or more for mixed hardwood-conifer stands, except the CWHR type Blue Oak-Foothill Pine, which for the Assessment is considered Hardwood Woodland); different from Hardwood Forest in species composition and in that trees are widely spaced, of shorter stature and often found in lower elevations in the transition between Grassland/Shrub and Conifer Forest. In the foothills of the Sierra Nevada and the eastside of the northern coast ranges, tree species typically include blue oak (*Quercus douglasii*) and interior live oak (*Quercus wislizenii*). In the mid to southern coast range, species include coast live oak (*Quercus agrifolia*) and California bay (*Umbrellula californica*) and further south, Englemann oak (*Quercus englemannii*). Typical understory is composed of extensive annual grass vegetation.

Hardwoods: Dicotyledonous trees; generally deciduous, broad-leafed species such as oak, alder, or maple.

Herbaceous: See grassland definition.

Hydroelectric: Of or relating to production of electricity from falling water that turns a turbine generator, referred to also as "hydro."

Impaired Water Bodies (303d): Section 303(d) of the federal Clean Water Act, requires states to identify waters that do not meet water quality standards (called "impaired water bodies") after the technology-based effluent limits or other required pollution control mechanisms are put into place. States are then required to prioritize waters/watersheds for total maximum daily loads (TMDL) development.

Interface: Development can be classified into two Wildland Urban Interface (WUI) classes (interface and intermix), each presenting unique fire protection problems and opportunities for risk mitigation. Interface represents dense urban development adjacent to wildland. The definable boundary between houses and wildland provides a line of defense, and focuses mitigation efforts along this boundary.

Intermix: Development can be classified into two Wildland Urban Interface (WUI) classes (interface and intermix), each presenting unique fire protection problems and opportunities for risk mitigation. Intermix represents sparse development interspersed within a landscape that maintains much of the wildland characteristics. Intermix areas often require fire agencies to devote resources to protect individual houses. Mitigation includes actions such as prevention efforts, fire resistant building materials, and defensible space clearance around structures.

Invasive Species: A species of plant or animal that can proliferate and alter native biological communities and ecosystem function.

Land Cover: Predominant vegetation life forms, natural features, or land uses of an area.

Land Trust: A private, nonprofit organization formed to protect natural resources such as wildlife habitat, prime farmland, and recreational lands. It accomplishes this through a variety of means, including outright purchase, securing donations, and receiving conservation easements.

Litter: The uppermost layer of the forest floor consisting chiefly of fallen leaves and other decaying organic matter.

Livestock: Domestic animals, such as cattle or horses, raised for home use or for profit, especially on a farm.

Management Landscape: FRAP has developed the Management Landscape applied to productive forestlands (including timberland plus productive forest withdrawn from timber production) to characterize how unique owner objectives translate into timber management emphasis. Management emphasis relates not only to harvest volume, but also to the silvicultural systems and practices used to grow and harvest timber and the level of associated ecosystem services provided.

Meadow Restoration: Montane meadows consist of wet and dry grassland vegetation. Impacts to meadow systems from forest encroachment, grazing, and other land management practices can degrade montane meadows. The restoration of these meadow systems can enhance water quality, water quantity, and improve wildlife habitat.

Megafire: A wildfire that burns at least 100,000 acres and poses a great risk to human lives and resources.

Megawatt: One thousand kilowatts; one megawatt is approximately the amount of power required to meet the peak demand of a large hotel.

MIROC ESM: Under this hotter and drier climate scenario, by the end of this century mean annual minimum temperatures increase by 3.95°C and total annual precipitation decreases by 26% (- 6.9 inches) under the RCP8.5 scenario.

Mitigation Banking: The restoration, creation, enhancement, or preservation of a habitat conservation area which offsets expected adverse impacts to similar nearby ecosystems. In the United States, the federal government as well as many state and local governments, require mitigation for the disturbance or destruction of wetland, stream, or endangered wildlife habitat. Once approved by regulatory agencies the mitigation bank may sell credits to developers whose projects will impact these various ecosystems.

National Forest: Federal lands that have been designated by Executive Order or statute as national forest or purchased units and other lands under the administration of the U.S. Forest Service (U.S. Department of Agriculture).

Native Species: A species of plant or animal present prior to European settlement.

Natural Community Conservation Plan (NCCP): A cooperative effort to protect habitats and species, between private landowners, the California Department of Fish and Wildlife (CDFW) and other interested parties. The primary objective of NCCPs is to conserve natural communities at the ecosystem scale while accommodating compatible land use. CDFW seeks to anticipate and prevent the controversies and grid-lock caused by species' listings by focusing on the long-term stability of wildlife and plant communities and including key interests in the process.

Niche Product: A good or service with features that appeal to a particular market subgroup. A typical niche product will be easily distinguished from other products, and it will also be produced and sold for specialized uses within its corresponding niche market (Business Dictionary definition).

Nonindustrial Forestland: Forestlands owned by private individuals, groups or corporations that do not also own a wood processing facility (USFS-FIA definition).

Nonindustrial Timber Management Plan (NTMP): Owners of up to 2500 acres of timberland can streamline the Timber Harvesting Plan process by preparing a NTMP. NTMPs have a core requirement for an assessment of long-term sustained yield based on an uneven-aged silvicultural prescription. Plans also must include provisions for protecting environmental and ecological values.

Non-Point: Pollution whose source cannot be ascertained, including runoff from storm water and agricultural, range, and forestry operations, as well as dust and air pollution that contaminate waterbodies.

Nutrient Cycling: The exchange or transformation of elements (nutrients) among the living and nonliving components of an ecosystem.

Old Growth Forest: A stand or stands of natural forest trees that have developed over a long period of time with trees that are at least 150 years old, without experiencing severe stand replacing disturbance, and have developed a complex structure characterized by large, live and dead trees, down woody debris, multiple canopies and multi-aged trees, and a distinctive habitat with a diverse group of plants, fungi and animals.

Open Space: Land free from intensive residential or commercial uses.

Option A: The California Forest Practice Rules (14 CCR 913.11) require that a forest landowner with more than 50,000 acres must demonstrate Maximum Sustained Production of High Quality Timber Products (MSP), via a Sustained Yield Plan (SYP), a Programmatic Timber Environmental Impact Report (PTEIR), or an Option A document. An Option A document defines how a landowner will manage for sustained yield, consideration of non-timber values, maintaining stand vigor, and ensuring adequate regeneration.

Ozone (O_3): An unstable, poisonous allotrope of oxygen that is formed naturally from atmospheric oxygen by electric discharge or exposure to ultraviolet radiation. It is also produced in the lower atmosphere by the photochemical reaction of certain pollutants.

Parcelization: The process of land ownership being broken into increasingly smaller tracts; by definition in the Assessment, housing density of one or more units per 20 acres and less than one unit per acre.

Perennial: 1) A plant which lives or continues over two years, whether it retains its leaves in winter or not; 2) A stream or water body that persists year-round in normal weather years.

Pest: As used in this Assessment, pests includes both insects and diseases that affect vegetation in California.

Population: The number of individuals of a particular taxon in a defined area.

Post-Fire Erosion: The accelerated soil loss that can occur after a large fire event. The rate of loss is a function of factors such as slope, soil type, geology, burn severity, vegetation, and rainfall.

Prescribed Fire: A deliberate burn of wildland fuels in either their natural or modified setting and under specific environmental conditions which allow the fire to be confined to a predetermined area and intensity to attain a planned resource management objective (Dictionary of Forestry).

Public Water Supply: Water supplied to a group through a public or private water system. This can include residential, commercial, and industrial uses.

Rangelands: Any expanse of land not fertilized, cultivated or irrigated that is suitable, and predominately used for grazing by domestic livestock and wildlife. These include the Conifer Woodland, Hardwood Woodland, Shrub, Grassland, Desert Woodland and Desert Shrub classes as well as some habitats within the Wetland and Hardwood Forest classes.

Reforestation: The natural or intentional restocking of existing forests and woodlands that have been depleted, usually through deforestation.

Renewable Energy: A power source other than a conventional power source within the meaning of Section 2805 of the Public Utilities Code, provided that a power source utilizing more than 25% fossil fuel may not be included.

Reserve: This includes forestland withdrawn from timber utilization through statute or administrative designation (Forest Service definition). It also includes rangelands with permanent legal protection, and typically dedicated for a specific public purpose or program.

Riparian Area: Transition zone between a stream's edge and the drier uplands.

Riparian Vegetation: Vegetation found on the interface between land and a stream or waterbody. Plant communities that develop along the banks of streams are referred to as riparian vegetation and are characterized, but not exclusively defined, by hydrophytic (water adapted) plants. California Wildlife Habitat Relationships (CWHR) types include Montane Riparian, Valley Riparian, and Desert Riparian.

Riparian: Relating to or located on the banks of a river or stream.

Salmonids: Any of the family Salmonidae, some of which are freshwater species, such as golden trout (*Salmo aquabonita*) and Lahontan cuththroat trout (*Salmo clarki henshawi*), and some of which are anadromous (spending part of their life cycle at sea and returning to freshwater to reproduce), such as coho (*Onocohynchus kisutch*) and chinook (*Onocorhynchus tshawytscha Walbaum*).

Seed Tree: A silvicultural method in which all trees are removed except for a small number of seed bearers left singly or in small groups, maybe 10 per acre. The seed trees are generally harvested after regeneration is established. An even-aged stand results.

Seral Stage: A temporal and intermediate stage in the process of succession.

Shelterwood: A silvicultural method to establish seedling regeneration via a series of partial harvests, followed by the almost complete removal of overstory trees in a removal harvest once adequate numbers of seedlings are in place to permit the seedlings to grow in full sunlight.

Shrub: A woody, perennial plant differing from a perennial herb in its persistent and woody stem, and less definitely from a tree in its lower stature and the general absence of a well-defined main stem (The Dictionary of Forestry). California Wildlife Habitat Relationships (CWHR) types include, but are not limited to, bitterbrush, sagebrush, coastal scrub, chamise-redshank, alpine-dwarf shrub, desert scrub and montane and mixed chaparral.

Silviculture: The science and art of cultivating (such as with growing and tending) forest crops, based on the knowledge of silvics. More explicitly, silviculture is the theory and practice of controlling the establishment, composition, constitution, and growth of forests.

Site Class: A species-specific classification of forest land in terms of inherent capacity to grow crops of industrial, commercial wood (Dictionary of Forestry).

Size Class: An interval into which a tree is classified based on its trunk diameter at breast height (DBH), often in two-inch size classes.

Small Hydro/Hydroelectric: A facility employing one or more hydroelectric turbine generators, the sum capacity of which does not exceed 30 megawatts.

Snags: Standing dead trees with a minimum DBH of 10 inches and a height of 10 feet.

Soil Organic Carbon: Organic carbon in mineral soils to a specified depth and applied consistently through a time series. This is a generic term referring to all organic material in soil that is not part of a root system.

Soil Productivity: The capacity of a soil, in its normal environment, to support plant growth. This capacity can be diminished by large wildfire events, due to post-fire soil erosion.

Species of Greatest Conservation Need (SGCN): Species of wildlife that are indicative of the state's biological diversity and have the greatest need for conservation. The California Department of Fish and Wildlife sets the criteria to determine the list.

Species of Special Concern: An administrative designation given to animals that were not listed under the federal Endangered Species Act or the California Endangered Species Act at the time of designation but are declining at a rate that could, and sometimes does, result in listing.

Species Recovery Plan: A program to develop protocols for protecting and enhancing federally rare and endangered species populations. A recovery plan is a non-regulatory document that may apply to one species or an ecosystem.

Species Richness: The total number of species, based on species range overlap and taken from "A GAP Analysis of California."

Stand: A group of trees sufficiently uniform in composition, age, and/or condition forming a management entity and distinguishable from adjoining tree groups.

Stand Age: Hardwood or forest stands that are characterized into classes according to their age.

Stand Density Index (SDI): Stand Density Index is one way to measure tree stocking levels, based on stand basal area. To identify overstocked stands, we looked at two thresholds - stands that exceed 100% of stand density as determined from Stand Density Index (SDI) values (i.e. the upper limit of self-thinning zone), and 60% SDI (the lower threshold of the self-thinning zone, where competition due to tree density begins to induce tree mortality).

State Responsibility Area (SRA): CAL FIRE has a legal responsibility to provide fire protection on all State Responsibility Area (SRA) lands, which are defined based on land ownership, population density and land use. For example, CAL FIRE does not have responsibility for densely populated areas, incorporated cities, agricultural lands, or lands administered by the federal government.

Strategically Placed Landscape Treatments (SPLATS): Groups of disconnected patches of fuel treatments placed strategically across a landscape, typically overlapping perpendicular to the direction of heading fire spread, in order to reduce fire intensity and forward spread rate in the absence of active suppression.

Stocking Level: A measure of the quantity of wood fiber growing in a standing timber acre.

Stressor: Pressure that directly or indirectly influence the quality and quantity of habitat used by terrestrial and aquatic wildlife, mainly from human-induced changes in the landscape. Stressors include agricultural and urban land use, introduced invasive and exotic species, nutrient enrichment, direct human disturbance, water management conflicts, climate change and toxic chemicals.

Structures: Residential and commercial development, which is measured using housing density classes applied to census blocks from the 2010 U.S. Census, and commercial areas mapped in National Land Cover data.

Succession: The process of a predictable sequence of changes in the species structure and composition of an ecological community over time, usually following a disturbance or the initial colonization of new habitat.

Sudden Oak Death (SOD): A brown algae species, *Phytophthora ramorum*, that infects a variety of host plant species, including several coastal oak species.

Sustainable Management: Ensures forests and rangelands can contribute to the resilience of ecosystems, societies, and economies while also safeguarding biological diversity and providing a broad range of goods and services for present and future generations (U.S. Forest Service).

Taxon: The name that is applied to a group in biological classification, for example, species, subspecies, variety, or Evolutionarily Significant Unit (ESU). The plural is taxa.

Terrestrial Landscape Intactness: The condition of the landscape based on disruption of human impacts such as agriculture, urban development, natural resource extraction, and invasive species.

Threatened and Endangered Species: Legally protected plants and animals under the State and/or Federal Endangered Species Act.

Timber: Standing trees which will be used for lumber and other wood products. The value depends on tree species present, tree size, and stocking.

Timberland: Land capable of producing over 20 cubic feet/acre/year of wood with commercial value and not withdrawn from timber utilization by statute or administrative regulation (U.S. Forest Service).

Timberland Production Zone (TPZ): A statutory designation for lands assessed for taxes based on growing and harvesting timber as the highest and best use of the land.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, as well as an estimation of the percentage originating from each pollution source. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for State-designated purposes. The calculation must also account for seasonal variation in water quality.

Transfer Payments: Income payments to persons for which no current services have been performed. They consist of payments to individuals and to nonprofit institutions by businesses and federal, state, and local governments.

Turbidity: The relative clarity of water that may be affected by material in suspension in the water.

Understory: The trees and other woody species growing under a relatively continuous cover of branches and foliage formed by the overstory trees.

Uneven-aged: A silvicultural system in which individual trees originate at different times and result in a forest with trees of many ages and sizes; stands where less than 70% of the tree stocking falls in three adjacent 10-year age classes.

Unsuitable: Lands that are not in a reserved status through removal of the area from timber utilization by statute, ordinance, or administrative order, but in practice or as prescribed in management plans or regulatory rules, are not primarily managed for timber production.

Urban Forest Carbon Stocks: Refers to the carbon stocks associated with trees planted within the urban area. It can include both the above and belowground carbon stocks. See aboveground carbon stocks.

Urban Forest Expansion: The planting of trees and associated vegetation in urban areas that is additional to a baseline measurement and will increase economic, environmental, and social benefits to urban residents. Often the tree planting is a cooperative venture with the community and is completed with citizen participation and labor.

Urban Forest Management: The care and management of urban forests (i.e., tree populations in urban settings) for the purpose of improving the urban environment.

Urban Heat Island: An urban or metropolitan area that is significantly warmer than its surrounding rural areas. There are concerns that average annual days over 90 degrees are increasing in many urban areas, and urban heat islands may contribute to changing climatic conditions.

Urban Tree Canopy (UTC): The layer of tree leaves, branches, and stems that provide tree coverage of the ground when viewed from above (U.S. Forest Service).

Urban Tree Maintenance: The systematic technical care of trees in urban areas that conforms to currently accepted national standards. Such standards currently are the ANSI A-300 tree care standards in association with the International Society of Arboriculture Best Management Practices. Such activities include tree inventory (measurement), young tree care, root management, tree pruning, tree removal, stump removal, and pest and disease assessment and treatment utilizing Integrated Pest Management techniques.

Urban Tree Planting: This involves expanding or augmenting the urban forest through tree planting. Often the tree planting is a cooperative venture with the community, and is completed with citizen participation and labor.

Urban: A Census-defined area comprised of a densely-settled core of census tracts and/or census blocks that meet minimum population density requirements. The Census Bureau identifies two types of urban areas: 1) Urbanized Areas (UAs) of 50,000 or more people; 2) Urban Clusters (UCs) of at least 2,500 and less than 50,000 people.

Value-Added: Of or relating to the estimated value that is added to a product or material at each stage of its manufacture or distribution.

Vegetation Zone: Based on CALVEG Zones that are large-scale assemblages of plant species that co-occur according to climatic and soil variations, heavily influenced by latitude, distance from the coast, and elevation, as well as by human activities.

Very High Fire Hazard Severity Zone: Areas protected by local fire agencies (LRA) receive a Very High FHSZ recommendation from CAL FIRE, and adoption of these zones carries state-level minimum regulations for fire safety and building codes.

Watercourse and Lake Protection Zone (WLPZ): A strip of land, along both sides of a watercourse or around the circumference of a lake or spring, where additional practices may be required for protection of the quality and beneficial uses of water, fish and riparian wildlife habitat, other forest resources and for controlling erosion.

Water Conservation: This refers to reducing the use of water and reducing the waste of water.

Water Demand: The desired quantity of water that would be used if the water is available and several other factors such as price do not change. Demand is not static. Water demand is assessed as part of the California Water Plan.

Water Supply Watersheds: Those areas that contribute to public water supply. These are watersheds that drain downstream to a reservoir or major water storage facility.

Watershed Groups: Community based groups that conduct planning and restoration projects to protect and enhance the broad range of natural resources found within California watersheds.

Watershed Management Plan: The goal of watershed management is to plan and work toward an environmentally healthy watershed that provides a broad range of ecosystem services and benefits to all who live in the watershed. Typically, watershed management plans bring together stakeholders to develop solutions to address environmental issues of concern.

Watershed Restoration: Restoration of a watershed returns the ecosystem to as close an approximation as possible of its state prior to impairment. This typically benefits water quality that has been degraded by non-point source pollution.

Watershed: The land area drained by a single stream, river, or drainage network (Dictionary of Forestry).

Wetland: A transitional area between aquatic and terrestrial ecosystems that is inundated or saturated for periods long enough to produce hydric soils and support hydrophytic vegetation (The Dictionary of Forestry). California Wildlife Habitat Relationships (WHR) types include fresh and saline emergent wetlands.

Wildfire: Any fire occurring on undeveloped land; the term specifies a fire occurring on a wildland area that does not meet management objectives and thus requires a suppression response. Wildland fire protection agencies use this term generally to indicate a vegetation fire. Wildfire often replaces such terms as forest fire, brush fire, range fire, and grass fire.

Wildland Urban Interface (WUI): The geographical intersection of two disparate systems, wildland and structures. At this interface, structures and vegetation are close enough that a wildland fire could spread to structures or fire could spread from structures to ignite vegetation.

Wildland: Land other than that dedicated for other uses such as agricultural, urban, mining, or parks (Dictionary of Forestry).

Wildlife Habitat: The physical and biological characteristics of the natural environment where a particular species can find food, shelter, protection and space to live.

Woody Debris: Fallen dead wood or large branches; woody debris is an important source of nutrients and habitat as well as a source of fuel for fire.

Woody Plant: A plant having hard lignified tissues or woody parts, especially stems.

Working: Lands managed for commodity output, including livestock grazing (rangelands) or wood products (forestlands).

Zone of Infestation: CAL FIRE, with the approval of the California Board of Forestry and Fire Protection (BOF), has broad authority (PRC § 4716) to deal with large scale pest outbreaks through declaration of a Zone of Infestation for native and exotic forest pests. Within a declared Zone, CAL FIRE employees may go on private lands to attempt eradication or control in a manner approved by the BOF.

Zoning: Assigning a legal status to land that defines permitted uses. Zoning can be a tool for keeping lands as working landscapes for a set period of time. Examples of state-level zoning mechanisms include Timberland Production Zones (TPZ) that designate lands for timber production, and Williamson Act lands that are designated for livestock grazing. Local governments also define zoning which can include timber zones, agriculture preserve zones, etc.

Acronyms

AB	Assembly Bill
ABAG	Association of Bay Area Governments
ACA	Affordable Care Act
ACEP	Agriculture Conservation Easement Program
ADS	Aerial Detection Survey
AG	Aboveground
AGL	Aboveground Live
AQ	Air Quality
ARB	Air Resources Board
AUM	Animal Unit Months
BA	Basal Area
BCPI	Beef Cattle Price Index (aka Prices Received Index)
BG	Belowground
BioMAT	Bioenergy Market Adjusting Tariff
BLM	Bureau of Land Management
BMI	Benthic Macro Invertebrates
BOF	Board of Forestry and Fire Protection
BVOC	Biogenic Volatile Organic Compound
C	Carbon
CAL FIRE	California Department of Forestry and Fire Protection
Caltrans	California Department of Transportation
CFPC	California Forest Pest Council
CAL-IPC	California Invasive Plant Council
CAR	Climate Action Reserve
CAR	Community At Risk
CARS	Community Accomplishment Reporting System
CAUFC	California Urban Forests Council
CBC	California Building Code
CDFW	California Department of Fish and Wildlife
CDP	Census Designated Place
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFIP	California Forest Improvement Program
CFPC	California Forest Pest Council
CFRI	California Forest and Rangeland Indicators
CIG	Conservation Innovative Grants
CLFA	California Licensed Forester Association
CNPS	California Native Plant Society
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
COG	Council of Government
CPAD	California Protected Areas Database
CRCC	California Rangeland Conservation Coalition
CSCI	California Stream Condition Index
CSP	Conservation Stewardship Program
CWD	Cumulative Water Deficit
CWHR	California Wildlife Habitat Relationships
CWPP	Community Wildfire Protection Plan
cwt	hundredweight
DOF	Department of Finance
DPA	Direct Protection Areas
DRECP	Desert Renewable Energy Conservation Plan
DWR	Department of Water Resources
ECP	Emergency Conservation Program
EIR	Environmental Impact Report
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
ERS	Economic Resource Service
ESA	Federal Endangered Species Act
FHAAST	USDA Forest Health Assessment and Applied Sciences Team
FHRWG	Forest Health and Resilience Working Group
FHSZ	Fire Hazard Severity Zone
FIA	Forest Inventory and Analysis
FMMP	Farmland Mapping and Monitoring Program
FPODA	Forest Pest Observation Database Application
FPR	Forest Practice Rules
FPS	Forest Practice System
FRAP	Fire and Resource Assessment Program
FRASC	Forest and Rangelands Assessment Steering Committee
FRI	Fire Return Interval
FRID	Fire Return Interval Departure

FSC	Forest Stewardship Council
FY	Fiscal Year
GCM	Global Climate Models
GDP	Gross Domestic Product
GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas
GIS	Geographic Information System
GSP	Gross State Product
HCP	Habitat Conservation Plan
HFRA	Healthy Forests Restoration Act
HFRP	Healthy Forests Reserve Program
HHZ	High Hazard Zones
HU	Housing Units
HWP	Harvested Wood Products
ICLUS	Integrated Climate and Land Use Scenarios
IOU	Investor-Owned Utility
IPCC	Intergovernmental Panel on Climate Change
IRWMP	Integrated Regional Water Management Plan
LAFCO	Local Area Formation Commission
MMT	Million Metric Tons
MOU	Memorandum of Understanding
MPC	Montreal Process Criterion
MSG	Monitoring Study Group
MSP	Maximum Sustained Production
MT	Metric Ton
MTC	Metropolitan Transit Commission
MW	Megawatt
NAIP	National Agricultural Imagery Program
NASS	USDA National Agricultural Statistics Service
NCCP	Natural Community Conservation Plan
NFPA	National Fire Protection Association
NIDRM	National Insect and Disease Risk Map
NO2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NTMP	Nonindustrial Timber Management Plan
O3	Ground Level Ozone
OMB	U.S. Office of Management and Budget
OTR	Online Technical Report
PCAPCD	Placer County Air Pollution Control District
PET	Potential Evapotranspiration
PFE	Pre-Fire Engineer
PM	Particulate Matter
PPI	Prices Paid Index
PRC	Public Resources Code
PRIA	Public Range Improvement Act of 1978
PTEIR	Program Timber Environmental Impact Report
R&D	Research and Development
RAM	Renewable Auction Mechanism
RCD	Resource Conservation District
RCP	Representative Concentration Pathway
RCPP	Regional Conservation Partnership Program
RDM	Residual Dry Matter
RHNA	Regional Housing Need Allocation
RPF	Registered Professional Forester
RPS	Renewables Portfolio Standard
SAF	Society of American Foresters
SALC	Sustainable Agricultural Lands Conservation Program
SB	Senate Bill
SDI	Stand Density Index
SERGoM	Spatially Explicit Regional Growth Model
SGCN	Species of Greatest Conservation Need
SNAMP	Sierra Nevada Adaptive Management Program
SNC	Sierra Nevada Conservancy
SOD	Sudden Oak Death
SOFAR	South Fork American River
SOI	Sphere of Influence
SO2	Sulfur Dioxide
SPLAT	Strategically Placed Landscape Treatment
SRA	State Responsibility Areas
SRR	Sustainable Rangelands Roundtable
SST	Seedlot Selection Tool
SWAP	California State Wildlife Action Plan
SWRCB	State Water Resources Control Board
SYP	Sustained Yield Plan
THP	Timber Harvesting Plan
TMDL	Total Maximum Daily Load
TMTF	California Tree Mortality Task Force
TPZ	Timberland Production Zones
TRFRF	Timber Regulation and Forest Restoration Fund
UA	Urban Area

UC ANR	University of California Division of Agriculture and Natural Resources
UHI	Urban Heat Islands
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
UTC	Urban Tree Canopy
VOC	Volatile Organic Compound
WA	Williamson Act
WET	Watershed Enforcement Team
WFMP	Working Forest Management Plan
WHR	Wildlife Habitat Relationships
WIP	Watershed Improvement Program
WLFW	Working Lands for Wildlife
WLPZ	Watercourse and Lake Protection Zones
WUI	Wildland Urban Interface
ZOI	Zone of Infestation

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