California Forest Carbon Plan:

Managing our Forest Landscapes in a Changing Climate

January 20, 2017

Draft for Public Review

Table of Contents

0 Executive Summary

Passage of Assembly Bill 32, the California Global Warming Solutions Act of 2006, marked a watershed moment in California's history. By requiring in law a sharp reduction of greenhouse gas emissions, California set the stage for its transition to a sustainable, low-carbon future. Assembly Bill 32 created the first program in the country to take a comprehensive, long-term approach to addressing climate change, and does so in a way that aims to improve the environment and natural resources while maintaining a robust economy.

The 2008 Climate Change Scoping Plan (the initial framework for implementing Assembly Bill 32) recognized the important role forests play in meeting the state's greenhouse reduction goals, stating that actions should be taken to "[p]reserve forest sequestration and encourage the use of forest biomass for sustainable energy generation." The 2014 Scoping Plan Update emphasized our forests' importance given recent information identifying the threats faced:

> This information underscores the importance of managing our forests and other natural and working lands to maximize the net benefits-- increasing sequestration while reducing conversion and carbon stock losses, and maximizing associated co-benefits.

The Forest Carbon Plan will be the detailed implementation plan for the forest carbon goals embodied in the 2030 Target Scoping Plan Update.[1] Similarly, the California Air Resources Board's (CARB) Proposed Short-Lived Climate Pollutant Reduction Strategy points to the Forest Carbon Plan as the mechanism for addressing black carbon emissions from forest sources such as wildfire.[2]

Today, many forests are unhealthy, with unnaturally dense stands that lack resilience, making them more susceptible to drought, disease, insect pests, and uncharacteristically large, severe wildfires. In fact, there is growing evidence that many of California's forests have become net emitters of carbon due primarily to the uncharacteristic fire and mortality we are witnessing. These events result in massive amounts of dead trees that are no longer removing carbon from the atmosphere and that will continue to emit greenhouse gasses for decades as they decay. The vegetation that replaces the trees that have died will not compensate for the carbon loss for decades (if ever; for example where forest converts to shrubs). Managing forests in California to be healthy, resilient net sinks of carbon is a vital part of California's climate change policy. Forested lands in the state are the largest land-based carbon sink, but recent trends and long-term evidence suggest that these lands will become a source of overall net greenhouse gas (GHG) emissions if actions are not taken to protect these lands and enhance their potential to sequester carbon. Decades of fire exclusion, coupled with ongoing drought and the growing impacts of climate change, have dramatically increased the size and intensity of wildfires and bark beetle infestations; exposed millions of urban and rural residents to unhealthy smoke-laden air; and threaten progress toward meeting the state's ambitious 2030 and 2050 targets for GHG reductions.

More than 100 million trees are dead or dying, and recent wildfires have been among the most destructive and expensive in state history. It is estimated that as many as 15 million acres of California forests are unhealthy and some form of restoration activity is needed. This area is comprised of more than 9 million acres identified by federal land management agencies and 6 million acres of State and

[1] California Air Resources Board, 2016a
[2] California Air Resources Board, 2016b

privately managed forests. The number of acres to be actually treated will be less than this total amount, given that strategic treatments can have broader benefits beyond the specific area treated.

California's urban forests also are facing multiple challenges, including drought and invasive exotic insects. Urban forests require maintenance in order to preserve the multiple values they provide and merit expansion to further sequester carbon and to secure other benefits to urban dwellers and the state.

The California Forest Carbon Plan seeks to reverse these trends and firmly establish California's forests as a more resilient and reliable long-term carbon sink, rather than a GHG and black carbon emission source. The Plan provides multiple strategies to promote healthy wildland and urban forests that protect and enhance forest carbon and the broader range of ecosystem services for all forests in California. It emphasizes working collaboratively at the watershed or landscape scale to restore resilience to all forestlands in the state.

This Forest Carbon Plan describes forest conditions across California today; provides a projection of future conditions given the ongoing and expected impacts of climate change; and describes goals and related specific actions that can be taken to improve overall forest health, including resilient carbon storage, and principles and policies to guide and support those actions. These principles and policies, which are grounded in existing laws and regulations, place carbon sequestration and reducing black carbon and GHG emissions as one set of management objectives in the broader context of forest health and other climate change objectives. California will manage for carbon alongside wildlife habitat, watershed protection, recreational access, traditional tribal uses, public health and safety, forest products, and local and regional economic development.

In considering these needed actions, it is important to recognize that ownership of California's forests spans a variety of public agencies and includes various types of private owners. Management objectives, processes to be followed, and capacity to act vary greatly among and within these ownership types. This variety results in forest management for multiple objectives across the state, serving multiple interests and user groups. It also results in management challenges in engaging in large-landscape planning and implementation efforts.

It is essential to recognize the important role federally managed lands play in the achievement of the California climate goals established in AB 32 and subsequent related legislation and plans. The majority of the forestland in California is managed by the federal government, primarily by the USDA Forest Service Pacific Southwest Region, and these lands comprise the largest forest carbon sink under one ownership in the state. Several regulatory, policy, and financial challenges have hindered the ability of the Forest Service and Department of Interior agencies (Bureau of Land Management and National Park Service) to increase the pace and scale of restoration needed, such as the current budget structure to fund wildland fire suppression and the procedural requirements of a number of federal environmental and planning statutes. The State of California has a vested interest in working closely with the federal government to help resolve these obstacles and to achieve forest health and resilience on the lands that federal agencies manage.

Key Findings:

- California's forested landscapes provide a broad range of public and private benefits.
- The health of forests in many regions of the state is deteriorating rapidly.
- Extreme fires and fire suppression costs are increasing significantly, and these fires are a growing threat to public health and safety.

- Reducing carbon losses from forests is essential to meeting the state's GHG reduction targets.
- Current rates of fuel reduction, thinning of overly dense forests, and use of prescribed and managed fire are far below levels needed to restore forest health, prevent extreme fires, and meet the state's GHG reduction targets.
- The state must work closely with Federal and private landowners to manage for forest health and resiliency efficiently and at scale.
- The limited infrastructure capacity for forest management, wood processing, and biomass utilization, and the limited appropriately trained supporting workforce, are major impediments to forest restoration.
- Regionally-based efforts can best identify the areas that pose the greatest threat to forest health and offer the best opportunities to restore resilience.
- Landscape- or watershed-level collaboration—with leadership by federal agencies such as the USDA Forest Service and Bureau of Land Management, state agencies such as conservancies, nongovernmental organizations, and large private landowners—is the most promising approach to greatly increasing the pace and scale of forest restoration treatments.

Proposed Actions

Below is a summary of the goals of the Forest Carbon Plan. The majority of these goals have a target date of 2030 for full implementation; this is intended to align with 2030 interim targets that will be established through the Scoping Plan Update that will be finalized in spring 2017. Other target dates are used where timelines already exist in another established state or federal plan (e.g., all targets associated with the State Wildlife Action Plan have 2025 target dates), or for activities that currently have historically elevated scales of implementation that will need to be sustained and surpassed in order to efficiently and effectively reach the targeted 2030 goals. For example, the 2020 short-term target for fuels reduction rates would be benchmarks in route to the 2030 targeted scale. These short-term benchmarks will serve as an opportunity to evaluate progress to date, consider the effects of actions taken, and utilize new information and data to guide longer-term goals for 2030 and beyond.

A. Significantly increase the pace and scale of forest and watershed improvements on nonfederal forest lands:
    1. In order to address the forest health and resiliency needs identified on nonfederal lands, CAL FIRE estimates that the rate of treatment would need to be increased to approximately 500,000 acres per year. This acreage is currently in excess of what CAL FIRE considers operationally feasible, should be considered a target to work toward, and is achievable pending increased resources. These treatments can include those that generate revenue from harvest materials, such as commercial thinning and regeneration harvests.
    2. By 2020, increase the rate of fuels treatment from the recent average of 17,500 acre/years to 35,000 acres/year.
    3. By 2030, further increase the rate of fuels treatment to 60,000 acres/year.
    4. By 2030, increase the area reforested annually by 25 percent above the current level.
    5. By 2025, expand areas of high priority habitat by 5 percent above current levels, as provided in the State Wildlife Action Plan.
    6. Ensure that timber operations conducted under the Forest Practice Act and Rules contribute to the achievement of healthy and resilient forests that are net sinks of carbon.

7. By 2030, lead efforts to restore 10,000 acres of mountain meadow habitat in key locations.

B. Support Federal goals and actions to improve forest and watershed health and resiliency:
   1. By 2030, increase forest resilience through treatments including fuels reduction, managed and prescribed fire, noxious weed removal, and road improvements to reduce sedimentation, resulting in resource benefits to approximately nine million acres on National Forest System Lands in California.
   2. By 2030, bring resource benefits to approximately 1.2 million acres of forests and woodlands on Bureau of Land Management lands in California through national landscape conservation networks, landscape mitigation strategies, native seed rehabilitation and restoration, and vegetation treatments including fuels reduction, managed and prescribed fire, and weeds management. Forestry and fuel reduction targets will expand from a current average of 9,000 acres/year to 20,000 acres/year.
   3. By 2020, on lands managed by the USDA Forest Service, increase treatments from the current approximately 250,000 acres/year to 500,000 acres/year, and on BLM managed lands increase from approximately 9,000 acres/year to 10-15,000 acres/year.
   4. By 2020, eliminate the current USDA Forest Service Reforestation Need balance and sustain future treatments at levels where annual additions are matched by treatments.
   5. By 2030, the USDA Forest Service will restore 10,000 acres of mountain meadow habitat and target reliable funding for such activities on National Forest System lands in California.

C. Prevent forest land conversions through easements and acquisitions, as well as land use planning:
   1. By 2030, increase the acreage of forestland protected by conservation easements by ten percent above the current level.
   2. Promote the adoption of regional transportation and development plans, such as SB 375 Sustainable Communities Strategies and Climate Action Plans, and recognize the climate change mitigation impacts of land use and forest conditions in those plans.

D. Innovate solutions for wood products and biomass utilization to support ongoing forest management activities.
   1. Expand wood products manufacturing in California, and take actions to support market growth scaled to the longer-term projections of forest productivity.
   2. Increase the total volume of carbon stored through greater use of durable wood products from California forests, particularly in buildings.
   3. Continue public investment to build out the 50 MW of small scale, wood-fired bioenergy facilities mandated through Senate Bill 1122 (Rubio, 2012).
   4. Maintain large-scale bioenergy capacity in the short term at a scale necessary to meet the public safety and tree disposal needs stemming from widespread tree mortality in the central and southern Sierra Nevada.
   5. Continue to support research into the potential to convert woody biomass into transportation fuels both statewide and regionally.
   6. Develop and support the generation of and markets for compost from forest biomass for agricultural, rangeland, municipal, and residential soil amendments.

E. Support key research, data management, and accountability needs.
    1. Centralize and standardize tracking of implementation activities to meet Forest Carbon Plan targets to fully account for all efforts; quantify carbon sequestration and GHG and black carbon emission outcomes; identify areas of underperformance; and effectively work toward the ultimate performance objective of maintaining California's forests as net sinks of carbon. Develop a centralized database or other information management system to track implementation.
    2. Complete forest carbon inventories (stocks and emissions), accounting methodologies at multiple scales, and GHG emissions projections for both a reference case and scenarios that include increased management and conservation activity.
    3. Standardize methods, data, and modeling across state agencies (and Federal agencies, where possible) to facilitate planning for forest health and resilience management activities across ownership boundaries.
    4. Develop and disseminate tools to assist landowners and local and regional land use planners and forest managers in assessing current forest conditions and desired future conditions.
    5. Develop a better understanding of how different fire types and different forest fuels affect black, brown, super-aggregate, and GHG carbon emissions.

F. Protect and enhance the carbon sequestration potential and related co-benefits of urban forests.
    1. Protect the existing tree canopy through policies and programs targeting ongoing maintenance and utilization of industry best management practices.
    2. By 2030, increase total urban tree canopy statewide by one-third above current levels, to 20 percent coverage of urban areas.
    3. Assist local governments and others in locating optimal sites for early green infrastructure solution implementation.
    4. Provide resources and technical assistance to local governments as they assess local policies and regulations in regard to urban forestry and green infrastructure.

Recommendations for Implementation

Implementation will be undertaken by a diversity of public and private entities (including State Conservancies, federal land management agencies, local governments, nongovernmental organizations, and individual private landowners) that will need to collaborate in order to achieve success. Forest health outcomes derived from this work will benefit a broad constituency of stakeholders, with many benefits being realized over a long timescale. There is a clear need to identify and increase the resources available for implementation in a manner that reflects these broad beneficiaries, and to identify and pursue ways to improve the efficiency of any funds spent. The Forest Carbon Plan makes the following recommendations to initiate and guide implementation:

1. Regionalize implementation of the Forest Carbon Plan, including development of regionally driven Forest Carbon Action Plans. This regionalization should be led by state conservancies in geographies where they exist; alternative leadership capacity will need to be identified in areas not covered by state conservancies.

2. Work collaboratively at the large landscape or watershed scale to define critical biophysical and often social units for analysis and work.

3. Identify and cultivate traditional and new sources of public funding, and public-private partnerships, to support the proposed actions A-F described above and to implement them at the regional level.
4. Explore opportunities for regulatory and policy changes and streamlining to advance the activities described in this Plan and implemented at the regional level. These might include:
    a. Increase use of prescribed and managed fire for restoration.
    b. Streamline permitting for certain restoration activities.
    c. Reduce small landowners' financial barriers to land management.
    d. Development of new wood product and biomass facilities.
    e. Modify the restrictions on the export of sawlogs from federal and other public lands.

Organization of the Forest Carbon Plan

The vision, scope, and purpose of this plan are described in the Introduction, Section 1. A summary of historic and current forest conditions, climate impacts on California forests, and fuel treatments to enhance forest health is provided in the Science Snapshot, Section 2. The goals and objectives for wildland (non-urban) forest health are described in Section 3, along with targeted supporting activity levels; the implementation of these goals is discussed in Section 4. The goals, objectives, and implementation strategies for urban forests are described in Section 7, Urban Forestry. Monitoring and reporting of annual outcomes for all goals and objectives is described in Section 5, Measuring Progress. Section 6, Forests of California Today, expands on the historic conditions and current challenges facing California forests, details ownership patterns, and describes forest carbon storage dynamics. The co-benefits provided by protecting and restoring forests through the management actions of the plan are described in Section 8, Co-benefits of Healthy Forests. Section 9, Wood Products and Biomass Utilization, identifies biomass utilization needs and potential market pathways that will allow woody material generated through increased management and restoration activities to be utilized in a manner that complements California climate change objectives. The recent forest-related policy arena is summarized in Section 10, including state legislation and regulations. Planning, monitoring, modeling, and other research needs that will be critical to successful implementation of the plan are described in Section 11.

There are three appendices to the Plan. Appendix 1 provides more detailed discussion of forest carbon inventories. Appendix 2 presents a tabular summary of modeled climate change impacts to the extent of individual California forest tree species. Appendix 3 provides a more in-depth, regional assessment of forest conditions in California, since important factors including disturbance regimes, the magnitude and variety of climate change stressors, and the proportion of public and private landowners are not uniform across the state.

1 Introduction

1.1 Vision Statement

This Forest Carbon Plan presents an assessment of forest conditions across California today, a projection of future conditions given the ongoing and expected impacts of climate change on forested ecosystems, and describes the overarching, shared goal of the Forest Climate Action Team member organizations to secure California's forests as a healthy, resilient net sink of carbon, while conferring a range of ecosystem and societal benefits, and minimizing the GHG and black carbon emissions associated with management activities, conversion, wildfire events, and other disturbances. Guided by best available science, this plan lays out a set of forest management goals that will move forests towards a more ecologically resilient state and identifies implementation pathways to increase the pace and scale of achieving these conditions. This plan also presents a vision for the role that urban trees can play when considered part of the overall carbon balance of California's forests, and the other values they can lend to communities across the state.

The Forest Carbon Plan will be the detailed implementation plan for the forest carbon goals embodied in the 2030 Target Scoping Plan Update.[3] Similarly, the Air Resources Board's (ARB) Proposed Short-Lived Climate Pollutant Reduction Strategy points to the Forest Carbon Plan as the mechanism for addressing black carbon emissions from forest sources such as wildfire.[4]

The Forest Climate Action Team has developed the following vision for forest protection, enhancement, and innovation:

- Sustainable forests that are a net sink of carbon.
- Healthy forests that are resilient to anticipated climate change effects such as increased forest insect and disease threats and higher wildland fire risks.
- Forests that provide for healthy watersheds and water supplies (quality, quantity, and infrastructure).
- Forests that provide management opportunities that generate long-term economic benefits for landowners, workers, and communities.
- Working forests that produce wood products and biomass for energy and are managed to maintain forest health and biodiversity.
- Forests that are protected from fragmentation and conversion and that provide a diverse range of high-quality, interconnected habitat types for terrestrial and aquatic wildlife species.
- Forests that provide an abundance of outdoor recreational and tourism opportunities.
- Forest that support people's well-being through connection to place, cultural identities, and contexts for social and spiritual engagement
- Expanded and more sustainably managed urban forests that are net carbon sinks and that deliver multiple benefits to urban residents.

1.2 Purpose and Scope of the Forest Carbon Plan

Through the Forest Carbon Plan and other collaborative work in local, regional and state-wide initiatives, the Forest Climate Action Team aims to develop and implement plans to improve the health and

[3] California Air Resources Board, 2016a
[4] California Air Resources Board, 2016b

resilience of California's forests, increase their carbon storage potential, and minimize their atmospheric emissions of GHG and black carbon. While the Forest Carbon Plan primarily targets carbon storage and emissions, it also emphasizes improving and safeguarding interrelated ecosystem services (co-benefits), as well as social and economic considerations.

This Forest Carbon Plan:

- Summarizes the best available science about carbon sequestration and climate pollutant emissions in California's forests over a wide range of natural conditions and management situations.
- Establishes forest health and resiliency conditions needed to reach carbon sequestration goals.
- Identifies targets and goals for implementation of forest management practices through 2030.
- Identifies implementation and investment strategies to achieve carbon sequestration goals.
- Provides a framework for managing California's forested landscapes to increase carbon sequestration alongside other values of healthy forests.
- Recommends a regional implementation approach to achieve the Plan's goal.
- Addresses both wildland forests and urban forests.
- Is consistent with state and federal wildland fire management goals and strategies.

2 Science Snapshot

2.1 Historic and Current Forest Conditions

Fire has historically been a natural and critical component of many California mixed conifer forest landscapes. Prior to 1900, wildfires in the many California mixed conifer forests were predominately low-intensity and removed excess fuel, thinned vegetation, and reduced competition for nutrients and water, resulting in healthy forests resilient against drought and native bark beetle outbreaks. It is estimated that over four-and-a-half million acres burned annually in California prior to European settlement, with much of the fire started or managed by indigenous peoples[5], and most of it completed in support of ecological objectives.[6] Outside of the redwood region, the result of frequent fire was a mosaic landscape dominated by very large pine trees that were clumped.[7,8,9] Occasionally a clump of trees would be killed by fire, with spacing between clump canopies limiting the severity of the fire. As a result, high severity fire made up a low percentage of many historic fires, allowing for a mosaic of forest seral stages within small areas that provided complex habitat structure with nesting and foraging habitat for a broad range of species. The large pine trees that dotted the landscape held enormous amounts of carbon, with a single 300-plus-year-old sugar pine containing more carbon than one hundred 30-year-old white firs. As a result, historic forests, despite their openness and heterogeneity, contained over 25% more carbon than current fire-suppressed forests.[10] The carbon in these forests was predominantly stored in stable, large living trees that were resilient to disturbance. As a result, very little carbon was emitted post-disturbance and the large trees rapidly sequestered that carbon, creating a stable forest carbon landscape.

After European settlement, many California forests began to change. Logging removed many of the larger old growth species, which not only removed much of the live forest carbon from the forest but also reduced canopy height, making it easier for fire to enter the canopy. European settlement eventually led to a nearly comprehensive exclusion of fire on the landscape and the absence of any of the proactive large-scale “protoagricultural” landscape management techniques that had been employed by Native Americans.[11,12] As stated by Kimmerer and Lake (2001), “[t]he loss of fire in the American Landscape is inextricably linked with the history of federal Indian policy that removed tribal people and, therefore, indigenous land management.” In other words, the vacuum created by the dispersal and loss of Native Americans from California’s landscape has had a direct impact on the current condition of California’s forests, to the point where Secretary of the Interior Bruce Babbitt, in 1997, called it “a crisis in forest health.” With fire removed, forests that typically experienced fire frequently (in some cases every 10 years) began to miss fire cycles, known as Fire Return Intervals (FRI). As more FRI were missed, dead material began to build up and fire-adverse species began to move in.

[5] Stephens et al., 2007
[6] Anderson, 2006
[7] North, 2012a
[8] Taylor, 2000
[9] Anderson & Moratto, 1996
[10] North, Hurteau, & Innes, 2009
[11] Kimmerer & Lake, 2001
[12] Anderson & Moratto, 1996

Figure 1 shows the current status of California's Fire Return Interval Departure (FRID) across the landscape, with condition 1 within historic parameters, condition 2 is a 33-67 % departure from historic, and condition 3 is more than 67% departed from this historic fire return intervals. A negative value indicates fire is occurring more frequently than historic (e.g., on shrublands) and positive indicates fire is occurring less frequently than historically. As can be seen from the colors on the map, the red of significantly less than historic fire rates dominates for much of the state. In Southern California, the yellow-tone colors indicated that fires are more frequent than historically. For more details, see the figures in the regional discussion (Appendix 3).

Today, many forested areas have missed five or more natural cycles and the biomass buildup, species change, and other factors have led to an increase in fire severity when fire does finally return to those areas, compared to historical levels.[13] Multiple missed FRIs have resulted in overly-dense stands comprised of smaller trees and in some cases a shift in species type and, thus, habitat suitability. This has created a homogenous forest landscape with few available niches, which respond similarly to disturbance, resulting in a post-disturbance homogenous landscape, in stark contrast to the historic conditions. From a carbon perspective, more of the forest carbon in modern, fire-suppressed forests is in vulnerable smaller trees and in the dead pool, not in large pine trees. The limited resource availability in these forests (e.g. water, sunlight) stunts growth and reduces annual carbon sequestration. Disturbance events, such as fire, drought, and insect and diseases, mobilize significant portions of the forest carbon back to the atmosphere and changes much or all the forest carbon into the dead pool, where it will decay and emit its carbon back to the atmosphere over several decades.[14] Depending on climate conditions and the impact of the disturbance on soils and seed banks, regrowth of the live forest carbon pool in the disturbed area could be delayed a decade or more.

Modeling suggests that as a result of the fire deficit, annually treating at least three percent of the landscape results in an immediate 40 percent improvement in resilience to large landscape disturbances, allowing the landscape to peak in resilience over 20 years of annual treatments.[15] This approach would get California forests closer to the landscape management completed by Native Americans in prehistory, preparing California forests for future disturbance.

2.2 Climate Impacts on California Forests

The goal of the Forest Carbon Plan is to stabilize and ensure forest carbon benefits for California's long-term greenhouse gas (GHG) reduction efforts. To meet this objective, management actions need to factor in the impacts of climate change itself on forests and the benefits they provide. Climate change will exacerbate existing stressors on the forest, diminish carbon sequestration rates, and decrease the quantity, quality, and stability of carbon stocks. Future climate change estimates predict increases in temperature, increases in atmospheric CO2 concentrations, and changes in the amount and distribution of precipitation, all of which can act as stressors on forests. Recent forest trends along with climate change modeling efforts are providing a glimpse of the changes we may expect under climate change conditions and if forest management efforts are not significantly increased.

[13] Mallek, Safford, & Viers, 2013
[14] Campbell, Fontaine, & Donato, 2016
[15] Finney et al., 2007

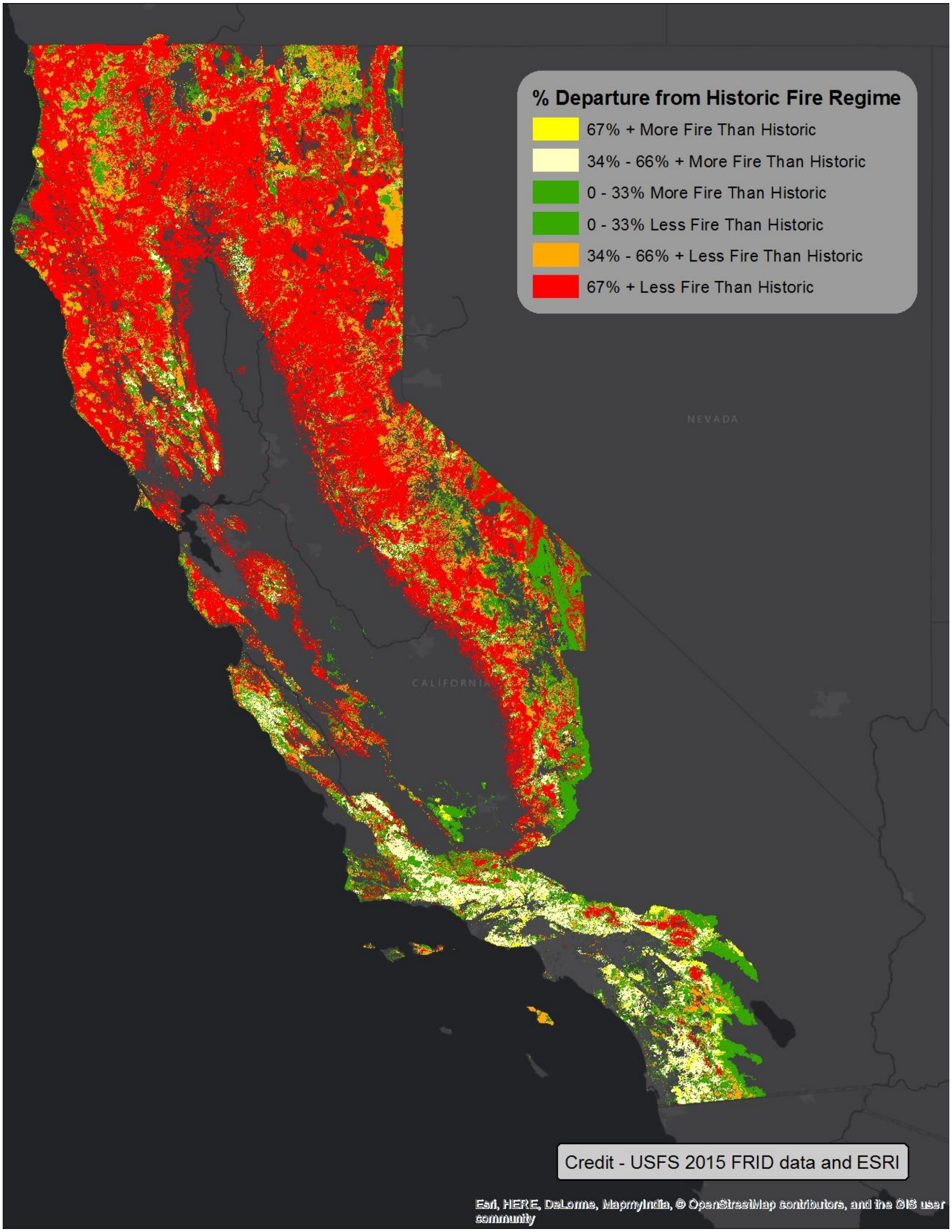

Figure 1. Fire Return Interval Departure for California.
Source: USDA Forest Service 1025 FRID data.

2.2.1 Recent Forest Trends

Figure 2 shows how the average annual forest acreage burned (the first three bars from on left in each set) on a decadal basis has increased in California from the 1960s to 2015. Over the last few decades, wildfires in California's conifer forests have grown bigger and have exhibited larger and larger uniform patches of severe fire. Between 2003 and 2012, the US Southwest experienced a 1,266% increase in burned area compared to the period of 1973 – 1982.[16] Fire severity has been increasing as well, which is out of the historical norm. Surveyors in the 1800s wrote that large tree death from fire was an uncommon occurrence, and by the 1980s, approximately 20% of fire footprints were severely burned.[17] By the early 2000s, the percent of high severity in fires over 500 acres in size increased to almost 30%, and the Rim Fire of 2013 and King Fire of 2014 were almost 40% and 50% high severity, respectively. High severity burn patches were historically small, commonly under 10 acres in size, which allowed living trees on the edges to quickly reseed the burned area, and it created diverse habitat in a small area. In contrast to this healthy functionality, the King Fire had a single high-severity burn patch of over 30,000 acres in size and the Rim Fire had a high-severity burn patch over 50,000 acres.

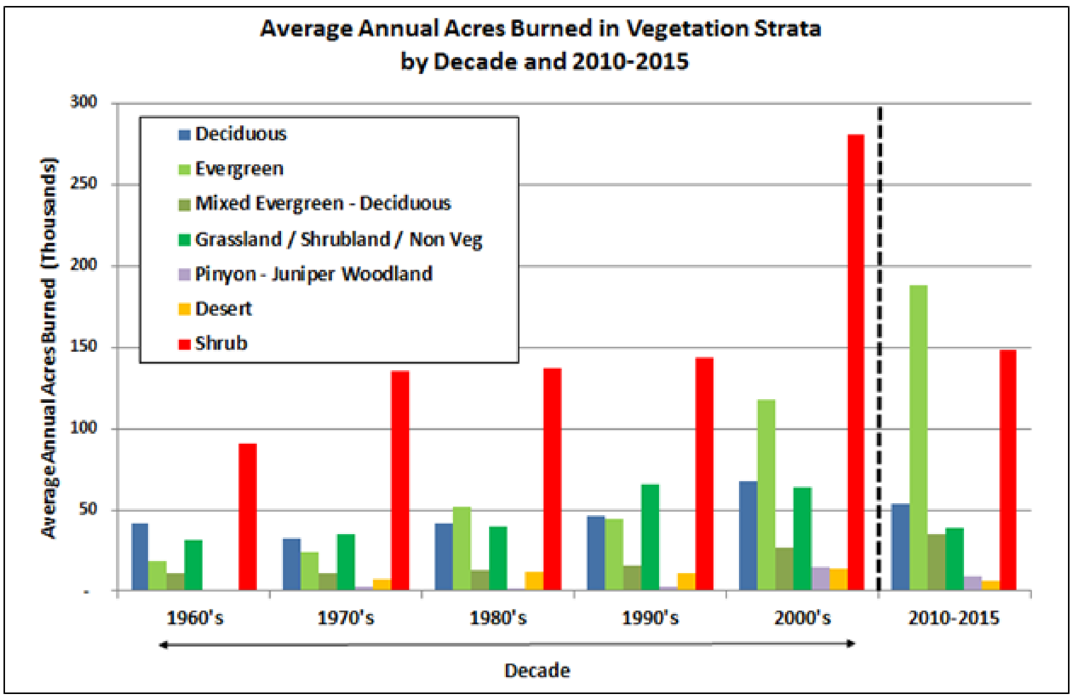

Figure 2. Decadal Mean Annual Burn Rate by Vegetation Type, 1960s – 2010s (abbreviated).
From Section 2.2.1, Climate Impacts – Recent Forest Trends.
Source: FRAP unpublished data; FRAP Assessment, in progress[18]

Similarly, tree mortality from native bark beetles and cycles of drought are part of the natural forest cycle in many forests in California. In the 1970s, over 12 million trees died in a three year period from bark beetles, and an estimated 3.5 million died in the early 2000s in southern California. The recent

[16] Westerling, 2016
[17] McKelvey et al., 1996
[18] California Department of Forestry and Fire Protection, 2016d

drought and warmer temperatures have intensified the mortality. From 2013 to 2014, there was a 300% increase in tree mortality in the Sierra Nevada due to insects and disease (885,000 dead trees to 3.3 million). This trend has continued through 2015 and 2016, as surveys have found that a total of more than 102 million trees have died during the current drought (2010-2016), with the vast majority in the Sierra Nevada region. While the drought is obviously a clear driver in the insect induced mortality, it is important to recognize the already existing lack of resiliency that characterizes many forests as a significant contributing factor. North et al. (2009) found higher than expected large tree mortality in untreated stands, "possibly due to collateral bark beetle attacks when high densities of small-diameter stems surround large trees of the same species." Field reports suggest that treated stands are experiencing significantly lower mortality rates.

2.2.2 Species Range Shift

Climate change impact modeling done in the 1990s began to predict a shift in distributions of vegetation types as climate change progressed. When comparing vegetation surveys for the Sierra Nevada region from the early 1900s to those of today, researchers are already seeing this shift occurring: vegetation is moving upslope (meaning some vegetative types are being found at higher elevations than in the past). As this shift continues, it will have significant implications for how our forests will look and function into the future. For example, with increased warming forests may be able to expand their range further upslope to areas where they could not survive previously, increasing the potential carbon pool but also potentially significantly negatively affecting water supply downstream by increasing evapotranspiration.[19]

High-elevation tree species adapted narrowly to historical temperature ranges at those elevations will be particularly vulnerable to range contraction and extirpation. Forest management and restoration practices should be informed by the expected future changes, and should be robust over a wide range of plausible future climate change outcomes.

In support of CAL FIRE's Forest and Range Assessment, researchers at University of California, Davis conducted an analysis to predict shifts in ranges for tree and shrub species that is expect under future climate scenarios (Appendix 2). In addition, a climate exposure analysis was run for six major vegetation types to estimate climatic risk under future climate scenarios. Two climate models (CNRM, which projects a warm and wet future climate; and MIROC, which projects a hot and dry future climate) and two levels of climate warming emissions were used.

The following results are an excerpt from an internal report done for CAL FIRE.[20] Figure 3 shows the spatial pattern and locations that are expected to experience the greatest climatic stress, defined as locations where vegetation currently resides, but where future climate conditions will likely be unsuitable for that vegetation type. Climatic stress appears most acute under higher emission scenarios and geographically at low to mid elevations across the Sierra. The State Wildlife Action Plan provides additional analysis of potential shifts in vegetation.

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[20] Thorne et al., 2016

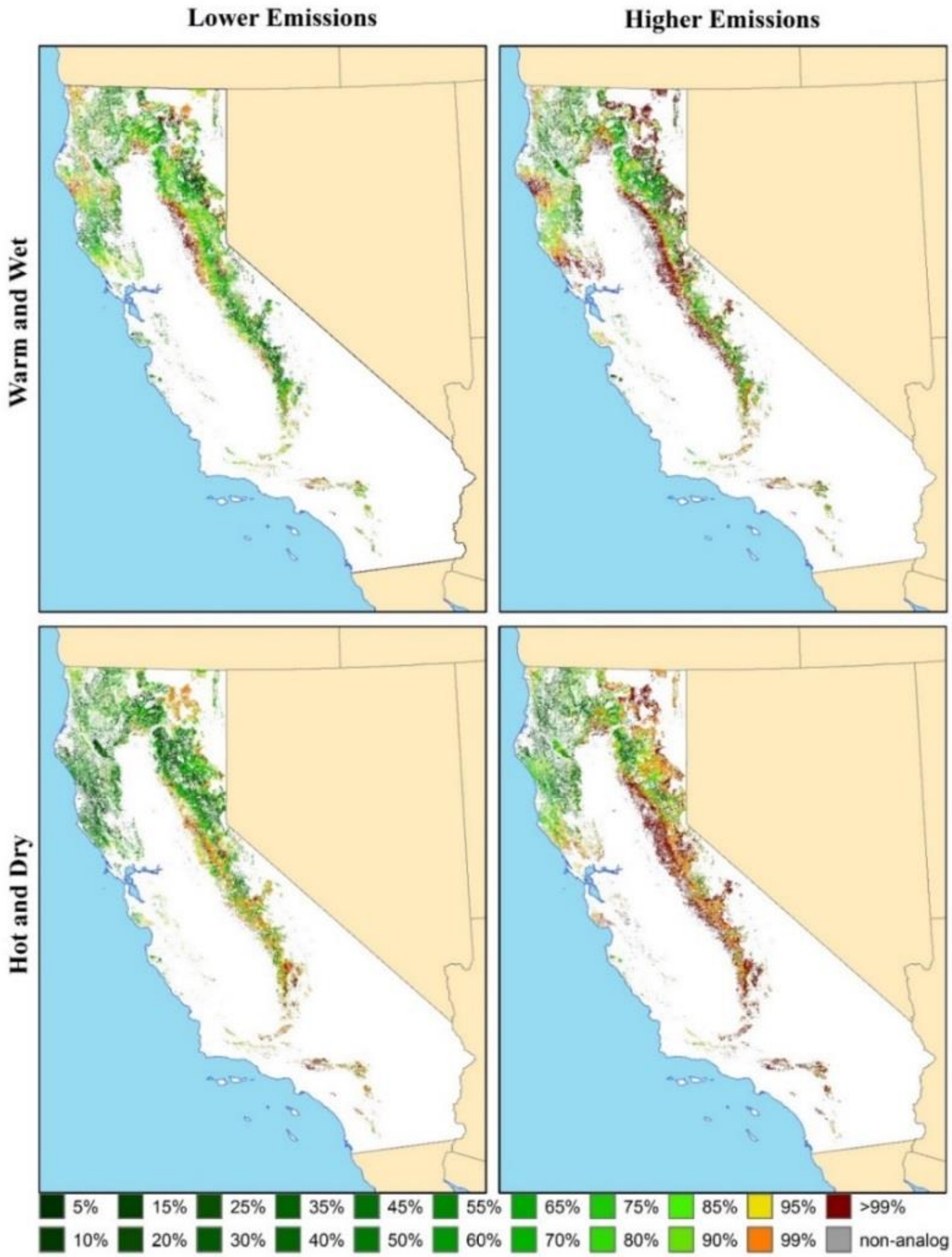

Figure 3. Combined Exposure Map of 6 Wildlife Habitat Relationship (WHR) Types to the End of the Century (2070-2099).

Note: WHR types represented include: MHC = Montane Hardwood Conifer; MHW = Montane Hardwood; RFR = Red Fir; EPN = Eastside Pine; SMC = Sierra Mixed Conifer; KMC = Klamath Mixed Conifer.

Source: Climate Related Species Distribution Model Database: A report for California Department of Forestry and Fire Protection[21]

[21] Thorne et al., 2016

2.2.3 Climate Stressors

Forest Health and Function

Current climate models are not in concert on how precipitation amounts may change into the future in California, but there is consensus that temperatures will be warmer, more precipitation will fall as rain rather than snow, and that extended droughts are likely to be more common. Dore et al. observed the interaction of productivity and environmental conditions during their research on the effects of treatment and fire on an existing ponderosa pine stand in Arizona. [22] The researchers found that treated forests were better able to sustain their carbon sequestration rates under significantly hotter and drier conditions than the untreated stands. Given our potential future under climate change, the increasing range of climate conditions under which the forests could remain productive through treatment could be critical to continued carbon storage. In fact, a drought hit the study area in the third year following the implementation of their treatments and the authors observed that during the drought the treated site had higher carbon uptake than the untreated site, despite the fact that the treated site had fewer trees and leaf area. Anderegg et. al.[23] found that not only does drought impact tree growth (and therefore carbon sequestration rates) during the drought itself, but that growth rates post-drought can remain stunted for one to four additional years. If the same pattern holds true in treated versus untreated stands as found in Dore et al.,[24] then the treatment benefits could extend beyond drought periods.

Forest Health Impacts Associated with Insects and Disease

Historically, the most significant widespread effect on vegetation has been conifer mortality associated with bark beetles and severe moisture stress. Conifer mortality tends to increase when annual precipitation is less than about 80% of normal. Trees stressed by inadequate moisture levels have their normal defense systems weakened to the point that they are highly susceptible to attack by bark, engraver, and wood-boring beetles. Areas with high tree density or trees not adapted to a site are very susceptible to high levels of mortality. When, where, and the extent to which mortality occurs is influenced by forest stand conditions and weather patterns. A dramatic rise in the number of dead trees follows one to several years of inadequate moisture. Dense stands are particularly susceptible to bark beetle attacks due to stress caused by constant competition for limited resources. Stressed trees are suitable host material for bark beetles, and their successful colonization results in more beetles and high levels of tree mortality. The more severe and prolonged the drought, the greater the number of dead trees.[25]

Prior to the insect and drought-related tree mortality crisis that has recently impacted California, the USDA Forest Service Forest Health Protection forecasted insect and disease-related tree mortality across the United States from 2013 to 2027.[26] According to the USDA Forest Service risk assessment, California is at risk of losing at least 25 percent of its standing live forests due to insects and disease over 5.7 million acres, or 12 percent of the total forested area in the state (Table 1).[27]

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[22] Dore et al., 2012
[23] Anderegg et al., 2015
[24] Dore et al., 2012
[25] USDA Forest Service Region 5 Forest Health Program Staff, 2016
[26] Krist Jr. et al., 2014
[27] Krist Jr. et al., 2014; Table 4 and Table 8

Table 1. Statewide Summary of Expected Insect and Disease Risk Areas by 2025.

State	Risk area (acres)	Treed area (acres)	State area (acres)	% of state with trees	% of treed acres at risk
California	5,697,000	47,237,000	101,218,000	47	12

Source: Table 4, Krist Jr. et al. 2014

Based on this analysis, there are five National Forests in California facing significant losses from insects and disease on a large percentage of the forested base, as summarized in Table 2. The estimates in their report are based on current trends and did not include expected changes in weather patterns based on climate change projections.

Table 2. Highlighted National Forests with Very High Levels of Expected Tree Loss from Insects and Disease.

National Forest	Treed area (1,000 acres)	% treed	Total Basal area loss (1,000 sq. ft)	Basal Area loss rate, %	Basal area loss rate (sq ft./acre)	Area at risk (1,000 acres)	% of treed area at risk
Modoc	1,743	88	32,005	32	18	675	39
Lassen	1,333	97	44,180	28	33	651	49
Sierra	1,317	93	47,380	27	36	480	36
Tahoe	1,199	99	31,494	18	26	353	29
Plumas	1,379	99	34,569	18	25	320	23

Source: Table 8, Krist Jr. et al. 2014

Although the results of the risk analyses in terms of predicted levels of mortality was highest for these five National Forests (Table 2), many other forests throughout the State are also currently susceptible to high levels of tree mortality. Since drought is the primary trigger for dramatic increases in tree mortality in California, had the northern Sierra Nevada range experienced the same drought conditions as those in the southern Sierra Nevada over the past few years, similar high levels of mortality would have occurred. In addition, several forested areas in southern California, are also extremely susceptible to high levels of mortality as seen during the catastrophic tree die-off during 2003-2004. Over $500 million dollars were spent to abate the large number of hazardous dead trees, reduce fuel loads and restore forests following that event.

Vegetation management (thinning) is the most effective tool we have for reducing bark beetle-caused tree mortality. Thinning improves tree vigor, reduces a tree's susceptibility to bark beetles, and lowers the potential for severe fire. With drought projected at greater rates combined with warmer winters in a climate-altered future, the risk posed by insects, particularly native bark beetles, will likely increase if California's forests remain unhealthy and overcrowded, without treatment. Forest restoration has been demonstrated to attenuate outbreaks of bark beetles under current climate conditions and it provides the best opportunity to minimize outbreaks under a more strenuous climate.

An urgent, collaborative, and financially supported effort is needed among forest land management agencies, private land owners and the public to implement large-scale thinning treatments. Extensive and timely thinning of California's forests, and re-introducing managed fires, will make them healthier and more resilient for many generations to come, while significantly reducing the threats to life and property during high fire danger years.[28]

Wildfire

As described earlier, despite the extensive fire suppression efforts of the last decade or two, undesired fire burn area has increased significantly since the 1980s, as has fire severity. A recent study has attributed 55% of the increase in dry fuels to human-caused climate change, resulting in an increased burn area of 4.2 million acres between 1984 and 2015.[29] While California is experiencing the nascent effects of what climate change will bring later this century, the impacts are already significant and expected to get worse. In addition to the increasing dead pool fuel stocks and ladder fuels unhealthy forests often experience, wildfire activity is also tied to earlier spring snowmelt and warmer temperatures.[30] Using low, medium, and high emissions profiles for climate change predictions, burned area in California by 2085 is estimated to increase between 36% and 74%.[31] Regardless of emissions profile, most of the forested areas in Northern California are predicted to experience a growth in burned area by 2085 of over 100% above 1975 reference levels.[32]

Like wildfire activity overall, fire severity has been increasing over the last few decades as demonstrated in the Moonlight, Chips, King, and Rim fires, for example. Recent observations suggest that a portion of the high severity burn areas within these fires may not regrow as forests and instead transition to shrub or grasslands. Fire frequency has been found to increase in these areas as fuel conditions are created that allow for repeated high-severity fire in short succession, hindering the regrowth of forest and maintaining shrub dominance.[33] New research suggests that as a result of the shift in the vegetation composition and fuel loads across the west from forest to non-forest, fire severity may decrease in much of the western US by 2050.[34] At the same time, this shift in vegetation would result in a significant decrease in carbon stocks in vegetated areas in the western United States.[35]

As climate change advances and concentrations of carbon dioxide increase, the availability of CO_2 for plant growth may interact in unknown ways with factors that may influence wildfire activity, such as longer growing seasons, expanded territory (climate supports forests at higher elevations), and drought. While increased CO_2 availability may overwhelm negative growth pressures (e.g., water stress) from climate change and spur growth, it may spur growth early in the year which then dries out late in the fire season, leading to more burned area. Alternately, if drought does suppress growth and therefore the amount of vegetation available to burn, that would result in decreased carbon sequestration in untreated areas compared to treated areas.[36]

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[28] USDA Forest Service Region 5 Forest Health Program Staff
[29] Abatzoglou & Williams, 2016
[30] Westerling, 2016
[31] Westerling et al., 2011
[32] Westerling et al., 2011
[33] Coppoletta, Merriam, & Collins, 2016
[34] Parks et al., 2016
[35] Parks et al., 2016
[36] Dore et al., 2012

2.2.4 Emissions

With the estimated increase in wildfire burn area across California under climate change and no change in present management, wildfire emissions are estimated to increase as well. Using 1970 as a reference period, by 2085 emissions from wildfires are expected to increase between 24% and 56% on average, depending on the global emissions rate.[37] The outcome of continuing down the path of status quo, both with regards to global emissions and to forest management, will be a significant increase in wildfire smoke in California and the subsequent human health impacts that result from more smoke in the air at the worst times (i.e., late summer when air quality problems are already significant)[38] and an increase in GHGs commensurate with that smoke. As fire occurrence, size, and intensity increase under climate change if the status quo is maintained, smoke from fires even in remote areas will impact populated regions with greater frequency and duration, imperiling the health of a greater percentage of the population.[39]

2.2.5 Conclusions

The authors of a recent Rocky Mountain study conclude by saying "fire exclusion is not a sustainable option for forests of the Interior West. The inevitable result is that more area is burned in fewer, more unmanageable events with greater consequences, including higher carbon emissions, greater losses to biodiversity, and larger threats to communities and homes."[40] Many of California's conifer forests evolved under the pressure of frequent disturbance and are therefore somewhat able to withstand degrees of climate change. The current unhealthy state of forests significantly reduces their resilience, however, making them more vulnerable to climate change pressures.

Climate change projections suggest that our forests will be under increasing threat from large severe wildfire and tree mortality. The implications of this threat for the State's effort to reduce GHG emissions could be dramatic. Research has overwhelmingly shown that restoring the health of forests in California improves forest resilience and stability and at the same time reduces negative impacts to the ecosystem services upon which California relies. Policy and investment decisions should take into the account the opportunity that exists to reduce those potential impacts and secure long-term stable carbon storage in California's forests.

2.3 Fuel Reduction and Related Treatments

This Plan points to fuels reduction treatments and other similar stand-density reduction treatments to restore forest health and resiliency. Fuel treatments in densely stocked and unhealthy stands can vary in method, forest structure outcome, and therefore forest carbon impacts in both the short and long term. The methods and prescriptions are site-specific and are often determined by, among other things, existing conditions, desired conditions, cost, resource needs, impediments, and size of area to be treated. The USDA Forest Service Pacific Southwest Research Station produced two General Technical Reports[41,42] to provide a general guide to restoration treatments in certain forests in California. These reports highlight the need to restore with heterogeneity and with a focus on clusters of large fire-

[37] Hurteau, Westerling, Wiedinmyer, & Bryant, 2014
[38] Schweizer & Cisneros, 2016
[39] Schweizer & Cisneros, 2016
[40] Reinhardt & Holsinger, 2010
[41] North et al., 2009
[42] North, 2012

resilient trees. To reach these goals, there are a number of treatment methods that could be employed, including:

- Prescribed and managed fire
- Understory thin
- Overstory thin
- Thin followed by fire.

To learn more about some of the methods used in these individual treatment types, please see the Methods section of North et al.[43] Each treatment type confers an immediate carbon cost from a forest carbon-perspective, but depending on the fate of the material removed, carbon release to the atmosphere can be minimized, substituted, or significantly delayed. North et al. detail the carbon emissions associated with implementing some treatments, along with the carbon implications of hauling forest material offsite and milling. As described in Section 9, the carbon costs associated with these activities can be reduced or offset by expanding the biomass utilization infrastructure network. If a biomass utilization outlet is unavailable, the excess biomass from thinning treatment is typically either masticated and put back on the forest floor or piled and burned. Mastication and spreading the material back on the forest floor has its pros and cons, such as helping recycle nutrients and potentially increasing fire intensity for the first few years until the material decays. Masticated material represents a short-term carbon source. Pile and burning represents an immediate carbon emission back to the atmosphere with no co-benefits and significant implications for emission of GHG and criteria air pollutants. Prescribed and managed fire also represent immediate emissions back to the atmosphere, with some of the carbon sequestered back into the soil as charcoal[44]. More research is needed to better understand the emissions differences, especially in particulate matter, between wildfire, prescribed and managed fire, and pile burning.

A primary goal of the Forest Carbon Plan is to transfer carbon stocks from many small, fire-vulnerable trees into resilient large trees. Depending on the treatment type and how much carbon was removed during the treatment or transferred to the dead pool following treatment (i.e., unintended mortality), the amount of carbon removed from the forest by treatment, but not necessarily released back to the atmosphere, can be sequestered back into the remaining trees in the stand in as little as 10 years. Without factoring in biomass utilization benefits from excess biomass removed during treatment, a recent study in the Sierra Nevada found that prescribed fire and mechanical understory-thin treatments resulted in stands that sequestered within 10 years the equivalent of the carbon removed from the forest during treatment[45]. With the exception of the overstory thin and burn, which saw unintended mortality affect the resulting stand structure, the treatments in the study are expected to sequester their lost carbon within 15 to 20 years if stand growth continues on the same trend. All treated areas within the study experienced positive net ecosystem productivity over the 10 years of the study (2002 – 2011), while the control plots did not. The control plots had net negative ecosystem productivity over that same period, despite not experiencing a significant disturbance event. The results indicate that these treatments have been successful in shifting the carbon in the stand from smaller trees into the larger, more healthy trees, and those larger trees had more access to needed resources to continue to grow while the unhealthy control stand was unable to continue growing and sequestering carbon.

[43] North, Hurteau, & Innes, 2009
[44] Wiechmann et al., 2015a
[45] Wiechmann et al., 2015b

The first treatment in a stand that is very departed from its natural disturbance regime is necessarily a more carbon-impactful process in order to begin to shift the carbon in the stand to the larger trees. Once treated, maintaining the health of the stand requires subsequent disturbance, either natural or human-caused, the timing of which depends on the historic FRI and the results of the previous treatment. Some stands are so far removed from their historic patterns that reestablishing disturbance may result in unforeseen challenges. For example, one forest stand had been without fire for almost 100 years, and the seeds from a shrub which require fire to open built up over time and were released all at once when fire was reintroduced. In general, retreatment is required within 20 years of an initial treatment to maintain stand health and fire risk benefits. Retreatment involves the removal of significantly less carbon than the first treatment, and is more likely to be performed via prescribed or managed fire, where applicable. This reduces both economic and carbon costs, while at the same time allowing more acres to be treated more quickly.

There are limitations on the landscape that prevent some treatment methods from being applied. Looking at the constraints of mechanical treatments on National Forest System Lands in the Sierra Nevada region, Malcolm North and colleagues estimated that mechanical treatments could be limited to as little as 20% of the forested area in some locations[46]. Figure 4 shows these constrained areas and that non-mechanically treatable areas are more prevalent in some areas. Depending on the reasons for the constraints (e.g., slope, distance to road, sensitive species habitat), adjacent areas could be mechanically treated to reduce the risk of uncontrolled fire from entering these areas. Likewise, prescribed fire could potentially be used in these areas. Despite heavy fuel loads, overgrown forested areas far removed from their normal fire rotation can be safely burned in a prescribed fire under the right conditions, but may require multiple entries in short succession to achieve forest health goals. Similar to the constraints on mechanical treatments, there are many constraints to using prescribed and managed fire, many of which are outlined in Appendix 3. Prescribed and managed fires are less likely to be used in the wildland urban interface, and therefore mechanical treatments and the excess biomass they produce will consistently need a disposal outlet, preferably utilization-based, from these areas.

[46] North et al., 2015

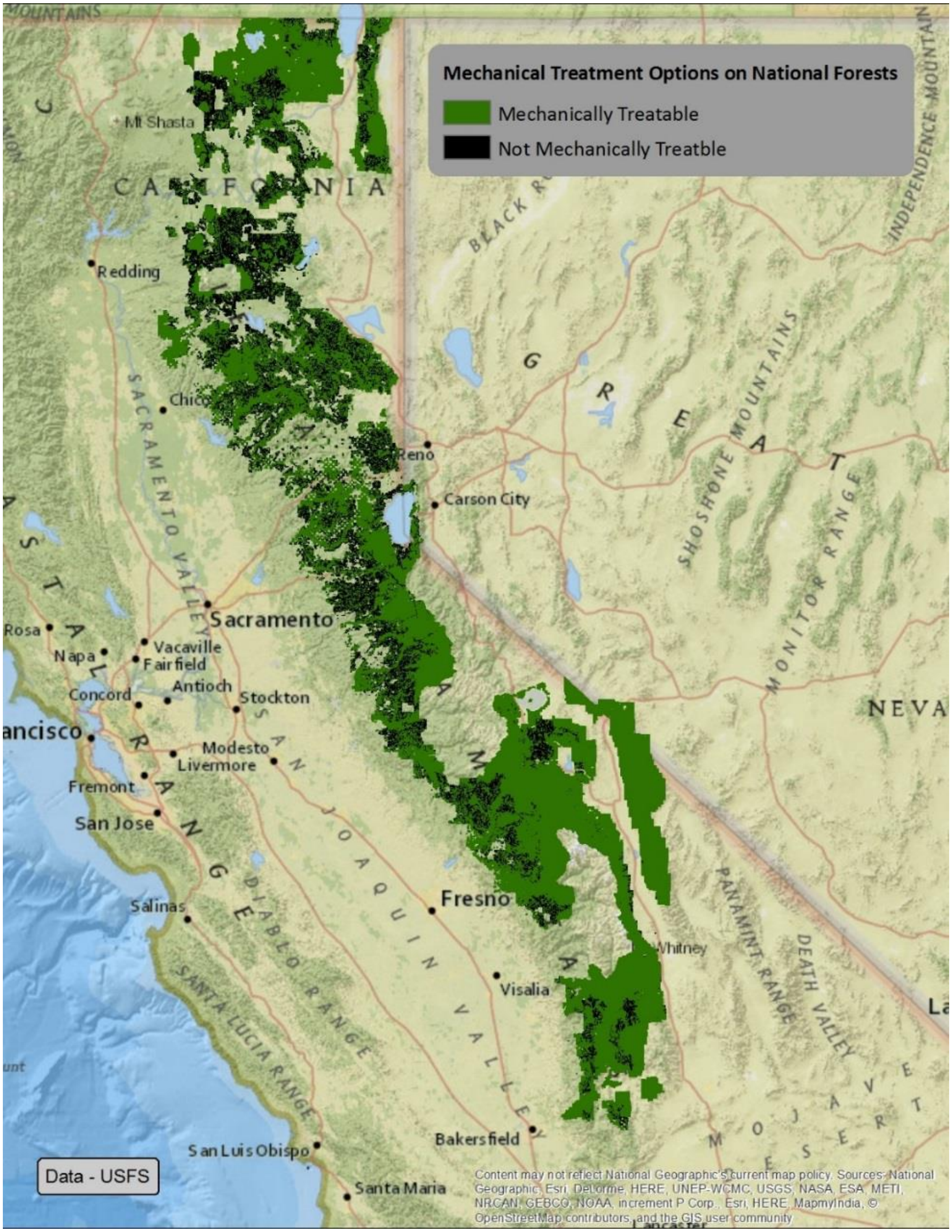

Figure 4. Scenario "A" of Recent Research into the Limitations of Using Mechanical Treatments, Showing where Mechanical Treatment Options are Significantly Constrained.
Source: USDA Forest Service

2.4 Black Carbon as a Short-Lived Climate Pollutant

Climate science unequivocally underscores the need to immediately reduce emissions of short-lived climate pollutants (SLCPs), which include black carbon, methane, and fluorinated gases. They are powerful climate forcers: SLCPs are estimated to be responsible for about 40 percent of current net climate forcing. Action to reduce these pollutants today will provide immediate benefits as the effects of our policies to reduce long-lived GHGs further unfold.[47]

Black carbon is a SLCP, contributing to climate change, air pollution, and negative human health impacts.[48] It is a component of fine particulate matter, which has been identified as a leading environmental risk factor for premature death.[49] It is produced from the incomplete combustion of fossil fuels and biomass burning, particularly from older diesel engines and forest fires. Black carbon warms the atmosphere by absorbing solar radiation, influences cloud formation, and darkens the surface of snow and ice, which accelerates heat absorption and melting.

Scientists have known for some time that sources that emit black carbon also emit other short-lived particles that may either cool or warm the atmosphere. Lighter colored particles, for example, tend to reflect rather than absorb solar radiation and so have a cooling rather than warming impact. Until recently, it had been thought that the impact of lighter colored and reflecting organic carbon from combustion sources largely offset the warming impact of black carbon from this source. However, new studies have suggested that certain fractions of organic carbon known as “brown carbon” could be a stronger absorber of solar radiation than previously understood.[50,51] The warming effect of brown carbon may offset the cooling impact of other organic carbon particles; hence, quantification of energy absorption is necessary so that climate models can evaluate the net climate effect of organic carbon.[52]

The largest source of black carbon emissions in California is wildfire: An average wildfire season contributes two-thirds of current black carbon emissions in the state.[53] There is very little knowledge surrounding production rates, timing, and the implications (on production and timing) of burn conditions. While regular, low-intensity burning (including wildfire, prescribed fire, and managed fire) can reduce fuel loads that cause large, severe fires, promoting ecosystem health and, therefore, system resilience, it is not clear as to whether the avoided large fires, in turn, reduce human exposure to black carbon.

Because reducing black carbon from wildfire could contribute to meeting California’s climate goals, it is important to address this gap moving forward.

2.5 The Landscape or Watershed Scale

The Forest Carbon Plan proposes working regionally at the landscape level. The watershed level has proven to be an appropriate organizing unit for analysis and for the coordination and integrated management of the numerous physical, chemical, and biological processes that make up a watershed

[47] California Air Resources Board, 2016b
[48] Haikerwal et al., 2015
[49] California Air Resources Board, 2016b
[50] Jacobson, 2014
[51] Kodros et al., 2015
[52] California Air Resources Board, 2016b
[53] California Air Resources Board, 2016b

ecosystem.[54] Similarly, a watershed can serve as an appropriate reference unit for the policies, actions, and processes that affect the biophysical system, and it also provides a basis for greater integration and collaboration.

Taking a socioecological system approach to forest management has been stressed as important to the successful management of forests of the Sierra Nevada and Southern Cascade, for example:

> A socioecological system is a dynamic association of biophysical and social factors that interact and continuously adapt to regulate flows of critical resources, such as biodiversity, water, nutrients, energy, materials, infrastructure, and knowledge.[55]

Similar approaches have been described for our redwood forests as well.[56]

The Sierra Nevada Adaptive Management Project offers another example of a collaborative adaptive management effort that was focused in particular on incorporating scientists and scientific experimentation into a landscape-level adaptive management process.[57]

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[54] California Department of Water Resources, 2013.
[55] Long et al., 2014.
[56] Hartley, 2011.
[57] http://snamp.cnr.berkeley.edu/index.html

3 Goals for Wildland Forests

The goals and objectives for wildland (non-urban) forest health are described in this section, along with targeted supporting activity levels. The goals and objectives for urban forests are described in Section 7, Urban Forestry. Monitoring and reporting of annual outcomes for all goals and objectives is described in Section 5, Measuring Progress. These goals and objectives are being established through a climate lens, but they will be pursued holistically to support the broader Forest Health Vision and existing natural resource policies, which include protection, maintenance, and restoration of watersheds of statewide and local importance; plant and wildlife habitat expansion and improvement; and improving the health, well-being and economic resilience of forested communities and other communities that depend on them. The management targets in this section are supported by a coarse-scale data analysis completed to provide an approximation of the extent of forest resources currently under threat and in need of forest treatments to improve long-term carbon storage and forest health goals. The management targets will be refined over time to reflect the findings from ongoing research.

California's overarching climate goals for forests are to (a) secure them as resilient net sinks of carbon; (b) minimize the GHG and black carbon emissions associated with management activities and wildfire events; and (c) employ management actions that deliver a full suite of ecosystem benefits to confer forest health. These goals will continue to complement broader, ambitious climate goals and support existing natural resources policies. Three primary objectives support these goals:

1. *Protect*: Increase protection of California's forested lands and reduce conversion to non-forest uses, resulting in a more stable forested land base.
2. *Enhance*: Expand and improve forest management to ameliorate forest health and resilience, resulting in enhanced long-term carbon sequestration and storage potential.
3. *Innovate*: Pursue innovations in wood products and biomass utilization and in markets that result in productive use of harvested woody material in a manner that reduces or offsets GHG emissions; promotes land stewardship; and strengthens rural economies and communities.

This Draft Forest Carbon Plan identifies conservation and management actions and identifies biomass utilization needs and potential market pathways that will serve to advance these objectives and the overall goal. A number of quantitative targets are included in this Draft Plan. These targets include specific actions needed to protect, enhance, and restore forests and watersheds and minimize carbon losses due to disturbances. The management targets support the substantial restoration effort required to meet the goals for carbon sequestration and overall forest and watershed health. These targets are beyond "business-as-usual" levels of action, thus meeting them will require a significant increase in investments, policy and institutional support, and collaborative partnerships. Achieving these targets also will require measuring progress according to longer time scales, as the management activities described will likely reduce carbon stocks in the near term. Monitoring achievement of management targets will allow the State to determine if goals and strategies are adequate to meet the longer-term goal of maintaining healthy and resilient forests that are a net carbon sink. Adaptive management will be necessary throughout the duration of the plan's implementation and beyond.

3.1 Increase Protection of Forested Lands and Reduce Conversion to Non-Forest Uses.

Protecting the forested landscape is an important objective for maintaining these lands as a carbon sink. California's forestland base has been relatively stable over the past three decades at approximately 32 million acres of forestland. However, due to regional development pressures, some forests are being fragmented or fully converted to other, commercial land uses. Some forest species (e.g., oaks; see

Appendix 2) may be at greater risk than others. Development can deforest and fragment forest lands, degrade forest health, disrupt wildlife habitat, and increase risk of wildfire, even if the development footprint itself is small relative to total forest acreage.

A variety of forestland protection mechanisms can be used to reduce the rate of conversion and degradation, including conservation easements that limit conversion, mitigation practices, county-level zoning ordinances, and incentives for private landowners to maintain forestland as resilient forest. The California Forest Legacy Program, the Wildlife Conservation Board, and other forest conservation granting programs directly protect forest lands through state funding for working forest and other conservation easements.[58,59,60] Collaboration between state agencies, land trusts and other related non-governmental organizations allows for the use of non-state funds to conserve additional lands. Other protection options include land use and tax incentives that enable the financial viability of forest ownership, and sharing best practices with private funders and federal agencies to ensure coordinated conservation strategies statewide. The following targets will advance this objective:

- By 2030, increase the acreage of forestland protected by conservation easements by ten percent above the current level, with a focus on areas under development pressure. These easements—which can protect both forests that are managed for timber harvest (sometimes called “working forests”) and those that are not, --will be paired with stewardship plans.
- Promote the adoption of regional transportation and development plans, such as SB 375 Sustainable Communities Strategies, where applicable, and Climate Action Plans in jurisdictions with substantial forest resources that prioritize infill and compact development and also consider the climate change impacts of land use and management.
- Provide support and technical assistance for counties, cities and regions to integrate forest resource conservation priorities into plans, drawing from Regional Conservation Investment Strategies, Natural Community Conservation Plans, Habitat Conservation Plans, the State Wildlife Action Plan, and critical agricultural lands where those plans already exist.

Beyond conservation of existing forests, the current spatial extent of certain forest habitat types may be expanded. Through development of the 2015 State Wildlife Action Plan, the state has identified terrestrial vegetative communities that are a high priority for conservation based on their benefits to fish and wildlife; for many of these priority vegetation types, increasing acreage is identified as a key conservation goal. Several of the vegetation communities (or habitat types) prioritized in the plan are forested (e.g., California Forests and Woodlands, Pacific Northwest Subalpine Forest, North Coastal and Montane Riparian Forest and Woodland). The following target will advance this objective:

- By 2025, expand acres of high priority forest habitat by five percent from 2015 acres.[61] This target may be adjusted as the State Wildlife Action Plan is periodically updated.

[58] California Department of Forestry and Fire Protection, 2016a
[59] USDA Forest Service, 2016c
[60] Wildlife Conservation Board, 2016
[61] California Department of Fish and Wildlife, 2015

3.2 Expand and Improve Forest Management to Ameliorate Forest Health and Resilience

California cannot meet the climate change goals of either this Draft Forest Carbon Plan or the broader Natural and Working Lands strategy without increasing the levels and resilience of forest carbon sequestration and storage in its wildland forests. Forests are shaped by disturbance and background levels of tree mortality. However, elevated tree mortality from overly dense stand conditions, fire exclusion, management practices, and impacts related to drought and a changing climate can have a substantial effect on the forest carbon balance. This is what we are seeing in California's forests today, particularly in non-urban forests. Wildfire is the single largest source of carbon storage loss and GHG emissions from forested lands: an estimated 120 million metric tons of carbon was lost through wildland fire over the period 2001-2010, out of a total estimated loss of 150 million metric tons.[62] Reducing the intensity and extent of these fires is therefore a top priority.

There are an estimated 20 million acres of forestland in California with high wildfire threat that may benefit from fuels reduction treatment, which would serve to both reduce the risk of wildfire (and the resulting carbon loss and black carbon and GHG emissions) and improve ecosystem health.[63] For example, it is estimated that less than 20 percent of forests in the Sierra Nevada region receive needed fuel treatments, leaving remaining forests in a degraded state with higher risk to losses from severe wildfires.[64] Treatments should have multiple objectives that strengthen provision of a broad range of services to both people and ecosystems. These objectives may include improved wildlife habitat, protection of water resources, and resilience of recreational lands, among others.

In addition to fuels reduction and prescribed fire treatments, commercial timber harvesting can play a beneficial role, both in thinning dense forests and financing additional treatments. The distinction between fuels treatments and timber management is often gradual. A commercial thinning from below may have very similar objectives and outcomes as a fuels treatment project. As indicated Section 6 and Appendix 1 (California Forest Inventory), sustainably managed working forests tend to have less mortality than reserved lands where no timber harvest or forest management occurs. In some management situations, sustainably managed working forests can store higher levels of more resilient carbon over time than reserved forests,[65,66] including carbon sequestered in durable wood products.

An example of the linkage between timber revenues and forest restoration is the 1992 Fountain Fire near Redding. Almost all of the 41,300 acres of industrial private forests that burned was reforested soon after the fire, financed by revenues from timber harvests.[67] Box 1 provides a case study of forest restoration following the Fountain Fire.

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[62] California Air Resources Board, 2016c
[63] California Board of Forestry and Fire Protection, 2010
[64] North et al., 2012
[65] Gustavsson et al., 2017
[66] Smyth et al., 2014
[67] Zhang et al, 2008

Box 1: Forest Restoration following the 1992 Fountain Fire

Recognized at the time as one of the worst fires in California history, the Fountain Fire started on August 20, 1992 in the Southern Cascade Mountains, about 40 miles east of Redding. By the time it was controlled eight days later, the fire had burned over 64,000 acres (100 square miles) and destroyed more than 300 homes. While it seemed like an insurmountable task to resurrect the devastated landscape, largely composed of private industrial forestlands including Roseburg Resources, Sierra Pacific Industries and W.M. Beaty managed lands, the area is now well on its way to a full recovery. Twenty-four years later, the young, vigorously growing forest is once again providing a home for forest wildlife, and the streams, whose condition was of great concern, are again teeming with fish, amphibians and other aquatic life.

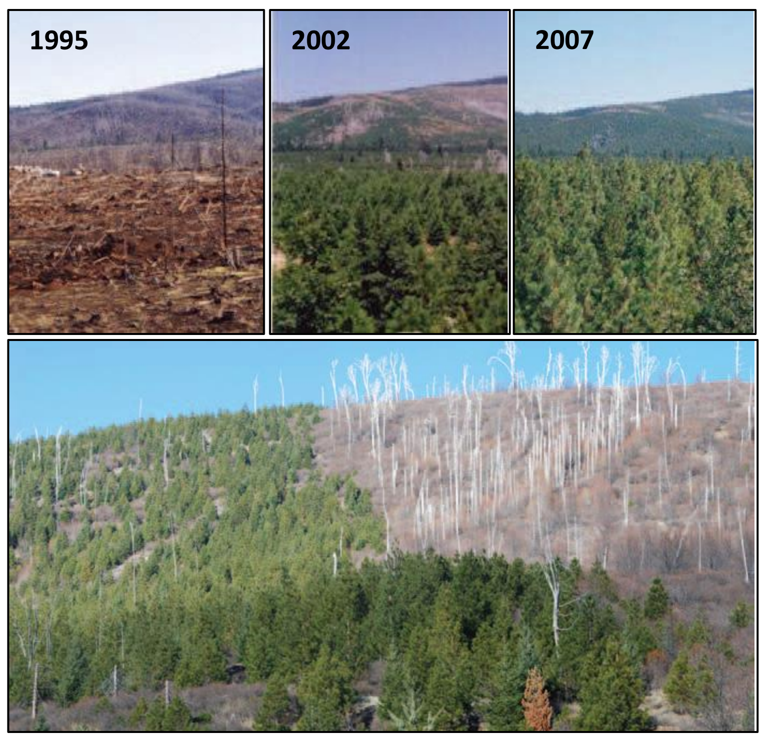
History has shown us that forests devastated by large scale wildfires do not rapidly recover on their own. The intensity and scale of large scale fires can compromise the natural ability of an ecosystem to regenerate, thus taking many decades, if not centuries, for natural succession processes to restore a forest to the pre-fire condition. However, if managed properly, the rehabilitation of a forest can achieve dramatic results in a few decades.

The successful recovery of the Fountain Fire was largely due to the restoration that landowners undertook immediately after the fire. Within weeks, operations were underway to salvage the dead timber, turning fire-charred trees into useful, carbon-storing wood products. Soil erosion was minimized, six fish-bearing streams were protected, and replanting of tree seedlings began in the spring of 1993, just seven months after the fire. To ensure the ongoing success of these recovery efforts, the timberlands have been actively managed since that time.

The Forest Foundation estimated that forests and shrublands burned in the Fountain Fire released 11.9 million tons of GHGs into the atmosphere through combustion and the subsequent decay of dead trees and shrubs. That is equivalent to the GHG emissions from more than 2.1 million cars for one year.[68] Because of the harvesting of dead trees and the forest restoration effort on these private industrial forestlands, it is estimated that about 8.1 million tons of carbon dioxide will be stored in wood products and growing trees over the next 100 years,[69] offsetting some of the impacts from the disastrous fire. Without this effort to re-establish trees, the land would have turned to shrub cover for many years, as many of the neighboring lands that were not restored did, resulting in far less carbon sequestration. Some of the burned and replanted forests have already been thinned, producing biomass for utilization and serving to concentrate future growth on fewer, larger trees.

Herbicides were used to control competing vegetation on the industrial lands, raising questions about native plant diversity. A chronosequence study on this site and two nearby burned sites (the Pondosa Burn of 1977 and the Tamarack Burn of 1986) indicated that initial plant diversity was richer in untreated plots.[70] But that diversity quickly fell as aggressive shrubs dominated the sites. Within 8 years, both species richness and diversity were greater in herbicide-treated areas.[71]

The Fountain Fire restoration effort illustrates how taking immediate and decisive action to restore forests that have been severely damaged by wildfire can benefit the environment by quickly restoring forest cover and once again sequestering atmospheric carbon.



Upper panels: plantation at the age of 0 years (1995), 7 years (2002), and 12 years (2007). Lower panel: Contrast of tree-planted and nonplanted areas December 2007. *Upper photos by Ted Silbersteins; lower by Jianwei Zhang.*

[68] Webster, 2007
[69] Webster, 2007
[70] Zhang et al., 2008
[71] DiTomaso et al., 1997

The objectives and activities described here are segmented between federal lands and all other lands, i.e., private, state-owned, and other publicly owned lands. In any case, implementation is expected to involve working across ownership and jurisdictional borders. Activities should be prioritized and coordinated by partners within each region.

3.2.1 Improve Health and Resilience on Federal Forestlands

While the USDA Forest Service and the Bureau of Land Management (BLM) determine management activities on their lands, which make up over half of California's forestlands, they have existing commitments to increase forest resilience that align with California's own forest health goals, which are intended to encompass federally owned lands. The most significant federal commitments are relatively broad in nature, and are therefore presented above the state's more specific management and restoration objectives. As a result of the strong partnership between federal landowners and state agencies, some of the California objectives and targets presented here are expected to unfold on federal lands. Given the intermix of federally, state/local, and private forestlands, these partnerships are critical to success.

USDA Forest Service Contributions:

The USDA Forest Service goal is based on a commitment to land and resource management that is infused by the principles of ecological restoration and driven by policies and practices that are dedicated to make land and water ecosystems more resilient and healthier under current and future conditions.[72]

- Increase forest resilience through treatments including fuels reduction, managed and prescribed fire, noxious weed removal, road improvements to reduce sedimentation, resulting in resource benefits to approximately nine million acres on National Forest System Lands in California by 2030.
- By 2020, increase treatments from the current approximately 250,000 acres/year to 500,000 acres/year on National Forest System Lands in California.

Ongoing state and federal cooperative efforts under the Farm Bill through the Good Neighbor Authority can help to advance opportunities on National Forest System Lands. Additional cooperative efforts in place with the state and other partners that can be used to meet ecological restoration goals include agreements to expand the use of fire on the landscape and agency commitments to support the California Headwaters Partnership and the Sierra Nevada Watershed Improvement Program. One further collaborative framework for the Forest Service is the National Cohesive Wildland Fire Management Strategy.

U.S Department of Interior Contributions:

The U.S. Department of Interior's Wildland Fire Resilient Landscapes Program is a new approach to achieve fire resiliency goals across landscapes with the collaborative efforts defined in the National Cohesive Wildland Fire Management Strategy, and in support of Secretarial Order 3336 - Rangeland Fire Prevention, Management, and Restoration. The approach uses integrated, place-based partnerships among programs, activities, and organizations to increase resilience to fire.[73] In addition, the BLM

[72] USDA Forest Service, 2015b
[73] U.S. Department of the Interior, 2015

utilizes a landscape-scale management approach to better support balanced stewardship of the diverse natural resources, ecosystems, and values on public lands.

- Increase forest and woodland resilience through national landscape conservation networks, landscape mitigation strategies, native seed rehabilitation and restoration, and vegetation treatments including fuels reduction, managed and prescribed fire, and weeds management. The goal will result in resource benefits to approximately 1.2 million acres of forests and woodlands on BLM public lands in California by 2030 and include forestry and fuels reduction targets expanding from the current annual average of 9,000 acres to 20,000 acres.
- By 2020, on BLM managed lands increase from the current approximately 9,000 acres/year to 10-15,000 acres/year.

3.2.2 Improve Health and Resilience on Nonfederal Forestland

Commercial and non-commercial private landowners may be induced to improve management for carbon sequestration and other public benefit outcomes through incentive payments for one-time forest improvement activities or long-term management changes. Mechanisms to incentivize one-time or temporary actions include grant programs, such as CAL FIRE's California Forest Improvement Program (Timber Regulation and Forest Restoration Fund), Fire Prevention Grants (State Responsibility Area Fire Protection Fee Fund), and Forest Health Grant Program (Greenhouse Gas Reduction Fund). The first year of Greenhouse Gas Reduction Fund-funded Forest Health and Urban and Community Forestry programs initiated 66 projects that are expected to reduce GHG emissions by 3,161,274 MT CO_2e over the course of implementation. Incentives for long-term management changes may include conservation easements (see Section 3.1) that contain forest improvement terms (e.g., requirements to grow large trees and retain some or all of them over time) or other contractual arrangements such as those required for participation in California's compliance market forest offsets program or other, voluntary forest carbon crediting standards. More than 15 MMT CO_2e in offset credits generated from California-based forest offset projects have been registered with CARB to date.[74]

As indicated above, the forest management deficit in California is significant, on both private forestlands (especially smaller ownerships) and public forestlands. In order to address this, action will be needed on the part of both state and federal agencies and on the part of landowners. The following targets are intended to address nonfederal forest lands (i.e., private, state, and local government; federal forestlands are addressed above in Section 3.2.1):

Target for Nonfederal Forest Lands:

- In order to address forest health and resiliency needs identified statewide on nonfederal lands, CAL FIRE has estimated that the rate of treatment would need to be increased to approximately 500,000 acres per year. This acreage is currently outside of what CAL FIRE determines to be operationally feasible. It should be considered a target to work toward, and is achievable pending increased resources. These treatments can include those that generate revenue from harvest materials, such as commercial thinning and regeneration harvests.

[74] Data as of January 2017. Available online: https://www.arb.ca.gov/cc/capandtrade/offsets/issuance/arb_offset_credit_issuance_table.pdf

- By 2020, increase the rate of fuels reduction treatments from the recent average of 17,500 acres per year to 35,000 acres/year.
- Increase fuels treatments, including mechanical thinning and prescribed burning, from the current rate of approximately 17,500 acres per year to 60,000 acres per year by 2030.[75] This target is based on CAL FIRE's determination of an operationally feasible increase in activity.
- Ensure that timber operations conducted under the Forest Practice Act and Rules contribute to the achievement of healthy and resilient forests that are net sinks of carbon.

Successful fuel reduction and forest management activities will result in reduced area of forestland impacted by wildfire statewide. This will have the result of reducing black carbon - a potent short-lived climate pollutant - brown carbon, and other particulate matter resulting from wildfire. Black carbon emissions from wildfire make up an estimated two-thirds of black carbon emissions from all sources and recent published estimates suggest the emissions from wildfire could increase significantly by 2050 under business-as-usual conditions and climate change.[76] Individuals and organizations commented on the need to include an explicit target for reducing black carbon emissions from wildfire in public workshops and written comments for both the Forest Carbon Plan Concept Paper and the Proposed Short-Lived Climate Pollutant Reduction Strategy. A number of individuals and organizations also commented that wildfire is a natural occurrence and either should not be considered an emission source, or that a "baseline" level of fire and resulting emissions should be established against which objectives are set and annual change is measured. However, neither this plan, nor the draft Short-Lived Climate Pollutant Reduction Strategy (November 2016), includes an explicit, numerical emission reduction target for wildfire black carbon emissions.

This decision is based on the Forest Climate Action Team's view that wildfire rates vary too much from year to year to identify an "acceptable" level of fire; that fire is a naturally occurring activity in California's forested ecosystems; and that fire is a tool of active forest management. One of the Forest Carbon Plan goals is to reduce the incidence and extent of those severe wildfire fires that might permanently alter site conditions and vegetation. Natural ignitions, under safe conditions and in appropriate areas, are considered a forest management tool that can advance forest health conditions and help to maintain forests as a net sink of carbon. A constant, year-to-year downward trajectory of wildfire acres therefore is not the ecologically or operationally preferable approach. Rather, this Plan proposes that fuel reduction treatments and sustainable forest management, including the emissions resulting from utilization pathways for excess biomass, will aim to minimize total black carbon emissions from forests. Over time, as forest health conditions improve and the carbon stock moves toward a more resilient state, black carbon emissions from wildfire are expected to fall from current levels.

3.2.3 Restore Ecosystem Health of Wildfire- and Pest-Impacted Areas through Reforestation

During the last decade, it is estimated that nearly 2.3 million acres of National Forest System Lands (or 4 million acres across all ownerships) have been affected by wildfire. Nearly 700,000 acres of these National Forest System Lands are classified as deforested, creating over 500,000 acres of planting need. Progress has been made to reestablish new forests, yet, given the effects of each year's new fires, over 270,000 acres of planned reforestation treatments remain as plans and have not been implemented.[77] The 2010 FRAP Assessment report estimated 2.35 million acres are high priority for restoring wildfire-

[75] California Board of Forestry and Fire Protection, 2016
[76] California Air Resources Board, 2016b
[77] USDA Forest Service, 2015g

impacted areas statewide.[78] In addition, the acreage affected by the current mortality event, currently estimated at 7.7 million acres statewide, may be added to the deforested total.[79].

The reestablishment of forests, for a variety of important natural and social reasons, will offer important ecosystem services. In order to make a significant reduction in USDA Forest Service Region 5 reforestation needs, an equally significant investment of human and financial resources will be needed. While natural regeneration will contribute to the solution, planting of desired tree species will also be needed. Both sources of seedlings will need fuel and competing vegetation reductions to increase the likelihood of success. Periodic future treatments, where allowed, can be implemented to facilitate a trend to create forest structures and compositions that will be resilient to the stressors anticipated in coming decades. Meeting the following targets goals will address the situation:

- Eliminate the current USDA Forest Service Region 5 Reforestation Need balance by 2020 and sustain future treatments at levels where annual additions are matched by treatments. Maintain seed collection, storage, and seedling production capacities to meet anticipated needs. Identify suitable seed collection areas and maintain existing seed orchards, to support future needs. Utilize genetically improved planting stock, while matching seedling source to anticipated climates.
- On nonfederal lands, increase annual area reforested by 25% over the current level by 2030. To achieve this goal, continue to work cooperatively with the Natural Resource Conservation Service, USDA Forest Service, Forest Landowners of California, reforestation seedling growers, and other partners to increase funding for reforestation assistance on non-industrial private forest lands and the availability of appropriate seedlings for planting.

3.2.4 Restore Mountain Meadow Habitat

Forested areas often contain multiple types of habitat, including meadows and riparian areas. These systems provide many ecosystem and recreational benefits. Healthy, functioning meadows host a diverse plant community with deep rooting systems that retain water, carbon and other nutrients, and provide important habitat for wildlife and other species. As meadows become degraded, plant diversity and rooting depth are reduced, thus decreasing water and carbon retention; GHGs are emitted as a part of this process. Management and restoration activities that restore riparian and meadow areas may in turn result in more carbon being retained in these areas, and continue to provide habitat for wildlife and other organisms. The California Water Action Plan[80] specifically recognizes the importance of restoring key mountain meadow habitats through broad, collaborative actions.

The commitments below also are supported in the Sierra Meadows Strategy,[81] which was developed by the Sierra Meadows Partnership. The Partnership has members from multiple state and federal agencies and nongovernmental organizations and has an overarching goal of restoring and/or protecting 30,000 acres of mountain meadows across “all lands” in the Sierra Nevada by 2030. The USDA Forest Service is a member, as is the California Department of Fish and Wildlife and the State Water Resources Control Board.

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[78] California Department of Forestry and Fire Protection, 2010
[79] USDA Forest Service, 2015a
[80] California Natural Resources Agency, 2016a.
[81] Drew et al., 2016

State Target:

- The state will lead efforts to restore 10,000 acres of mountain meadow habitat in key locations by 2030 and target reliable funding for such activities.[82,83]

Federal contribution:

- In addition to the state target, the USDA Forest Service will restore 10,000 acres of mountain meadow habitat by 2030 and target reliable funding for such activities on National Forest System Lands in California.

3.3 Innovate Solutions for Wood Products and Biomass Utilization to Support Ongoing Forest Management Activities

In order to support the goals of this Draft Forest Carbon Plan, wood and biomass material generated by commercial forestry operations as well as that produced through forest health and restoration treatments and hazardous fuels treatments must be either utilized productively or disposed of in a manner that minimizes net GHG and black carbon emissions. Timber and other biomass harvest volumes are expected to increase as a result of the forest management activities outlined above. These volumes will include green and dead trees suitable for timber production, smaller-diameter green and dead trees with little traditional timber value, and tops and limbs.

Removal will result in a temporary drop in carbon in standing live pools, which is expected to be replaced over time as carbon is sequestered in new tree growth on the treated area. Some of the residual biomass may be left in place for habitat or other purposes, but strategic utilization of the remainder can divert material from decay and open pile burning and produce net carbon benefits in the built environment, soils, and energy and fuels. Utilization of this material contributes to other beneficial uses including durable wood products, compost and other soil amendments, animal feed and bedding, and production of renewable electricity and biofuels. Research, development and implementation activities underway in energy, wood products, and soil amendment fields should be evaluated for utility in meeting disposal needs on regional and community scales.

A resilient forest products and biomass strategy is one that includes a diversity of utilization pathways (i.e., market end uses) that are scaled to handle the material generated through both public and private sector forest health activities, as well as the private timber industry. The approach should be regionalized, such that material production and utilization is balanced at scales appropriate to given markets and sustainable forest management. Transportation costs of forest biomass are significant relative to the material's value, so distance from source to processing site will determine feasibility for both private and public investors. Regional and local approaches will also be better suited to discussions related to facility siting, economic development strategies, local impacts of forestry operations, and climate resilience of both natural resources and the human populations that depend on them.

There is significant support for productive wood product and biomass utilization at the state level, which is described in detail in Section 9. The actions and targets described here underscore, accelerate, and expand on those commitments:

- Expand wood products manufacturing in California, and take actions to support market

[82] California Department of Water Resources, 2013
[83] California Natural Resources Agency, 2016a

growth scaled to the longer-term projections of forest productivity. In particular, identify potential for expanded and new markets, with a focus on products that can be made from traditionally low-value materials such as small diameter trees, limbs, and waste material from timber operations, to divert this material from open pile burning and provide alternatives to bioenergy and soil amendments as the primary form of low-value material utilization. This could include composite wood products such as cross-laminated timber.

    - The Wood Products Working Group established through Senate Bill 859 of 2016 will be the initial venue for this investigation, which builds on existing efforts at the local, state, and national (USDA Forest Service) levels. That interagency group, convened by the California Natural Resources Agency (CNRA) in September 2016, will make recommendations to the Legislature by June 1, 2017, on methods to expand wood products markets statewide and using trees killed through the recent drought and bark beetle epidemic.

- Increase the total volume of carbon stored through greater use of long-lived wood products from California forests, particularly in buildings. Ensure that the California Green Building Standards Code supports this objective.
- Build out the 50 MW of small scale, wood-fired bioenergy facilities mandated through Senate Bill 1122 (Rubio, 2012). Continue public investment in this build-out through the California Energy Commission's EPIC program. Expedite contracting and interconnection for facilities fueled by feedstock from tree mortality High Hazard Zones[84], as described in Governor Brown's State of Emergency Proclamation on the Tree Mortality Epidemic.[85]
- Maintain large-scale bioenergy capacity in the short term at a scale necessary to meet the public safety and tree disposal needs posed by widespread tree mortality in the central and southern Sierra Nevada. This is supported through the electricity procurement requirements in California Public Utility Commission Resolution E-4770, which calls for solicitation of 50MW through the BioRAM procurement process, and Senate Bill 859 (2016), which calls for procurement of 125 MW of bioenergy from facilities sourcing the majority of feedstock from tree mortality High Hazard Zones.
- Continue to support research into the potential for conversion of woody biomass to transportation fuels both statewide and regionally. Identify opportunities to support deployment of emerging fuels technologies, particularly those that advance multiple climate objectives and can utilize associated funding synergies.
- In support of the objectives above, initiate an interagency effort to identify, at the regional scale:
    - The sources and volumes of excess forest and agricultural biomass and scope the need for disposal and utilization projects that will minimize GHG and black carbon emissions and align with this Forest Carbon Plan;
    - Wood products market opportunities;

[84] High hazard zones are areas with elevated tree mortality and high fire threat that are a hazard to public safety, community assets and related infrastructure represent the primary focus of these zones. Where appropriate broader watershed protection and other important environmental services (i.e. water resources, carbon storage, wildlife habitat) will also be considered.

[85] Brown, 2015

    - Statewide renewable energy and fuels policies, practices, and implementation programs; waste diversion goals; and agricultural markets and the Healthy Soils Plan.
- Develop and support the generation of and markets for compost from forest biomass for agricultural, rangeland, municipal and residential soil amendments.

4 Implementation

Implementation of these goals will be undertaken by a diversity of public and private actors, who will need to collaborate in order to achieve success. Forest health outcomes derived from this work will benefit a broad constituency of stakeholders, with many benefits being realized over a very long timescale. There is a clear need to identify and increase the resources available for implementation in a manner that reflects these broad beneficiaries, and to identify and pursue ways to improve the efficiency of any funds spent. This Section 4 describes the top-level considerations for implementation of the Forest Carbon Plan.

4.1 Regional Prioritization and Implementation

The overall goal to secure forestlands as a resilient net sink of carbon and minimize the GHG and black carbon emissions is a statewide objective, but one that is best pursued at the ecoregional (see Section 6.2), or finer, scale. Priority landscapes for forest health can be informed with statewide data on forest conditions, but local landowners and managers, private and public, will need to prioritize implementation of forest health protection and management and restoration practices. Local actors, including landowners, local and regional governments, and NGOs active in forest conservation and restoration, as well as those involved in wood products market development, must be leaders in collaborative processes to identify priorities and pursue funding and other needed resources.

Therefore, regionalization of the goals and targets described in Section 3 is an important next step for Forest Carbon Plan implementation. Forest conditions at the ecoregional scale are described in Appendix 3, and can serve as a starting point or continuation of consensus-building conversations. Existing forest management collaborations may serve as the best venues for implementation; some current California collaborations are listed in Table 3. Going forward, it will be necessary to identify the resources and policies that would best serve local implementation collaborations and pursue those through state, federal, and other channels, including those for convening, planning, financing, and implementing.

The following factors should guide regional prioritization across all regions of the state:

- Forests at greatest risk to high-severity events (e.g., fire, insect outbreak)
- Stands with existing large trees
- Forests at high risk of type-conversion
- Overly dense forests with large growth potential
- Forests critical to state and local water quality and supply
- Areas with high habitat values at risk, such as owl Protected Activity Centers
- Need to reforest areas after high mortality events
- Forests at risk to conversion to other uses, including development and agriculture
- Previously treated areas that are in need of “maintenance” treatments, which are generally less costly and may be able to be accomplished via prescribed fire

4.1.1 Working Collaboratively at the Large Landscape Scale

Agencies, nongovernmental organizations, and landowners should undertake forest health assessments and actions at the large landscape scale to maximize ecoregional and statewide benefits. Land use and forest management activities on any given parcel or within any single stand are important, but ecoregional resilience depends on forest conditions across property lines. Large landscapes may be defined by, for example, ecoregional limits, watershed boundaries, biological needs, and/or regional economies. This imperative is further articulated in Sections 6 and 10. Management for large landscape outcomes requires significant collaboration among landowners, both public and private, and the agencies that are responsible for the protection of the wide range of forest-based natural resources. Landscape-level collaboration, such as exemplified in Table 3 (above), is one of the critical elements needed for the success of this Forest Carbon Plan. Successful implementation of this Plan will require these kinds of collaborative efforts in all forested ecoregions.

Table 3. Examples of Existing Forest Health Collaborations

- Sierra Nevada Watershed Improvement Program (Sierra Nevada Conservancy and USDA Forest Service, with other state and local agencies and nongovernmental organizations)
- Good Neighbor Authority (USDA Forest Service and the State of California)
- Collaborative Forest Landscape Restoration Act Projects (USDA Forest Service and other partners, on a landscape/regional basis)
- Memorandum of Understanding for the Purpose of Increasing the Use of Fire to Meet Ecological and Other Management Objectives (many signatory agencies and nongovernmental organizations)
- Cohesive Strategy Projects and Landscape Management Demonstration Areas (i.e., South Fork American River Fire-Adapted 50 Project, led by the USDA Forest Service with partners)
- Landscape Conservation Cooperatives
- Collaborative Climate Adaptation Committees established on a regional basis throughout California
- Joint Chiefs Landscape Restoration Partnership Program (USDA Forest Service and Natural Resources Conservation Service)
- California Headwaters Partnership (USDA Forest Service and Sierra Nevada Conservancy with other state and local agencies and nongovernmental organizations)
- Community wildfire protection plans (local collaborative groups)
- Tuolumne Community and Watershed Resilience Program (implementing the NDRC program);
- Yosemite-Stanislaus Solutions (USDA Forest Service, Bureau of Land Management, National Park Service, state and local agencies, and many nongovernmental organizations)

4.1.2 Funding and Other Resources

Existing funding sources for forestland protection, management and restoration, and investment in wood products and biomass utilization include public funding through a range of state and federal programs as well as various forms of private investment, both commercial and non-commercial. The goals for forest health described in this plan call for, in most instances, a significant increase in the pace and scale of management activity beyond what can be supported by existing funding levels.

To meet these goals, the complex collaborations and implementation strategies needed to achieve the goals of this Forest Carbon Plan will need to leverage resources from existing state, federal and private efforts. Table 4 lists some of the various state and federal programs that share broader forest health priorities and contribute to forest carbon goals. These programs should be taken into consideration in designing funding structures for forest health, although some of these funding sources are subject to annual appropriation decisions and shifting revenue availability themselves. For example, the California Conservation Corps (CCC) is a valuable resource for forest and other natural resource management, as well as youth development, and provides those services through its own annual budget as well as through external collaborations and funding; see Box 2.

Table 4. Funding Sources for Forest Restoration.

- *CAL FIRE:*
    - California Forest Improvement Program (Greenhouse Gas Reduction Fund, Timber Regulation and Forest Restoration Fund, USDA Forest Service Forest Stewardship Funds)
    - Vegetation Management Program (State Responsibility Area Fire Prevention Fund, Greenhouse Gas Reduction Fund)
    - Urban and Community Forestry Program (Greenhouse Gas Reduction Fund, USDA Forest Service Forest Stewardship Funds)
    - State Responsibility Area Fire Prevention Fee Fund Grant Program
    - Forest Stewardship Program (USDA Forest Service Forest Stewardship Funds, Greenhouse Gas Reduction Fund)
    - Forest Legacy Program (USDA Forest Service Forest Legacy Funds)
    - Seed Bank
    - Pest Management Program
- *CNRA*: Urban Greening (Greenhouse Gas Reduction Fund).
- *Sierra Nevada Conservancy*: Watershed Improvement Program (Proposition 1).
- *Department of Water Resources*: Integrated Water Resources Management Program (Proposition 1).
- *Department of Fish and Wildlife*:
    - Proposition 1 Restoration Grant Programs
    - Wetlands Restoration for Greenhouse Gas Reduction Program (Greenhouse Gas Reduction Fund)
    - State Wildlife Grant Program.
- *California Conservation Corps*: Efforts to assist firefighting and fuels management throughout California.
- *National Disaster Resiliency Competition*: A federal grant program through Housing and Urban Development designed to help communities in recovering from – and preparing for the next – natural disaster, this program identified Tuolumne County as a recipient of their 2016 competition.
- *USDA Forest Service and NRCS*: Joint Chiefs' Landscape Restoration Partnership
- *USDA Forest Service Landscape Scale Restoration Program (LSR)*
- *Natural Resources Conservation Service (U.S. Department of Agriculture)*: Environmental Quality Incentives Program and other programs.

Federal funding for the U.S. Forest Service and other federal land managers also is vulnerable, both to annual budget appropriations and priorities and to fire-borrowing, a condition wherein unobligated U.S. Forest Service funding is reallocated to fight wildfire, leaving restoration objectives underfunded. U.S. Forest Service spending on wildland firefighting has risen from 16 percent of their budget in

1995 to 52 percent in 2015, and is projected to demand 67 percent of their budget by 2025.[86]

To address this issue, efforts are underway to urge Congress to change the way wildfire suppression is funded through a comprehensive fire funding fix. By changing the way budgets are structured, disaster or emergency relief funds would be used to pay for these costly events, and funds initially allocated for restoration activities would not need to be transferred in the same way they are currently. The restoration activities needed to help prevent large high severity wildfire events in the future could still be funded, regardless of the fire season.

Private landowners also have limited resources (small forestland owners) to significant resources (corporate forestland owners) to support treatments to improve forest health and resilience. In some cases, this work can be done as a part of revenue-generating commercial timber harvests; in other cases, it can be done as a part of non-commercial forest management activities, which in some cases may receive funding from state and federal programs such as some of those listed in Table 4, above.

The insufficiency of existing funding to fulfill the needs identified in this Forest Carbon Plan highlights the need to identify new sources and mechanisms of funding for forest protection and management and to promote new wood products and biomass utilization markets, including energy and fuels. Some opportunities for generating new revenue for forest health include:

- **Ecosystem Services –** Linking and communicating the benefits of forest health – ecosystem services – to other sectors or markets could generate financing for forest protection and restoration. These financing mechanisms link ecosystem service producers and consumers directly, or through an organizing entity that functions to structure transactions and deliver on benefits. These arrangements can be funded by public and private entities, including non-profit organizations with a mission-driven interest in the outcome (e.g., a land trust can raise capital for a conservation easement).
- **GHG Compliance Market Offset Programs –** The one strategy most clearly linked to climate objectives is the ARB compliance market offset programs for improved forest management, reforestation, and avoided conversion. These projects allow the carbon sequestration benefits accruing from those activities to be monetized through sale of offsets. While not all of the offset projects enrolled in the ARB program are located in California, offsets represent one opportunity to link producers and consumers of environmental services. Forest offset projects in California have generated more than 15 MMT CO2e in early action and compliance offset program credits registered with CARB to date.[87]
- **Direct Benefits to Local and State Water Quality and Supply –** Collaborative watershed investments can bring together water utilities and users, air quality management districts, flood control districts, and land owners and managers to jointly implement watershed and riparian restoration efforts that reduce utility and district capital and operational costs and promote forest health activities.

Signed into law in 2016, AB 2480 identified watersheds as part of California's water infrastructure, further presenting an opportunity to grow constituencies around the multiple ecosystem services forested watershed investments deliver. (Ecosystem service linkages are described in Section 8, Co-

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[86] USDA Forest Service, 2015d

[87] Data as of January 2017. Available online: https://www.arb.ca.gov/cc/capandtrade/offsets/issuance/arb_offset_credit_issuance_table.pdf

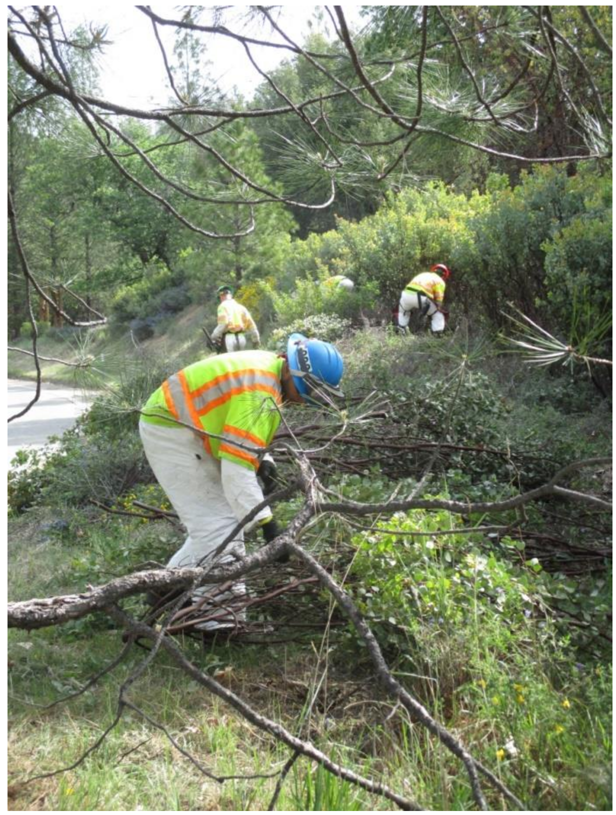
Benefits. New funding opportunities for wood products and biomass utilization are described in Section 9, Wood Products and Biomass.)

Other, non-monetary resources will advance the goals of this plan as well. For example, information, technical assistance, and tools that identify forest conditions and prescribe best management practices for private landowners would be useful in facilitating engagement in regional collaborations. As the Forest Carbon Plan proceeds into its implementation phases, regional and landscape-scale collaboratives should identify the information and tools that would be useful so that the state and federal agencies can seek resources to supply these at the appropriate scale and in their most useable forms.

Box 2: Role of the California Conservation Corps in Advancing Forest Health

The California Conservation Corps (CCC) is an important resource for addressing needs for environmental protection as well as youth development. Corpsmembers provide services that allow land management partners to protect, monitor, and care for land. Corpsmembers spend thousands of hours each year improving forest health, reducing the threat of fires, and planting trees. In the last fiscal year (2015-16), CCC spent almost 50,000 hours on forest improvements, over 300,000 hours on fire hazard reduction activities and over 5,000 hours planting trees. Work the CCC accomplishes to advance forest health includes brush clearance, controlled burns, fire hazard reduction, fire suppression, fuelbreaks/fire lines, slash removal/burning, removal of invasive species, timber stands thinning, urban forestry protection, and tree planting.

<u>State Responsibility Area (SRA) Projects</u>: Since 2012, CCC crews have collaborated with CAL FIRE to reduce and remove deadly ladder fuels and overgrown vegetation on lands within the State Responsibility Area (SRA). The focus of these efforts has been to slow the potential spread of wildfire and create buffer zones around evacuation routes. Funding through SRA has allowed CCC to be responsive to locally designated, critical fire prevention projects by covering the costs of the crews that work on the projects approved by local CAL FIRE Units, Fire Safe Councils, and Fire Protection Districts. Work completed has:



- Reduced fuel loads and created fuel breaks in State Parks, freeing up Parks personnel to concentrate on facility maintenance/repair or providing new services to the public.
- Benefitted emergency response organizations by widening access and evacuation routes.
- Created fuel breaks in the Wildland Urban Interface areas located adjacent to homeowners, Fire Safe Councils, local and regional parks, and private reserves or conservancies (entities that do not have the budgets to service the lands outside of their defined boundaries).
- Provided Post-Fire rehabilitation to remove dead and dying trees and prevent soil erosion to preserve and protect water quality.
- Provided additional training opportunities for Corpsmembers including Basic Fire Training, Chain Saw Training, Burn Pile Training, Exotic Plant Identification/Eradication, and Chipper Training.

<u>Sample SRA Project: Sierra County Fuel Load Reduction (Placer CCC Center, FY 15/16):</u> With direction from the Sierra County Department of Public Works (the Project Sponsor), crews hand-thinned hazardous fuels and vegetation to create a safe fuel break and proper road clearance within the county right of way on Ridge Road between Pike and Alleghany communities in Sierra County, California. Hand crews removed ladder fuels, shrubs and small trees (less than 10" DBH). Cut materials were chipped and broadcast on site with the use of a Sponsor-provided chipper. Crews worked a total of 5,528 hours completing 35 acres of fire hazard reduction work. The project provided public benefit through the reduction of wildfire risk by removing encroaching vegetation, ladder fuels, and snags from the understory. During the project, Corpsmembers had the opportunity for training in various areas of employable skills including, but not limited to, identifying and removing heavy accumulations of surface fuels, identifying and creating horizontal separation of crowns, chainsaw operation and maintenance, as well as team building skills. Corpsmembers learned how to reduce wildfire risk through the removal of encroaching vegetation by the use of power equipment and manual labor. The crew also learned about the different vegetation and other shrub cover in the understory. The sponsor conducted a brief presentation regarding the history of the area in Sierra County and the importance of the work crews were completing to help prevent wildfires.

4.2 Regulatory Opportunities

4.2.1 Flexible Elements of Major Regulatory Laws

Some of the most important laws for management of nonfederal lands—such as the California Environmental Quality Act (CEQA) and the Forest Practice Act and Rules—currently provide number of opportunities to exempt certain restoration activities from discretionary permits and environmental impact review. Actions by both the Legislature and the Board of Forestry and Fire Protection have recently provided additional ministerial permit options for management that can help to restore forest resilience, such as the Forest Practice Rule section 1038(k) exemption for the removal of dead and dying trees. In conjunction with these current permits, oversight by responsible agencies remains important, particularly because the use of several exemptions has been significantly expanding recently. For example, recent legislation (AB 1958, Wood, Stats. 2016, Ch. 583; AB 2029, Dahle, Stats. 2016, Ch. 563) requires the Board of Forestry and Fire Protection and CAL FIRE, working with the participation of the Department of Fish and Wildlife and the regional water quality control boards, to review and submit a report to the Legislature on the trends in the use of, compliance with, and effectiveness of the exemptions and emergency operations conducted under the Forest Practice Act and Rule. The report also is to include recommendations to improve the use of those exemptions and emergency notice provisions.

4.2.2 Increase Use of Prescribed and Managed Fire

In fall 2015, the USDA Forest Service Pacific Southwest Region, National Park Service Pacific Region, CAL FIRE, Sierra Nevada Conservancy, multiple environmental organizations, and two prescribed fire councils signed the Memorandum of Understanding for the Purpose of Increasing the Use of Fire to Meet Ecological and Other Management Objectives (MOU).[88] The MOU recognizes that the state's wildland ecosystems have evolved with fire, which provides resilience and renewal. The purpose of the MOU is to: "…document the cooperation between the parties to increase the use of fire to meet ecological and other management objectives in accordance with…" specified provisions. Modifications to the MOU are currently underway and a number of additional agencies and organizations have signed on to it.

See Box 3 below for a description of how prescribed fire is used regularly at Big Basin State Park.

[88] USDA Forest Service, 2015h

Box 3: Use of Prescribed Fire at Big Basin State Park

Big Basin Redwoods State Park in Santa Cruz County includes some of California's most storied redwood forests, and traces its history to the beginning of the movement to save the redwoods at the beginning of the 20th Century. Today, Big Basin contains some of the largest and oldest organisms on the planet, and is home to rare and magnificent wildlife. For example, the State endangered and Federally threatened marbled murrelet nests in the upper canopy of redwood trees and makes famously long daily journeys to the ocean to feed. Stewardship of these forests is important for the murrelets, which are dependent on old growth forest for their survival, and for the hundreds of thousands of visitors who visit the park each year. Protecting redwood forests has also taken on another meaning in recent years, as redwoods form some of the most carbon-dense forests in the state.

Image: Jonathan Knowles

The photo shows a member of the State Parks burn crew during a 2011 prescribed burn. These burns are generally low-severity and are designed to clear surface fuels (woody debris) rather than live trees.

Managers at Big Basin Redwoods State Park strive to maintain healthy forest conditions that protect old growth and restore older forest conditions at the park. At times they must take a hands-on approach to ecosystem stewardship. Since 1978, managers have utilized prescribed fire as a management tool at the park. Each year, California State Parks managers and CAL FIRE crews collaborate to treat 100-300 acres of redwood forest through prescribed burns.

These burns increase resilience and continue a practice employed by native people of the region for thousands of years. Coast Redwood forests are typically in foggy, moist regions with infrequent lightning strikes; given this climate and the absence of natural ignition sources, it is unlikely that redwoods would encounter much wildfire in the absence of humans. However, native people from the Big Basin area frequently used fire as a management tool—often starting in nearby grasslands to stimulate food and other resource production. As a result, fire scars from the trees indicate that these forests actually may have burned every 10-15 years (Stephens and Fry 2005). Fire provides important functions in the forest, such as stimulating nutrient cycling and promoting redwood tree resprouting. Thus, State Parks has found that continued use of prescribed burning is crucial for cultural values as well as for protecting the ecological integrity of these iconic natural resources.

4.2.3 Small Landholders and Land Management

FIA data indicate that there are 7.6 million acres of non-corporate forest land in California, and that 61 percent (about 4.6 million acres) of that land is family-owned parcels of 500 acres or less. There are significant financial barriers to small landholder management, including costs associated with completing a timber harvesting plan (THP) or Nonindustrial Timber Management Plan (NTMP). In-place statutes have modified the costs of landowners to prepare applications for discretionary permits for commercial timber operations,[89,90] but the costs of regulatory compliance still may exceed the benefits, making forest management financially infeasible. In some cases, financial assistance may be available to landowners to complete forest improvement activities that do not generate timber revenues, and these incentive programs are discussed below. Discussions surrounding legislative and regulatory solutions to high regulatory costs have been ongoing. Successful progress and outcomes on this topic are important to make forest health and resilience improvement work by small landowners more feasible through reduction of regulatory costs, while still ensuring that natural resources are protected.

4.2.4 Explore Approaches to Securing Exemptions to Federal Restrictions on the Export of Sawlogs from Federal and Other Public Lands.

Federal and state restrictions on log export from public lands have ebbed and flowed since the 1800s, with major adjustments made in the late 1980s and early 1990s.[91] While these restrictions made sense at that time, certain conditions in California are much different today, where there is much less mill capacity and where drought- and beetle-ravaged and severely burned forests have resulted in material that far exceeds this mill capacity. Federal statutes and regulations in this area do provide processes for securing exemptions from export restrictions in certain circumstances, including an excess of materials beyond domestic processing capacities.

[89] AB 904, 2013
[90] AB 1492, 2012
[91] Daniels, 2005

5 Measuring Progress

Monitoring adherence to this plan and measuring progress is crucial to its success. This plan contains both high-level performance objectives for climate change mitigation–securing California's forestlands as a net carbon sink and minimizing the GHG and black carbon emissions associated with wildfire events and management activities – and implementation goals that are intended to lay out on-the-ground forest protection and management and related activities that will move forests across the state towards resilient conditions. Monitoring must also measure the other key attributes of healthy forest systems, biodiversity, and economic and ecological sustainability.

Monitoring, performance assessment, and public reporting must be characterized by consistency, utility, and transparency. Because of the rapid and unprecedented changes many California forests are undergoing, comprehensive and timely monitoring is required to understand the continuing challenges climate change poses for forest health. California's forest carbon monitoring must also be aligned with federal and international standards for carbon accounting and forest management (e.g., USDA Forest Service, other federal climate programs, and guidance of the Intergovernmental Panel on Climate Change). Where possible, state-produced and maintained planning tools and databases should be accessible to local land-use decision-makers and private and public landowners to facilitate adoption of best practices and information-sharing across jurisdictions. Working with landowners, communities, collaborative stewardship groups, tribes, etc. on monitoring and adaptive management responses is also an important component of measuring progress and responding to what is found.

5.1.1 Monitoring and Reporting on Carbon Stock and GHG and Black Carbon Emissions

Carbon Stock and GHG Emissions

Performance with regards to these objective will be measured using a combination of stock-change and GHG flux approaches for forest carbon and GHG emissions statewide, measured in metric tons of carbon, on an annual, calendar-year basis relative to a ten-year baseline period ending in the year 2015 (i.e., 2006 to 2015). Carbon stock assessments will include carbon stored in durable wood products. Black carbon emissions will be assessed separately from GHG emissions.

If forests statewide are performing as a net sink, the average change in carbon stock over the period should be positive. The carbon stock reported in each year will be the ten-year rolling average of carbon stocks, so the value reported for 2015 is the average carbon stock over the years 2006 to 2015. Using the most recent ten-year period, 2006 to 2015, corresponds to the initiation of the landmark California Global Warming Solutions Act of 2006, and includes climatic conditions that are likely to be more representative of future climatic conditions than would an earlier period (e.g., one that includes 1990, the baseline year for Assembly Bill 32 GHG emission reduction requirements). Some organizations submitted comments with the suggestion that the baseline for forest carbon should refer to an earlier year (e.g., 1990) or to a period prior to the early 21st century, in response to both the Forest Carbon Plan Concept Paper and presentation of ARB's Natural and Working Lands GHG Inventory. However, modern FIA and geospatial data used for baseline development became widely available only after 2000, limiting the analysis of early carbon stocks prior to 2000.

Forest carbon stock inventories will be reported directly by the Board of Forestry and Fire Protection and serve as a data source to inform ARB's Natural and Working Lands GHG Inventory ("ARB Inventory"). The Board of Forestry and Fire Protection will provide annual reports on wildland forest carbon stocks pursuant to compliance monitoring for AB 1504 (Skinner). The first AB 1504 report is expected to be released in early 2017. The AB 1504 inventory methods rely on FIA data, and will use a rolling, 10-year average as described above. The ARB Inventory uses FIA data and satellite imagery to inform its inventory of carbon stock in wildland forests and other lands at discrete points in time; ARB is currently developing methods to inventory carbon sequestered in urban forests, which will ultimately be included in the ARB Inventory. ARB plans to update the Natural and Working Lands Inventory on a bi-annual basis. More detailed descriptions of the data and methods used for both the AB 1504 and ARB inventories are contained in Appendix 1.

The ARB Inventory measures both carbon stock and GHG flux associated with stock-change on categories of forests and other lands.[92] This inventory will include GHG emissions associated with disturbance events, including wildfire, and is therefore an important source of information to determine net GHG emissions from forests. In addition to a Natural and Working Lands sector, the ARB statewide GHG inventory includes other sectors such as power generation, transportation, industry, and waste management. It can provide a holistic assessment of carbon stocks from natural and working lands as they interact with other sectors. The ARB Inventory is a suitable stand-alone reporting mechanism for the goals of the Forest Carbon Plan, which are aimed at both securing carbon stock and reducing system-wide GHG emissions. The assessments of carbon stock in the ARB and AB 1504 inventories should be consistent. To promote this consistency, ARB, in consultation with CNRA and CAL FIRE, will engage in a comprehensive review and complete a standardized GHG inventory for natural and working lands, including forests, by Dec. 30, 2018, as called for in Senate Bill 859 (2016), Sec.15.

Determining the *net* GHG emissions associated with fluctuations in carbon stocks, disturbance events and other processes, active management, and biomass utilization across multiple applications may require additional accounting considerations. For example, the biomass utilization targets described in Section 3 engage the electricity, fuels, and agricultural sectors to move forest biomass to carbon-beneficial uses. The end-use efficiency, measured in CO_2e, must be understood and accounted for in order to evaluate the effectiveness of the policies and programs that will implement this Forest Carbon Plan. This accounting will be undertaken through the process established to accomplish the mandates in SB 859 (2016), Sec. 15 and will be completed by Dec. 30, 2018.

Black Carbon Emissions

Black carbon emissions from wildfire will be estimated using the inventory methods developed by ARB.[93] This method uses the ten-year average from 2001 to 2011 of Particulate Matter 2.5 ($PM_{2.5}$) emissions from wildfire to represent average conditions and avoid large year-to-year variations in the inventory. Similar to carbon stock figures, black carbon emissions will be assessed as a rolling average of annual emissions over ten year periods, expressed in metric tons carbon dioxide equivalent. Data on emissions from prescribed fire can also be tracked and reported. Bi-annual reporting will include the aggregate number for black carbon emissions associated with wildfire statewide.

5.1.2 Monitoring and Reporting on Implementation Activities

Centralized and standardized tracking of implementation activities to meet Forest Carbon Plan targets will be necessary to fully account for all efforts, identify areas of underperformance, and effectively work towards the ultimate performance objective of maintaining California's forests as

[92] California Air Resources Board, 2016c
[93] California Air Resources Board, 2016d

net sinks of carbon. There are a number of acreage-based numerical targets, or numerical ranges, for implementation of forest management activities over time. This implementation will flow from programs and responsibilities across multiple local, state and federal agencies, and actions of local public and private landowners and managers. In many cases, there are not reporting structures or tools in place for consistent tracking that can be accessed and utilized to support policy-making and implementation along multiple channels. For example, reforestation activities are currently undertaken or funded by federal and state agencies including the Natural Resources Conservation Service, CAL FIRE, the California Department of Parks and Recreation and the California Department of Fish and Wildlife, among others, but are not tracked in a centralized database.

There is currently no centralized database that includes a full listing of forest management and conservation activities that have taken place and are underway throughout California. Forest management and conservation activities are initiated by public and individual private landowners and entities, and are either voluntary or mandated actions. Voluntary actions are funded by a range of state, federal, local and private funding sources, through various programs, often of limited duration tied to funding availability. State and federal agencies currently maintain a number of databases that track and report on management and conservation activities.

Databases in use include:

- CAL FIRE uses CalMAPPER and has a database with certain information contained in timber harvesting plans, forest improvement projects, and fuels reduction[94];
- The California Department of Fish and Wildlife uses the California Environmental Data Exchange Network[95], EcoAtlas[96], and Miradi[97] for various project types and programs;
- CNRA maintains grant-specific information associated with bond initiatives[98]; and
- The USDA Forest Service reports forest activities through regional and national databases[99].

These databases vary in their level of detail and are not currently fully compatible. Also, most are not designed to provide data on expected carbon stock or GHG or black carbon emissions associated with management and conservation activities. Developing a centralized database or an automated system that can pull and standardize data from disparate sources will be important to track progress in a way that links policies, programs and funding sources to outcomes. The CNRA will seek resources to develop and implement a centralized database or other information management system to track implementation activities identified in this Draft Forest Carbon Plan across its boards, departments, and offices by December 30, 2018. Where possible, this system will be designed to accommodate additional inputs from local and federal agencies and organizations to build a complete picture of statewide implementation activities.

[94] California Department of Forestry and Fire Protection, 2016b, 2016c
[95] State Water Resources Control Board, 2016
[96] California Water Quality Monitoring Council, 2016
[97] Conservation Measures Partnership and Sitka Technology Group, 2016
[98] California Natural Resources Agency, 2016b
[99] USDA Forest Service, 2016d, 2016e

6 Forests of California Today

6.1 The Western Forest Context

The conditions of California's forests today share similar conditions with forests elsewhere in the western United States. Forest health problems, increasing wildfire, and a changing climate are common themes. A recent journal article found:

> Large stand-level shifts underway in western forests already are showing the importance of interactions involving drought, insects, and fire. Diebacks, changes in composition and structure, and shifting range limits are widely observed.[100]

Most forests across the western United States are fire-prone. The ecosystems of these forests have adapted to fire as a primary source of disturbance.[101] Wildfire is an essential part of these ecosystems, and many of the native tree and plant species are dependent on periodic disturbance from wildfire. However, altered wildfire regimes and changes due to land management have affected forest structure. A century of fire suppression, preferential harvesting of large, fire resistant trees, and opposition to timber harvesting on public lands have all contributed to create the forests we have today. Under these conditions many western forests are now overly dense, unhealthy, and continue to experience large and severe wildfires.

6.2 California's Forests

The Forest Carbon Plan focuses on forested ecosystems and associated ecological communities, as well as urban forests. California has a large forestland base (approximately 32 million acres, or almost one-third of the state).[102] California forests are exceptionally diverse, with a wide variety of tree species, including but not limited to, many types of conifers (e.g., Douglas-fir, ponderosa pine, sugar pine, bristlecone pine, incense-cedar, coast redwood, giant sequoia) and also many species of oaks and other hardwoods (e.g., blue oak, black oak, coast live oak, tanoak).This diversity of forests results from a similar diversity of climatic zones, soils, elevations, and other environmental factors.

Given the diversity of California's forest ecosystems, it is important to be able to distinguish these, at least at a general level, in order to be able to discuss their specific condition, risks, and management goals. The ecoregions used within the Forest Carbon Plan were developed by CAL FIRE as part of the FRAP Assessment update process and are based on Bailey's ecological sections (Figure 5).

An ecoregion represents large landscape areas that share common environmental conditions, natural communities, and assemblage of species. Bailey's ecological sections are part of a national hierarchical framework. The largest ecosystems are domains, which are groups of related climates that are differentiated based on precipitation and temperature. Divisions represent a further refinement of the climates within domains and are differentiated based on precipitation levels and patterns as well as temperature. Divisions are subdivided into provinces, which are differentiated based on vegetation or other natural land covers. Beneath provinces are eco-sections, called ecoregions in this report, which are subdivisions of provinces. The map below shows these units as used in the Forest Carbon Plan. For this report the term ecoregion and eco-section refer to the same planning unit.

[100] Clark et al., 2016
[101] Agee, 1996
[102] California Department of Forestry and Fire Protection, 2010

Figure 5. CAL FIRE Ecoregions Based on Bailey's Ecosystem Sections.

Accumulating evidence suggests that in Mediterranean-climate forests such as those of California, the optimal, resilient level of carbon storage in living trees is much less than what the site can maximally support at a given point in time, and strongly reflects the disturbance regime under which the forest grows.[103,104] That is, redistributing the total carbon storage among fewer, larger, and more fire resilient trees has the highest chance of safeguarding the most carbon in the long term. Research has suggested that the presence of very large trees in pre-1900 California forests resulted in higher carbon storage per acre than the overgrown stands of many California forests today[105]. This is demonstrated by measurements in the Sierra Nevada where a remaining 300-yearold sugar pine contains as much carbon in its trunk as 175 thirty year old white fir growing nearby (see Section 6.3 and Figure 8). Carbon storage strategies must also consider the broader range[106] of environmental services that forests provide (e.g.,

[103] North and Hurteau, 2011
[104] Collins et al., 2015
[105] North, Hurteau, & Innes, 2009
[106] Millar & Stephenson, 2015

clean water, water storage, clean air, soil productivity, nutrient cycling, wildlife habitat, forest products, and recreation) and the tradeoffs that may occur among them. The forest carbon strategies presented in the Forest Carbon Plan can support most, if not all, of these benefits in any given ecoregion or forest stand.

Forest carbon is stored in both forest ecosystems and in harvested wood products; and there is increasing interest in storing forest carbon in non-forest soils as a component of compost, biochar, or other soil amendments, e.g. through the California Department of Agriculture's Healthy Soils Initiative.[107] The degree to which California forests operate as a sink and source) is influenced by land management, by range of forest health issues (e.g., growth, tree mortality from drought, pest and disease outbreaks, wildfire, other agents of disturbance), and weather. In recent years, the prolonged drought conditions have resulted in elevated tree mortality that is widespread across the southern Sierra.[108] When combined with extensive wildfires, the capacity for forests to store carbon could be diminished. For all forestlands, improving forest health and managing to reduce losses from mortality can greatly increase and protect the carbon balance on forestlands. On commercial and other actively managed forestlands in California, efficient uses of long lasting wood products and residues for energy can yield GHG benefits.

6.2.1 Ownership Patterns

California's forestland is divided between private and public ownership (see Table 5 and Figure 6). The federal government manages 58 percent of these lands, with the remaining areas under state and local government (3.4 percent) and private management (39 percent). Despite the challenges diverse landowners introduce, coordination among state agencies, private landowners, and federal agencies is essential to the success of a comprehensive forest climate strategy in California. Culture and mission differences are embedded within government institutions, private organizations, and individual landowners, making coordination and cooperation a challenge at times. Practical and political strategies should openly address these different objectives and the capacities of different forest landowner and land management agencies to better take advantage of the opportunities inherent in diversity. Box 4 presents one example of a proposed effort among the Tahoe-Central Sierra region's public agencies, the private sector, and key stakeholder groups. Other examples of efforts include Collaborative Forest Landscape Restoration Program[109] efforts such as Dinkey Creek[110] or Burney-Hat Creek[111]

The proportions of forest in public or private ownership in California have not changed substantially over the past several decades and the extent of forestland has remained stable. Use and management can differ across any given ownership type. Of the estimated 32 million acres of forestland, approximately 17 million acres are timberland[112]. Unreserved forestland makes up an estimated 69 percent of public forest, with the remaining 31 percent in reserved status unavailable for timber harvest.

[107] California Department of Food and Agriculture, 2016
[108] Potter, 2016
[109] www.fs.fed.us/restoration/CFLRP/
[110] https://www.fs.fed.us/restoration/documents/cflrp/2015AnnualReports/Dinkey.pdf
[111] https://www.fs.fed.us/restoration/documents/cflrp/2015AnnualReports/BurneyHatCreekBasinsProject.pdf
[112] 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.

Table 5. Forestland Area by Land Status and Ownership Group, California 2005-2014

	Ownership group						
	National forest	BLM	NPS	Other federal	State and local govt.	Private	Total
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	8,894	310			141	7,258	16,616
Other unreserved forest land	2,516	941		105	170	5,190	8,994
Total, unreserved	11,410	1,251		105	311	12,448	25,610
Reserved forest land:							
Reserved productive forest land	2,791	50	981		330	--	4,155
Other reserved forest land	1,196	211	452	14	458	--	2,336
Total, reserved forest land	3,987	261	1,433	14	788	--	6,492
Total, forest land	15,397	1,512	1,433	119	1,099	12,448	32,102

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data.

How a forest is used and managed, not just ownership type, ultimately impact forest health and resilience. Forests in which trees are harvested regularly are referred to as working forests. California's forested landscape consists of a mosaic of land uses including working forests, conservation reserves, and those associated with human-dominated uses. These landscapes function at multiple scales to provide ecosystem services, such as carbon sequestration, aesthetic resources, recreational opportunities, wildlife habitat, and water quantity and quality. Forested landscapes may also provide economic opportunities to residents and others who participate in timber harvesting and production and who provide recreation- or tourism-related services. Increasingly, forests have been used for illegal marijuana production, which brings loss of habitat, instream water quality and quantity impacts, and chemical contamination to our forests.[113] Conversion of forest to vineyards also has been occurring and at times created localized controversy. Timber harvest volume has generally declined since the mid- to late-1980s, but has been trending upward in the last five years, from 1.3 billion board feet in 2011 to 1.6 billion board feet in 2015[114], or a 24% increase.

[113] California Department of Fish and Wildlife, 2015
[114] California State Board of Equalization, 2016

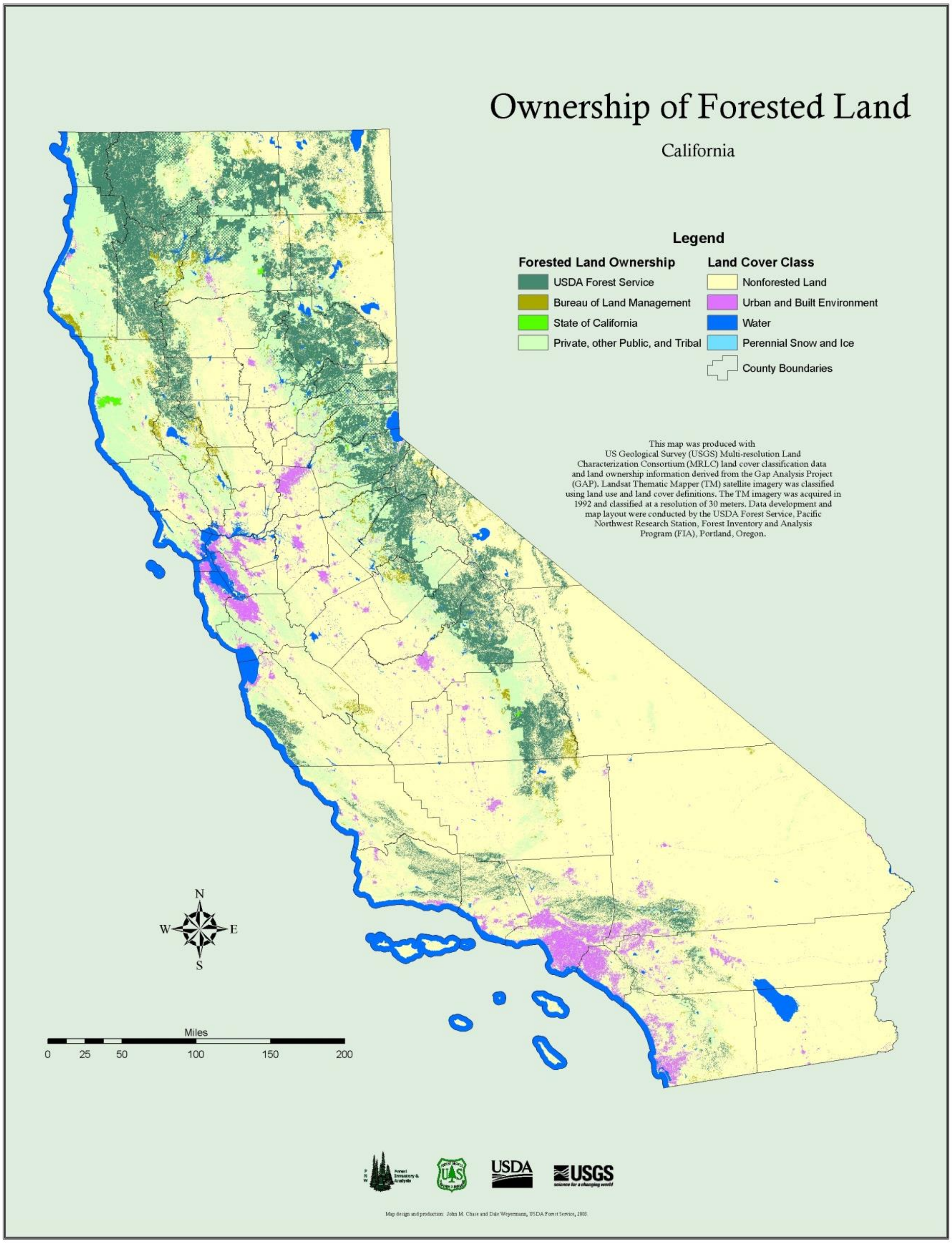


Figure 6. Ownership of Forested Land in California
Source: USDA Forest Service, 2016

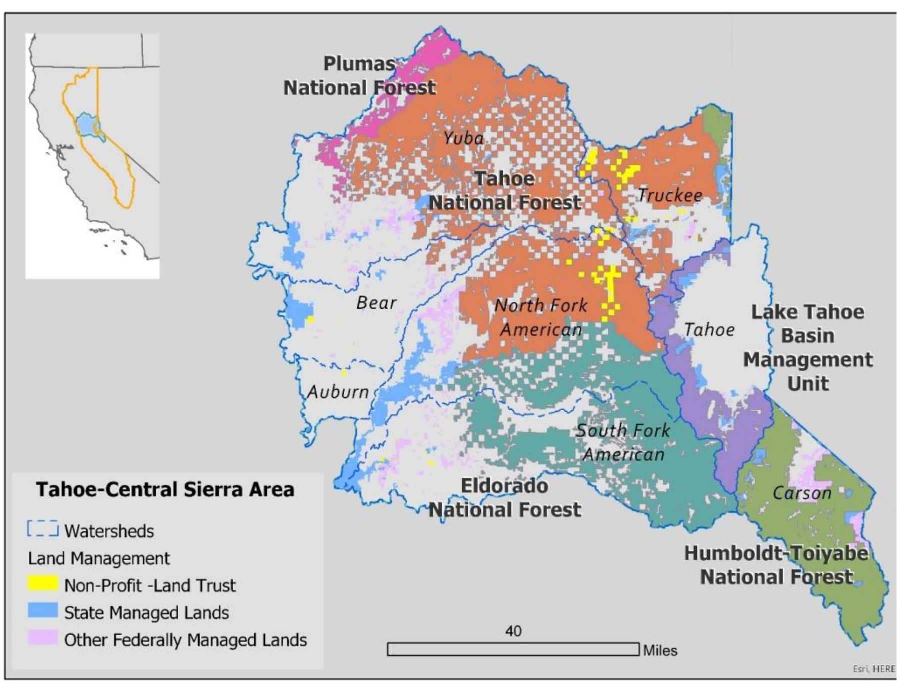
Box 4: Large Landscape Collaborative – The Tahoe-Central Sierra Initiative

Building upon the activities of the California Governor's Tree Mortality Task Force and several large-scale regional efforts, the Sierra Nevada and Tahoe Conservancies, in partnership with the USDA Forest Service, are proposing a Tahoe-Central Sierra Initiative. The planning landscape is comprised of the Lake Tahoe Basin and the watersheds of the American, Bear, Yuba, Carson, and Truckee Rivers. Although tree mortality and other drought impacts have been much more severe, to date, in the southern Sierra, the central Sierra and the Lake Tahoe Basin are also likely to face devastating impacts without an aggressive coordinated effort among the region's public agencies, the private sector, and key stakeholder groups. Further, it is possible that a robust forest health program in the central Sierra will help in preventing, or at least slowing, the effects of the pine bark beetle.

The Tahoe-Central Sierra Initiative will seek to accelerate implementation of large landscape forest health projects and the development of biomass utilization infrastructure, while providing the opportunity to explore innovative process, investment, and governance tools. The initiative is a key component of the Sierra Nevada Watershed Improvement Program, a collaborative effort led by the State's Sierra Nevada Conservancy and the USDA Forest Service. The Tahoe-Central Sierra Initiative's objectives will be achieved through the following goals and activities:

- Supporting, developing and implementing science-based large landscape projects with integrated design, implementation and monitoring;
- Accelerating planning, permitting and implementation of high priority projects;
- Increasing and leveraging federal, state, local, and private funding;
- Integrating research and monitoring into activities to guide creation of fire and climate resilient forests and fire–adapted communities across ownerships;
- Developing a regional biomass utilization strategy to improve air quality, reduce GHG emissions, and offset forest restoration costs;
- In concert with existing efforts, establishing a regional, science-based, conservation planning and implementation framework;
- Developing a collaborative communications network which will share and amplify messages about successes, needs, lessons learned, and opportunities to duplicate innovative pilot approaches in other locations;
- Developing a strong relationship between this landscape and nearby urban areas so that downstream stakeholders can see firsthand the impact of restoration activities in their upstream headwaters; and
- Exploring a pilot to demonstrate the possibility of successful private investment in headwaters restoration to yield an improvement in ecological services for investors.

To learn more, visit: www.restorethesierra.org



6.2.2 Climate Impacts on Forest Health

Climate is a primary driver of the dynamics of forest and range ecosystems, especially the type, species, and productivity (including rates of carbon sequestration) of species. Future climate change scenarios predict increases in temperature, increases in atmospheric carbon dioxide concentrations and changes in the amount, form, and distribution of precipitation.[115] Altering these fundamental climate variables will result in changes in tree growth, in the range and distribution of species, and in disturbance regimes (e.g., wildfires, outbreaks of pests, invasive species). Relatively small changes in temperature and precipitation can affect reforestation success, growth, susceptibility to pests, and forest productivity. However, restoring forests to healthier and more resilient conditions will reduce their vulnerability to these changes.

Historically, forests in California experienced periods of drought and temperature changes over the centuries and were in general resilient to these changes. As climate change impacts unfold over the next few decades, the forest structure and health of today's forests are already significantly altered from historic conditions. As a result, scientists are concluding that California forests as they currently are will not be as successful in absorbing these changes as they once did.

Given the long lifespan of trees in a forest stand, from decades to hundreds of years, the effects of climate change on disturbance regimes may become apparent prior to noticeable changes in forest species composition. These include changes in the timing, frequency and magnitude of wildfires, pest infestations, and other agents of disturbance.[116] While disturbances occur regularly in these ecosystems, large changes in the patterns of disturbance could make forests less resilient, especially in unhealthy stands already under significant stress from competition. Vegetation types with restricted ranges may be more vulnerable than others and are already under stress from land use changes (i.e., expanding wildland urban interface) and management.[117] Similarly, existing forest stands may not demonstrate significant impacts from effects of climate change, but forests recovering from a high severity event may have difficulty reestablishing.

The influence that climate has on disturbance regimes is already affecting forests. Until recently, much of California was in the fifth year of a severe drought; significant portions of the state remain in a significant drought condition. Recent research has demonstrated that up to 27 percent of this drought can be ascribed to climate change-driven warming.[118] The ongoing drought in California is making many forests less resilient to wildfire and more susceptible to bark beetles, especially overgrown forests that have missed multiple natural fire cycles. In a cyclical fashion, increased beetle activity from climate change leaves behind greater tree mortality, which in turn contributes to more severe wildfires while in the red needle phase, but 3-5 years post outbreak are less flammable than green needle trees.[119] Additionally, low severity fire has been shown to increase production of tree defenses against bark beetles, which then wanes if fire is absent too long, leaving the trees more vulnerable to attack.[120]

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[115] Dale et al., 2001
[116] Dale et al., 2001
[117] Foster, 2003
[118] Williams et al., 2015
[119] Simard et al., 2010
[120] Hood et al., 2015

Extended drought and earlier snowmelt may become the new norm, as southern California is expected to see conditions up to 30 percent drier and one to two degrees Fahrenheit hotter than historical norms in the next 15 years.[121] Additionally, increasing temperatures and decreasing precipitation caused by climate change contribute to dry and hot conditions favorable for wildfires and will therefore continue to increase the risk for wildfire beyond what California faces today. Fire seasons in the U.S. west have already increased by 78 days since the mid-1980s[122], so greater increases in the length of fire seasons in coming years are likely. In the U.S. southwest, human-caused changes to forest structure also are primary contributors to the recent growth in wildfire activity[123].

As discussed above in Section 2.2.3, tree growth and carbon sequestration rates are stunted during drought periods. The findings reported above have important implications for the benefits of forest treatments on the resiliency of forest carbon sinks in times of drought.

6.2.3 Insects and Diseases

Native insects and diseases are an integral part of California's forests and provide important ecosystem functions. Most are host specific, only attacking one or a few closely related tree species. At endemic levels, insects and diseases and the dead trees they leave behind provide food or habitat for wildlife, recycle nutrients within the environment, thin over-stocked stands, create essential snags and forest openings and help maintain forest diversity.

Non-native insect and disease pests (also called exotics or invasive species) can cause great harm to forests. Trees often lack natural resistance to these pests with which they have not co-evolved and many such pests have large host ranges. They can impact the environment by causing local or widespread species extinctions, displacing native species, altering forest fire behavior or increasing tree mortality above expected background levels.

Some insects and diseases are found at varying levels throughout California while others are found predominantly in specific regions of the state. Table 9 lists the major pest in the state.

[121] Krist Jr. et al., 2014
[122] Westerling et al., 2006
[123] Westerling, 2016

Table 6. Major California Forest Pests.

ECOREGION	NATIVE PESTS	EXOTIC PESTS
Eastside	Bark Beetles, Root Disease	Satin Moth
Sierra Nevada and Cascade Range	Bark Beetles, Root Disease, Dwarf Mistletoes	White Pine Blister Rust
Klamath and Interior Coast Range	Bark Beetles, Root Disease, Defoliator Insects	Port Orford Root Disease, White Pine Blister Rust
North Coast	Bark Beetles, Root Disease, Animal Damage	Sudden Oak Death
Central Coast and Interior Ranges	Bark Beetles, Root Disease, Foliar Diseases	Sudden Oak Death, Pitch Canker Disease
South Coast and Mountains	Bark Beetles, Defoliator Insects, Root Disease, Air Pollution	Gold Spotted Oak Borer, Polyphagous Shot Hole Borer, Kuroshio Shot Hole Borer

Source: CAL FIRE Pest Management Program Staff.

To recap from above, per the USDA Forest Service's National Insect and Disease Forest Risk Assessment, 2013-2027[124] , California is at risk of losing at least 25 percent of standing live forest due to insects and disease, over 5.7 million acres, or 12 percent, of the total forested area in the state. Some species are expected to lose significant amounts of their total basal area (i.e., whitebark pine is projected to lose 60 percent of basal area, while lodgepole pine is projected to lose 40 percent). While future climate change is not modeled within the risk assessment, and current drought conditions are not accounted for in these estimates, the projected climate changes over the next 15 years are expected to significantly increase the number of acres at risk from already highly destructive species such as mountain pine beetle.

Sudden oak death, a disease caused by the non-native *Phytophthora ramorum*, has been found in California since the mid-1990s. It has a host range of over one hundred species but is most damaging and deadly to tanoaks and true oaks. Three to four million trees have been killed by the disease in the central and northern coastal regions of the state to date. The mortality has resulted in changes in stand species compositions, reduced mast production for wildlife, loss of cultural heritage and traditions for Native American tribes in the area, and an increased fire danger due to increased fuel loads. In particular, redwood tree mortality has been found to increase during wildfires in areas with high sudden oak death mortality of tanoaks.[125]

A warming and drying climate may have several impacts upon sudden oak death disease. The disease may spread more slowly since it requires humid and wet conditions for infection. However, when conditions do occur for infection, mortality may increase due to the greater stress of a hotter and drier climate. Long-term changes in stand structure and composition due to the combination of the disease and a changing climate are uncertain.

Native bark beetles are currently causing high levels of tree mortality in California. When, where, and the extent to which mortality occurs is primarily influenced by forest stand and drought conditions. A dramatic rise in the number of trees killed by bark beetles follows one to several years of drought: the

[124] Krist Jr. et al., 2014
[125] Metz et al., 2013

more severe and prolonged the drought, the greater number of dead trees. Dense groups of trees are particularly susceptible to bark beetle attacks due to stress caused by competition for limited resources, and stressed trees equate to suitable host material for bark beetles and successful reproduction results in more beetles and higher levels of tree mortality.[126] A number of other factors in overly dense stands increase the damage bark beetles can inflict. Dense stands have decreased airflow, allowing successful attack pheromones to remain in the air for longer, attracting more beetles to join in the attack[127]. Stands with similar species closer together are within easier reach to bark beetles, compared to a more open stand with a more diverse species makeup[128]. Large trees are preferred by bark beetles and where large trees are surrounded by smaller trees, bark beetles are able to launch more attacks on the larger tree, draining its defenses to the point that the attacks eventually become successful[129].

Tree mortality is on the rise in California (Figure 7, Box 5). In response to the very high levels of tree mortality concentrated in the Sierra Nevada, Governor Edmund G. Brown Jr. issued an emergency proclamation on October 30, 2015.[130] Under authority provided under the 2013 Farm Bill, the Secretary of Agriculture and the Chief of the USDA Forest Service as of late 2015 had designated 6.7 million acres of National Forest System Lands in California as insect- and disease-threatened. For certain collaborative projects less than 3,000 acres in size, this designation can provide a streamlining of National Environmental Policy Act planning processes.

There is usually a lag time between drought years and tree mortality, and the recent sharp rise in mortality reflects the cumulative impacts of the past four years of drought. Field data from the USDA Forest Service State and Private Forestry Aerial Detection Surveys in 2016 show elevated tree mortality associated with bark beetles primarily in the southern Sierra Nevada and in southern California mountains[131][132]. As shown in Figure 7, tree mortality has also increased significantly in the northern Sierra Nevada from 2015 to 2016. High-level statistics from the Forest Service Aerial Detection Survey underscore the extent of the recent die-off:

- At least 102 million dead trees are associated with severe drought (see Figure 7), bark beetles, warmer temperatures change, based on 2010 to August 2016 surveys.
- From 2015 to August 2016 alone, 62 million trees have died, not including trees that died in fires, such as the Soberanes Fire.
- 7.7 million acres (2016) with some level of drought related tree mortality were mapped in California, starkly higher compared to about 871,220 acres in 2014.

[126] USDA Forest Service, 2016f
[127] Fettig & Hilszczański, 2015
[128] Fettig & Hilszczański, 2015
[129] North, Hurteau, & Innes, 2009
[130] Brown, 2015
[131] Information available from Forest Service website: http://www.fs.usda.gov/main/catreemortality/home
[132] More recently there are reports from the field that increasing tree mortality also is being seen further north in the Sierra Nevada mountains.

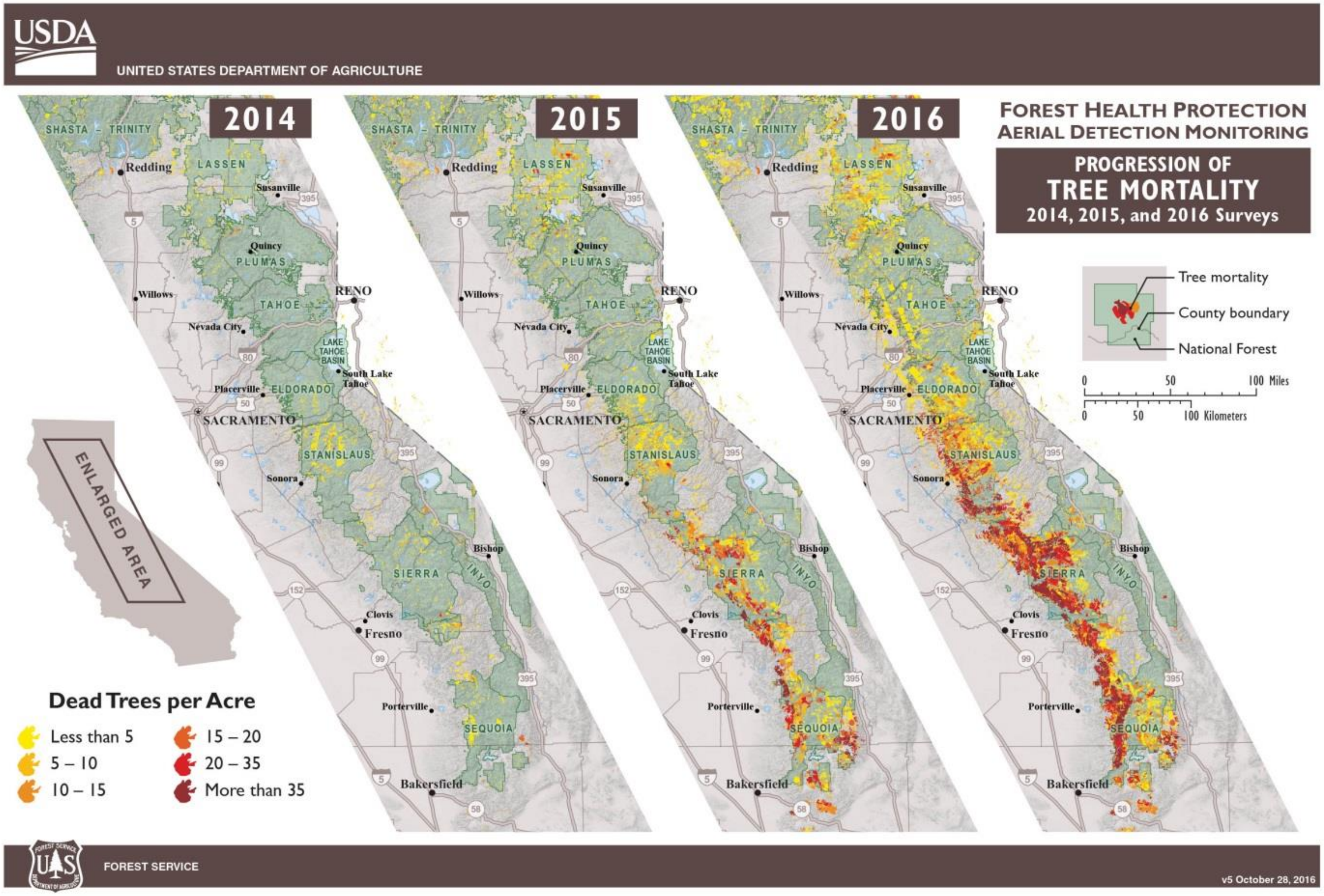

Figure 7. Progression of Tree Mortality in the Sierra Nevada, 2014-2016.

Source: USDA Forest Service, 2016

Box 5: Tree Mortality and Carbon – Southern Sierra

Tree mortality in California has reached previously unseen levels, with 62 million trees dying in 2016 from disease, bark beetle, and drought, not including trees killed by fire. Of the recorded non-fire tree mortality, over 50 million were in the forests of the southern Sierra Nevada. From a carbon perspective, this represents 50 million trees that are no longer pulling carbon from the atmosphere but instead will release their carbon back to the atmosphere. Adding to the dead pool, the carbon in these trees will slowly decay over the next few decades, be quickly released in future fire events, or be used in in a biomass industry. The timing and form (e.g., carbon dioxide, methane, black or brown carbon) of these trees' carbon emissions will have major implications for California's climate forcing emissions and air quality.

There remain significant gaps in our understanding of the sizes of trees that have died, although larger trees are preferred by bark beetles, therefore it is difficult to make accurate estimates of the amount of carbon that has transitioned from the aboveground live to aboveground dead carbon pools. Further refinement, discussion, and data are needed to better understand the carbon consequences of this year's mortality. Tree mortality and aboveground live carbon that has transitioned to the dead pool in 2016 is estimated by southern Sierra Nevada county, below.

County	Number of Dead Trees	Metric tons of carbon	Metric tons of CO2e
Placer	574,000	150,000	500,000
El Dorado	1.4 million	350,000	1,400,000
Amador	665,000	200,000	700,000
Calaveras	1.8 million	500,000	1,800,000
Tuolumne	6.1 million	1.6 million	6 million
Mariposa	6.7 million	1.8 million	6.5 million
Madera	8.8 million	2.5 million	9 million
Fresno	12.1 million	3.4 million	12.5 million
Tulare	13.2 million	3.7 million	13.4 million
Total	51 million	14.2 million	51.8 million

The tree mortality in unhealthy forests in 2016 has resulted in over 50 million metric tons of CO2e changing to the dead pool, or the equivalent of adding 11 million internal combustion engine cars to California roads. This recent tree mortality adds to unstable dead carbon pool that has been building this decade, with over 100 million trees dying since 2010, before factoring in trees killed by fire.

6.3 Forest Carbon Storage Dynamics

California's forests currently have higher densities of small trees and fewer large trees on the landscape overall compared to historic forest conditions.[133, 134, 135] These conditions have detrimental implications for both the resilience of the forest and quality of the forest as a carbon sink. In dense stands, competition for scarce resources can stunt individual tree growth rates, and therefore, sequestration rates. Stands that have reduced tree competition, achieved by fire or mechanical treatment, can experience greater growth rates in the live trees that remain,[136] allowing carbon sequestration rates to continue increasing over time. Under stressful conditions, such as drought, overly dense stands can stunt their growth and take years to recover once the drought subsides, while healthier stands may continue sequestering carbon across those years.[137,138]

Large trees store and sequester more carbon than small trees.[139] One large, old sugar pine tree, approximately 300 years old, stores as much carbon as 175 younger, 30-year-old white fir (Figure 8). Large trees also contribute the greatest amount of carbon sequestration on an annual basis in California, as shown in Table 7, while smaller trees are a net negative. In dense forest stands, large trees are more vulnerable to forests pest and drought, causing larger trees to experience higher-than-expected levels of mortality.[140] The mortality of large trees causes significant carbon to shift from live to dead pools, along with a significant drop in annual sequestration rates. While this shift may not cause noticeable changes in the total amount of forest carbon,[141] more of the carbon pool is shifted into dead material which is unstable, and the overall sequestration rate of the stand slows and may be negated by emissions from increased decay over time. If the dead pool emissions exceed carbon sequestration, the forest becomes a net source of GHGs to the atmosphere, contributing to California's overall emissions totals on an annual basis.

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[133] Stephens et al., 2015
[134] North, Hurteau, & Innes, 2009
[135] North, 2012b
[136] Stephenson et al., 2014
[137] Dore et al., 2012
[138] Anderegg et al., 2015
[139] Stepheson et al., 2014
[140] North, Hurteau, & Innes, 2009
[141] Wiechmann et al., 2015a

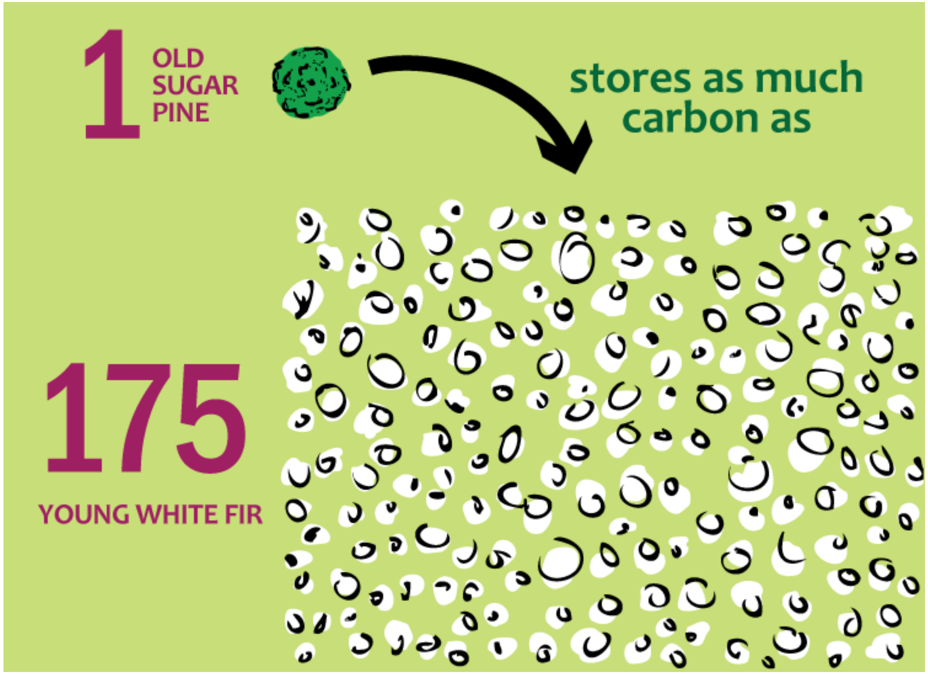

Figure 8. The Value of Old, Large Trees Demonstrated by the Difference in Carbon Stored in Young and Old Trees.

Figure 8 compares sugar pine to white fir because that was what was measured in the field, but it demonstrates a broader point of the importance of protecting the remaining old growth trees – replacing the carbon lost if they are lost will take decades or more.

Table 7. Average Annual Net Growth of Live Trees (at least 5 inches diameter breast height.), in CA Forests (cubic feet).

	Stand-size class			
Total	**Large diameter**	**Medium diameter**	**Small diameter**	**Nonstocked**
1,149,947,522	1,177,959,761	91,198,719	-24,051,891	-95,559,126

Source: USDA Forest Service FIA – November 22, 2016 update[142]

The carbon benefits from treatments that promote growth and retention of larger trees include increased sequestration rates, more stable carbon storage, and decreased risk from the growing threats of climate change. The recent tree mortality from drought and bark beetle highlights the benefits of fuel treatments even in the absence of wildfire as stands that were treated prior to the drought are showing significantly less mortality than adjacent untreated stands.

Wildfire burned area and severity has been increasing in recent decades[143,144] and is expected to continue to rise as California forests become warmer and receive less snowfall over the course of this century[145]. At present, the statistical likelihood that a treatment will have an impact on the size and

[142] Christensen, 2016
[143] Miller & Safford, 2012
[144] California Department of Forestry and Fire Protection, 2016e
[145] Westerling et al., 2011

severity of wildfire is roughly one-half to one percent annually in dry, frequent fire adapted conifer forests[146] and this intersecting probability will continue to grow as both burned area and treated areas increase over time. While these likelihoods appear relatively low, the benefits of stand manipulations emphasizing carbon sequestration on long-lived large trees persist even in the absence of wildfire, and likely include increased resilience to non-wildfire disturbance losses (e.g., forest pests).[147][148] It is important to note that doing one-off treatments is not sufficient for mitigating the impacts of wildfire, particularly in stands dense with smaller trees. Repetition and maintenance of that fuels treatment is necessary to maintain the reduced fire risk.[149] Optimally, treated acreage would increase in a coordinated, fashion across the landscape, thus increasing the effectiveness of each treatment activity, highlighting the need to work across ownership boundaries to most effectively and efficiently implement these projects. One current example of this collaboration is the Amador-Calaveras Consensus Group.[150] For more discussion of landscape-level collaboration, please see Section 4.

Although treatments result in short-term forest carbon losses through biomass removal, studies have shown that carbon can quickly be recovered to pre-treatment levels if large, fire-tolerant overstory trees are not removed in large quantities.[151, 152, 153, 154] This result is due to the fact that the treatment frees up critical resources, leading to increased growth rates in the trees that remain. This effect is amplified if the remaining trees are larger trees, which sequester carbon at a faster rate than smaller trees.[155] Treatments also reduce the impact of future stress events on the remaining trees, allowing them to continue to sequester and grow. The net result is that, within a decade or two, the larger, more resilient remaining trees and other forest carbon pools (e.g., soils) will contain the carbon lost due to the treatment removal of smaller trees and material and the stand will be growing faster than if the treatment had not occurred.[156]

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[146] Martinson & Omi, 2013
[147] Hurteau & North, 2010
[148] Van Mantgem et al., 2016
[149] Restaino and Peterson, 2013
[150] Amador-Calaveras Consensus Group, 2016. See more: http://acconsensus.org/.
[151] Dore et al., 2012
[152] Wiechmann et al., 2015a
[153] Stephens et al., 2009
[154] Hurteau & North, 2010
[155] Stephenson et al., 2014
[156] Battles et al., 2015

6.3.1 California Forest Carbon Inventory

The carbon contained in a forest represents the accumulated carbon dioxide uptake and carbon sequestration in woody tissues and soils. The difference in the amount of biomass contained in a forest between two points in time represents the overall change in in-forest carbon stocks resulting from growth, mortality, harvest or other disturbances over time.

In this report, we rely primarily on FIA data for forest carbon statistics. These statistics have limitations, in that much of the FIA-based data available for analysis at this time does not fully reflect dramatic forest changes witnessed in recent years, in particular in the Sierra Nevada and Cascades. Uncharacteristic large, severe wildfire and unprecedented tree mortality has occurred during this period, resulting in significant changes that will not be fully reflected in the FIA data for a number of years, given the ten-year collection cycle currently in place.

As detailed below, data from the FIA Program was used to evaluate changes in biomass on private, state, and local ownership between 1991 and 1994 and 2007 and 2010, finding a net gain of 1.7 million metric tons (MMT) carbon per year.[157] Similar data was used to evaluate National Forest System Lands between 2001 and 2006, and between 2007 and 2010, finding a net gain of 0.89 MMT carbon per year.

Although a net gain was shown, it should be noted that much of the data used for this evaluation were collected before California's current elevated tree mortality episode began, and recent research suggests that, during the drought, forest carbon stocks are destabilized, and that drought induced beetle mortality can transfer large portions of live above-ground carbon into the dead biomass pool that then serves as a protracted emission source due to decay[158].

The following information on carbon storage in forests is based primarily on FIA Program data for California, which is collected by the FIA Program. Sources and methods meet Intergovernmental Panel on Climate Change guidelines for GHG inventory, and FIA Program products are used to fulfill federal national and international reporting obligations. This section provides summaries of estimates for carbon stocks in above- and below-ground carbon pools. Estimates for above-ground forest carbon include live trees, understory vegetation, down woody material and standing dead trees. Below-ground carbon pools include live and dead roots, and soil organic carbon. Carbon contained in wood products is also presented, based on results from McIver et al. (2015) and others.[159]

ARB also conducts periodic forest carbon accounting, using a mix of information resources including FIA data to inform its Natural and Working Lands Inventory. One way in which the ARB method differs from FIA data is that it also seeks to account for land carbon stocks and stock-change for nearly forty IPCC reporting categories associated with forests and other lands, as well as emissions of GHG and black carbon from disturbance events. This approach provides additional information that is not captured as a part of the stock-based FIA approach that is relied upon on this section. In this way, an FIA-only inventory is more concerned with forest conditions, growth, and mortality and if forest carbon is gained or lost, while the ARB approach is also interested in *how* it was gained or lost, which affects air quality and emission rates for GHGs, black carbon, and the exchange of carbon with the atmosphere (see Figures 9 and 10). Further discussion of various forest carbon inventory approaches are discussed in Appendix 1.

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[157] Christensen et al., 2016
[158] Earles et al. , 2014
[159] McIver et al., 2015

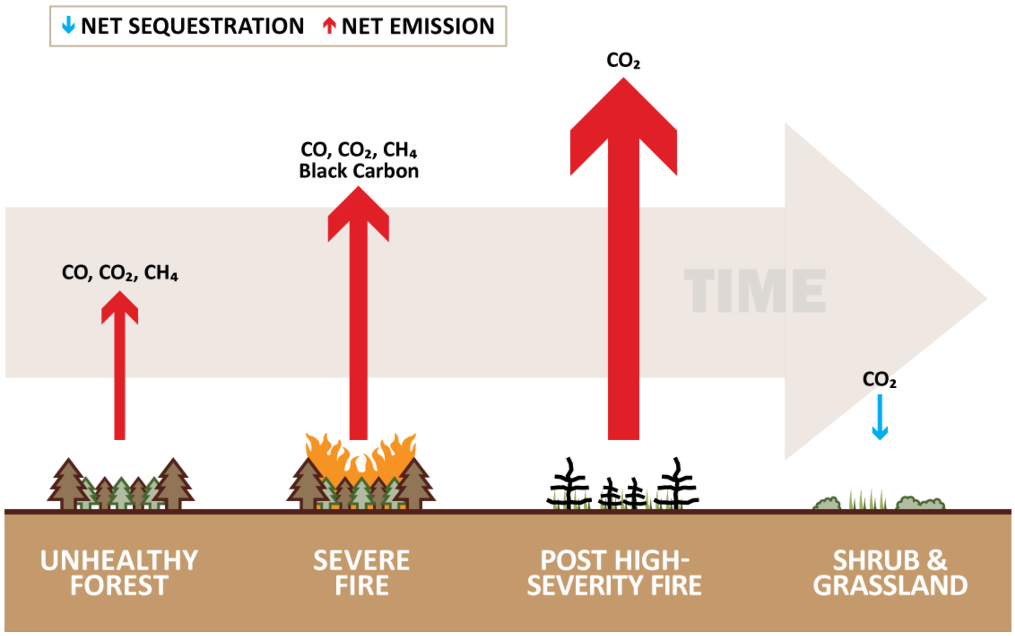


Figure 9. GHG Release and Absorption by Unhealthy Forests with Fire.
The size of the arrows represent the relative quantity of those GHGs released, but the time arrow is not linear (e.g. emissions associated with severe fire may last a few months but the decay in post high-severity fire stands may occur over decades).

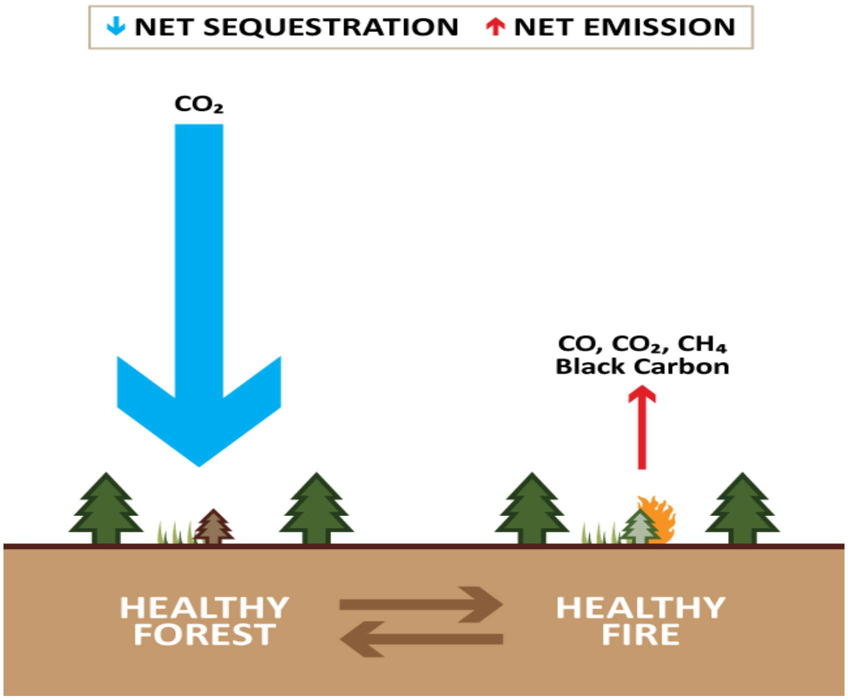


Figure 10. GHG Release and Absorption by Healthy Forests with Fire.
Healthy forests experience tree mortality and fire, but do so at a smaller scale. With carbon focused in the larger trees, sequestration rates are large and emissions from healthy fire are small comparatively. This represents a cycle.

In the 2016 Legislative session, Senate Bill 859 (Dahle, Chapter 368, Statutes of 2016)[160] was passed and signed into law. SB 859 directs ARB, in consultation with CNRA and CAL FIRE, to complete a standardized GHG inventory for natural and working lands, including forestlands, by the end of 2018. The bill also requires the state to provide a business-as-usual projection of emissions and carbon sequestration. While the Forest Carbon Plan uses the Forest Inventory and Analysis stock change data as its major information source on forest carbon, when completed, the new ARB-led inventory will serve as a useful data source going forward since it will address stocks, stock-change with attribution by process, and emissions.

Overall Carbon Inventory Statistics

California forest lands store and sequester carbon in above and below ground carbon pools. According to data from the FIA Program covering 2005-2014[161], California forests have substantial carbon storage of 1.29 billion MT carbon above ground and 873 MMT of carbon below ground (Table 8 and Figure 11), while sequestering 2.6 MMT carbon per year among private and public lands. See Appendix 1 for additional information on FIA Program data by ecological regions.

Table 8. Above- and Below- Ground Forest Carbon, 2014 (excludes harvested wood products; units in 1,000 metric tons of Carbon).

Owner	Above Ground	Below Ground	Total
USDA Forest Service:	688,308	438,442	1,126,750
Other federal government:	112,787	79,375	192,163
Local	13,352	9,141	22,492
State	47,196	22,483	69,679
Other public	457	524	981
Private Corporate Forestland	194,149	141,595	335,744
Non-corporate private:	234,143	181,322	415,465
All owners	1,290,391	872,882	2,163,273

Source: USDA Forest Service FIA – November 22, 2016 update[162]

Above ground includes: live tree, above ground dead tree, down wood, and aboveground understory vegetation. Belowground includes: Below ground live and dead tree roots, below ground understory roots, and soil organic carbon. Excludes harvested wood products.

[160] Dahle, 2016
[161] Christensen, 2016
[162] Christensen, 2016

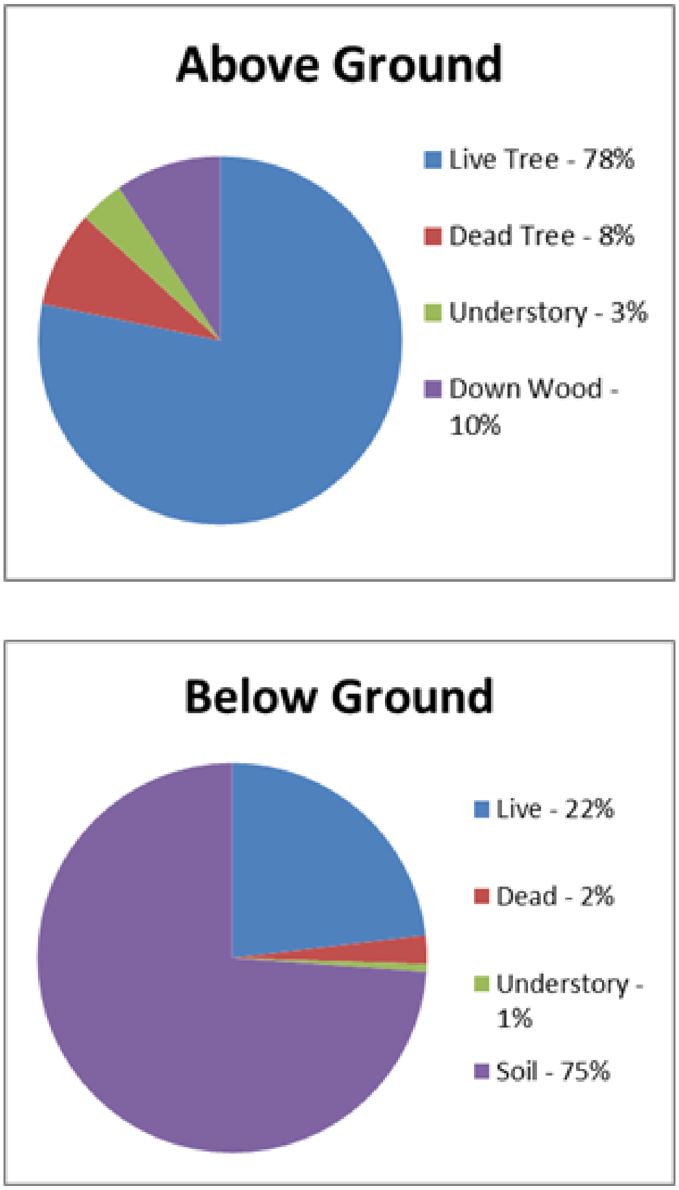


Figure 11. Above and Below Ground Forest Carbon, 2014.[163]

Above-ground carbon is stored predominantly in live tree carbon pools, which represent 78 percent of the above-ground carbon. The understory vegetation (three percent), dead standing vegetation (eight percent) and down woody material (ten percent) make up the remaining fraction. Soil organic carbon is the largest storage component (seventy-five percent) of the below-ground carbon pool, followed by below-ground live (twenty-two percent) and below-ground dead tree material (two percent) and belowground dead understory roots (one percent).

[163] Christensen, 2016

6.3.2 Carbon Storage by Forest Types

California possesses a great diversity of forest types, each with unique characteristics and responses to climate conditions. The FIA Program database reveals which forest types contain the greatest amount of carbon in the aggregate and on a per-acre basis (Figure 12). Estimated from FIA Program data (2005 to 2014), forest types that store the largest total amounts of carbon are the California mixed conifer group and the western oak group, reflecting the areal extent of these types. On a per-acre basis, for fully occupied stands, forest types with higher levels of live tree carbon density include: redwood (101.6 tons carbon per acre); Douglas-fir (70.1 tons per acre); fir, spruce and mountain hemlock (72.8 tons per acre); California mixed conifer group (66.4 tons per acre); tanoak and laurel (54.5 tons per acre); and alder and maple (51 tons per acre).

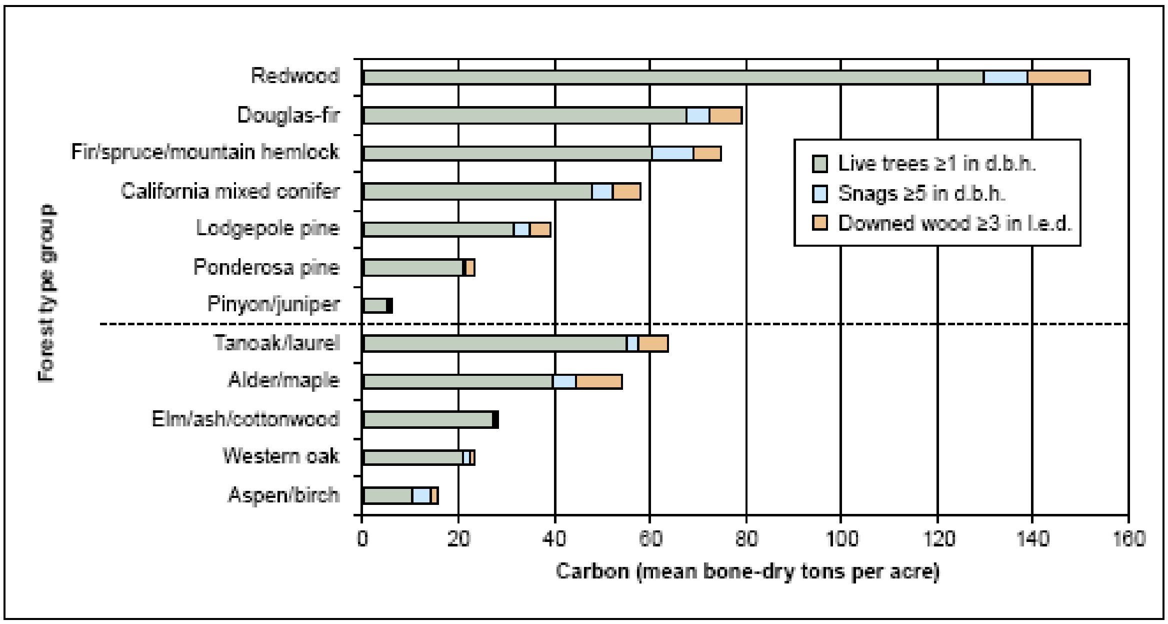


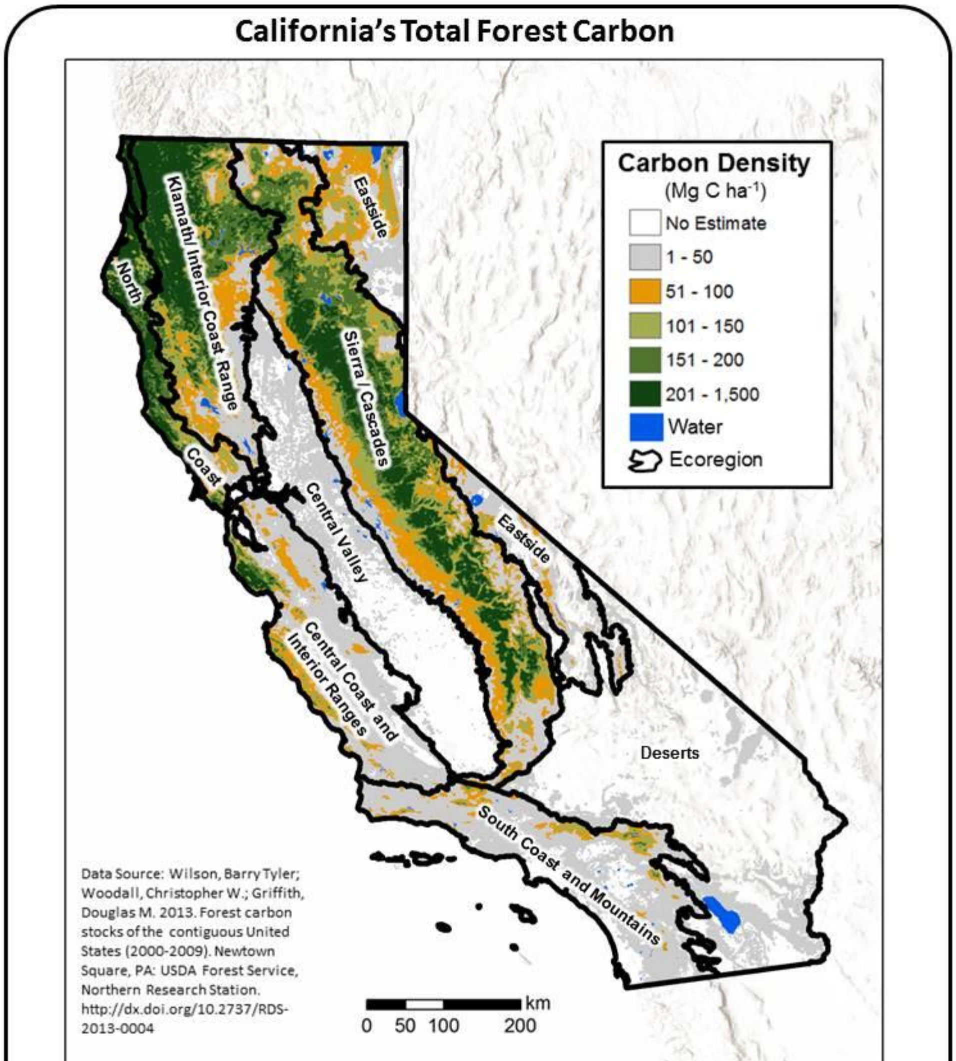
Figure 12. Estimates of Carbon Storage by Forest Trees in California.
Source: Christensen et al., 2008

6.3.3 Carbon in Forests – Regional Patterns

The redwood and Douglas-fir forests concentrated in the North Coast and Klamath interior coast range ecoregions contain the highest forest carbon densities in the state (Figure 13). Redwood trees, compared to other large conifers, are largely resistant to native insects and diseases allowing them to be reliable and secure places for long-term carbon storage. The Sierra-Cascades ecoregion contains several large conifer species, which include ponderosa pine, sugar pine, Douglas-fir, incense cedar, white fir and giant sequoia. This region also contains one of the largest reserves of carbon in California forests, but is susceptible to several native insects and diseases such as the mountain pine beetle, fir engraver, white pine blister rust and dwarf mistletoe, particularly where fire has been suppressed from the forests for decades. As detailed earlier, over the past several years, drought stress combined with unhealthy forest conditions and bark beetles has killed millions of trees in the southern Sierra Nevada. These areas and other areas in the region that have been devastated by high severity fire are at strong risk to type-convert, where conditions are such that the forest may not be able to regrow and instead shrub or grassland would result. Conversion to shrub or grassland would have a significant impact on California's future carbon storage, since these land types contain 10% or less carbon per acre than forested acres.[164] The forests and woodlands of the Central and South Coast Regions, which are comprised of several oak species such as coast live oak and blue oak along with smaller and shorter lived conifers such as Monterey pine, bishop pine and knob cone pine, generally contain lower forest carbon density than the Sierra. These pine species tend to have shorter lifespans than those in the Sierra and have adapted to higher severity stand replacement fire with serotinous cones. Some longer-living conifer species (e.g., redwood and Douglas-fir) are also present in this area in smaller numbers as well. Further regional inventory information can be found in Table 9.

Regional variation in the state's forests is discussed in more depth in Appendix 3, "Regional Assessments."

[164] Gonzalez et al., 2015



	Ecoregion Area (km²)							
Mg C ha⁻¹	Sierras/ Casacade	Central Valley	North Coast	Klamath/ Interior Coast Ranges	Central Coast and Interior Ranges	South Coast and Mountains	Deserts	Eastside
No Estimate	2,926	43,248	879	1,193	11,500	19,711	85,170	15,297
1-50	18,695	5,541	2,177	8,897	19,075	17,944	6,935	11,760
51-100	18,331	120	13,962	6,854	4,235	2,693	21	7,485
101-150	14,417	1	1,946	5,999	1,543	900	0	2,897
151-200	16,002	0	3,548	9,145	831	368	0	403
201-1500	16,435	0	6,292	13,952	937	9	0	61

Figure 13. Total forest carbon density for California (2000 to 2009) from FIA. includes live tree above-ground forest carbon, live tree below-ground forest carbon, forest down dead carbon, forest litter carbon, forest standing dead carbon, forest soil organic carbon, and forest understory carbon.

Table 9. Above and Below Ground Forest Carbon by Region, 2014 *(units = 1,000 metric tons of carbon).*

Ecological Regions	Above-Ground	Below-Ground	Total
Central Coast and Interior Ranges	64,208	44,939	109,147
Central Valley	1,757	2,507	4,264
Eastside	41,574	66,459	108,033
Klamath/Interior Coast Ranges	378,515	226,498	605,013
North Coast	187,799	89,871	277,670
Sierra/Cascades	594,429	416,790	1,011,219
South Coast and Mountains/Deserts	22,102	25,831	47,933
Total	1,290,383	872,895	2,163,278

Source: USFS FIAUSDA Forest Service FIA – November 22, 2016 update.

Above ground Includes: above ground live tree, above ground dead tree, down wood and understory vegetation. Belowground Includes: below ground live and dead tree roots, below ground understory roots, and soil organic carbon. Excludes Harvested Wood Products storage.

6.3.4 Carbon Storage in Wood Products and Other Uses

This section summarizes carbon contained in wood products, biomass for energy, and other utilization resulting from forest management and commercial timber harvest in particular. 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. For example, the carbon contained in a long-lived wood product can persist in a solid state for long periods, and some products may reduce demand for more fossil fuel energy or GHG -intensive building materials such as concrete or steel. Woody residues used in place of fossil fuels for energy may result in overall reductions in GHG emissions. The carbon, GHG, and climate implications of forest management and forest-product systems are an area of active research, and the quantification of the movement of carbon through these wood products pools is an important component of a forest carbon inventory.

Fuel treatment is a necessary action on thousands of acres across the state to protect forest carbon, and one result of fuel treatment is the removal of excess biomass. With no utilization outlet for harvested woody material, it would either be chipped and incorporated back into the forests where it would quickly decay and emit to the atmosphere, or the material would be pile burned, emitting significant quantities of particulate matter and gases, including GHGs.

Where forests are managed for timber production, carbon is removed in the form of harvested trees. Milling and manufacturing processes convert harvested wood into lumber and other products. McIver et al. (2015) estimated that 2.4 million metric tons of carbon was processed into finished lumber and other products in California in 2012. The analysis in their study of wood products details the many pathways that forest products are utilized and that less than one percent of the harvest material goes unused (Table 10 and Figure 14).[165]

Table 10. California Harvest 2012 Carbon in End-Uses.

Percentage of Harvest*	Metric Tons	Category
26	624,824	Finished lumber
10	236,435	Landscaping products
4	95,254	Veneer and other products
4	98,656	Pulp and fiberboard products
54	1,298,975	Residues combusted for energy
1	29,484	Other
Total	**2,383,628**	

*Includes bole (wood) volume and bark that went to mills and residue-utilizing facilities
Source: See McIver et al. (2015) for additional information.

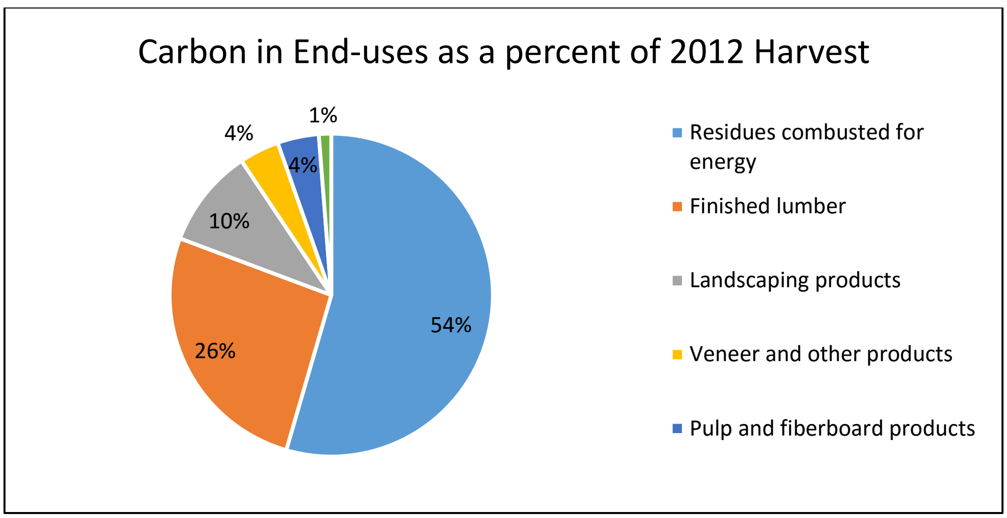


Figure 14. Carbon in the End-Uses of the Wood-Products Industry in 2012, including Bole (Wood) and Bark Numbers.
Source: McIver et al., 2015.

[165] McIver, 2015

The diversity in the mix of products derived from timber harvests has been fairly consistent over time with a notable increase in utilization for bioenergy in recent years.[166] Stewart and Sharma (2015) estimated that when carbon storage in wood products are included in forest carbon accounting, managed forest stands show substantial carbon sequestration benefits over unmanaged stands.[167] In a related study, Stewart and Nakamura (2012) estimated that using revised coefficients on mill and consumer wood utilization efficiencies substantially improves the estimates of climate benefits from harvested wood products.[168]

Timber harvesting has been on the decline since the mid-1980s. McIver et al. (2015), estimated that timber harvesting in California was 1.4 billion board feet in 2012, and this represents a decline of 18 percent from 2006 (1.5 billion board feet) and a 36 percent decline from 2000 (1.9 billion board feet).[169] During 2012, 83 percent of harvesting occurred on private timberlands, 14 percent on USDA Forest Service managed lands and three percent associated with other public lands. Nearly all of the wood from timber harvested was processed in California (i.e., 97 percent). The most recent data from the State Board of Equalization show that 1.591 billion board feet of timber was harvested in 2015, with 12.9 % of the harvest volume from public lands and the remaining amount from private lands.

The lumber and other products produced from forest biomass are then used by consumers and 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. Using data from the Board of Equalization, Saah et al. (2015) estimated the amounts of wood product carbon generated from timber harvests in California from 2001 to 2010 (Table 11).[170] Wood products produced from forests in the state take the form of durable products, such as dimensional lumber and panels. Over the period, approximately 90 percent of harvested wood product was generated from privately-owned forests, with the majority of produced wood product used within the state.

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 remainder carbon fraction that persists in solid form indefinitely. Using national and state mill efficiencies, wood product lifetimes and factors governing the fate of discarded wood products reported by Smith et al. (2006) and by Stewart and Nakamura (2012), respectively, Saah et al. estimated carbon losses to the atmosphere associated with each year's wood product cohort from 2001 to 2010, over 100-year timeframes (Table 11). Based on national factors, it was estimated that after 100 years, approximately 65 percent of wood product carbon would eventually be returned to the atmosphere. Using state-specific factors, the estimate was 61 percent. Using this approach, we estimate the ten-year average wood products in storage from 2001 to 2010 to range between 0.304 and 0.337 million metric tons of carbon per year. Long-term storage estimates from harvest activities on public lands ranges from 0.030 to 0.033 million metric tons of carbon per year, while private lands estimates range from 0.274 to 0.304 million metric tons of carbon per year from private land harvest activities.

[166] Note, however, that much of the material burned in biomass power plants in California comes from sources other than forestlands, such as agricultural and urban forest waste materials.
[167] Stewart & Sharma, 2015
[168] Stewart & Nakamura, 2012
[169] McIver, 2015
[170] Saah et al., 2015

Table 11. California Ten-Year Average Harvested Wood Products in Storage (2001 to 2010).

Source		Metric Tons of Carbon		
		Public Ownership	**Private Ownership**	**Total**
Smith et al., 2010, 2006	10-year average annual storage from harvested wood products (2001 to 2010)	29,974	274,070	304,045
Stewart and Nakamura, 2012	10-year average annual storage from harvested wood products (2001 to 2010)	33,203	303,591	336,793

*Based on 100-year life cycle; see Table 2 in Appendix 1 for annual reporting estimates.
Source: Saah et al., 2015

6.3.5 Carbon Stock-Change Rates

Using data from FIA Program reports, changes in biomass on private, state, and local ownership were evaluated between 1991 and 1994 and 2007 and 2010.[171] And USDA Forest Service managed lands were evaluated between 2001 and 2006 and 2007 and 2010. These tables do not include changes in carbon stocks in the down woody material and soil carbon pools or wood products and other end uses. Changes in plot design and inventory methods can influence the estimate of carbon stocks and stock-change in forests.

Tables 12 and 13 present the net change in biomass volume over time, by ownership category. The change in biomass volume on any given forested acre is a function of the gains from growth on live trees minus the losses from mortality and harvest. The net increase in live tree carbon stocks from the early 1990s to the late 2000s for private, state and local lands was estimated at 1.7 MMT carbon per year (Table 12)[172]. For federal forestlands, the net increase in carbon stocks for the decade starting in 2001 was 0.9 million metric tons of carbon per year (Table 13). In comparing rates of sequestration between nonfederal and federal forestlands, note that while nonfederal sequestration rates were 1.9 times those of federal lands, the area of nonfederal forestlands is just 73% the area of federal forestlands. Factors contributing to this difference include the relatively higher growing capacity of much of the nonfederal lands and the different management behavior of these two broad ownership classes. For the time periods in these analyses, growth exceeded mortality and removal for all ownerships except for USDA Forest Service reserved lands. On reserved lands mortality outpaced growth, a pattern that is consistent with more recent FIA Program inventories, which indicates that these lands were net sources of GHGs to the atmosphere. Combined, the net change in in-forest carbon stocks was estimated at 2.6 million metric tons of carbon per year across all forest lands (excluding wood products).

[171] Christensen et al., 2016
[172] Christensen et al., 2016

Table 12. Growth, Mortality, and Removals on Nonfederal Forest Lands.
(Thousand Metric Tons of Carbon per Year)

Land Ownership	Growth	Mortality	Harvest - Removal	Change
State and Local	55	2	-	53
Corporate	3,627	705	2,582	340
Non-corporate	2,739	730	690	1,318
Total	6,421	1,437	3,272	1,711

Source: Forest Inventory and Analysis Program data tables (1991 to 1994 and 2007 to 2010)[173]

Table 13. Growth, Mortality, and Removals on Federal Forest Lands.
(Thousand Metric Tons of Carbon per Year)

Land Classification	Growth	Mortality	Harvest - Removal	Change
Timberland	6,109	4,355	304	1,449
Reserve Forestland	1,479	2,211	13	-745
Low Productivity Forestland	552	443	-	108
Other Federal	113	26	10	78
Total	8,253	7,035	327	890

Source: Forest Inventory and Analysis Program data tables (2001 to 2006 and 2007 to 2010)[174]

6.4 Tree Growth and Harvest by Ownership

As reflected in Table 12 and 13, above, the live tree stock-changes associated with the current level of harvest (removals) and mortality is generally less than growth on both private and public forestland .[175] National Forest System Lands have substantial live tree inventories, but exhibit higher mortality rates. Private forests have lower live tree inventories and lower mortality rates because portions of live tree carbon stocks are being transferred to wood products and to energy production. The changes in growth, mortality, and removals among ownership groups reflect different forest management goals and approaches. This results in characteristic patterns of carbon stocks and change that are unique for each ownership group. Ancillary information on changes in forest tree volumes by USDA Forest Service and non-USDA Forest Service categories are contained in Appendix 1.

[173] Christensen et al., 2016
[174] Christensen et al., 2016
[175] Christensen et al., 2016

- National Forest System Reserves: This category is representative of lands permanently reserved from wood products utilization through statute or administrative designation, and includes designated wilderness areas. While there is moderate growth on these lands, it is outpaced by mortality rates. There are no harvest removals, but mortality from wildfire, pests, disease, and other disturbance agents is high. Thus, these lands exhibit net declines of live tree carbon. In turn, decay or disturbance processes transfer carbon from the dead tree pool to the atmosphere or to the soil.
- National Forest System Timberland: Timberland is available for harvest and capable of producing commercial crops of trees. These lands have higher per-acre levels of growth than reserve lands. They have a small amount of removal from harvest, and have slightly lower levels of mortality per acre per year than reserve lands. The rate of harvest on these federal lands has declined since the 1980s as a result of endangered species protections, legal challenges, changing management goals, declining USDA Forest Service budgets, and other factors. For example, some timber offerings go unsold due to lack of bids. Growth is higher than mortality on these lands, but the difference is much narrower than on private forest.
- National Park Service Lands: These landscapes represent a small percentage (4.5%) of California's forested areas, but they are important for reasons of management application. The hands-on restoration and fire/fuels management approach taken by the NPS, combined with the lower rate of legal challenges they receive to their management efforts, has resulted in landscapes that are more robust and resilient than most public landscapes in California. Active management policies that encourage the use of prescribed and managed fires has resulted in significant decreases in high severity fire compared to adjacent lands, as well as increased water quantities from their forests[176] .
- Private Corporate Timberland:[177] On private corporate timberlands growth only slightly exceeds removal and mortality, reflecting the practice of sustained yield as required by California's Forest Practice Act and Rules, as well as the profit objective inherent in industrial timberland management. These forests are managed to create relatively little annual mortality and the harvested volume is slightly less than forest growth. There is less carbon stored per acre in live tree inventories, as they don't get as old and large as trees on public landscapes, but mortality is much lower.
- Private Non-corporate Forestland:[178] This category represents private ownerships for which timber production may or may not be a primary management objective. These forest lands show increasing inventories and harvest less per acre than corporate timberlands; as a consequence, mortality rates are slightly higher than corporate, but much lower than federal lands. In addition, there are moderate levels of removal from harvesting.
- State and Local Government Forestland: This category of ownership manages a much smaller fraction of the forest land base, and represented by smaller-acreage ownership patterns. However, it is characterized by higher levels of growth that greatly exceed mortality and low levels of removal. The bulk of the area, 788,000 acres or 72 percent, is in reserved status.

[176] Boisramé et al., 2016

[177] Per FIA definitions, "An ownership class of private forest lands owned by a company, corporation, legal partnership, investment firm, bank, timberland investment management organization (TIMO), or real estate investment trust (REIT)."

[178] Per FIA definitions, "Private forest land owned by nongovernmental conservation or natural resource organizations; unincorporated partnerships, associations, or clubs; individuals or families; or Native Americans.

6.5 Discussion

Forest carbon is stored in both forest ecosystems and in harvested wood products. The degree to which California forests operate as a sink or source is influenced by land management, a range of forest health issues (e.g., growth, tree mortality from drought, pest and disease outbreaks, wildfire severity), and weather. In recent years, the prolonged drought conditions have resulted in elevated tree mortality that is widespread across the southern Sierra. When combined with extensive wildfires, the capacity for forests to store carbon has been diminished. For all forestlands, improving forest health and managing to reduce losses from mortality can greatly increase the carbon balance on forestlands. On commercial and other actively managed forestlands in California, efficient uses of long lasting wood products and residues for energy can yield GHG benefits. Keeping in mind the FIA data limitations described above, key inventory findings include:

- Based on FIA Program data from 2005-2014, California forests have substantial carbon storage; 1,290 MMT above ground and 873 MMT below ground, for a total of 2,163 MMT.
- Prior to the drought, carbon sequestration (in-forest) was estimated at 0.9 MMT of carbon per year on National Forest System Lands and other federal lands and 1.7 million metric tons of carbon per year on private, state and local lands. The net change across all forestlands is estimated at 2.601 MMT of carbon per year. This estimate excludes carbon stored in wood products and or used as bioenergy.
- Analysis of recent timber harvest data (2012) suggests an estimated 2.4 MMT of carbon were produced from wood products. Material from harvest is divided between wood products and bioenergy, with less than one percent unused material.
- We estimate the ten-year average wood products in storage from 2001 to 2010 to range between 0.304 and 0.337 MMT of carbon annually. Long-term storage estimates from harvest activities on public lands ranges from 0.030 to 0.033 MMT of carbon per year, while private lands estimates range from 0.274 to 0.304 MMT of carbon per year from private land harvest activities.
- On a per acre basis, redwood, Douglas-fir and other conifer forest types have enormous growth and storage potential.
- FIA Program data suggest that on private timberlands growth is slightly outpacing losses from harvest and mortality (excluding wood product storage).
- FIA Program data shows that non-corporate timberlands show the greatest net growth (i.e., growth minus mortality and harvest excluding wood product storage).
- Based on FIA Program data, tree mortality from forest health-related causes results in substantial declines in forest carbon. Tree mortality rates appear to be highest on federal forest lands in reserve (e.g., wilderness) lands, where mortality is outpacing growth.

6.6 Forest Fragmentation

Forest fragmentation through urbanization, conversion for agriculture, or other large scale or cumulative small-scale land use changes can negatively impact forest health. Isolated and disconnected forest stands often have less diversity and resilience to changing conditions. There is a reduction in gene flow within species and in-habitat connectivity for wildlife. Insects and diseases may become more concentrated with the potential for greater damage and localized species extinctions. Wildland fire probabilities increase with more human presence. This section summarizes the most impactful fragmenting activities facing California forests today: growth in the wildland-urban interface and marijuana cultivation.

6.6.1 Wildland-Urban Interface

Depicted below (Figure 15) is the wildland urban interface, which is the geographical intersection of two disparate systems, wildland and land occupied by human-inhabited structures. At this intersection, structures and vegetation are close enough that a wildland fire could spread to structures or fire could spread from structures to ignite vegetation. This type of development degrades and fragments wildlife habitat and contributes to loss of structures and human life during wildfires.

The wildland urban interface is composed of both interface and intermix communities. The distinction between these is based on the characteristics and distribution of houses and wildland vegetation across the landscape. Intermix wildland urban interface refers to areas where housing and wildland vegetation intermingle, while wildland urban interface refers to areas where housing is in the vicinity of a large area of dense wildland vegetation.[179] Martinuzzi et al. estimated total California wildland urban interface at 6.73 million acres, including 1.96 million acres of interface and 4.78 million acres of intermix.

[179] Martinuzzi et al., 2015

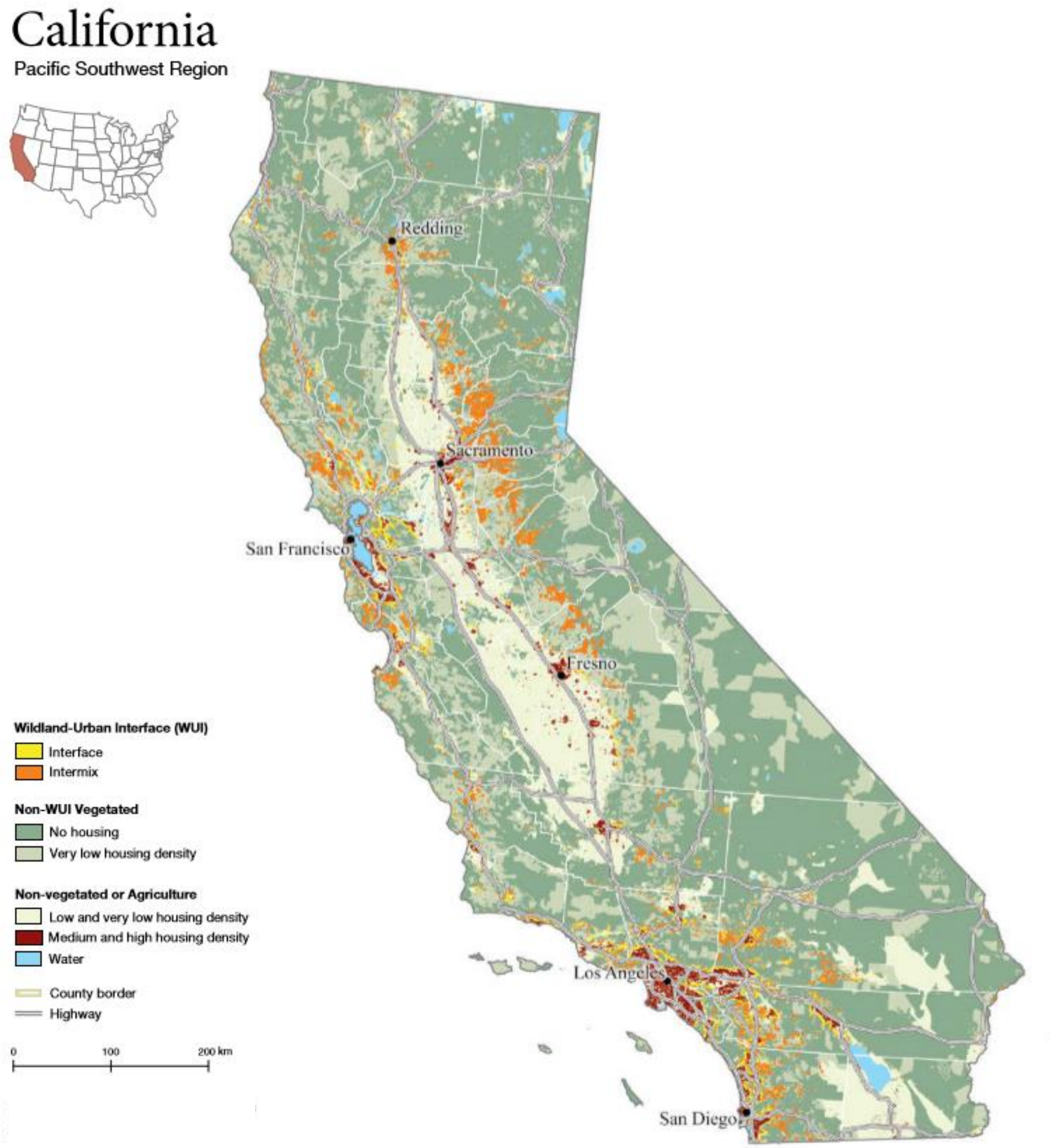


Figure 15. Wildland Urban Interface in 2010.
Source: Martinuzzi et al., 2015

Strong state and national programs are required for a concerted community effort wherever structures are near flammable vegetation.[180] For example, Fire Adapted Communities, Fire Adapted Communities Learning Network and, FIREWISE encourage integrative and cooperative partnerships aimed at landowner education.[181] In addition, risk assessment is an important component of any county general plan, and the wildland-urban interface/intermix must be considered as part of these local planning

[180] President, 2015
[181] Schoennagel et al., 2004

efforts. State and federal programs may feed information and suggestions into the process, but in the end, it is the responsibility of these local jurisdictions to consider the safety and risk associated with development in these areas.

As part of the Vegetation Treatment Program Draft Environmental Impact Report, CAL FIRE estimated the acres of wildland urban interface that is available[182] for fuels treatment activities.[183] The results are presented below in Table 14. Focusing just on tree-dominated landscapes, the analysis found that almost 2.9 million acres were available for treatment statewide.

Table 14. Modeled Available Wildland Urban Interface Fuels Treatment Acres by Bioregion.

Bioregion	Tree Dominated	Shrub Dominated	Grass Dominated	Total by Bioregion
Bay Area/Delta	**345,235**	152,571	794,135	1,291,941
Central Coast	**53,983**	410,122	1,162,785	1,626,890
Colorado Desert	**357**	109,459	3,849	113,664
Klamath/North Coast	**872,897**	226,236	505,615	1,604,748
Modoc	**377,423**	235,956	120,292	733,671
Mojave	**3,348**	185,511	37,398	226,257
Sacramento Valley	**15,173**	3,136	494,494	512,804
San Joaquin Valley	**4,959**	52,595	270,582	328,136
Sierra Nevada	**1,090,662**	323,025	1,470,973	2,884,660
South Coast	**101,424**	958,039	284,868	1,344,332
Total by Veg Type	**2,865,462**	2,656,649	5,144,991	10,667,101

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report

6.6.2 Marijuana Cultivation

Illegal marijuana production on forestlands is a serious issue in the state of California, with negative impacts to both humans and natural systems. In forests, sites are often cleared of trees and other vegetation to make way for grow sites. This clearance results in GHG emissions as well as a loss of carbon and the trees' carbon sequestration capacity. Further, these activities often result in erosion and sediment deposition into streams and lakes. Wildlife making use of the area, such as bears or deer, may be poached or snared. Fertilizer, pesticide, and rodenticide used at grow sites can have direct, detrimental effects on local wildlife. The chemicals may also end up in nearby water sources, degrading water quality.

In addition to degrading water quality, marijuana grow sites have negative effects on water quantity; marijuana production is very water-intensive, and the illegal diversion of water to irrigate marijuana

[182] "Available," under the Vegetation Treatment Program Draft Environmental Impact Report, refers to land, within State Responsibility Area, that is capable of undergoing a WUI fuels treatment, fuel break, or ecological restoration treatment.
[183] California Board of Forestry and Fire Protection, 2016d

plants has further exacerbated the drought conditions facing the state. Diminished stream flow as a consequence of this activity adversely impacts state and federally listed salmon and steelhead as well as amphibians and other sensitive species. Grow sites themselves can become dumping grounds for trash and human waste, severely degrading habitat. The sites can pose significant risks to human safety: hikers, hunters, and anglers may stumble upon armed growers and other defenses.

The state is working diligently to combat illegal marijuana cultivation, but it is a challenge. CDFW and the Regional Water Quality Control Boards are working in priority watersheds to bring illegal marijuana grows into compliance with environmental laws and to remediate the harmful effects of illegal grows on fish, water, and wildlife. The Governor's 2014-15 budget bill provided an increase of $1.5 million to CDFW to regulate and enforce unauthorized water diversions and pollution to surface and groundwater as a result of marijuana cultivation. The 2015-16 budget bill provided an additional $7.7 million to expand these efforts. Further, the passage of Proposition 64 in the November 2016 election will provide additional resources to clean up abandoned sites, and the potential price depression as a result of legal marijuana provision could potentially contribute to a significant reduction in illegal forest-based grow sites.

6.7 Regional Assessments

As described above in this section, climate change impacts California forests with more frequent and severe wildfires, pests, disease, increased temperatures, and changing precipitation and water availability. These effects may decrease forest growth (and hence decrease rates of carbon sequestration), cause geographic shifts in tree distribution and forest types (as presented in the Science Snapshot), and result in forest loss and tree mortality (and hence increase rates of GHG emissions). However, the types of impacts currently being seen and anticipated are not the same across all regions of the state. Hence, it is important to look at our forests in greater depth on a regional basis, using the ecoregions that were presented in Section 6.2. Appendix 3 provides detailed assessments for each of the ecoregions. These ecoregional assessments are intended to provide initial information to support regional implementation of the Forest Carbon Plan.

7 Urban Forestry

The term urban forest is used to mean those native or introduced trees and related vegetation in the urban and near-urban areas, including, but not limited to, urban watersheds, soils and related habitats, street trees, park trees, residential trees, natural riparian habitats, and trees on other private and public properties.[184]

California's urban forests are both similar to and different from wildland forests in form and function with regards to species composition, ecological and urban function, management, and climate change impacts. Urban forests are made up of trees on public and private lands in urbanized areas. Urbanized areas constitute approximately 5 percent of the state's acreage, and it is estimated that the tree canopy, the spatial extent by which urban tree cover is measured, occupies approximately 15 percent of all urban areas.[185, 186] Thus, the urban tree canopy covers approximately 791,725 acres of California. While census-defined urban areas represent only about five percent of the state's land area, almost 95 percent of the state's population, or over 35 million residents, are located in urban areas.

The "stocking rate" of urban forests is estimated to be just over a third (36.3%) of its potential statewide; both tree density and canopy cover has room to grow.[187,188] A large proportion (61 percent) of urban areas in California is considered to have low tree canopy cover of two to ten percent.[189]

The urban forest is made up of both native and non-native tree species, and tree selection is typically ad hoc or based on the improvements they offer to local residents and urban function. Whereas wildland forests are dominated by native species with few exceptions, many urban forests in California are dominated by species not native to that location or even the continent. Criteria for urban tree selection differs by locality and includes consideration of aesthetics; site suitability with regards to space, water, and light needs as well as interactions with surrounding infrastructure; and maintenance needs over time.

Urban forests in California, like wildland forests, are being impacted by climate change and drought. Elevated temperatures, reduced precipitation, and reduced landscape watering all contribute to losses. Water needs and climate must be considered when selecting species, but there are water-efficient and water-inefficient ways to maintain trees through periods of drought. Increasing the water use efficiency of tree maintenance can reduce mortality from drought going forward, so these methods should be adopted by public and private stewards statewide.

Invasive pests and diseases continue to enter the state and cause damage to urban forests. The golden spotted oak borer, polyphagous shot hole borer, and Kuroshio shot hole borer are examples of such pests. The two shot hole borers are of particular concern as they have wide host species ranges. Sudden oak death is a major disease problem in northern California urban forests.

[184] California Public Resources Code Section 4799.09, 1978
[185] Klass-Schultz, 2016
[186] Bjorkman et. al., 2015
[187] McPherson et. al., 2016
[188] Bjorkman et. al. 2015
[189] Bjorkman et al., 2015

7.1 Benefits of Urban Forests

Urban trees have always been valued for their aesthetics and other passive improvements to streetscapes, but are becoming increasingly valued for their potential to contribute to the state's climate and water management goals. Trees function to cool urban and surrounding areas, which mitigates the public health impacts of excessive heat and criteria air pollution in urban areas; reduce energy demand for cooling; and improve conditions for active transportation options such as walking and bicycling.[190] Some of these values have been estimated monetarily statewide: reduced energy use from canopy shading and cooling saves an estimated $568 million annually, and annual benefits to water infrastructure – rainfall interception, reduced water pollution, and reduced flood risk – are estimated at $324.6 million.[191] The revenues directly associated with urban forestry in 2009 in California were over $3 billion, and urban forestry related jobs in California totaled nearly 60,000 in that year.[192]

Trees are therefore a critical component to broader urban greening programs and objectives statewide. Trees and other vegetation provide evaporative cooling to their surroundings; absence of vegetation exacerbates warming caused by heat absorption (e.g., dark pavement and roofs) and heat-generating sources (e.g., engines) concentrated in urban areas. The resulting phenomenon is called the Urban Heat Island (UHI) effect.[193] The UHI can lead to daytime temperatures in urban areas on average one to six degrees Fahrenheit higher than in rural areas, while nighttime temperatures can be as much as 22 degrees Fahrenheit higher as the heat is gradually released from buildings and pavement.[194,195] Increasing the amount of vegetation in cities, in addition to increasing area covered by water-permeable surfaces, functions to increase evapotranspiration and combat the UHI. These features also lower temperatures and provide shade at street level, which improves livability and encourages active transportation. Areas with the greatest UHI effect and air pollution are seen as priority areas for tree planting.[196] Box 6 on the following page contains more information about Urban Heat Islands.

There are also well-documented cognitive, public health and community benefits of urban greenspace. These are not limited to tree canopy or California but do apply to the goals and implementation activities described here. These include:

- Strengthening of social cohesion within communities[197]
- Support for cognitive functioning and place attachment[198, 199]
- Support for psycho-social-spiritual engagement[200]
- Increased physical activity[201]

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[190] McPherson & Simpson, 2015
[191] McPherson et al., 2016
[192] Templeton et al., 2013
[193] California Environmental Protection Agency, 2015
[194] California Environmental Protection Agency and California Department of Public Health, 2013
[195] U.S. Environmental Protection Agency, 2008
[196] Bjorkman et. al., 2015
[197] Sullivan et al., 2004
[198] Gómez-Baggethun, 2013
[199] Place attachment and meaning are the person-to-place bonds that evolve through emotional connection, meaning, and understandings of a specific place and/or features of a place (Shumaker & Taylor, 1983). Higher levels of place attachment are positively associated with environmental stewardship (Clayton & Myers, 2015), pro-environmental attitudes, and climate change adaptation (Adger et al., 2013).
[200] McMillen et al., 2016
[201] Kaczynski & Henderson, 2007

- Decreased childhood obesity[202]
- Longevity among seniors[203]
- Improved concentration among children with attention deficit disorder[204]
- Amelioration of stress,[205] and
- Self-reported quality of health.[206]

California's urban tree canopy also includes trees that produce food. Community managed agricultural production areas have been documented in multiple urban areas of California, including those that are socio-economically challenged.[207,208] In response to strong community interest, San Francisco, Los Angeles, and San Diego have recently updated municipal policies to facilitate urban agriculture. Along with the benefits already described for the urban canopy, urban agriculturalists and their networks enjoy benefits of food as well as the social networks, social cohesion, and cultural identity that are fostered through the acts of planting, stewarding, harvesting, preparing, and sharing the food grown on trees. These trees are found in a range of spaces from public to private areas, non-profit and commercial enterprises, and range from actively managed farms to 'wild' lots. Examples include gardens, orchards, farms, schools and more.

Management of the urban tree canopy varies widely across the state and at the local level. Generally speaking, management of publicly accessible urban trees is the responsibility of a combination of parties, including local government, private landowners, and local organizations established to support the urban forest at the community or city-wide level. Utility companies also play a role where trees interact with utility infrastructure, such as power and communications lines. Private landowners also host the urban forest, in yards and as part of landscaping.

All of these actors will need to be engaged in order to manage California's urban forests, as a whole, as a resilient store of carbon. Baseline planning and management decisions will occur at the local level; local governments and local organizations may need assistance in assessing the extent and conditions of existing urban forests, and planning for maintenance and expansion. Urban forests also benefit from the stewardship of organizations and individuals in the communities they shelter. The case study in Box 7, on a tree planting project undertaken by the Koreatown Youth and Community Center and CityPlants in Los Angeles, is one example of a community-based organization working hand-in-hand with a city and local neighborhoods.

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[202] Wolch et al., 2011
[203] Takano et al., 2002
[204] Taylor & Kuo, 2009
[205] Adevi & Mårtensson, 2013
[206] van den Berg et al., 2010
[207] Galt et al., 2014
[208] Peña, 2015

Box 6: Urban Heat Islands

Large urban areas often experience higher temperatures, greater pollution and more negative health impacts during hot summer months when compared to rural communities. This phenomenon is known as the urban heat island (UHI). Heat islands are created by a combination of heat-absorptive surfaces (such as dark pavement and roofing), heat-generating activities (such as engines and generators) and the absence of vegetation (which provides evaporative cooling). Sometimes, due to wind and topography, the heat island can be created in one area, and manifest as increased heat in another area.

In July 2015, CalEPA released a study on urban heat islands, "Creating and Mapping an Urban Heat Island Index for California." Based on atmospheric modeling, the study defines and examines the characteristics of the urban heat island, and assigns an urban heat island index (UHII) for each census tract in and around selected urban areas throughout the state.

The modeling shows that urban areas with relatively well defined boundaries (i.e., urban islands) typically exhibit single- or multi-core UHIs. On the other hand, large urban archipelagos and coastal regions, such as the Los Angeles Basin and the Santa Clara Valley consist of sustained and contiguous urban land use with no well-defined boundaries, except for breaks by topography.

In urban archipelagos, urban heat is continuously injected into an air mass advecting across the urban area. As a result, an air mass warms up continuously, masking localized rises and falls in temperature along the trajectory. Thus the local UHI in an archipelago additionally includes the superimposed effects of upwind urban warming. In this case, the UHII often peaks in areas near the downwind edges of the archipelago.

Furthermore, in coastal areas the UHIs are also superimposed on the onshore warming of air. Thus the UHIIs in these regions and in urban archipelagos also capture that warming effect. All of these factors contribute to differences between the spatial patterns of air-temperature UHII and skin-surface temperature.

Urban Heat Island Index in Southern California. Yellow pegs indicate reference points, used to calculate difference between urban and nonurban temperatures.

Box 7: Community Forestry – Koreatown Youth and Community Center and CityPlants

Koreatown Youth and Community Center (KYCC) provides numerous community services in the Koreatown neighborhood of Los Angeles, as well as surrounding neighborhoods. Many of these neighborhoods are located in disadvantaged communities. KYCC is a partner with CityPlants, the tree planting coordination organization of the City of Los Angeles Mayor's Office. KYCC received an Urban and Community Forestry Greenhouse Gas Reduction Fund grant from CAL FIRE in FY2014-15, and leveraged funds from the Los Angeles Department of Water and Power that are used to purchase and grow trees. These trees are then distributed to organizations like KYCC. They in turn use their own funding and grant funding like that provided by this grant to get transformational tree planting work done in disadvantaged communities.

The grant project area is within the City of Los Angeles, bounded by the neighborhood of Pico-Union to the north, Arlington Boulevard to the west, Vernon Avenue to the south, and the 110 Freeway to the east. The 69 census tracts where this project is located are designated as disadvantaged communities per CalEnviroScreen 2.0. Communities like these bear a disproportionate burden of the effects of climate change, for example, the urban heat island effect. The project truly engages the communities in the project area and will address resident concerns by increasing tree canopy cover. By developing relationships and involving local communities in the process and the work, the community will have ownership of the transformative results.

This project will reduce GHG and urban heat islands by planting 1,120 trees while also making needed infrastructure modifications to support growing of large trees. This project will result in GHG reductions of approximately 1,900 metric tons CO_2e. In addition to the GHG reduction, the project will: increase permeability and water capture potential by adding mulch to hard-packed soil and by increasing the number of trees and expanding their planting sites; conserve potable water by removing turf on medians and coordinating turf removal in yards; conserve electricity by planting hundreds of shade trees near residences thereby reducing the need for air-conditioning; reduce the heat island effect by creating a dense canopy; reduce particulate matter in residential neighborhoods by planting near-roadway trees; and add beauty and increased property values to disadvantaged communities.

7.2 Carbon Stored in Urban Forests

According to Bjorkman et al. (2015), an estimated 103 MMT of carbon is stored in the urban forests of California.[209] On an annual basis, the amount of carbon dioxide sequestered by urban forests was assessed at 7.2 million metric tons of carbon per year. This estimate is based on tree growth rates associated with existing statewide urban forest cover at a point in time, and does not include effects from new plantings, mortality, or removals. The amount of carbon dioxide emissions avoided (attributed to modeled reductions in building energy use) was estimated to be 1.3 million metric tons of carbon per year.

There are a number of tools to quantify urban forest carbon storage. There is a USDA Forest Service urban tree carbon calculator to estimate carbon sequestered and stored by a tree over time. It also estimates avoided emissions. Additionally, there is the iTree suite of tools that are a joint project of the USDA Forest Service and the Davey Tree Expert Company. This suite of tools can be used to quantify carbon benefits of urban forests, as well as many co-benefits. There are also both regulation-level (ARB) and voluntary carbon protocols (Climate Action Reserve). Information on other urban forest attributes and services is contained in Appendix 1.

7.3 Goals for Urban Forestry

The Forest Carbon Plan proposes to protect and enhance the carbon sequestration potential of urban forests in support of the broader goal to manage California's forests as resilient stores of carbon, while producing other co-benefits. This goal will be accomplished by protecting the existing tree canopy and expanding it:

- Protect the existing tree canopy through policies and programs targeting ongoing maintenance and utilization of industry best management practices.
- Increase total urban tree canopy statewide by one-third above current levels, to 20% coverage of urban areas by 2030.[210]

The state, through CAL FIRE and CNRA, currently provides urban forestry grants and urban greening grants through the cap-and-trade supported Greenhouse Gas Reduction Fund. These grant funds create incentives for local activity, result in quantifiable GHG emission reductions, and require best management practices in order to receive funding. Such grants contribute to achieving tree canopy cover goals both by financing tree planting and care and providing incentives for the preservation of existing tree canopy through better management and policy, as well as improved maintenance practices. However, municipal and community-level support will be essential to meeting these targets. Urban forests are long-lived, and it is difficult to manage them adequately on often-fluctuating city budget cycles. The state can also improve outcomes at the local and regional scales through continued spatial data sharing, collaborative programs, direct investment, and improved methods of quantifying the value of ecosystem services, including carbon sequestration and other GHG benefits of urban trees.

In addition to the goals and objectives outlined in CAL FIRE's Urban and Community Forestry Program Strategic Plan 2013-2018, the following are suggested management actions:[211]

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[209] Bjorkman et al., 2015

[210] Canopy cover is currently 15% of urban area; Bjorkman et. al., 2015

[211] California Department of Forestry and Fire Protection, 2013

- Move green infrastructure solutions from being an exceptional occurrence closer to being standard practice by 2030. This can be accomplished with policy guidance and incentives.
- Ensure that tree canopy cover and green infrastructure project increases are prioritized in disadvantaged communities. This will maximize the impact of tree canopy cover increases that are achieved.
- Assist local governments and others in assessing their urban forest resources and better managing them. This can be done by obtaining urban tree canopy cover data to share on a periodic basis, performing urban tree inventories on a periodic basis and putting urban forest management plans in place that are comprehensive and long-term.
- Assist local governments and others in locating optimal locations for early green infrastructure solution intervention.
- Provide resources and technical assistance to local governments as they assess local policies and regulations in regards to urban forestry and green infrastructure.
- Consider creating incentives for the use of best management practices, including tree maintenance and preservation, by local governments and others. This would help protect large, established trees and increase both short-term and long-term tree canopy above the baseline.
- Improve and expand use of urban biomass that is removed for valid management purposes, including, but not limited to, pests and disease. The highest and best use should be sought for this resource, rather than viewing it as a waste product.

8 Co-benefits of Healthy Forests

The process of restoring degraded forests into healthy, resilient forests, offers more than just carbon storage, it also provides a range of quantifiable and intrinsic benefits, or co-benefits. Examples include environmental co-benefits such as clean air, clean water, and wildlife habitat, as well as socioeconomic co-benefits such as opportunities for recreation, tourism, and the forest management and wood products industries. Achieving healthy and resilient forests throughout California will increase the value of natural ecosystems to all Californians.

The Forest Carbon Plan does not include targets or propose direct protocols for the co-benefits that are expected to be impacted through activities leading to improved forest health, or from healthy forests. Co-benefits such as air quality, biodiversity, and watershed function are the foci of other state plans, assessments, and regulations and have well-established monitoring procedures and, in some cases, performance targets already in place. Therefore, the performance targets and monitoring protocol described in those plans and mandated through regulation or by policy should serve as the yardstick for measuring co-benefits to pursuing the carbon sequestration and supporting goals that are the focus on this Forest Carbon Plan. These plans and standards include but are not limited to:

- State Wildlife Action Plan at the statewide level, as well as regional and local regulatory structures and priorities
- California Water Action Plan and the activities, projects, and mandates described therein
- Fire and Resources Assessment Program Forest and Range Assessment
- Air quality attainment standards enforced by the California Air Resources Board, Air Pollution Control Districts, and Air Quality Management Districts

8.1 Sustainable Rural Economies

Rural economies benefit from healthy forests and the employment and economic activity generated by forest health treatments. Wood products and outdoor recreation industries can both contribute significantly to rural communities' economic wellbeing. Outdoor recreation generates significant local and regional income, as referenced in the section above, and is responsible for over 732,000 direct jobs throughout the state.[212] The timber industry employs approximately 78,100 workers, earning $4.4 billion annually, in the primary and secondary wood and paper products industry in California.[213]Spending on activities related to healthy and resilient forests contributes to training and job opportunities and earnings in these sectors, as well as the potential for local tax revenue collection on the goods and services purchased.

Maintaining the economic sustainability of these sectors is also important to support the ability of land managers to undertake the management actions needed to improve forest health and reduce fuels: while some forest management activities may pay for themselves through wood products production and other existing revenue streams, most of the restoration activities needed on National Forest System Lands, other public lands, and small private land ownerships will require investment. Sustainable forest product and service industries within a given region present opportunities to supplement public and other investments.

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[212] Outdoor Industry Association, 2012
[213] Morgan et al., 2012

8.1.1 Recreation and Tourism

The variety of recreational opportunities in California forests attracts both in- and out-of-state tourists. From wilderness excursions, hunting and fishing, rock climbing, and snowsports to motorized and non-motorized activities, recreation opportunities contribute significantly to the economies of rural communities. The outdoor recreation sector alone is a vital contributor to the state's tourism industry sector, generating $122.5 billion in direct travel spending and $9.9 billion in state and local taxes.[214] These economic contributions, resulting from visitor spending, include service-based jobs and earnings as well as sales and lodging tax revenues that are critical in supporting local public services. Recreation and tourism benefits are important factors that drive public support for forest conservation efforts: one of the strongest predictive factors that determine public support of diverse forest projects is whether the project is perceived to improve access to recreational opportunities.[215] Recreation and tourism also provide opportunities to interact with family and friends; this is one of the main reasons Californians enjoy outdoor recreation.[216] These social interactions can strengthen relationships among people as well as between people and place.

Uncharacteristically large and severe wildfires can, likewise, negatively affect access and support. Forests impacted by high severity events, such as wildfire or insect outbreaks, can be dangerous for recreation as falling trees are a hazard. These conditions can close trails and campgrounds for extended periods. Similarly, recreational demand can significantly decline if most of the canopy has been removed. Smoke impacts on recreational activities were common during the King Fire, with an Ironman Triathlon in the Lake Tahoe area canceled due to health concerns.[217] More research needs to be done on how megafires impact tourist decisions, both to specific areas near the fire and the state as a whole.

8.1.2 Wood Products and Biomass Industries

Wood product manufacturing and various biomass utilization pathways contribute to local and regional economies by creating jobs and generating revenue through forest management and restoration activities; commercial harvesting; product manufacturing and energy or fuels production and related support businesses (e.g., sales and marketing); and transportation and shipping. Sustainable industries support land tenure, which underpins the entire economy, and broader economic activity in a region. The economic value of these products and processes to rural economies is described below. Additional information on wood products and biomass can be found in Section 9.

i. <u>Lumber</u>: Lumber is an essential material of life in California, and producing it locally results in a lighter carbon footprint than out-of-state products would. In addition, local production usually occurs in rural communities, close to the source of timber, thus providing jobs and economic activity in these sometimes economically constrained areas.

ii. <u>Biomass Use</u>: The woody biomass from unhealthy forests is often not of a size or quality to be used in lumber production at traditional sawmills. It may be of an undesirable species, or possibly damaged due to unnatural growth patterns or forest disturbance. It is important to landowners and local communities that markets for this woody biomass be developed to help defray the costs associated with forest restoration done for carbon and/or wildfire

[214] Visit California, 2016
[215] Barrio & Loureiro, 2010
[216] Roberts et al., 2009
[217] Ironman.com, 2014.

protection, or with the purpose of any other co-benefit listed in this section.

iii. Bioenergy Development: Biomass generated by forest management activities can be used to generate electricity, cooling, heat, and biofuels. Current research and early-stage deployment is testing the economic viability of biomass-sourced biofuels, liquid fuels, and biogas; this renewable source of energy can reduce the need for fossil fuels and support rural economies. Bioenergy provides opportunities for rural development and job creation in economically depressed regions. The value of the environmental services provided by biomass energy production, listed above and related to forest management and emissions reduction, is estimated to be in excess of ten cents per kilowatt hour.[218] Relatively small bioenergy facilities placed in rural communities and/or serving institutions or remote consumers can support rural and community energy self-sufficiency. These can be expanded to heating and cooling production, often used for rural schools and other rural community structures.

Section 10 describes legislation and administrative actions have provided new opportunities for forest biomass energy production initiatives and contains additional description regarding the market for bioenergy and the hurdles faced by this industry.

iv. Biochar: Biochar is a potential co-product of bioenergy production, and can be added to agricultural soils for added tilth and for water retention capacity. Biochar can replace activated charcoal used as for odor control at facilities such as wastewater treatment plants. The market for this product is being developed, but it holds some promise – and numerous co-benefits in its own application – for rural communities and for the state of California as a whole.

v. Emerging Markets: Other applications for materials beyond traditional wood products are in different phases of commercial viability. These items might include nanocellulose particles or cross-laminated timber. These applications could increase the value of woody biomass – and thus forest management activities – to the state and to the more immediate communities around affected forests.

8.2 Non-Timber Forest Products

Non-timber forest products (NTFP) have a high importance to a range of stakeholder groups but their collection is less understood and documented than timber harvesting. NTFP collected in California include bark, berries, boughs, bulbs, grasses, Christmas trees, cones, ferns, fungi (mushrooms), mosses, nuts, roots, seeds, fuelwood, transplants, and wildflowers. These products are highly valued for their "medicinal properties, decorative uses, native propagations, landscaping, family or tribal tradition, or for ceremonial purposes."[219] Native Americans and tribes in California have a particular depth and breadth of knowledge about NTFP. Like other indigenous people, they have been collecting NTFP and continue to collect them as part of traditional subsistence practices for material and cultural survival.[220] NTFP are also collected by a wider group for recreational purposes and commercial sale.

[218] Morris, 1999
[219] USDA Forest Service, 2016g
[220] Emery and Pierce, 2005

Box 8: Integrating Conservation and Improved Forest Management in the McCloud Watershed

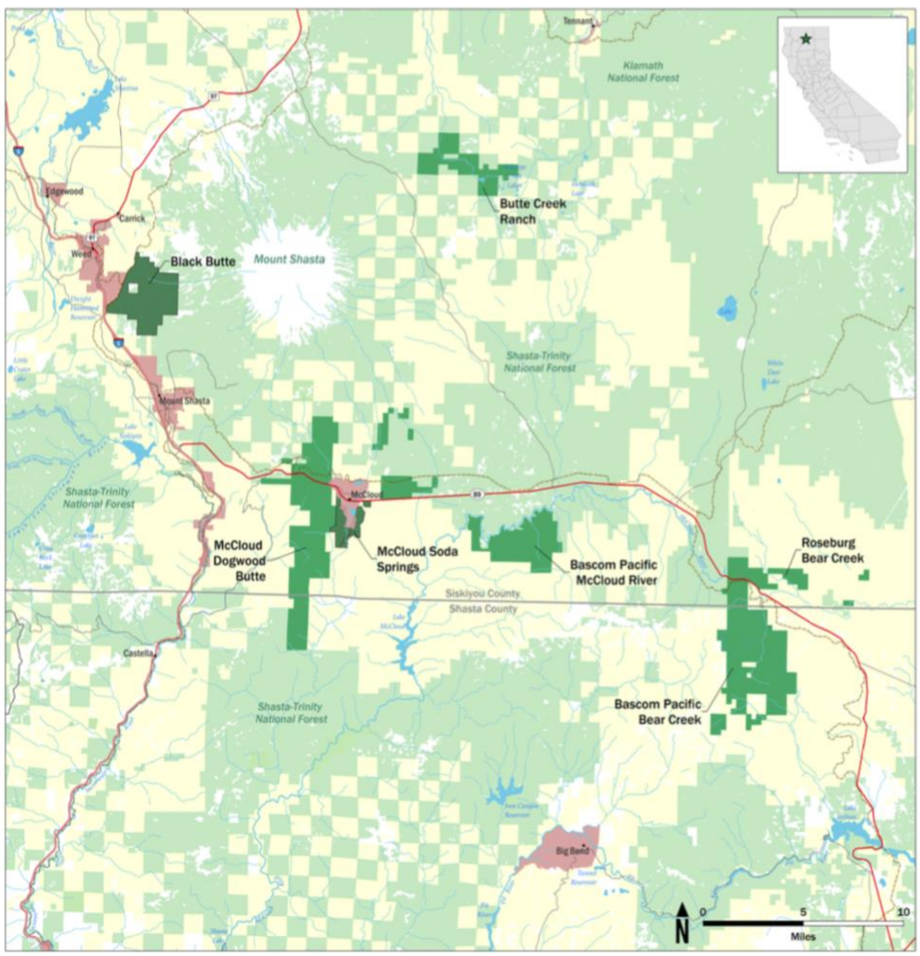
Courtesy of the Pacific Forest Trust

The vast forested arc of mountains that encircle California's northern Central Valley is remarkable for its enormous carbon stores, globally important biodiversity, and role0020as the water fountain for the state. This roughly 10 million acre region provides an outstanding opportunity to safeguard and improve the watersheds feeding California's most important reservoirs, provide for wildlife adaptation at a landscape scale and restore larger, more resilient stores of carbon while also reducing catastrophic fire intensity. With roughly a fifty-fifty public and private ownership, this region at the intersection of northern Sierra, southern Cascade and Klamath mountains can provide a living and enduring demonstration of cooperative management across federal and well-managed private lands.

Employing a suite of restoration management approaches, these forests can be pivoted from relatively homogeneous, often crowded younger forests to older, more natural forests with a mix of species and age classes that are more fire and stress resistant and resilient. Deploying thinnings and controlled burns and managing for older, more stress resistant stands are key management actions. Such restoration is particularly important for many public forests. Equally, with relatively larger private ownerships, there is the opportunity to conserve well-managed private forests to ensure a cohesive and functional watershed for the future, avoiding a patchwork of fragmented and degraded forest holdings.

An example of this approach is in the McCloud watershed. In 2016, the Hancock Timber Resource Group worked with the Pacific Forest Trust to conserve 20 square miles of well-managed private forest, creating permanent connectivity between 2.15 million acres of public lands. Conducted in cooperation with DFW and WCB, and with funding from state and private sources, this project achieves some of California's climate adaptation goals. It will double the carbon stocks on this forest over 50 years, removing 1.8 million metric tons of CO2 from the atmosphere, equivalent to the annual emissions of 380,000 cars, while maintaining continuous management and timber flows. It benefits many imperiled species that rely on this crucial habitat while expanding access for recreational uses. It conserves over 30 miles of streams and creeks as well as 74 springs, prioviding critical cold water to the McCloud River, a key water source for the state.

Mt. Shasta Headwaters Conservation Area



This management approach melds restoration, landscape goals and collaboration across public and private ownerships. Implemented over the larger landscape, such approaches will benefit all Californians in multiple ways, from safely reducing excess carbon dioxide to promoting adaptation to revitalizing rural economies and safeguarding the state's water supplies.

8.3 Public Health

In addition to sequestering carbon dioxide, trees can remove airborne pollutants such as ozone, nitrogen dioxide, and particulate matter via uptake by leaf and needle surfaces. Forests can also be a source of air pollution as a result of wildfire or open pile burning of biomass. Forest management and biomass utilization can play important roles in maximizing the air quality benefits of forests: by treating forests to reduce the potential for severe wildfires, and using the waste products from the forest in a productive way, there is the opportunity to reduce wildfire and wood-waste-burning emissions that have impacts on both human health and the climate.[221]

Studies suggest stand-replacing forest fires are increasing in frequency and extent and climate change will likely exacerbate the situation by leading to increases in wildfire size and severity.[222, 223, 224] While treatments that involve the use of prescribed fire can result in similar emissions constituents, the scale of those emissions is much smaller compared to a wildfire. In addition, such activities are regulated based on local favorable atmospheric conditions and managed to minimize air quality impacts.[225] Prescribed fires are timed to occur when impacts on the region will be minimal and during periods when air quality is good. Megafires, on the other hand, tend to occur during months when air quality is already bad, exacerbating the situation with little control of the duration of the impacts. Reviewing public policy and wildfire emissions of recent megafires, Schweizer and Cisneros concluded that "policy makers need to question the path of full suppression and ask the question—is fire suppression the most appropriate way to protect air quality or just the easiest way for us today to handle a difficult decision while we mortgage the health of future generations?"[226]

With wildfire comes smoke, which contains black carbon and other climate pollutants including nitrogen oxide (NOx), a precursor to ozone. Black carbon is a very small particle (PM 2.5) that is formed with incomplete combustion and is characteristic of wildfires. In addition, black carbon represents a public health risk for cardiovascular and respiratory disease, as well as cancer and, potentially, birth defects.[227]

While a number of external factors affects how and what type of smoke is formed, where it goes, and how long humans are exposed to it, research is clear that wildfire smoke, and all of its constituents, is unhealthy for humans.[228,229, 230] Managing forests and watersheds for greater health and resilience minimizes the risk for large scale, destructive fire. This risk reduction, in turn, will minimize human exposure to wildfire smoke on the intense and extended timescales experienced in the last ten years, improving public health in the immediate fire area as well as populations affected for the many hundreds of miles that wildfire smoke can travel.[231]

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[221] Stephens et al., 2009
[222] Westerling et al., 2006
[223] Miller & Safford, 2009
[224] Garfin et al., 2013
[225] Wiedinmyer & Hurteau, 2010
[226] Schweizer & Cisneros, 2016
[227] U.S. Environmental Protection Agency, 2016.
[228] Reisen et al., 2015
[229] Liu et al., 2016
[230] Delfino et al., 2009
[231] Liu et al., 2016

The health impacts of air pollution are likely to be modified by climate change, due mainly to the exposure of populations to increased levels of air pollutants and the enhanced pollutant emission and production rates in a warmer climate: climate change is projected to increase cardiovascular and respiratory morbidity and mortality associated with ground-level ozone.[232, 233] Most California residents are currently exposed to levels at or above the current State ozone standard during some parts of the year, and exposure to ozone has been shown to be associated with decreased lung function, respiratory symptoms, hospitalizations for cardiopulmonary causes, emergency room visits for asthma, and premature death.[234] At higher daily concentrations, ozone increases asthma attacks, hospital admissions, daily mortality, and days of restricted activity and school absences.[235]

The mobilization of historic pollutant loads is another danger from forest fires. For much of the 20th century, automobiles used a lead additive in fuel to reduce engine problems. Over 4.5 MMT of lead additives were used in California alone.[236] As a result of this application, soils around urban areas and within urban airsheds saw significant increases in lead concentrations in excess of the background levels, some of which was transported into the vegetation and ultimately soils throughout the airshed. Soil contamination is persistent, even if forest vegetation has turned over one or more times, and continues to contaminate vegetation, including trees, due to continual uptake of nutrients and water.

When forests growing in contaminated soils burn, as occurred in the Williams Fire of 2012 near Los Angeles, they can re-release toxins to the atmosphere that have accumulated in the soil: lead, zinc, nickel, and copper, among others, can be re-emitted to the air in the smoke plume.[237] These containments then become constituents of smoke and ash that spreads downwind of the fire site.. Water sampling in recently burned watersheds in southern California in the 2000s found a more than 100-fold increase in copper, lead, and zinc contaminants in the water compared with nearby unburned basins.[238] More research needs to be done to identify forests near urban areas with increased contaminant loads, and appropriate treatment methods need to be identified to ensure that management activities – or uncontrolled wildfire – do not affect and remobilize the contaminants.

Human health can be enhanced through recreation opportunities that allow California's citizens greater access to and activity options within the outdoors. This increased access can improve public health conditions and also provides significant mental health benefits. Additionally, at least 59% of Californians participate in one or more outdoor recreation activities, with many of these activities taking place in the state's forests[239], contributing greatly to Californians' quality of life.

8.4 Water Quality, Timing, and Yield

As described in the California Water Action Plan, investments in forest health in headwaters help provide high-quality water downstream.[240] At least 60 percent of California's developed water supply comes from forested watersheds in the Sierra Nevada.[241] The USDA Forest Service Strategic Plan:

[232] Sujaritpong et al., 2013
[233] Confalonieri et al., 2007
[234] Drechsler et al., 2005
[235] Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure, 2008
[236] Odigie & Flegal, 2014
[237] Odigie & Flegal, 2014
[238] Stein et al., 2012
[239] Outdoor Industry Association, 2016

FY2015-2020 recognizes that a strategic objective of the agency is to provide abundant clean water and maintain watersheds in good condition.[242] The California Department of Water Resources also highlights the nexus between forest management and water resources in its California Water Plan Update 2013 Forest Management Resource Management Strategy.[243] Healthy forested ecosystems can improve the quality and supply of these water resources, as well as contribute to resilience in terms of timing of spring melt. The forested lands of California are of significant value to both California and the nation as a whole, as exemplified by the designation of the California Headwaters Partnership Region as one of seven Resilient Lands and Waters regions in the United States; see Box 8.

High sediment loads, conveyed during the high-flow events typical of California's precipitation regime, typically occur for a number of years after large, high-severity fires. This sediment and debris can reduce reservoir capacity, increase water turbidity, interfere with other critical infrastructure, and negatively affect aquatic habitat. Post-fire reforestation and restoration can improve watershed health and benefit water resources. Forest management efforts help to reduce the need to remove silt and debris from reservoirs and recharge basins, make more space for water supply storage and hydropower generation capacity, and increase the economic value of these activities.

High severity fires can expose snowpack to direct sunlight, shifting melt times to earlier in the spring when the water flowing downstream is less able to be captured. This exposure can persist for decades, until forests regrow. Forest management actions have been shown to increase snowpack accumulation and retention over unhealthy, overgrown forests.[244]

Timing of flows is also tied to the feasibility of hydropower production. Severe wildfires such as the Rim and King Fires resulted in significant reservoir impairment downstream, through erosion and resulting sedimentation in watercourses, affecting both reservoir capacity and water quality for hydropower production. Through timing and mandated reservoir curves informing operational actions, there may be more or less water available for hydropower production during the height of need, during California's summer.

From a quantity perspective, it is possible to manage forests to increase the annual average of water quantity they deliver, although measuring this can be challenging. The Nature Conservancy conducted a meta-analysis of 150 existing studies on forest management and water supply and analyzed the impacts on potential water yield of a number of diverse forest management strategies. The analysis found possible returns of between zero and six percent in overall potential yield.[245] Similarly, a study located in Arizona examined the snow retention rate of a number of locations under a variety of treatments. Treated sites resulted in greater snow accumulation, as well as longer snowpack persistence into the spring.[246] While this topic requires additional research in California, it is a promising co-benefit for managing California's forests for carbon capture and sequestration.

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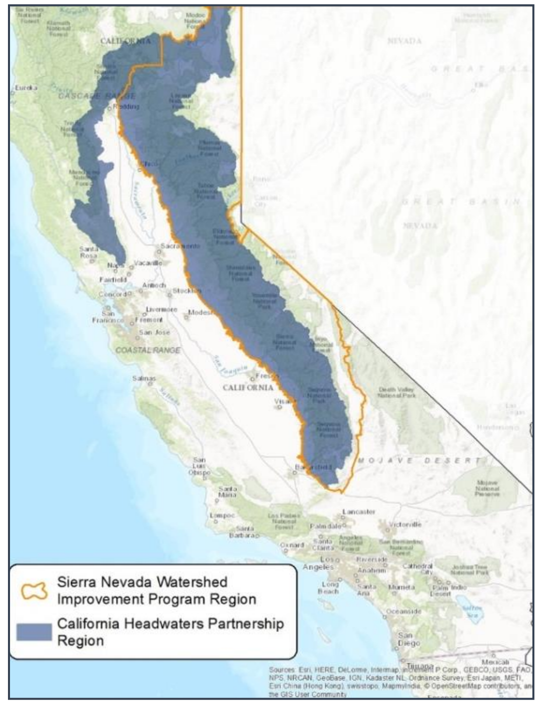
[240] California Natural Resources Agency, 2016a
[241] Sierra Nevada Conservancy, 2014b
[242] USDA Forest Service, 2015c
[243] California Department of Water Resources, 2013
[244] Sankey et al., 2015
[245] Podolak et al., 2015
[246] Sankey et al., 2015

Box 9: California Headwaters Partnership

Courtesy of the USDA Forest Service

The California Headwaters Partnership is one of seven regions in the United States named a Resilient Lands and Waters region, as called for in President Obama's Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources. These partnerships build on existing collaborative efforts to help maintain and restore resilience in regions vulnerable to climate change. They also showcase the benefits of large-landscape management approaches.

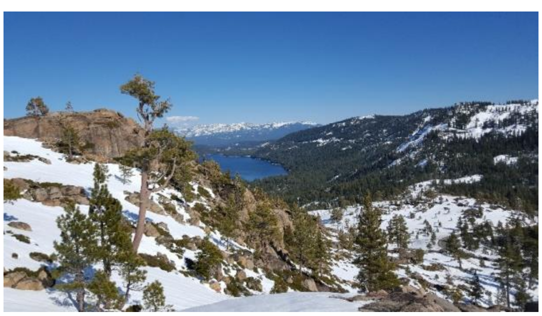
The California Headwaters Partnership region includes watersheds in the Sierra Nevada and portions of the Cascade and Coast Mountain Ranges. Combined, these watersheds provide water for over 25 million Californians, and supply the majority of water for irrigated agriculture. Due to the ever increasing threats to the forests in the California Headwaters Partnership region and the importance of this source of water to so many Californians, large-landscape restoration at an unprecedented scale is critical.



The USDA Forest Service and California Natural Resources Agency are leading this effort to:

- Restore forests and watersheds
- Reduce the risk and consequences of uncharacteristically large wildfires
- Improve and protect the quantity and quality of water
- Improve habitat for wildlife, fish, and plants
- Preserve working landscapes

The California Headwaters Partnership aims to restore resiliency across "all lands" by knitting together and building on existing collaborative efforts in the region. There are over 35 partners that support the California Headwaters Partnership and ten national forests are included in the Partnership area. A Memorandum of Understanding between the California Natural Resources Agency and the USDA Forest Service has been signed, committing to ongoing support of the California Headwaters Partnership and the Sierra Nevada Watershed Improvement Program (WIP), as the WIP is one of the primary means for implementing the goals of the California Headwaters Partnership.



Forest restoration activities across "all lands" are a key long-term climate solution. To accomplish the Partnership goals, partners are working to align existing collaborative efforts, increase investment for restoration, address policies that limit or slow restoration, and increase infrastructure needed for forest restoration. The Partnership region is socially, economically, and environmentally diverse, but the threats the region faces from climate change, which include the increasing size and severity of wildfires, and increased drought, fire, and insect-related tree mortality, are common across the landscape.

Taking a collaborative approach to addressing these threats creates the best products and the best outcomes.

To learn more about the California Headwaters Partnership and to access products, such as the ESRI Story Map and handouts, visit the USDA Forest Service or Sierra Nevada Conservancy California Headwaters Partnership websites.

8.5 Wildlife Habitat

California forests are a biological hotspot of wildlife diversity. Climate, geology, and ecological processes (fire, water, nutrient cycles, etc.) combine to create habitats and corridors that support an abundance of the high biodiversity and endemism found in the state. The threats to forestlands discussed earlier can also impact wildlife and their habitat, as can certain management practices that lead to the reduction of habitat diversity and the simplification of forest structure. The key to long-term preservation of wildlife is the conservation, improvement, reestablishment and management of their habitats;[247] active forest management can restore forests so that they are more representative of a diverse, native, fire-dependent ecosystem. Active management will not touch every acre of forestland in California, but management should be implemented in a manner that supports ecological function of unmanaged areas, including designated wilderness, and vice-versa.

In the absence of fire over the past 100 years, many forests in California have transitioned away from historically prevalent plant species mixes and towards species that thrive in shady, dense conditions that are characteristic of a fire-suppressed landscape. This has negatively affected the availability of some habitats. Restoration activities should be implemented in a way that protects crucial habitat types and elements for a range of species, including sensitive and listed species. Best practices exist for balancing the need to thin forests while protecting wildlife habitat including implementing treatments outside of the breeding season, retaining large snags that do not pose threats to public safety or significantly conflict with management goals, and promoting the retention of a diverse set of native trees.[248]

Recent research has found that the California Spotted Owl (*Strix occidentalis occidentalis*), a California bird species of special concern, is extirpated from sites experiencing uncharacteristically high severity fire. Additionally, after the King Fire, these owls avoided the high severity burn areas when foraging as well, instead foraging on the fringes of the high severity burn where burn severity was more moderate and in line with historic burn patterns.[249] This finding should inform future forest management in accounting for the needs of California's sensitive, threatened, and endangered species. High severity wildfire, out of character with historic patterns, poses a threat to the state's treasured biodiversity. Concluding their research on high severity fire impacts on California Spotted Owl, Jones et al. (2016) stated "increasing frequent megafires pose a threat to spotted owls and likely other old-forest species and, as a result, suggests that forest ecosystem restoration and old-forest species conservation may be more compatible than previously believed." However, post-fire extinction rates in areas of low severity burning – that which would be characteristic of prescribed fire – was estimated to be zero[.250, 251] This data, while reflective of a single study, is indicative of other research that has been completed, including projections that, if the present fire pattern is continued, all high-quality owl habitat will be lost to severe wildfire within 75 years.[252]

Current federal management objectives and regulatory and permitting processes result in no treatment on a significant number of federally managed acres due to the presence of sensitive, threatened, and

[247] California Department of Forestry and Fire Protection, 2010
[248] Jones et al., 2016
[249] Jones et al., 2016
[250]Lee, 2012
[251] Roberts, 2011
[252] Stephens et al., 2016

endangered species. While some of these lands could be treated from a scientific and legal perspective, the cost, in both time and financial resources, tends to be prohibitive. The absence of management is not a regulatory mandate, but is rather a result of insufficient budgets or a preference on the part of managers to avoid potential negative effects or legal challenges. The result of this is an absence of positive effects, as well as the unintended loss of many of the resources the regulations aim to protect. The above example of the California Spotted Owl is an example of this no-management outcome.

8.6 Historic and Cultural Resources

Because of their thousands of years of intimate ancestral, cultural, subsistence, and spiritual connections to forests and forest-associated habitats, Native Americans and tribes are discussed separately here. While tribes realize all the same benefits from forests that others do, they stand to be impacted in different ways by changes to forests. As with many other indigenous people, the way Native Americans and tribes perceive and categorize the benefits from forests can be distinct from the conventional categories of ecosystem services. Traditional activities related to subsistence (e.g., hunting, fishing, trapping, gathering berries and fibers for basketry) are seen not as employment or recreation, but primarily as activities that perpetuate family and cultural traditions and knowledge, provide physical and cultural sustenance for families, and support an ongoing spiritual connection to the land and its resources.[253, 254, 255,256] These intrinsic and intangible values are not widely understood by outside groups, nor can they be quantified.

While a wide range of people value California forests for non-timber forest products (NTFP), the relationships Native Americans and tribes have with these resources is closely tied to their psycho-social-spiritual, cultural, and physical well-being. This is reflected in their vast knowledge of plants and their uses. As one example, an ethnobotanical study from the 1920s-1930s documented the knowledge of Costanoan Indians of central California. This included 157 plants and their uses: 63 for food, 101 for medicinal preparations and 48 were used in other ways as raw materials, such as for fuel, cordage, construction materials and containers, clothing, tools and musical instruments. Other plant uses might include applications as detergents, cosmetics and dyes, poisons, insecticides and hallucinogens.[257] Due to socialecological change over time, ethnobotanical knowledge may have declined but the practices and relationships to natural cultural resources continue to evolve, adapt, and perpetuate values and culture. The loss of access to NTFP, and perhaps especially traditional foods (e.g., acorns) and their habitats, can affect more than diets: it can threaten the associated knowledge and identities embedded in stories, ceremonies, songs, and the community processes of collecting, preparing, and sharing foods.[258, 259]

[253] Anderson & Moratto, 1996
[254] Kimmer & Lake, 2001
[255] McAvoy et al., 2004
[256] USDA, 2014
[257] Bocek, 1984
[258] Nabhan, 2010
[259] Vinyeta & Lynn, 2013

In the past, Native Americans and tribes used fire as a tool for managing access to healthy habitats and populations of valuable species (see sidebar). The absence of fire, or non-traditional applications of fire (such as uncharacteristically severe) poses a threat to cultural resources, as well as traditional cultural knowledge and lifeways.[260, 261] Beyond culturally important plants and animals, wildfire also threatens Native American and tribal homes, safety, economies, and cultural sites. It is important to note that sacred sites and heritage sites in forests are a critical aspect of living culture that is not just frozen in times past as archaeological sites, they are elements of cultural practices today. More information on the history of fire and California's indigenous tribes can be found in Section 2.1.

Examples of fire-associated plants valued highly by Native Americans and tribes:

- willows (Salix L. sp.),
- Indian hemp (Apocynum L.),
- milkweed (Asclepias L.),
- skunkbush sumac (Rhus trilobata Nutt.),
- sedges (Carex L.),
- deergrass (Muhlenbergia rigens (Benth.) Hitchc.),
- California redbud (Cercis orbiculata Greene),
- Pacific dogwood (Cornus nuttallii Audubon ex Torr. & A. Gray),
- beargrass (Xerophyllum tenax (Pursh) Nutt.);
- California black oak (Quercus kelloggii Newberry),
- beaked azelnut (Corylus cornuta Marshall),
- elderberry (Sambucus L.),
- woodland strawberry (Fragaria vesca L.),
- blueberry (Vaccinium L.);
- snake lily (Dichelostemma Kunth),
- mariposa lily (Calochortus Pursh),
- camas (Camassia Lindl.),
- wild tobacco (Nicotiana L.),

(Anderson 1994, 1999, 2006a).
(Taken directly from Lake & Long 2014: 176)

In addition to preserving traditional cultural resources and practices, responsible forest management helps some of California's Native American Tribes today. A growing number of examples exist that make use of these peoples' legacy knowledge of and connection with their lands to shape forests into resilient, carbon-capturing landscapes. In many cases, Tribes have legal and financial resources additive to conventional landscape management agencies', and their participation can create synergies in application, permitting, and financing forest management activities. In return, participating Tribes have the opportunity to work on and, in some cases, manage landscapes to which they have historic and pre-historic ties. This connection can increase tribal financial, organizational, and institutional capacity, giving these entities some of the essential tools for operating as a sovereign nation within the most populous and ecologically diverse state in the nation.

[260] Karuk Tribe Department of Natural Resources, 2010
[261] Lake & Long, 2014

Box 10: Tribal Forestry – Maidu Summit Consortium at Tásmam Kojóm (or Humbug Valley) *Courtesy of the Maidu Summit Consortium*

Tribal non-profit stewards large restorative forest landscape, by way of a unique and exciting new management scenario.

In the increasingly threatened mixed-conifer forests of Plumas County, along the picturesque high-montane meadow that most Californians now call Humbug Valley, an important and monumental restoration project is well underway. After a land grant recommendation by Pacific Forest and Watershed Lands Stewardship Council was made in 2013, the Maidu Summit Consortium (MSC) is now poised to reclaim this culturally and spiritually significant site, so that it may be restored.

Tásmam Kojóm will be carefully managed based upon the Maidu cultural and philosophic perspectives as expressed through traditional ecology. Tásmam Kojóm is an important place for the demonstration of how Maidu traditional ecology and contemporary ecological science can be woven together for the benefit of the land. It also is essential to the perpetuation of the unique culture from which our traditional ecology was derived.

For our basic survival, our People knew of the complexity and importance of maintaining resilient and productive forests. Until not so long ago, our daily lives included the human workings required of the active stewardship of healthy and balanced forest communities, the very means of our existence. When it comes to conservation of natural resources, this work held meaning near and far when considering the extent and distribution of Tribal People across what is now the State of California.

Long-term, large landscape-level projects such as ours will demonstrate how much potential California forests hold for producing more of the highest-quality fresh water found here, critical evermore to the survival of modern people living elsewhere in our state. We also feel that slowing the devastating effects of air pollution is done by better managing forest growth cycling and transpiration over much longer periods of time. Smart forest carbon planning is our path forward.

It is also extremely important to note the rural development investment potential work like ours provides to economically stressed communities in the Sierra.

MSC have contracted with Ascent Environmental to help guide ongoing planning work, which is presently supported by the Stewardship Council, Sierra Nevada Conservancy, and the Lannan Foundation. The California Department of Fish and Wildlife will also be partners in co-managing certain aspects of the project.

Learn more at: http://www.maidusummit.org/current-projects.html

8.7 Reduced Long-term Costs for Fire Suppression

The federal Resources Planning Act Assessment[262] estimates that forests in the western states, including California, are likely to be increasingly affected by large, intense fires that are the result of complex interactions between past management practices and changing climate. Unhealthy forests in the low- to middle elevations are overly dense and homogenous with large amounts of down woody fuels, and are more prone to large intense wildfires.[263] These conditions pose higher risks and costs for access and firefighting activities. In addition, large intense, wildfires in forests not adapted to them can lead to long-term change, including vegetation type conversion, more frequent fire return intervals, and ultimately higher fire suppression costs. Despite these changes, wildfire suppression in the US remains highly effective, with nearly 98% of all ignitions suppressed before reaching 300 acres.[264]

For low- and mid-elevation forests in California, health and resilience implies restoration of conditions (lower stem densities, larger more fire resistant trees, reduced fuel loads) that support a reduction in the propensity for highly damaging and costly wildfires and other disturbance events such as drought and insects. Activities aimed at improving resilience in these forests are often center around reduction of hazardous fuels and modification of degraded stand structure.[265, 266] Forest management policies on various scales have highlighted the importance of these activities[267], but, as discussed earlier, the pace and scale of implementation has lagged far behind need, owing to societal and organizational barriers and disincentives.[268, 269]

Between 1985 and 1999, the annual cost for federal firefighting exceeded $600 million only twice. Between 2012 and 2015, federal agencies spent no less than $1.6 billion each year on firefighting. In 2015, costs surpassed $2 billion for the first time.[270] The USDA Forest Service, which accounts for about 70 percent of these federal costs, spent 16 percent of its 1995 appropriated budget on firefighting; in 2015, firefighting accounted for more than 50 percent.[271] Fire suppression has increasingly come at the expense of other programs, including fuel and vegetation management and forest restoration.

While fire suppression will continue to be vitally important in protecting lives, property and assets at risk, continued exclusion of fire from California's dry fire-adapted forests without commensurate restoration and fuel reduction will result in continued buildup of fuels and conditions which support more damaging fire that is difficult and costly to control. In a self-reinforcing fashion, more damaging wildfire can promote more risk aversion and discounting of long-term benefits of restoration.[272] Mitigation of this feedback loop can result in reduced suppression costs in the long-term.[273] Restoration of California's forests to a

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[262] USDA, 2016h.
[263] Stephens et al., 2016
[264] Calkin et al., 2005
[265] Hessburg et al., 2015
[266] North et al., 2009
[267] NCWFMS, 2014
[268] North et al., 2015
[269] Calkin et al., 2015
[270] NIFC, 2015
[271] USDA, 2015
[272] Calkin et al., 2015
[273] Collins et al., 2013

condition less prone to severe fire will be more cost effective over time, but it will require a long-term perspective, commitment, and significant structural changes in wildland fire and vegetation management.

Various frameworks have been proposed for this type of restructuring and re-focusing on resilience, and a "one size fits all" approach will not work, given the complexities and barriers in different regions, communities and forests.[274, 275, 276] As an element of fire and forest management, land use planning will need to take a central role. 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.[277] Restoration treatments in the WUI may require more intensive fuel treatments and focus on home ignition zones. In non-reserve forests, achieving health and resilience may require road networks for access to conduct management and restoration activities such as thinning and prescribed burning, which will also improve fire suppression access. In more remote areas, naturally ignited or prescribed fire may be used under moderate weather conditions to reduce fuels loads and restore forest structure. In this type of framework, fires can be suppressed and managed at lower size and intensity, resulting not only in lower fire suppression costs, but also improved forest health and resilience.

8.8 Co-benefits Conclusions and Policy Recommendations

Climate resilience is the most important aspect of healthy forests, when considering a range of benefits as described here. Managing forests for carbon as described in this Plan will result in increased climate adaptive capacity and greater climate resilience. A strong indicator of resilience is a landscape's biodiversity: higher rates of diversity across a landscape (within individual stands and up to the bioregional scale) and within individual landscape elements (species, genes, etcetera) result in greater resilience.[278] Managing a forest for diversity and, thus, resilience, will ensure that, over the long term, California has the resources on which it has come to depend, allowing the state to manage adaptation at a more realistic rate and to reduce costs by addressing problems before they start. The management activities necessary to restore forest health vary by region, forest type, and climate change stressors, and therefore no single approach is appropriate. The approach and co-benefits outlined here describe generalized forest needs and benefits as a whole; more specific details on approaches in each region can be found in the regional section in this document.

Current scientific understanding of forest dynamics strongly supports forest management that promotes diverse forest stands that are dominated by large trees that are resilient to fire, drought, insects, and diseases. These conditions, in turn, result in enhanced carbon storage and multiple co-benefits of forests restored to healthy conditions. It is a win-win situation for both carbon sequestration and the benefits we desire from our forests, since the co-benefits inherent in responsible and healthy forest management coincide with carbon capture.

In most management regimes, carbon capture and sequestration is a minor or incidental consideration. A focus on overall forest health and accompanying implementation of the recommendations identified in

[274] North et al., 2015
[275] Stephens et al., 2016
[276] Calkin et al., 2015
[277] FRAP, 2016
[278] Thompson et al., 2009

this document will help to diversify management practices, and will achieve the Forest Carbon Plan goal of sequestering and maintaining more carbon over time. There may be circumstances where, for a variety of reasons, a landowner may manage forests for maximum rates of carbon sequestration. While this is not currently the case in most situations, it is important that an understanding of the effects of different management activities be developed in order to better equip land managers and policy makers to incentivize desirable activities.

There is often a time lag between forest management actions and their effects on net carbon storage. Not only does the living forest system require time to adjust and stabilize following dramatic disturbance (often up to five years), but carbon benefits of forest management actions can be years, and even decades, in the making. From an investment perspective, this can have the net effect of handicapping long-term forest management projects. Co-benefits such as avoided catastrophic wildfire, increased recreation opportunity, snow water retention or rural economic growth provide near-term benefits and increase the return on investment from the project. Measuring the return on investment of co-benefits associated with forest management will be an important part of ensuring that California invests in the best possible outcome for the greatest number of citizens over the long term.

9 Wood Products and Biomass Utilization

California is the third largest producer of timber in the nation, while at the same time importing over 75 percent of its wood for consumption from other states and countries. This presents a significant opportunity to increase in-state utilization of timber products while simultaneously focusing on forest restoration. Increased production of timber and wood products, particularly if used in-state or in nearby states, may reduce the overall transportation emissions associated with wood products used in California and regionally. This utilization approach also ensures that the lumber and other wood products used in California are produced in alignment with California's high standards for environmental protection, both in the forest and during manufacturing. Section 6 details the fate of wood-based carbon in the production of forest products in California.

California seeks to implement a resilient forest products and biomass strategy that is diversified, scaled to address both private and public biomass utilization needs, and advances climate change and economic development objectives regionally and statewide. This section provides an overview of existing utilization pathways than can be scaled up to take woody biomass to its highest and best use.

As described in Section 3, the woody material generated through increased management and restoration activities (including addressing the current massive tree mortality due to drought and bark beetles), as well as the byproducts resulting from ongoing timber harvest, exceeds the existing, productive biomass utilization capacity in the state. In order to maximize contributions to climate change objectives, this material must be utilized in a manner that minimizes net GHG and black carbon emissions. This emissions accounting should include the carbon stored in harvested wood products produced.

Social co-benefits of successful implementation of this strategy include creation of revenue streams to fund forest health treatments partially or in full; skilled job creation in rural areas and downstream manufacturing and use; and improved diversification and resilience of rural economies. The carbon sequestration and emission reduction benefits can be multiple and varied. Diversion of material from open pile burning, the traditional method of in-field disposal, to renewable energy and fuels reduces GHG and black carbon emissions from the forestry sector and contributes to meeting the state's Renewable Portfolio Standard and Low Carbon Fuel Standard, respectively. And soil amendments such as compost and biochar can contribute material to advance the state's Healthy Soils Initiative.

Traditional lumber products and engineered wood products such as cross-laminated timber and oriented strand board can displace metals, bricks, and concrete, which have higher lifecycle GHG emissions than wood, in both low- and mid-rise building. Wood material substitutions, analyzed across multiple applications and studies, have been shown to displace an estimated 3.9 tons CO_2e per ton of dry wood used.[279] These engineered products can be manufactured from smaller dimensional lumber and wood chips, which makes them potential higher-value channels for traditionally low-value material.

9.1 Traditional Wood Products

The California Forest Practice Act, which governs nonfederal timber operations in California, cites carbon sequestration as "a critical and unique role" that forests play in the state's carbon balance (Public Resources Code Section 4512.5). The threat to this important role is also identified; and it is clear that

[279] Sathre & O'Connor, 2010

climate change will continue to stress public and private forest ecosystems. The Act also notes that proactive management is essential for adaptation and the maintenance of forests' carbon-sequestration role. California's detailed timber harvest regulations seek to balance the ecological, societal, economic, and other public trust values of California forests with those of landowners. These regulations include requirements that nonfederal timber harvests meet replanting or "stocking" requirements within five years.[280]

Where forests are managed for sustainable timber production, carbon is removed in the short-term, in the form of harvested trees. Longer term, working forests managed for sustainable timber production can provide greater carbon storage than unmanaged forests.[281,282] The primary products of commercial timber operations are lumber, other wood products, and biomass energy, but there are a number of other products that are produced as the byproducts of these operations (Table 10 in Section 6.3.4). McIver et al. estimated that, in 2012, 2.4 million metric tons of carbon was processed into energy, finished lumber, and other products.[283] In the reporting year, less than 1% of the products went unused. As can be seen in Table 10 in Section 6.3.4, finished lumber production accounted for only 26% of the carbon stored in 2012, leaving 73% of the carbon as byproducts of the industry, most of that going to energy production. How this byproduct is managed has implications for California's overall GHG and black carbon emissions, and is discussed below.

Timber harvesting activities in California have been on the decline since the mid-1980s. McIver et al. (2015), estimated that timber harvesting in California was 1.425 billion board feet in 2012, representing a decline of 18 percent from 2006 (1.504 billion board feet) and of 36 percent from 2000 (1.886 billion board feet). Since reaching a low of about 750 million board feet in 2009, harvest has picked up somewhat to approximately 1.5 billion board feet in 2015.[284] Finding policy solutions that encourage sustainable management and use of California's forestlands and wood products to reduce business and emissions leakage while ensuring a decreasing carbon footprint is acritical consideration.

While current utilization practices throughout the full wood products use cycle increases the carbon benefit, as compared with historic estimates[285], wood products do decay over time, returning carbon to the atmosphere. The climate change impacts of this decomposition are dependent on the manner of disposal. In anaerobic environments (such as in landfills), the byproduct of wood decay includes methane, a short-lived climate pollutant. In open air (such as in buildings), wood can last a long time, though it will decompose and slowly release carbon over its lifetime.

Using national and state mill efficiencies, wood product lifetimes and factors governing the fate of discarded wood products were reported by Smith et al. (2006) and by Stewart and Nakamura (2012). Using California-specific factors, they estimated that 61 percent of wood product carbon (for all wood products) would eventually be returned to the atmosphere through decay or combustion after 100 years. The ten-year average carbon storage in wood products from harvesting from 2001 to 2010 ranged

[280] California Department of Forestry and Fire Protection, 2016e
[281] Gustavsson et al., 2017
[282] Smyth et al., 2014
[283] McIver et al., 2015
[284] California State Board of Equalization, 2016
[285] Stewart & Nakamura, 2012

between 0.304 and 0.337 MMT of carbon per year in California, with the bulk of this (approximately 90 percent) coming from private forestlands.

The state's goals related to climate change and healthy forests (Section 3.2) will require the participation of all interest groups and land managers. Most working forests with regularly occurring timber harvests are privately owned. In 2012, 83% of the 1.4 billion board feet of timber harvested in California came from private lands.[286] National Forest System Lands, while comprising 54 percent of timberland in the state,[287] produced 14 percent of the 21012 timber harvest. [288]

Differing management strategies and competing regulatory objectives (habitat values for example) likely mean that carbon storage will rarely be the primary focus of landowners, at least under existing scenarios. Private timberland management practices can result in conditions different from the desired healthy forest conditions described in this Plan of more large, widely spaced trees. These differing imperatives can create conflict, but are inherent in a diverse, healthy economy and must be understood in order to get California to a sustainable carbon future in a way that serves the community, landowners, and the state. Understanding the implications of various forest management practices on carbon storage and carbon emissions, including both on the forest and in forest products streams, will be an essential component of determining overall strategies needed to achieve the State's forest climate change objectives.

9.2 Woody Biomass

Biomass generated from forest management activities, or woody biomass, is playing an increasing role in forestry. [289] This biomass can be used to produce secondary wood products, such as landscaping materials, compost, and wood stove pellets. Markets forces tend to favor low grade, small diameter trees (eight inches to 12 inches) and wood residues that can be chipped and used as fuel or sold for uses other than saw logs.[290,291] Wood chips and smaller dimensional lumber can be transformed into engineered products used in buildings, including tall wood buildings. However, significant economic challenges exist: it is particularly expensive to haul heavy, moisture-rich, low-energy wood over long distances[292,293], and the market in California for woody biomass is not yet fully developed to the point where diversification plays a role in price stability. Current state and local building codes also limit the structural use of timber and engineered wood products.

Biochar is another biomass-derived product, and it is created either as a byproduct of bioenergy generation or as a primary product. Heating biomass in the absence of oxygen is a process called pyrolysis that thermo-chemically transforms organic material into a stable char residue that resists decomposition, while also producing bio-oil and syngas that can generate renewable energy.[294] This residue is called biochar.[295,296,297] Carbon originally sequestered in the biomass will be stored for a much longer time in

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[286] McIver et al., 2015
[287] Christensen, 2016
[288] McIver et al., 2015
[289] O'Neill, 2011
[290] Evans & Finkral, 2009
[291] Barbour et al., 2008
[292] Becker et al., 2009
[293] Han et al., 2004
[294] Weisberg et al., 2010
[295] Driver & Gaunt, 2010

biochar (on the order of millennia) because it is significantly more inert than the original feedstock from which it is derived.[298,299] When biochar is put in the soil, it provides additional adaptive capacity for forests and other lands because it helps soils to retain moisture through increased tilth.[300] Currently, excess forest material that could be pyrolyzed is burned in open piles, left to decompose in the forest, or (primarily wood from urban sources) undergoes anaerobic digestion in landfills in the absence of oxygen (a process that releases methane, a strong GHG, which could be avoided through the production of biochar). To produce biochar that meets the standards and needs of its application, a facility must be managed specifically for its production. The Healthy Soils Initiative, led by the California Department of Food and Agriculture, will help develop and support the generation of, and markets for, biochar as well as compost from forest biomass for use in agricultural, rangeland, municipal, and residential soil amendments.

Nano-cellulose particles can be prepared from any cellulose source material, but wood pulp is normally used. This material can then be used to create plastics, food additives, antimicrobial films, lightweight body armor, and ballistic glass. This is a very early technology which does not yet have consistently viable markets.

California is the largest consumer of engineered wood products west of the Mississippi River, yet in-state production volumes are virtually zero.[301] Cross-laminated timber (CLT) is a wood panel typically consisting of three, five, or seven layers of dimension lumber oriented at right angles to one another and then glued to form structural panels. Because of this process, the panels can be created with small diameter timber (such as that resulting from forest restoration), and creates a product with exceptional strength, dimensional stability, and rigidity. All of the CLT used in California is imported from out of state or overseas. A lumber facility in Oregon expanded its production to CLT in 2016, becoming the first U.S. manufacturer of CLT panels certified for structural use.[302] This facility's product will be used to build a 12-story building in Portland; this development is one of two winners of the U.S. Department of Agriculture's U.S. Tall Wood Building Prize Competition.[303]

9.3 Biomass Energy

Biomass generated from forest management activities, can be used to generate electricity, heat, and transportation fuel. There is ongoing research testing the viability of biomass-sourced electricity generation, liquid biofuels, and biogas. These renewable sources of energy can reduce the need for fossil fuels and can support rural economies. Given the alternative of open-pile burning or broadcast burning biomass, bioenergy development through burning wood in a controlled environment with efficient boilers, or converting to biofuels to displace fossil fuel emissions, provides multiple benefits, including a reduction in GHG and criteria air pollutant emissions, providing an economic impetus to perform forest restoration work, and retaining existing primary wood-processing infrastructure through value-added product made from wood residuals.

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[296] Lehmann, 2007
[297] Roberts et al., 2010
[298] Woolf et al., 2010
[299] Lehmann, 2007
[300] Sohi, 2009
[301] The Beck Group, 2015.
[302] Oregon Forest Resources Institute, 2016
[303] U.S. Department of Agriculture, 2015

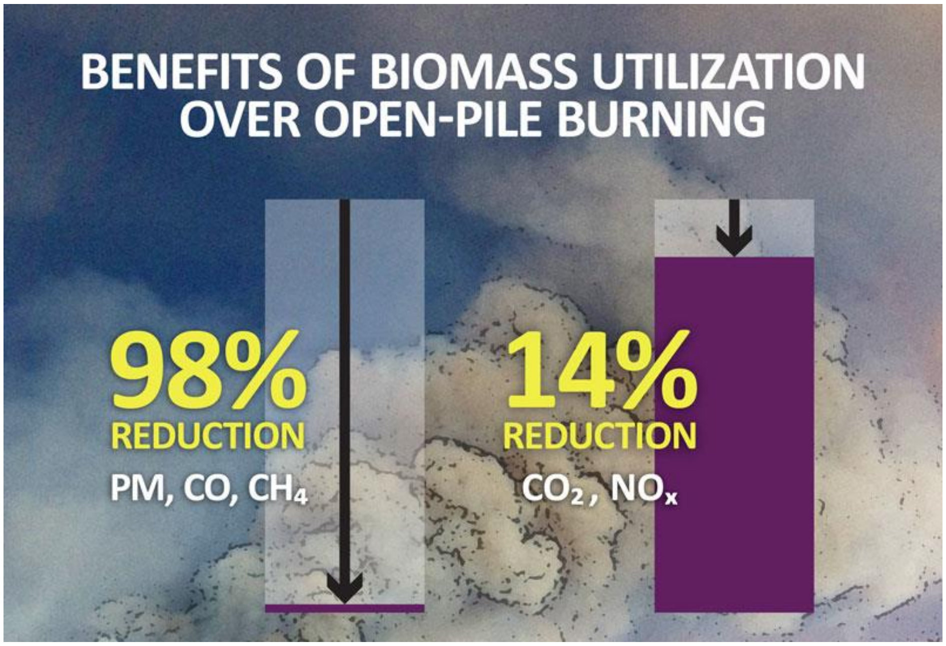


Figure 16. Emissions Comparison between Bioenergy Production and Open-Pile Burning.
Source: Baker et al., 2015

Biomass energy provides opportunities for rural development and job creation in economically-depressed regions. Additionally, the value of the environmental services provided by biomass energy production is estimated to be in excess of ten cents per kilowatt hour.[304] Energy self-sufficiency in the form of relatively small, distributed bioenergy plants throughout the state is one reason for biomass energy development. Extracting low-value biomass from the forest through thinning and fuel reduction projects promotes growth of higher-value, larger and more fire-resistant trees, which also tend to provide more wildlife benefits.

9.3.1 Challenges for Bioenergy and Biofuel Development

Woody biomass utilization has played an increasing role in California forestry over time.[305] Concerns over rising energy costs, climate change, forest health, and hazardous fuel buildups have led to executive orders and legislation that encourage the use of trees and woody plants as sources of energy. However, significant technical and economic challenges exist.

For instance, it is particularly expensive to haul heavy, moisture-rich, low-energy-density wood over long distances .[306,307] Haul distance, along with other site-specific variables, such as forest type and condition, influences the market value for wood energy chips. Market forces dictate that low grade small diameter (eight inches to 12 inches) trees and wood residues be chipped and used as fuel or sold for uses other than saw logs.[308,309] In scenarios where utilizing waste from commercial timber harvests offers an opportunity to

[304] Morris, 1999
[305] O'Neill, 2011
[306] Becker et al., 2009
[307] Han et al., 2004
[308] Evans & Finkral, 2009

reduce risk of damage to forest watershed, reduce costs of fire suppression, and/or meet other forest management objectives, biomass projects can potentially offer net benefits to forest stakeholders.[310,311,312,313]

Furthermore, several critical barriers exist that must be overcome to allow for effective utilization of forest biomass for transportation fuels. These include: high costs of aggregating feedstocks and delivering finished biofuels from remote and inaccessible locations, and high capital costs of mature technologies that inhibit investment. Additionally, emerging technologies for woody biomass conversion show significant promise, but require public financial support to help mitigate perceived risks and overcome early technology development costs. The solution to addressing these critical barriers may require targeted government funding in the near-term.

9.3.2 Legislative Support for Forest Biomass

Markets for biomass energy in California are complex and in flux. The vast majority of California's biomass conversion facilities were built in the 1980s, when regulatory and economic conditions were more favorable. Now these plants are 25-30 years old and need upgrading. The number of biomass facilities producing energy in the state has diminished over time primarily due to economic issues. Facilities are shutting down or idling due to expiring power contracts. Bioenergy generation prices in current contracts are often unfavorable due to competition from cheaper wind and solar generation, as well as natural gas power production. To aid new biomass plants, Senate Bill 1122 (Rubio, Chapter 612, Statute of 2012) established a feed in tariff to new bioenergy facilities that are 3 MW and less. This program, called the Biomass Market Adjusting Tariff (BioMAT) program, tasks the three largest Independently 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. In September 2016, Governor Brown signed Assembly Bill 1923 (Wood), which adjusts the BioMAT size limits to allow electric generators to have a nameplate capacity of 5 MW while maintaining the export limit to the grid of 3 MW. In addition, in 2016 the Legislature passed Senate Bill 859, which requires that investor-owned utilities and the larger local publicly owned utilities purchase their proportionate share of 125 megawatts of electricity from existing bioenergy facilities that use a specified percentage of fuel from High Hazard Zones (HHZ) in California.

Contributing to the biomass energy market is the state's Renewables Portfolio Standard (RPS). California's 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.

Facilities that generate electricity using biodiesel derived from biomass feedstock, a biomass fuel, or biomethane derived from digester gas and/or landfill gas are eligible for the RPS. Eligible feed stocks for biomass facilities certified under the RPS include, in part, "any organic material not derived from fossil

[309] Barbour et al., 2008
[310] Lowell et al., 2008
[311] Mason et al., 2006
[312] Snider et al., 2006
[313] Liu, 2016

fuels, including, but not limited to, …, mill residues that result from milling lumber, rangeland maintenance residues, …, wood and wood waste from timbering operations, and any fuel that qualify as "biomass conversion" as defined in Public Resources Code section 40106. Currently, there are 35 biomass facilities in California certified and eligible for RPS, and five pre-certified biomass facilities with future commercial operations dates. These 40 facilities have a combined nameplate capacity of 944 MW. Of these 40 biomass facilities, 22 were operational at the end of 2015.

In addition, California's Low Carbon Fuel Standard (LCFS), administered by ARB, can provide a strong incentive for converting forest biomass into fuel. Support for biofuels from the LCFS has been strong since December 2014, as credit prices have increased, and should continue to strengthen as CARB's regulatory caps on carbon intensity of transportation fuels are lowered in each successive year.

Strong policies are critical to fostering development of biomass markets. Biomass utilization could support activities to reduce hazardous forest fire conditions and support a resources-based industry in local communities. However, the low financial value of biomass for energy production means that it is likely to be only a marginal driver of harvesting activities, absent some kind of subsidization of the harvesting and/or the hauling of the material to the power plant.

9.3.3 Forest Biomass Research and Development

The California Energy Commission's (CEC) research and development on biomass in general, and forest biomass and forest management activities in particular, is supported under the Electric Program Investment Charge (EPIC) Program, the Natural Gas (NG) RD&D Program, and the Alternative and Renewable Fuel and Vehicle Technology Program's Sustainability Research.

Specifically, under the CEC's Energy Research and Development Division, the EPIC Program's 2012-2014 Triennial Investment Plan allocated 20 percent of funding, or about $26 million, for bioenergy technology development and demonstration (TD&D). The EPIC's 2015-17 Triennial Investment Plan allocated $18 million for bioenergy TD&D and $5 million for bioenergy applied R&D.

Research and development on forest biomass and forest management activities addresses the broad challenges to the widespread commercialization of bioenergy systems. For the applied R&D in the first EPIC investment plan, the emphasis was on modular bioenergy systems for forest/urban interface which will support sustainable collection, management, and power generation from forest residue thinning. The applied R&D in the second plan complements the efforts in the first plan by targeting other key anticipated areas such as:

- Identifying and customizing application of advanced conversion technologies in a larger forest or woody biomass application to support sustainable forest practices and help reduce fire hazards;
- Advancing sustainability standards for biomass collections to ensure environmentally sustainable systems; and
- Improving performance and efficiency in electricity and heat generation; and now largely supporting the state's efforts to address the problem of wide-scale tree mortality.

The CEC's first bioenergy solicitation under EPIC addressed key challenges such as costs and environmental impact, improved efficiency by demonstrating bioenergy technologies that are proven in the pilot or bench scale, and demonstrating effective business models for bioenergy systems. The TD&D efforts placed emphasis on community-scale bioenergy facilities and on low emission or zero emission distributed generation technologies, including combined heat and power.

The CEC released a new EPIC bioenergy solicitation in summer 2016 to address fire-hazard reduction focused forestry biomass to energy. In response to the Governor's 10-30-2015 Proclamation of a State of Emergency to protect communities against unprecedented tree die-off, the EPIC program accelerated the release of the bioenergy solicitation by a year and dedicated $15 million of the $23 million available for bioenergy research to support technologies that can help mitigate drought-related tree mortality. The solicitation has both applied research and development (AR&D, $5M) and technology demonstration and deployment (TD&D, $10M) components that propose solutions for biomass from high hazard zones. The AR&D supports early stage development on technologies and strategies for the sustainable use of forest residue and thinning to generate renewable electricity, while reducing catastrophic fire hazards. The projects funded through this research group must use technologies and strategies sized for environmentally and economically sustainable use of locally available woody biomass resources and provide benefits to local communities and IOU electricity ratepayers. The TD&D component was designed to demonstrate innovative technologies, techniques, and deployment strategies to expand the efficient and sustainable use of California's woody biomass from the CAL-FIRE-defined high hazard zones (per the Governor's Proclamation of a State of Emergency) to generate electricity and, where possible, useful thermal energy. Additionally, the woody biomass must be a byproduct of sustainable forest management activities as defined by the CPUC's BioMAT program.

Box 11: EPIC-Funded Forest Biomass Gasification Project in North Fork, CA

The North Fork Community Power Forest Bioenergy Facility Demonstration project provides one example of recent efforts to develop new biomass energy capacity. Located in North Fork, California, it is a technology demonstration and deployment project supported by a $4.9 million grant from the California Energy Commission (CEC). The project, managed by the Watershed Research and Training Center, will install and demonstrate a commercial-scale, gasification-to-electricity system that converts wood waste from forest management activities to renewable electricity.

The CEC funds are part of a larger project that will ultimately result in a 2 MW biomass gasification plant. The project is a public/private partnership between Phoenix Energy and the North Fork Community Development Council, and includes more than $1.36 million in match funding. This project supports the Forest Carbon Plan goals by reducing fire risk, and improving watershed protection and air quality, and providing local jobs.

The plant will use forest biomass from forest management operations and hazardous fuels treatment activities in the greater North Fork area, in a high priority tree mortality zone. Researchers will investigate technical, environmental, and economic aspects of operating the biomass gasification facility including: evaluation of the reactor, gas cleanup and automation and controls; protocols to improve performance and reduce operating costs; feedstock characteristics; feedstock consumption in combination with other gasifier parameters and its impact on product gas quality; engine-generator performance, air emissions, and quality of ash and biochar byproducts.

The facility features a GE-supplied biomass gasification system—the gasifier, gas conditioning system and engine. GE and Phoenix Energy are collaborating on design and implementation, and plan to replicate the system at different locations in the state. The system is anticipated to consume about 8,000 bone dry ton (BDT) or woody biomass per year for a 1 MW system and be able to operate at least 7,000 hours per year. The facility will help reduce emissions by diverting biomass from burn piles and utilizing the biomass as an energy resource in a controlled environment, with projected annual emission reductions of 10 tons of NOx, 38.2 tons of particulate matter, and 2,430 tons of carbon dioxide equivalent (CO_2e).

Electricity generated from the plant is anticipated to be sold to PG&E through the California Public Utilities Commission (CPUC) SB 1122 Bioenergy Feed-in-Tariff. Under California's SB 350 program, electric utilities must procure 50% renewables by 2030. This project will help PG&E meet its RPS obligation.

The project broke ground in November 2016.

In 2015, the Public Interest Natural Gas R&D program allocated about $4.4 million for biogas and renewable natural gas research. These programs include bioenergy research that also supports advancements for biochemical conversion of other organic wastes. A more detailed description of the CEC's bioenergy R&D portfolio for forest biomass follows. Biogas and renewable natural gas research under the Natural Gas R&D program aims to lower the cost, improve the efficiency and reduce associated emissions of the production biogas, cleanup, upgrading to pipeline quality biomethane, and onsite use for power generation. Opportunities for forest biomass include conversion to syngas via a thermochemical process and subsequent upgrading to biomethane through a process such as methanation.

The CEC Research and Development Division manages several active research and development projects funded under the 2012-2014 EPIC plan and the Natural Gas Research and Development Program.

9.3.4 Forest Biomass for Transportation Fuels

The CEC's Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) has funded a comprehensive investigation of sustainable forest biomass utilization, four forest biomass pilot-scale, various demonstration projects, and is currently reviewing several proposed technologies that could process woody biomass into fuels under an open solicitation, Community-Scale and Commercial-Scale Advanced Biofuels Production Facilities solicitation (GFO-15-606). These projects are displayed in the tables attached and show that pilot-scale technologies are being developed for the commercial production of multiple fuels, including biomethane, ethanol, renewable diesel, and renewable gasoline.

Additionally, the ARFVTP has funded research conducted by the USDA Forest Service. The USDA Forest Service, supported by university and private subcontractors, recently completed an applied research project, which provides tools to evaluate and prescribe sustainable harvest and utilization of forest biomass in California. Tasks include:

- Developing a revised version of BioSum model, which provides an analysis and planning tool for modeling the impacts of alternative forest treatment prescriptions under site-specific conditions in California forest lands;
- Quantifying carbon storage and mass balances following wildfires, by measuring carbon losses from fire compared to adjacent unburned lands, to quantify benefits from treatments to reduce the intensity of high severity fires;
- Measuring forest ecological impacts from recent fires, to measure rates of forest recovery from high severity wildfires; modeling impacts of biofuel demand, to develop scenarios measuring the economic viability and potential locations of forest biofuel facilities, based on alternative technology, cost, and price assumptions; and
- Quantifying the efficacy of fuel reduction treatments and looking at their impacts on reducing wildfire severity and lowering carbon emission from wildfire.

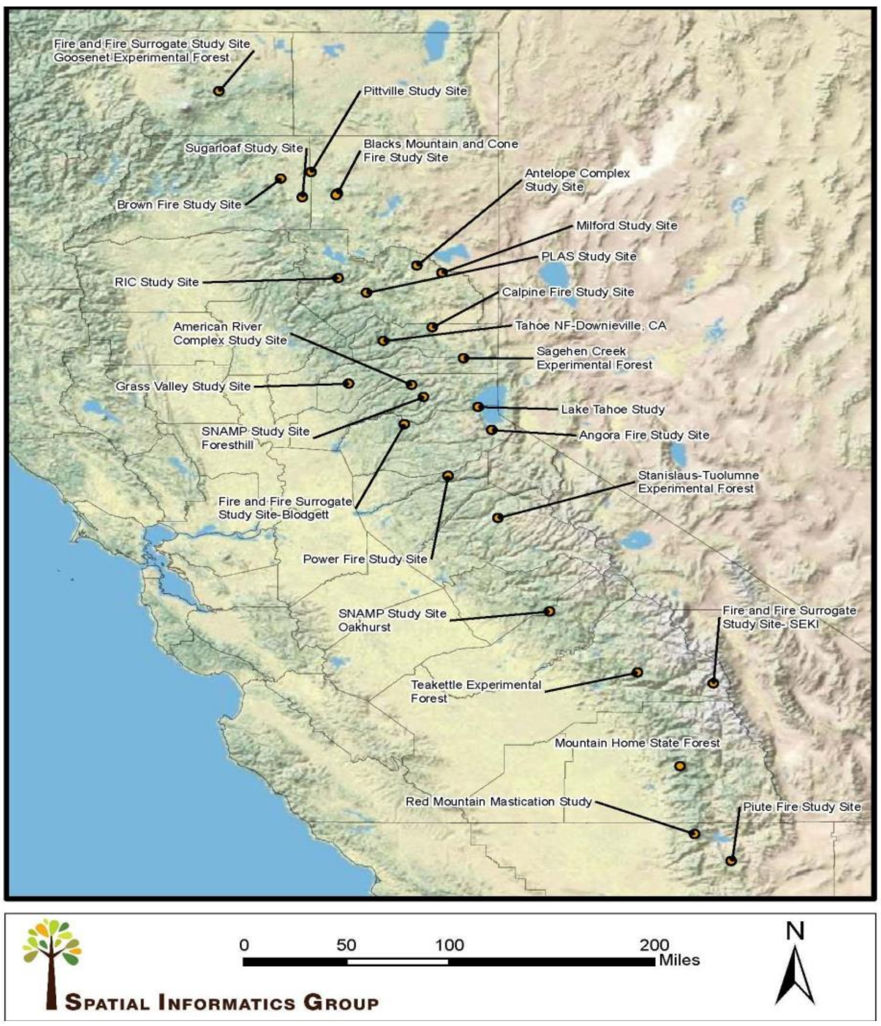
The CEC is considering a targeted ARFVTP solicitation for forest biofuels projects in the near future. An allocation of extramural funding from outside the ARFVTP allocation process would greatly facilitate such an offering. Since many forest communities are among the most socio-economically challenged in the state, and lie within or in near proximity to impacted air districts, such a solicitation would complement emerging State policy goals.

Box 12: Sustainability of Biomass Utilization

A suite of interrelated studies were integrated to evaluate the sustainability of increased forest biomass utilization for transportation fuels under differing management practices across public and private lands and expected fire regimes. Several field studies at the stand scale quantified the direct ecological effects of treatments and wildfires. Other studies using these field data modeled effects of treatments and wildfires on carbon stocks within the forest under a range of site conditions. Twelve individual tasks were included to address ecological, environmental, and socio-economic dimensions of biomass harvest.

In this project, researchers assessed the large-scale impacts of forest practices designed to reduce risk of severe wildfire by developing an analytical tool that simulates 40-year impacts of optimally selected treatments on net carbon sequestration, costs of implementation, and reduction in severe fires.

The BioSum model was developed and applied on California's total timberland base, using Forest Inventory Assessment (FIA) data, to evaluate optimum treatment sequences for reducing severe fire probabilities in each stand. BioSum evaluated dozens of promising management prescriptions with respect to a set of key metrics. By optimizing to select the best 40-year sequence of prescriptions to minimize fire hazard for each stand, the resulting scenarios also improved overall forest health as indicated by multiple performance metrics such as improved stand vigor, increased long-term net carbon sequestration, and reduced mortality losses. Implementing these optimal silvicultural sequences over a 40-year time horizon would eventually reduce the fire hazard across most of California's timberlands by 50 percent.



Map of facility locations for one scenario

Several tasks were designed to look at how a sustainable biomass utilization industry could be developed in California. The research team also investigated how a set of biofuel production facilities using forest residues can induce increased demand for forest biomass utilization. Using a spatially-explicit site simulation model, various scenarios were analyzed to identify the optimal number of facilities, their locations, sizes, and total throughput.

Under scenarios that cover all areas generating substantial forest residuals under BioSum prescriptions, several dozen facilities could be sited within the State, each producing 15-20 million gallons per year. This assumes that federal lands are included in forest restoration management plans, and also assumes currently favorable carbon credit market prices for low carbon biofuels from forest biomass. The resulting build out would sustainably utilize 9.2 million bone-dry tons (BDT) per year, and generate gross revenues, including carbon credit sales, of close to $1 billion per year.

10 Existing State Legislation and Regulation

Forest lands, even those held in private ownership, are considered “public trust” resources: that is, the owners of the forests manage for their specific objectives, but their management must preserve certain public trust or societal values inherent in them. These values are discussed further in Section 8, identified as “co-benefits”, but generally include benefits such as water quality and quantity, wildlife habitat, aesthetics and recreation, and air quality. It is because of the public trust values inherent in California’s landscapes that we have forest and landscape management regulations in place, and it is the underlying objective inherent in all new state legislation.[314]

10.1 State Regulatory Framework

While the California Environmental Quality Act (CEQA; Public Resources Code Section 21000 et seq.) provides overarching protections for the state’s environment, the Z’berg-Nejedly Forest Practice Act, passed in 1973, establishes the primary vision, values, and regulatory framework around which all non-federal forest lands in California must be managed. It is recognized as the most comprehensive forest regulatory framework in the nation.[315] This Act is implemented through the Forest Practice Rules (FPRs), which are promulgated by the Board of Forestry and Fire Protection. The FPRs require a Timber Harvesting Plan (THP), which is a CEQA-equivalent document, to be completed by the landowner and approved by CAL FIRE prior to most forest management efforts. The THP takes into consideration stream course protection, risk to wildlife and habitat, fire protection, water quality issues, and sustainable forest yield, among other factors. As part of the regulatory process, a THP is submitted to, and must be reviewed by, the following state agencies: CAL FIRE (the lead agency), the Department of Fish and Wildlife, the Regional Water Quality Control Board, the California Geological Survey. As a part of this process, most of these agencies also administer their own resource protection laws for fish, wildlife, and water quality.

There are circumstances in which a permit is not required. These are called emergencies or exemptions. Currently, some of the most well-known and well-used exemptions include those for dead and dying trees and for substantially damaged timberlands (FPR Section 1038).

The cost and complexity of California’s FPRs can create challenges for, small, private forestland owners in particular. These landowners own approximately 20 percent of California’s forested landscape[316] , but the FPRs are structured in a way that makes active management prohibitively expensive for many of these landowners. Solutions to ameliorate this concern have been attempted – most notably the Nonindustrial Timber Management Plan (NTMP) and the more recent Working Forest Management Plan program, enacted through AB 904 (Chapter 648, Statutes of 2013)–but while these strategies reduce regulatory costs for landowners in the long term, they still present substantial up-front costs that are problematic for some small landowners.

The California Forest Improvement Program, or CFIP, is an incentive program for landowners holding less than 5,000 acres of forestland. It provides cost-share funds for development of forest management plans and conducting forest improvement work, such as tree planting, thinning, addressing insects and disease, reducing stream sedimentation, and improving wildlife habitat. While this program currently provides

[314] Morrison et al., 2007
[315] Morrison et al., 2007
[316] American Forest Foundation, 2015

meaningful investment into California's forest resources, its resources do not match the scale of need for forest health and resilience improvements on small forestland holdings.

Assembly Bill 1492 (Chapter 289, Statutes of 2012) established the Timber Regulation and Forest Restoration Fund (TRFRF) to finance the timber harvest regulatory programs at state agencies and a grants program for forest restoration. These funds are generated by a one percent assessment on lumber and wood products sold at the retail level in California. Forest restoration grant programs using these funds are currently being administered by CAL FIRE, the Department of Fish and Wildlife, and the State Water Board.

In fall 2015, the USDA Forest Service Pacific Southwest Region, National Park Service Pacific Region, CAL FIRE, Sierra Nevada Conservancy, multiple environmental organizations, and two prescribed fire councils signed the Memorandum of Understanding for the Purpose of Increasing the Use of Fire to Meet Ecological and Other Management Objectives (MOU).[317] The MOU recognizes that the state's wildland ecosystems have evolved with fire, which provides resilience and renewal. The purpose of the MOU is to: "…document the cooperation between the parties to increase the use of fire to meet ecological and other management objectives in accordance with…" specified provisions. Modifications to the MOU are currently underway and a number of additional agencies and organizations have signed on to it.

10.2 Recent Forest-Related Legislation

Forest issues have seen an increase in legislative attention and regulation over the past several years. Some of the legislation passed is listed below, including how it may affect California's forest management efforts.

- Senate Bill 859 (Chapter 368, Statutes of 2016): Among other things, this bill established new procurement requirements for bioenergy generated with forest-sourced biomass from tree mortality High Hazard Zones in California.[318] It also calls for ARB, in consultation with CNRA and CAL FIRE to complete a standardized GHG emissions inventory for natural and working lands, including forests. Further, the legislation directs CNRA to establish a working group on expanding wood products markets that can use woody biomass, especially that from high hazard zones determined by the Tree Mortality Task Force. Recommendations from the working group are due to the Legislature by June 2017.
- Assembly Bill 2480 (Chapter 695, Statutes of 2016): This statute identifies watersheds as part of California's water infrastructure. While no implementation conditions are included, it is possible that this bill could result in increased investment in California's headwaters in the future.
- Assembly Bill 417 (Chapter 182, Statutes of 2015) provides the Board of Forestry and Fire Protection with additional flexibility in setting post timber harvest tree stocking standards in order to, in part, contribute to specific forest health and ecological goals as defined by the Board.
- Senate Bill 1122 (Chapter 612, Statutes of 2012) requires production of 50 megawatts of biomass energy using byproducts of sustainable forest management from fire threat treatment areas as

[317] USDA Forest Service, 2015h

[318] High Hazard Zones are areas designated by California State government as being in greatest need of dead tree removal due to severe tree mortality levels caused by 5 years of drought and subsequent bark beetle infestations. These areas are designated in two tiers, representing both potential direct threat to people, buildings and infrastructure from falling trees (Tier One), as well as broader fire risk and forest health considerations (Tier Two).

determined by CAL FIRE. The aim of the law is distributed generation of small-scale power facilities less than 5 MW (a change enacted by AB 1923) and delivering 3 MW to grid.

- Assembly Bill 1504 (Chapter 534, Statutes of 2010) requires the Board of Forestry and Fire Protection to ensure that its rules and regulations that govern timber harvesting consider the capacity of forest resources to sequester carbon dioxide emissions sufficient to meet or exceed the state's GHG reduction requirements for the forestry sector, consistent with the AB 32 Climate Change Scoping Plan goal of 5 million metric tons CO_2 equivalent sequestered per year. The Board is implementing an annual monitoring and reporting process, based on USDA Forest Service Forest Inventory and Analysis data, to meet this requirement. The first report is anticipated in early 2017.

11 Research Needs

This section compiles, by topic area, a number of important research needs that were identified in the course of preparing the Forest Carbon Plan. Finding opportunities to address these needs will be part of the implementation Forest Carbon Plan implementation actions (see Section 4).

11.1 Planning, Monitoring, and Modeling

- Enhance the predictive capacity of forest carbon models to aid in planning, policymaking and investment.
- Standardize methods, data, and modeling across government agencies and landowners to facilitate planning for forest health management activities across ownership boundaries and at the landscape scale.
- Develop a forest carbon monitoring program that reports on forest carbon stock changes more frequently than current methods, such as shortening the FIA sampling cycle to 5 years (as is done in a number of Southern states) from the current 10 years, and/or measuring stocks on an annual basis using a remote sensing technique such as LiDAR. This more rapid updating of forest carbon stocks, especially when paired with information forest carbon emissions, will greatly aid adaptive management under the current circumstances of relatively rapid forest change.
- Develop an information management system to track implementation activities across local, state and federal agencies and private landowners in a standardized way that includes cost and other elements that would allow for improvement in cost-efficiency and overall effectiveness over time.
- Perform full GHG and carbon lifecycle analyses for wood products and biomass utilization pathways, including those imported from out of state and sold in California, to inform policymaking and potential incentives and regulation related to wood products markets, building codes, and energy.

11.2 Forest Restoration and Protection

- Initiate and continue research relating to appropriate restoration efforts in areas affected by uncharacteristic wildfire or tree mortality or both, including incorporation of climate change modeling.
- Develop a multi-disciplinary science panel to track and study new issues that arise with climate change and/or interactions of forest stressors significantly beyond levels previously experienced, for example tree mortality and fire behavior.
- Develop best management practices consisting of silvicultural systems that are likely to create forest structure and composition that are likely to be optimal over a wide range of as-yet unknown future climate situations.
- Continue research into the long-term impacts of forest management practices on site productivity and resilience. This is especially important where natural disturbance has been suppressed for decades and response to reintroduced disturbance may have unexpected outcomes.
- Gain a better understanding on how to minimize habitat impacts and stress on forest species from forest treatment activities.
- Better information on genetic and species selection of tree planting stock that can best thrive under changing climate conditions.
- Correlate, to the extent possible, actions taken to enhance carbon storage with downstream

water supply quantity values. Pay special attention to forest losses and changes due to climate change, including forests moving upslope.
- Identify forests at greatest risk to type conversion.
- Identify areas with the most forest carbon at the greatest risk to loss.

11.3 Forest Management and Markets

- Comprehensively calculate the costs and benefits of forest treatment activities compared with a status quo approach, to include suppression, insurance, water quantity and quality, recreation, wildlife habitat, air quality, and other ecosystem services.
- Develop new products/markets for excess biomass material.
- Identify soil types that are best suited for biochar integration, and the best application strategies for this material.
- Develop opt-in carbon maximization practices for forests that are managed for other uses, including timberlands, similar to the Natural Resources Conservation Service farming strategies.

11.4 Forest Carbon Emissions

- Develop a better understanding of how different fire types (i.e., low, medium, severe, and pile burning) and different forest fuels affect black, brown, and superaggregate carbon emissions to better understand how different management practices affect climate forcing potential and human health.
- Investigate the process of forest dead pool decay and emission rates and timeframes.

11.5 Education

- Develop and disseminate tools to assist landowners and local and regional land use planners and forest managers in assessing current forest conditions and desired future conditions for carbon resiliency and forest health, and identifying management activities to facilitate the transition to a resilient state.
- Develop infrastructure for relaying advisories and information about upcoming prescribed burns to populations likely to be impacted.

New information and tools will have a great impact as the Forest Carbon Plan begins implementation at the regional level and as strategies turn into actions. Key studies already underway include the resource economics study being conducted by the University of California, Berkeley for the Forest Climate Action Team, research to support CNRA's Fourth Climate Change Assessment[319], and research by Lawrence-Berkeley National Lab in support of the natural and working lands component of the 2030 Target Scoping Plan. As other gaps in knowledge emerge, key research priorities must be identified, developed, and funded in order to ensure that science-based, cost-effective strategies continue to move the state of practice forward, informing government agencies, private businesses and landowners as to the best investment for the cost.

[319] California Natural Resources Agency, 2016c

12 Conclusions

California's Forest Carbon Plan seeks to firmly establish California's forests as a more resilient and reliable long-term carbon sink, rather than a GHG and black carbon emission source. The information presented here acknowledges both the resilience and weaknesses of forest health in regions across the state, and provides multiple strategies to promote healthy wildland and urban forests that protect and enhance forest carbon and the broader range of ecosystem services for all forests in California. It emphasizes working collaboratively at the watershed or landscape scale to restore resilience to all forestlands in the state. It builds on existing regulations, incentive structures, and programs that are already aimed at securing carbon on forestlands, including the Timber Harvest Practice Rules, offset projects eligible for crediting in California's cap-and-trade program, and the Greenhouse Gas Reduction Fund Forest Health and Urban and Community Forestry programs, respectively, and recognizes the criticality of partnering with federal and private landowners and managers.

Key findings of the Forest Climate Action Team that serve to guide the proposed goals and implementation described in the Forest Carbon Plan include the following:

- California's forested landscapes provide a broad range of public and private benefits.
- The health of forests in many regions of the state is deteriorating rapidly.
- Extreme fires and fire suppression costs are increasing significantly, and these fires are a growing threat to public health and safety.
- Reducing carbon losses from forests is essential to meeting the state's GHG reduction targets.
- Current rates of fuel reduction, thinning of overly dense forests, and use of prescribed and managed fire are far below levels needed to restore forest health, prevent extreme fires, and meet the state's GHG reduction targets.
- The state must work closely with Federal and private landowners to manage for forest health and resiliency efficiently and at scale.
- The limited infrastructure capacity for forest management, wood processing, and biomass utilization, and the limited appropriately trained supporting workforce, are major impediments to forest restoration.
- Regionally-based efforts can best identify the areas that pose the greatest threat to forest health and offer the best opportunities to restore resilience.
- Landscape- or watershed-level collaboration—with leadership by federal agencies such as the USDA Forest Service and Bureau of Land Management, state agencies such as conservancies, nongovernmental organizations, and large private landowners—is the most promising approach to greatly increasing the pace and scale of forest restoration treatments.

The Forest Carbon Plan will move into implementation following its finalization in spring 2017. The Forest Carbon Plan will be a foundational component of the Natural and Working Lands Climate Change Action Plan identified in the 2017 Climate Change Scoping Plan Update.

Implementation will be undertaken by a diversity of public and private entities (including State Conservancies, federal land management agencies, local governments, nongovernmental organizations, and individual private landowners) that will need to collaborate in order to achieve success. Forest health outcomes derived from this work will benefit a broad constituency of stakeholders, with many benefits being realized over a long timescale. There is a clear need to identify and increase the resources available for implementation in a manner that reflects these broad beneficiaries, and to identify and pursue ways to improve the efficiency of any funds spent. The Forest Carbon Plan makes the following recommendations to initiate and guide implementation:

1. Regionalize implementation of the Forest Carbon Plan, including development of regionally driven Forest Carbon Action Plans. This regionalization should be led by state conservancies in geographies where they exist; alternative leadership capacity will need to be identified in areas not covered by state conservancies.
2. Work collaboratively at the large landscape or watershed scale to define critical biophysical and often social units for analysis and work.
3. Identify and cultivate traditional and new sources of public funding, and public-private partnerships, to support the proposed actions A-F described above and to implement them at the regional level.
4. Explore opportunities for regulatory and policy changes and streamlining to advance the activities described in this Plan and implemented at the regional level. These might include:
    f. Increase use of prescribed and managed fire for restoration.
    g. Streamline permitting for certain restoration activities.
    h. Reduce small landowners' financial barriers to land management.
    i. Development of new wood product and biomass facilities.
    j. Modify the restrictions on the export of sawlogs from federal and other public lands.

Successful implementation will require ingenuity, strong partnerships, and financial and information resources. It will also require commitments to stay the course to 2030, 2050, and beyond, so that California's forests can continue to serve as a resilient carbon sink and as a source of ecological, spiritual, and life-giving abundance for future generations of Californians.

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Appendix 1: California Forest Inventory

Overview

Forest ecosystems are an important part of the carbon cycle, taking in carbon dioxide, storing carbon as part of its woody biomass, and releasing oxygen back into the atmosphere. Forests exchange carbon with the atmosphere through photosynthesis, converting carbon dioxide to biomass (i.e. plant organic material) in trees, shrubs, and plants. Biomass is a term used to denote live and dead plant material in ecosystems. In turn, forests release carbon during respiration, decay, removal, or combustion of plant materials. Forests store carbon in above-ground plant materials, litter and woody debris on the forest floor and in the soil profile. The capture of carbon by forests from the atmosphere is termed sequestration. Carbon is also stored in wood products derived from harvested trees. Through natural disturbance and management actions carbon is stored and released at varying rates; moving between the pools described in the diagram as part of an integrated system (Figure 1). The quantity of material stored in a pool at a given point in time is referred to as the carbon stock and the rate at which the stock changes over time is the carbon flux. Forests can switch between a carbon sink and source over time given the range of management practices and variable environmental conditions.

Forest management activities can influence the carbon balance in many different ways. For example, fuel reduction projects involve thinning and burning to reduce fuel loads and wildfire risk. Initially, this creates a short-term reduction in live tree biomass until the stand recovers, but it can also reduce the greenhouse gas emissions from wildfire and improve the health of overly-dense forest stands. In some cases, forest biomass from fuel reduction projects can be utilized as bio-energy. Timber harvesting also removes forest biomass, but carbon storage accrues from harvested material that is used in long-lasting wood products that can provide stable long-term climate benefits. In addition, wood products can have a lower emissions profile when they are used instead of other, more energy intensive building materials such as cement and steel. Additional benefits are gained by creating energy from biomass that would otherwise have come from fossil fuels.

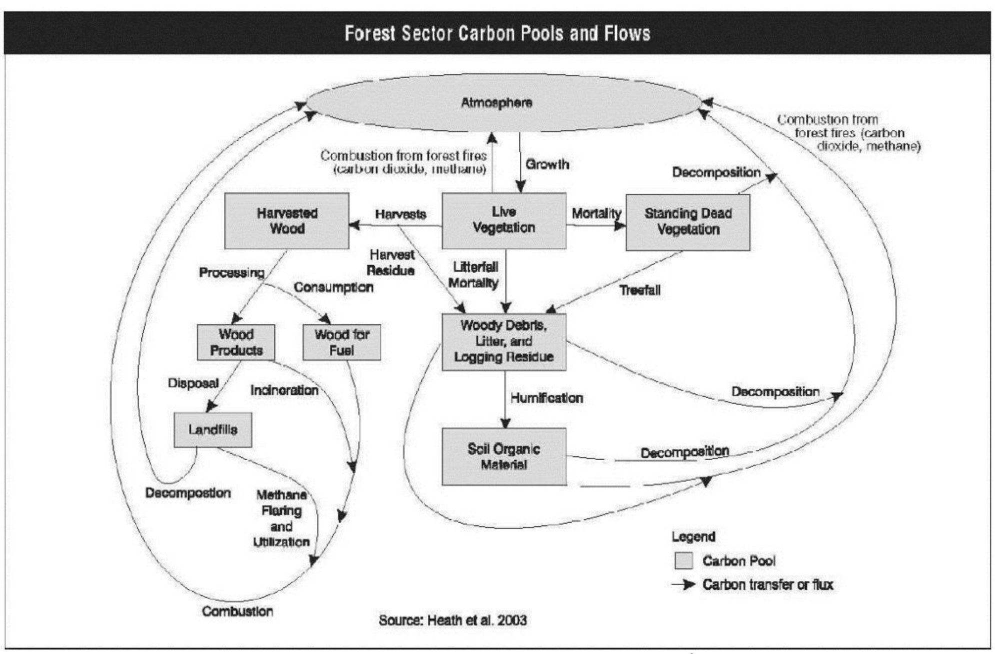

Figure 1. Forest Sector Carbon Pools[1]

Introduction to Methods

Two general approaches are used to estimate the exchange of carbon dioxide and other gases between forests and the atmosphere. These approaches may be implemented using direct measurements, process models, or reference values from published sources.[320] One approach is to estimate the net change in the amount of carbon contained in forests (carbon stocks) over time. The stock-change approach typically involves direct measurements, with deployment of a statistically-designed network of on-the-ground plots over an area, in which attributes for vegetation species, size, and the amount of dead organic matter present on site are periodically recorded over many years using standard measurement methods. Specialized calculations are then used to convert plot data to estimates of carbon. Carbon is estimated for defined pools (i.e., above- and below-ground live, understory, herbaceous and grass, shrub, standing dead, dead downed, litter and debris, duff and soil carbon). These pools correspond to Intergovernmental Panel on Climate Change (IPCC) categories for biomass, dead organic matter, and soils, while special consideration is also given to harvested wood products.[321] In turn, statistical procedures are used to aggregate data from many plots in order to generate estimates that are representative for a large area (i.e., the state or ecoregion) at a point in time. An example of this approach is the FIA Program of the USDA Forest Service. The federal government uses national FIA data (together with other sources and methods meeting guidelines of the IPCC to fulfill climate-related national and international reporting obligations. Emerging applications augment plot-based approaches with spatially explicit data from technologies such as Light Detection and Ranging or Synthetic Aperture Radar. These technologies (typically mounted on aircraft or other platforms such as satellites) yield a snapshot of wall-to-wall information on the three-dimensional structure of forests. Other satellite-based instruments provide information in other regions of the radiative spectrum, from which other forest attributes are inferred. Such information is then combined with plot-based data to directly estimate quantities at variable spatial resolution over large areas. A second approach, called the gain-loss method, involves subtracting carbon losses from carbon gains. This method also may utilize models, default or reference data on growth and losses, or location-specific data.[322]

A third approach involves directly measuring the exchange of trace gases between forests and the atmosphere. This approach is found in research applications in the fields of earth and atmospheric sciences and biogeochemistry. Research applications involve specialized equipment and combinations of data measured with varieties of instruments near the ground within a forest and from other platforms such as aircraft, satellites, or towers. Their typical purpose is to advance understanding of the processes that govern the exchange of matter (including greenhouse gases) and energy between forests and the atmosphere. These approaches are tailored for use at specific spatial and temporal scales, for example, for a forest stand and a five-year research project, or for large areas or regions and for long periods.

Approaches have strengths and limitations. Plots need to be deployed in sufficient numbers to be statistically representative, field data collection is time-consuming, and years transpire before plots are re-measured. Depending on the density of plot deployment, recent disturbance events (such as fire) may or may not be detected in plot data. However, ground-based approaches provide statistically robust crucial information unavailable by other means. Airborne technologies such as Light Detection and Ranging or

[320] Intergovernmental Panel on Climate Change, 2006
[321] Intergovernmental Panel on Climate Change, 2006
[322] Intergovernmental Panel on Climate Change, 2006

Synthetic Aperture Radar can augment plot-based networks or overcome some of their limitations at a cost. Airborne or space-based technologies afford opportunities to augment ground-based measurement systems by covering large areas. Remote sensing products vary in ease of use and range from open source to proprietary. Process models can be useful provided they are well developed and calibrated against real-world data. The utility of these approaches likely depends on the scope and purpose of a given forest carbon monitoring effort.

Examples of programs measuring forest carbon and other stand characteristics.

- Forest Inventory and Analysis (FIA) Program http://www.fia.fs.fed.us/
- LandTrendr combines time series satellite data with plot data from the Forest Inventory and Analysis Program to generate spatially explicit estimates of forest carbon stocks and change. http://landtrendr.forestry.oregonstate.edu/
- LandCarbon is a national assessment of ecosystem carbon sequestration and greenhouse gas fluxes. LandCarbon combines Forest Inventory and Analysis Program and other ground-based data together with remote sensing products and models. Assessments are produced for regions of the U.S. http://www.usgs.gov/climate_landuse/land_carbon/ ; http://landcarbon.org/
- USDA CarbonScapes is a web map application that reports carbon pools in the landscape by areas (county, watershed, and major land resources) within the conterminous United States. CarbonScapes is designed to inform stakeholders about USDA inventory, modeling, and mapping of terrestrial biosphere carbon across the landscape. http://www.carbonscapes.org/index.html
- LandfireC is the name of an approach developed at University of California, Berkeley to estimate carbon stocks and change on forests and other natural lands in California. It uses geospatial vegetation data from the federal consortium Landfire.gov, data from Forest Inventory and Analysis Program and other sources. http://www.landfire.gov/ ; http://ucanr.edu/sites/forestry/files/212528.pdf
- CarbonTracker is a carbon dioxide measurement system developed by the National Ocean and Atmospheric Administration to track emissions and sinks of carbon dioxide in North America and around the world. http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/
- NASA Carbon Monitoring System develops new technologies and methods to improve monitoring of carbon stocks and fluxes, and operates technology demonstration projects with state and local partners. http://carbon.nasa.gov/ ; https://cmsun.jpl.nasa.gov/
- AmeriFlux is a national network of research sites making long-term measurements of carbon dioxide, water vapor, and energy exchange in forests and other lands. http://ameriflux.lbl.gov/

Carbon Storage

The following information on carbon storage in forests is based primarily on FIA Program data, which is collected by the USDA Forest Service Pacific Northwest Research Station. The data presented here were collected on a ten-year cycle ending in 2014. FIA remeasures one-tenth of the plots every year. This data collection process is very sound for long-term assessment, however it should be noted that these data do not well represent the significant levels of severe wildland fire and tree mortality that have visited our forests over the last five years.

The section provides summaries of FIA Program estimates for carbon stocks in above- and below-ground carbon pools. Estimates for above-ground forest carbon include live tree, understory vegetation, down woody material and standing dead trees. Below-ground carbon pools include live and dead roots, and soil organic carbon. Carbon contained in wood products is also estimated based on results from McIver et al. (2015).

The amount of carbon currently stored above ground in California's forests has been quantified by the FIA Program (Table 1). Estimates for above-ground forest carbon include live tree, understory vegetation, down woody material and standing dead trees. Below-ground carbon pools include roots of live and standing dead trees and soil organic carbon. Trees store carbon as they take on growth and release carbon due to disturbance and natural mortality. Emissions result when trees die from natural and human causes such as fire, insects, drought or harvest. These various processes, including decay, release carbon over different time horizons, which can affect how and when the carbon moves between the various forest carbon pools. The USDA Forest Service manages lands containing the most above-ground carbon; the private lands (corporate and non-corporate) are the next highest (Table 1).

Table 1. Above- and Below- Ground Forest Carbon, 2014 (excludes harvested wood products) ***Units in 1,000 metric tons of Carbon.***

Owner	Above Ground	Below Ground	Total
USDA Forest Service:	688,308	438,442	1,126,750
Other federal government:	112,787	79,375	192,163
Local	13,352	9,141	22,492
State	47,196	22,483	69,679
Other public	457	524	981
Private Corporate Forestland	194,149	141,595	335,744
Non-corporate private:	234,143	181,322	415,465
All owners	1,290,391	872,882	2,163,273

Source: USDA Forest Service FIA – November 22, 2016 update[323]
Includes: Above ground live tree, above ground dead tree, down wood, and aboveground understory vegetation; Belowground Includes: Below ground live and dead tree roots, below ground understory roots, and soil organic carbon. Excludes harvested wood products.

Growth and Harvest by Ownership

According to the 2014 FIA Program data, the live tree stock-changes associated with the current level of harvest (removals) and mortality is generally less than growth on both private and public forestland. National Forest System Lands have substantial live tree inventories, but exhibit higher mortality rates. Private forests have lower live tree inventories and lower mortality rates because portions of live tree carbon stocks are being transferred to wood products and to energy production. The changes in growth, mortality, and removals among ownership groups reflect different goals for, and approaches to, forest

[323] Christensen, 2016

management. This results in characteristic patterns of carbon stocks and change that are unique for each ownership group. The figures below illustrate tree volume per-acre annual changes due to growth, mortality and harvest (removals) by land status on National Forest System Lands (Figure 2) and by ownership type on non- National Forest System Lands (Figure 3) reported by the FIA Program. National Forest System Lands exhibit high rates of mortality generally outpaced by growth, whereas reserved areas (Wilderness) exhibit a net decline in tree volume (Figure 2). Other public forest lands exhibit net increases in tree volume, while corporate and non-corporate private forest lands exhibit contrasting rates of harvest and net change (Figure 3). The analysis periods for National Forest System Lands and non-National Forest System lands vary, due to changes in FIA Program plot design initiated in 2000.

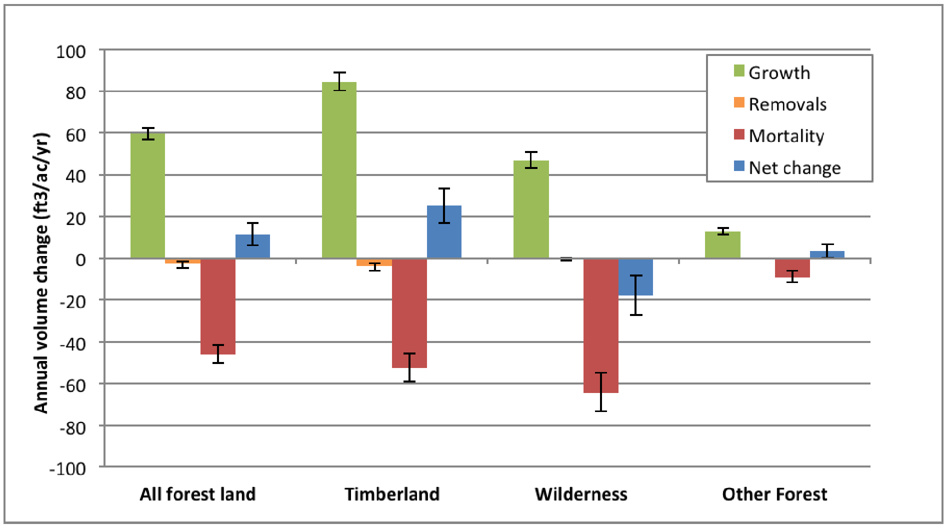

Figure 2. Average Annual Change in Volume (cubic feet) Growth, Removals and Mortality per Year on National Forest System Lands between 2001 to 2006 and 2006 to 2010 by Land status in California (error bars represent sampling error).

Source: Christensen et al. (2014)

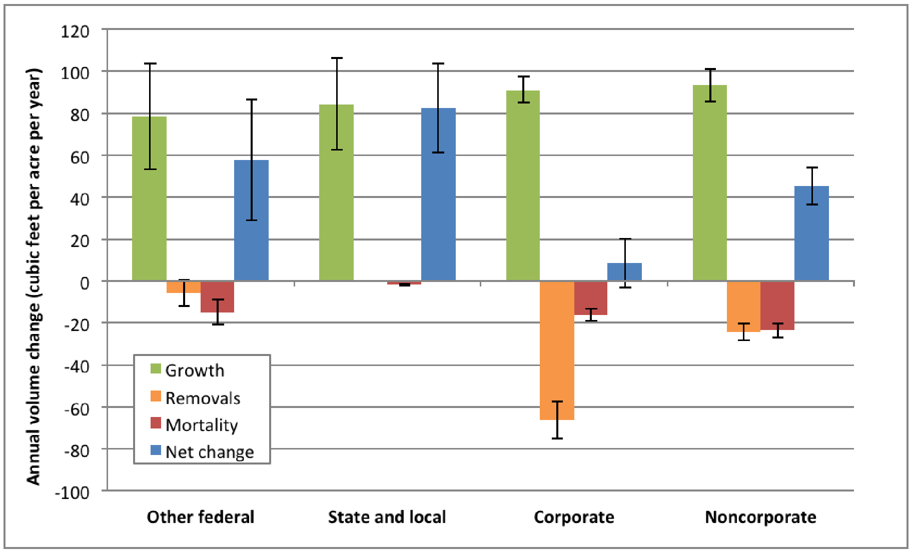

Figure 3: Average Annual change in Volume (cubic feet) Growth, Removals and Mortality per Acre per Year on -on- National Forest System Timberland between 1991 to 1994 and 2007 to 2010 by Ownership in California (error bars represent sampling error). *Source: Christensen et al. (2015)*

Urban Forests

Heat Islands

The urban areas of California have on average of nearly 35 percent of their land area covered by impervious surfaces, such as pavement and buildings. Impervious surfaces are often dark surfaces and combined with excessive heat can absorb solar radiation and reflect heat, creating what is called the urban heat island effect. The heat island effect compounds the effects of air pollution. According to a 2013 report,[324] urban heat islands lead to daytime temperatures in urban areas on average one to six degrees Fahrenheit higher than in rural areas, while nighttime temperatures can be as much as 22 degrees Fahrenheit higher as the heat is gradually released from buildings and pavement.[325] Urban heat islands can affect human health by contributing to respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke and heat-related mortality.

Environmental Justice

It is very important to note that tree canopy cover and other green spaces (parks, open space, etc.) are distributed highly unevenly in California. For instance, according to a USDA Forest Service 2010 tree canopy assessment of Los Angeles,[326] some portions of the city have tree canopy cover of over 38 percent, while other areas of Los Angeles have tree canopy cover of less than five percent. Perhaps not surprisingly, lower tree canopy cover in urban areas is often an indicator of areas that bear a higher pollution burden and are more socio-economically depressed. This can be seen when comparing low tree canopy cover

[324] California Environmental Protection Agency and California Department of Public Health, 2013
[325] U.S. Environmental Protection Agency, 2008
[326] McPherson et al., 2010

areas with areas that have a high CalEnviroScreen 2.0[327] score (designated as disadvantaged communities). It is exceedingly important that communities are engaged early and often with these types of projects. The community should identify if, when, and where tree canopy and green infrastructure efforts will take place.

Other Co-Benefits

Urban forests, including green urban infrastructure solutions, reduce energy use[328] and storm water runoff and make urbanized areas more resilient to climate change. Urban forests benefit areas by providing recreation, pollution reduction, carbon storage, heat island mitigation, noise reduction and increased wildlife habitat. Increased property values are often also realized. These ecosystem service benefits are very well-documented by the USDA Forest Service amongst others. Benefits achieved vary with tree size, canopy cover, and location, and are generally heightened in hotter climates.

Activities associated with urban forestry and green infrastructure can add jobs and economic value to the California economy.[329] In fact, in 2009, there were nearly 60,000 urban forestry related jobs in California. The revenues directly associated with urban forestry in 2009 in California were over $3 billion.

Urban forests also produce a usable wood fiber resource. Trees in urban areas have a finite life. When trees become hazardous, pest-infested, diseased, or cause excessive infrastructure damage, they must be removed. Trees removed for these valid management purposes are considered to be an emission of carbon dioxide since they are routinely deposited in landfills or chipped for land cover. If urban trees were utilized to make high quality wood products or to generate electricity at a biomass generation facility, these emissions are reduced or eliminated.

Summary of Forest Carbon Estimates from Other Assessments

A number of projects have reported estimates of the amount of carbon contained in the above-ground live pool in U.S. forests. Some are reported here for background and are not directly comparable to the categories reported in Table 1. Using a combination of FIA Program plot data and geospatial vegetation data from the federal consortium Landfire.gov, Gonzalez et al. (2015) estimated that in 2010 California's forests contained 840 million metric tons of carbon (plus or minus 210 million metric tons of carbon) in the above-ground live pool. Other remote-sensing based assessments report above-ground live forest carbon stocks ranging from 970 million metric tons of carbon[330] to 870 million metric tons of carbon.[331]

FIA Program data has been used to evaluate forest carbon stocks for national reporting. Results from FIA show that national forest carbon stocks increased by 15 percent between 1990 and 2008.[332] However, for this same time period carbon stored in harvested wood and wood products have declined. The most recent U. S. Environmental Protection Agency national report estimated mean annual stock change from 2004 to 2013 at 10.6 million metric tons of carbon per year[333] for California. This estimate did not include

[327] Office of Environmental Health Hazard Assessment, 2014
[328] McPherson & Simpson, 2015
[329] Templeton et al., 2013
[330] Kellndorfer et al., 2012
[331] Wilson et al., 2013
[332] Heath et al., 2011
[333] U.S. Environmental Protection Agency, 2015b

harvested wood products or carbon storage in forest soils.

National Forest Carbon Accounting Framework

The need for a standard forest carbon accounting framework has been recognized at the federal level. The United States government is adopting a cohesive carbon accounting framework that links the FIA annual inventory system of all forest carbon pools to modules that compile predictions of carbon stocks and stock changes back to the 1990 baseline and forward to user-defined time horizons.[334] The new framework can estimate carbon implications of past disturbances and management and separate land use change into deforestation and afforestation effects on carbon stocks and stock changes at national and regional scales.

While the National Forest Carbon Accounting Framework is designed to meet national-scale monitoring needs, it is hoped that through research partnerships with stakeholders such as states, valid down-scaling techniques can be developed to disaggregate national results to smaller scales. For example, in order to use the National Forest Carbon Accounting Framework at smaller scales, research is currently underway to incorporate finer spatial resolution imagery (i.e., Landsat time series, which is available everywhere since 1972) with FIA Program data. To help down-scale the National Forest Carbon Accounting Framework, strategic partners have the opportunity to increase the base intensity of FIA Program plots (one plot per 2,248 hectares) through direct or in-kind contributions.

Additional efforts are being made to integrate Landsat data with Light Detection and Ranging or Synthetic Aperture Radar information. This integration will allow high-quality, current biomass maps to be derived for any location where there are samples of Light Detection and Ranging or Synthetic Aperture Radar data supported by field measurements, such as Forest Inventory and Analysis Program data. This approach will also provide an annual time series of biomass maps using a consistent set of methods so that trend lines are devoid of artifacts associated with changes in sample design or approach.

Lastly, efforts are underway to more directly incorporate harvested wood products through the Woodcarb II model within the National Forest Carbon Accounting Framework[335] to further increase the analytical capacity to assess carbon dynamics in the United States and provide for consistent scenario-based projections.

Improving Carbon Quantification at the Landscape and Project Levels Going Forward

The forest management objectives described here, and the diversity of implementation mechanisms that will be used to realize them, will likely require new methods of carbon stock, stock-change and greenhouse gas quantification, monitoring and verification. Since the 1990s, forest carbon accounting has evolved globally and in California, from the scale and methods used for offset projects, to statewide inventories, to county-scale or regional accounting used in some climate action plans.[336,337,338,339] These methods have been and will continue to be informed by field-based measurement, the FIA program and otherwise, as well as satellite imagery and spatial analysis. Advancements in the availability and quality of satellite

[334] Woodall et al., 2015
[335] Woodall et al., 2015
[336] California Air Resources Board, 2015
[337] Climate Action Reserve, 2012
[338] American Carbon Registry, 2011
[339] The Nature Conservancy, 2016

imagery are rapid and may offer new methods for cost-effective carbon stock analysis at statewide and regional or jurisdictional scales. As outlined in the inventory discussion above, California's accounting will need to include wood products, which may necessitate new tracking and monitoring systems for wood intended for durable, long-term use or other uses. Down woody material and soil carbon constitute significant forest carbon pools, play important roles in the cycling of carbon and nutrients through processes such as fire and decomposition, and present unique challenges for inventory. Inventory improvements will need to leverage advances in monitoring, quantification and understanding of the processes that govern these pools.

While forest health will be pursued at the landscape scale, the Forest Carbon Plan will effectively be implemented at all scales, across property boundaries, and using different policy and incentive tools, so we will need methods of tracking performance that can accommodate this complexity. Moreover, alignments will develop between state and federal programs as federal climate policy evolves. For example, California's Forest Practice Act and Rules and inclusion of sustainable harvest requirements in bioenergy production (through Senate Bill 1122) can inform accounting for the carbon and greenhouse gas outcomes for bioenergy under the federal Clean Power Plan.[340] In addition, methods to assess the outcomes of managing forests for climate and other benefits should seek to incorporate impact or performance metrics for climate co-benefits cited as indicators of forest health, including water quality and wildlife habitat. California's focus on rigorous accounting, monitoring, and verification for carbon may offer opportunities to track these co-benefits as well.

Agencies are working together to establish this accounting framework, building on existing inventory methods and project-based and regional accounting frameworks for carbon and greenhouse gases, and integrating new data and methods as needed to fill gaps. This work will be accelerating in 2016 and 2017 to facilitate goal-setting for the Forest Carbon Plan and the 2030 Target Scoping Plan Update[341] and will be ongoing. Advances in biological and spatial science and technology, will need to be incorporated regularly, over time. State agencies plan to work with local jurisdictions, federal partners, and stakeholders from non-governmental organizations, the forest products industry, and academia to develop these quantification methods.

Stand Conditions – Impacts on Forests

Wildfires, drought, insects and disease are all natural agents of disturbance that healthy forests experience and respond to. Under conditions of prolonged drought the effect of disturbance can be amplified. Stand characteristics influence the resilience of forests to respond to disturbance. They also present opportunities for management strategies that can improve forest carbon outcomes.

The USDA Forest Service maintains an inventory of areas within its California lands affected by wildfire.[342] Between 2000 and 2013 those fires totaled nearly four million acres. Of that total, about 400,000 acres potentially requires planting to restore forest cover. An additional 140,000 acres is expected to naturally regenerate to forest. As a rule, planting is not considered for lands that were hardwood, pinyon-juniper or closed-cone conifer types. The analysis indicated that planting is required for mixed conifer, pine, fir and Douglas fir forest types.

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[340] U.S. Environmental Protection Agency, 2015a
[341] California Air Resource Board, 2016a
[342] USDA Forest Service, 2016b

Stand Conditions - Under-stocked Forest

According to FIA Program data there are seven to eight million acres of understocked forest land in California (Table 2). Some of the forest types with substantial acreage of understocked stands include: western oak group, California mixed conifer group, ponderosa pine group, other western softwoods group and fir, spruce and mountain hemlock group.[343]

An analysis of the FIA Program data was performed to determine which forest types would provide the greatest stored carbon if they were fully stocked. The five top forest types that store the greatest amount of carbon dioxide per acre in live trees when fully stocked are the redwood group (291.8 tons per acre), the fir, spruce and mountain hemlock group (219.9 tons per acre), the Douglas-fir group (210.5 tons per acre), the California mixed conifer group (201.9 tons per acre) and the tanoak and laurel group (161.8 tons per acre). Of these, redwood, Douglas-fir and California mixed conifer are also principal sources of timber in the state. The ponderosa pine group, which is the other major source of timber in the state, stores relatively less carbon when fully stocked (122.7 tons per acre).

Table 2. Understocked Non-Reserved Forest Stands (thousands of acres).

	Timber land	**Other forest**	**Total**		**Timber land**	**Other forest**	**Total**
Forest type group	**Total**	**Total**	**Total**	**Forest type group**	**Total**	**Total**	**Total**
Softwoods:				**Hardwoods:**			
California mixed conifer	1,026	7	1,033	Alder and maple	18	2	20
Douglas-fir	64	--	64	Aspen and birch	--	1	1
Fir, spruce and mountain hemlock	199	25	224	Elm, ash and cottonwood	1	7	7
Western hemlock and Sitka spruce	--	--	--	Tanoak and laurel	38	19	57
Lodgepole pine	105	6	111	Western oak	282	2,132	2,413
Pinyon and juniper	12	1,035	1,047	Woodland hardwoods	60	219	279
Ponderosa pine	828	28	856	Exotic hardwoods	2	--	2
Redwood	56	--	56	Other hardwoods	19	96	115
Western white pine	9	6	15				
Other western softwoods	103	810	913				
Total	2,403	1,916	4,319	Total	419	2,475	2,895
				Unknown (mostly seedlings)	88	14	102
				Non-stocked	428	105	533

2005 to 2014 FIA Program data

Stand Conditions – Overstocked

Current forest inventories provide estimates of forest health and suggest there are opportunities to increase forest management to reduce overstocking on an estimated one to two million acres of non-reserved forest lands. Using FIA Program data, Table 3 estimates the acreage of overstocked stands by

[343] Christensen et al. 2016

forest type. Note that this estimate may not adequately represent stand characteristics. There are likely to be millions of additional acres of forest that would benefit from fuel treatments to reduce wildfire hazard and improve forest health.

Table 3. Overstocked Non-Reserved Forest Stands (thousands of acres).

	Timberland	Other forest	Total		Timberland	Other forest	Total
Forest type group	**Total**	**Total**	**Total**	**Forest type group**	**Total**	**Total**	**Total**
Softwoods:				**Hardwoods:**			
California mixed conifer	305	--	305	Alder and maple	8	--	8
Douglas-fir	52	--	52	Aspen and birch	5	7	12
Fir, spruce and mountain hemlock	86	--	86	Elm, ash and cottonwood	--	--	--
Western hemlock and Sitka spruce	8	--	8	Tanoak and laurel	400	33	433
Lodgepole pine	2	14	16	Western oak	206	295	501
Pinyon and juniper	--	--	--	Woodland hardwoods	--	1	1
Ponderosa pine	51	--	51	Exotic hardwoods	--	--	--
Redwood	57	--	57	Other hardwoods	37	1	37
Western white pine	--	--	--				
Other western softwoods	7	6	13				
Total	569	20	589	Total	657	337	993

Source: 2005 to 2014 FIA Program data

Appendix 2: Estimated Changes in Extent for Individual Tree Species

This summary table provides more details from the work of Thorne et al. (2016) that was presented in Section 2. The table shows current extent of presence of the individual species (in 1,000 of acres) and the increase or decrease of extend of the species under the four modeled climate change scenarios over three periods of time. A key to the species name abbreviations is provided below.

Tree Species Code	Tree Species Name	Individual Tree Species Gained/Lost Acres (Thousands)												
		Current	CNRM RCP 4.5			CNRM RCP 8.5			MIROC RCP 4.5			MIROC RCP 8.5		
			2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099
ABCO	white fir	15,527	4,850	2,106	308	4,900	1,775	-5,993	3,336	-1,483	-3,849	4,018	-3,319	-9,792
ABMA	California red fir	4,630	2,975	1,241	224	3,319	988	-1,536	2,119	-200	-1,730	35	-3,289	-3,989
ADFA	chamise	15,240	8,710	9,764	11,800	5,505	9,436	15,911	6,359	7,666	8,962	5,018	5,640	9,503
AMDU2	burrobush	23,876	-721	542	1,832	-1,609	1,557	-88	2,624	7,241	9,123	3,793	10,750	14,490
ARCA11	coastal sagebrush	15,248	-883	1,102	2,348	68	1,854	7,995	4,312	4,948	3,965	3,445	3,724	7,289
ARMA	whiteleaf manzanita	15,698	503	1,141	1,950	1,145	-707	6,432	-2,413	-3,686	-2,298	-3,909	-2,825	263
ARME	Pacific madrone	15,205	2,429	3,603	6,106	1,065	2,916	10,494	-1,754	-2,368	-1,159	-2,796	-1,134	-559
ARPA6	greenleaf manzanita	12,816	-176	-1,750	-4,034	-4,351	-5,427	-9,763	-3,350	-4,218	-5,933	-1,791	-5,164	-8,853
ARTR2	big sagebrush	22,804	-3,085	-4,428	-5,670	-4,754	-5,448	-15,003	-2,288	680	-73	3,502	4,503	-2,013
ARVI4	sticky whiteleaf manzanita	11,377	6,056	7,286	9,246	6,945	8,941	16,445	2,536	2,252	4,386	2,874	4,406	6,522
BAPI	coyotebrush	23,145	-794	2,904	3,712	2,500	1,273	9,474	1,980	-1,420	-721	2,710	1,684	5,256
CADE27	incense cedar	15,819	8,804	7,620	7,021	9,243	10,546	3,981	6,261	4,195	3,807	6,066	2,559	-2,726
CECU	buckbrush	21,491	4,998	3,474	2,837	1,271	-2,002	-1,710	-1,377	-2,063	-1,879	-372	-709	1,342
CEIN3	deerbrush	13,035	2,435	2,857	3,728	4,477	6,914	10,525	4,156	4,043	5,566	2,750	4,716	5,381
CHSE11	bush chinquapin	4,772	-457	-1,798	-2,187	-1,664	-2,394	-3,366	-1,776	-2,222	-2,922	-1,050	-2,942	-3,982
CORA	blackbrush	4,824	-1,100	-1,519	-1,651	-494	-2,206	-3,346	-458	736	-1,110	378	2,226	-665
ERFA2	Eastern Mojave buckwheat	31,074	7,734	7,814	7,422	7,212	6,536	9,342	1,009	5,716	4,190	4,170	7,448	9,795
JUCA	Southern California walnut	5,613	1,297	2,885	5,027	1,522	4,244	9,404	2,209	4,342	6,498	2,291	3,484	8,786
JUOC	western juniper	10,934	-3,973	-7,446	-8,525	-6,836	-9,173	-9,921	-2,676	-6,723	-8,051	-3,299	-8,578	-10,392
LATR2	creosote bush	23,156	-1,187	285	1,501	-1,065	3,129	215	2,490	4,994	4,597	3,482	4,331	5,645
NODE3	tanoak	8,230	2,710	2,853	3,831	1,952	1,709	1,524	-788	-3,105	-3,349	-2,937	-3,604	-5,003
PIAL	whitebark pine	1,969	-1,089	-1,474	-1,745	-1,035	-1,655	-1,952	-1,424	-1,719	-1,881	-1,707	-1,969	-1,969
PICO3	Coulter pine	3,005	1,309	-19	-653	1,578	-403	-557	450	-855	-1,027	1,017	-651	-63
PIJE	Jeffrey pine	18,475	4,693	2,309	-530	1,524	-1,188	-11,188	1,957	-570	-2,455	2,149	-2,947	-10,970
PILA	sugar pine	15,174	7,121	4,848	4,599	6,235	6,646	2,268	1,933	-444	-1,171	2,755	-1,232	-5,086

Tree Species Code	Tree Species Name	Individual Tree Species Gained/Lost Acres (Thousands)												
		Current	CNRM RCP 4.5			CNRM RCP 8.5			MIROC RCP 4.5			MIROC RCP 8.5		
			2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099	2010-2039	2040-2069	2070-2099
PIMO	singleleaf pinyon	4,881	5,887	4,693	2,992	4,521	2,816	-2,175	5,825	6,944	6,798	8,471	8,430	5,257
PIPO	ponderosa pine	19,801	3,558	5,425	4,936	5,000	7,582	6,312	5,614	5,152	5,293	2,912	2,604	-654
PISA2	California foothill pine	19,778	2,599	2,947	2,947	3,323	444	4,179	621	-306	13	-484	-491	3,341
POTR5	quaking aspen	6,664	1,618	-2,040	-3,548	-2,015	-4,364	-5,644	-951	-2,756	-3,734	6,548	-830	-4,594
PSMA	bigcone Douglas-fir	1,653	6,925	4,580	4,067	5,450	4,090	3,265	1,192	1,358	2,034	1,778	1,523	3,176
PSME	Douglas-fir	17,101	-1,715	-1,909	-1,371	-3,092	-5,717	-1,733	-4,973	-8,793	-9,153	-4,614	-7,068	-7,672
QUAG	California live oak	17,391	9,053	10,650	11,416	6,547	7,376	15,565	8,788	7,121	7,409	6,698	6,247	9,099
QUCH2	canyon live oak	20,696	5,269	4,804	4,911	6,043	6,517	5,438	1,069	139	102	579	-168	-3,432
QUDO	blue oak	26,706	2,530	3,391	3,713	2,379	330	3,817	4,680	5,001	3,692	2,386	2,317	3,142
QUEN	Engelmann oak	1,030	2,175	3,289	4,756	5,972	7,943	9,416	2,252	4,172	4,275	2,925	5,751	6,911
QUGA4	Oregon white oak	10,689	800	2,196	3,577	1,762	4,030	10,658	-2,256	-1,454	-49	-473	1,184	1,667
QUKE	California black oak	20,188	7,059	8,762	9,117	7,614	10,267	8,782	7,282	6,134	6,536	5,808	4,587	3,230
QULO	valley oak	26,540	6,480	8,946	11,456	3,763	4,921	14,039	5,977	3,529	6,181	7,971	7,142	13,434
QUWI2	interior live oak	12,910	9,533	9,157	10,329	10,527	12,659	16,342	3,404	4,444	7,954	4,076	5,095	10,234
SEGI2	giant sequoia	838	1,172	1,669	1,984	1,073	1,674	1,948	1,294	1,256	969	1,435	68	-287
SESE3	redwood	7,063	-370	38	-985	928	-3,093	-1,456	-1,469	-3,383	-3,843	-2,876	-3,075	-3,089
UMCA	California laurel	18,076	-2,126	-2,126	-1,738	-932	-3,980	734	-5,101	-7,452	-7,418	-6,321	-7,379	-8,123
YUBR	Joshua tree	5,369	365	-840	-1,636	-941	-2,809	-4,574	-1,277	-662	-1,031	-1,671	-837	-2,245
ABMAS	Shasta red fir	1,590	816	-285	-664	1,252	-447	-1,217	-242	-1,471	-1,559	-557	-1,566	-1,590
PAAC3	Jerusalem thorn	9,965	6,712	8,558	13,283	3,622	8,321	14,520	2,381	7,093	8,354	2,747	10,980	18,629

Appendix 3: Ecoregional Assessments

1 Overview

As described in the Forest Carbon Plan, climate change impacts California forests with more frequent and severe wildfires, pests, disease, increased temperatures, and changing precipitation and water availability. These effects may decrease forest growth (and hence decrease rates of carbon sequestration), cause geographic shifts in tree distribution and forest types (as presented in the Science Snapshot), and result in forest loss and tree mortality (and hence increase rates of GHG emissions). However, the types of impacts currently being seen and anticipated are not the same across all regions of the state. Hence, it is important to look at our forests in greater depth on a regional basis, using the ecoregions that were presented in Section 6.2.

1.1 Regional Forest Information

1.1.1 Klamath-Interior Coast Ranges Ecoregion

1.1.1.1 Overview of the Ecoregion

The Klamath-Interior Coast Ranges Ecoregion lies between the North Coast Ecoregion to the west and the Southern Cascades Ecoregion to the east (Figure 1). It extends north into Oregon and is bounded to the south by the Central Valley. It is characterized by the steep, complex mountainous terrain of the Klamath Mountains, which include the Siskiyou, Marble, Scott, Trinity, and Salmon Mountain systems. The bulk of the Klamath and Trinity River systems flow through the region, as well as a portion of the Sacramento River. It covers approximately 8,690 square miles, with elevations ranging from 100 to 9,038 feet.

The climate is Mediterranean, with cool, wet winters and warm summer droughts that support complex vegetation patterns and high floristic diversity. The mean historical maximum temperature has increased one degree Fahrenheit over the past century.[344] Precipitation declines with distance from the coast, though the eastern Klamath region receives high precipitation from warm air lifting.

Figure 1 provides a broad overview of the Klamath/Interior Coast Ranges Ecoregion's forest types. The conifer forests of the ecoregion are among the most diverse in North America.[345] The region is thought to have been critical to the development of western forest vegetation. That is, during earlier periods of climate change this region was left untouched by glaciers. As a result, it served as a refuge and contains a mix of floras from the Cascades, Sierra Nevada and coastal ranges.[346,347]

Conifer and mixed hardwood-conifer forests comprise the majority (74 percent) of the Klamath Mountains bioregion by area, and are generally organized along elevational and longitudinal gradients[348] Hardwood-dominated woodlands cover an additional nine percent. Shrubs and grasslands comprise approximately 11

[344] Thorne et al., 2016
[345] DellaSala et al., 1999
[346] Whittaker, 1961
[347] Wagner, 1997
[348] FRAP 2015

and 3 percent of the area, respectively. Edaphic (soil type, depth) and topographic factors (aspect, slope position) play a significant role in the distribution of vegetation types.

Conifer stands in this ecoregion usually consist of Douglas-fir in combination with any of five other species, including sugar pine, ponderosa pine, incense cedar, Jeffrey pine, and white fir. An upper montane zone can be distinguished from a lower zone by the increased presence of white fir and Shasta red fir, and decreased presence of black oak and other hardwoods.[349]

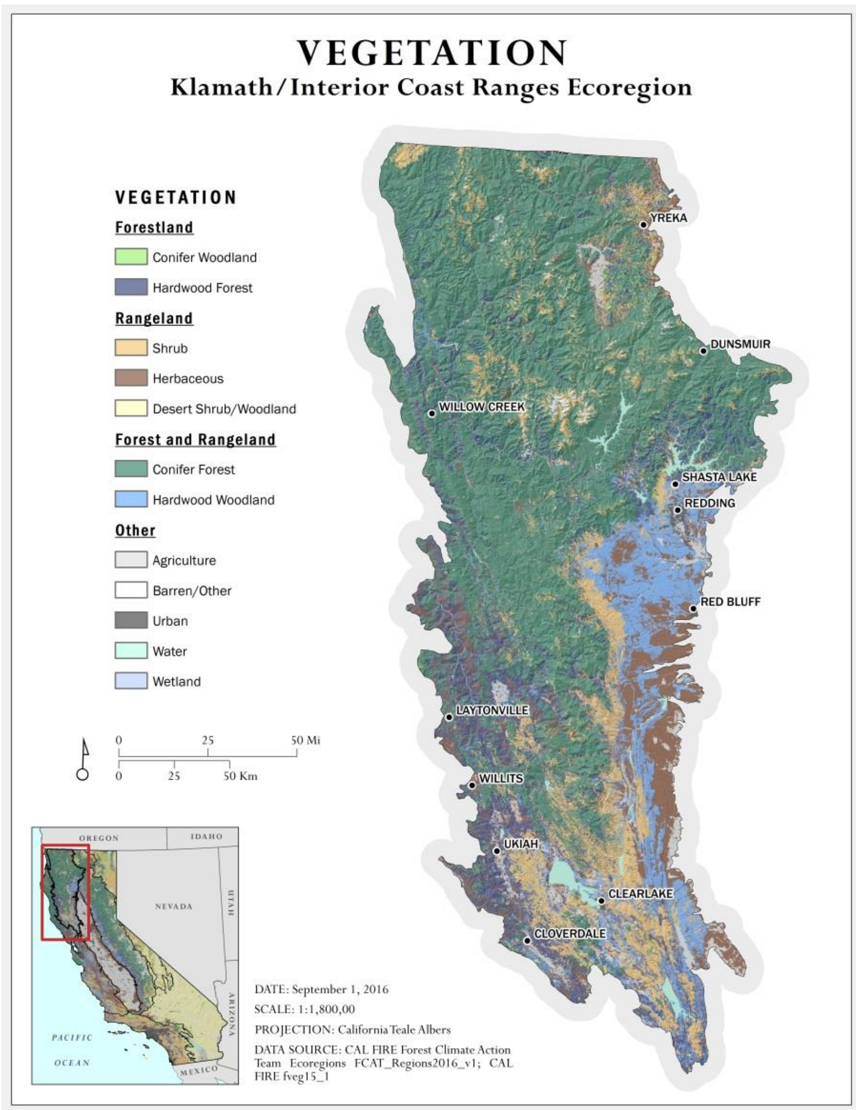

Figure 1. Vegetation of the Klamath-Interior Coast Ranges Ecoregion.

[349] Skinner et al., 2006

There are almost eight million acres of forestland in the Klamath-Interior Coast Ranges ecoregion (Table 1).[350] The federal government is responsible for 63 percent of the forestland in the region, and private owners manage the bulk of the remainder (37 percent). Most of the forestlands are in unreserved status (78 percent), and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation. Reserve lands (22 percent) may be available and suitable for prescribed or managed fire.

Table 1. Area of sampled land by status and ownership group, California 2005-2014; Klamath/Interior Coast Ranges Ecoregion.

	Ownership group						
	National forest	**BLM**	**NPS**	**Other federal**	**State and local govt.**	**Private**	**Total**
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	2,590	134	--	--	18	1,674	4,416
Other unreserved forest land	391	126	--	6	20	1,206	1,749
Total, unreserved	2,981	260	--	6	38	2,880	6,165
Reserved forest land:							
Reserved productive forest land	1,316	6	67	--	7	--	1,396
Other reserved forest land	258	17	28	1	25	--	329
Total, reserved forest land	1,574	23	94	1	32	--	1,724
Total, forest land	4,555	283	94	7	70	2,880	7,889

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data

The Klamath/Interior Coastal Ranges Ecoregion has substantial water supply assets, but little storage capacity. These watersheds are predominately rain-fed; the water supply impacts from climate change will likely be less dramatic than those in the Sierra Nevada. The level of climate impacts in the Klamath Mountains are expected to be between those in the Sierra Nevada and those in the coast ranges.[351]

Salmonid fish populations are declining in the region. This is in part a reflection of water quality impairments and constrained water management options in the large Klamath River watershed, which originates in southern Oregon and crosses through northern California before draining to the ocean. A recent settlement proposes to remove four large dams on the Klamath River as part of a major fisheries restoration plan.

1.1.1.2 Disturbance Regimes

Fire has been an important and widespread disturbance factor in the Klamath Mountains bioregion for millennia.[352] Though steep slopes and large, continuous areas of flammable vegetation are common, the variability and fine grained scale of forest types in the region prevent clear assignment of fire regimes to distinct ecological or elevational zones. Prior to Euro-American settlement, Native Americans ignited fires for various purposes. Settlers in the historical period (ca. 1850-1910) likely replaced or increased Native

[350] Christensen, 2016
[351] California Department of Forestry and Fire Protection, 2010
[352] Skinner et al., 2006

American ignitions with accidental or intentional ignitions of their own[353] until comprehensive federal policies of fire suppression in the western U.S. resulted in a fire-free period, the likes of which are not present in the record for at least the preceding 400 years.[354] Fire suppression is believed to have decreased the heterogeneity of the vegetation in the region. Lightning is a common and important ignition source, with lightning-caused fires accounting for much of the area burned in recent decades, including the 2002 Biscuit Fire which burned nearly 500,000 acres (a significant portion of which burned in Oregon).

Studies of pre-settlement fire regimes[355, 356, 357, 358, 359, 360] suggest that the predominant fire regime of the area was one of relatively frequent fires (median return intervals of 10-50 years), on the order of several hundred hectares, though this may have varied significantly by landscape. Fires in the lower and upper montane conifer forests burned mostly at low-moderate intensity, but exhibited moderate to high degree of spatial complexity. Topography was an important factor, with topographic features constraining size in most years, except for those with particularly severe fire conditions. Aspect and slope position likely affected fire severity, with the upper third of slopes on southern and western aspects experiencing more severe fire. Moisture patterns played an important role as well, with surface fires more dominant as one moves from mesic western forests to dry eastern portions of the region.[361]

Fire return interval departure (FRID; also discussed in Section 2) is an analytical method used to quantify the difference between current and presettlement fire frequencies.[362] This tool allows managers to identify areas that are at a high risk of significant wildfires due altered fire regimes, which also may interact with other factors such as climate change or drought. Figure 2 shows FRID on a percentage basis for the Klamath/Interior Coast Ranges Ecoregion based on 2015 data. As is evident from the figure, bulk of the ecoregion is highlighted in red, indicating that much of the area has seen 67% or greater departure from the historic fire interval (i.e., much lower fire frequency than historically). The figure indicates that a very large area would need to be treated for ecological restoration, fuels reduction, certain fire or habitat management practices, or other activities to bring the effective fire return interval back closer the historical level. While the historical fire return interval may be a somewhat less appropriate benchmark today due to a number of factors, including climate change, the current FRID provides a strong indicator of the direction of fire return interval correction that is needed.

[353] Taylor & Skinner, 2003
[354] Skinner et al., 2006
[355] Wills & Stuart, 1994
[356] Taylor & Skinner, 1998
[357] Stuart & Salazar, 2000
[358] Skinner, 2003
[359] Taylor & Skinner, 2003
[360] Fry & Stephens, 2006
[361] Hessburg et al., 2016
[362] Safford & Van de Water, 2014

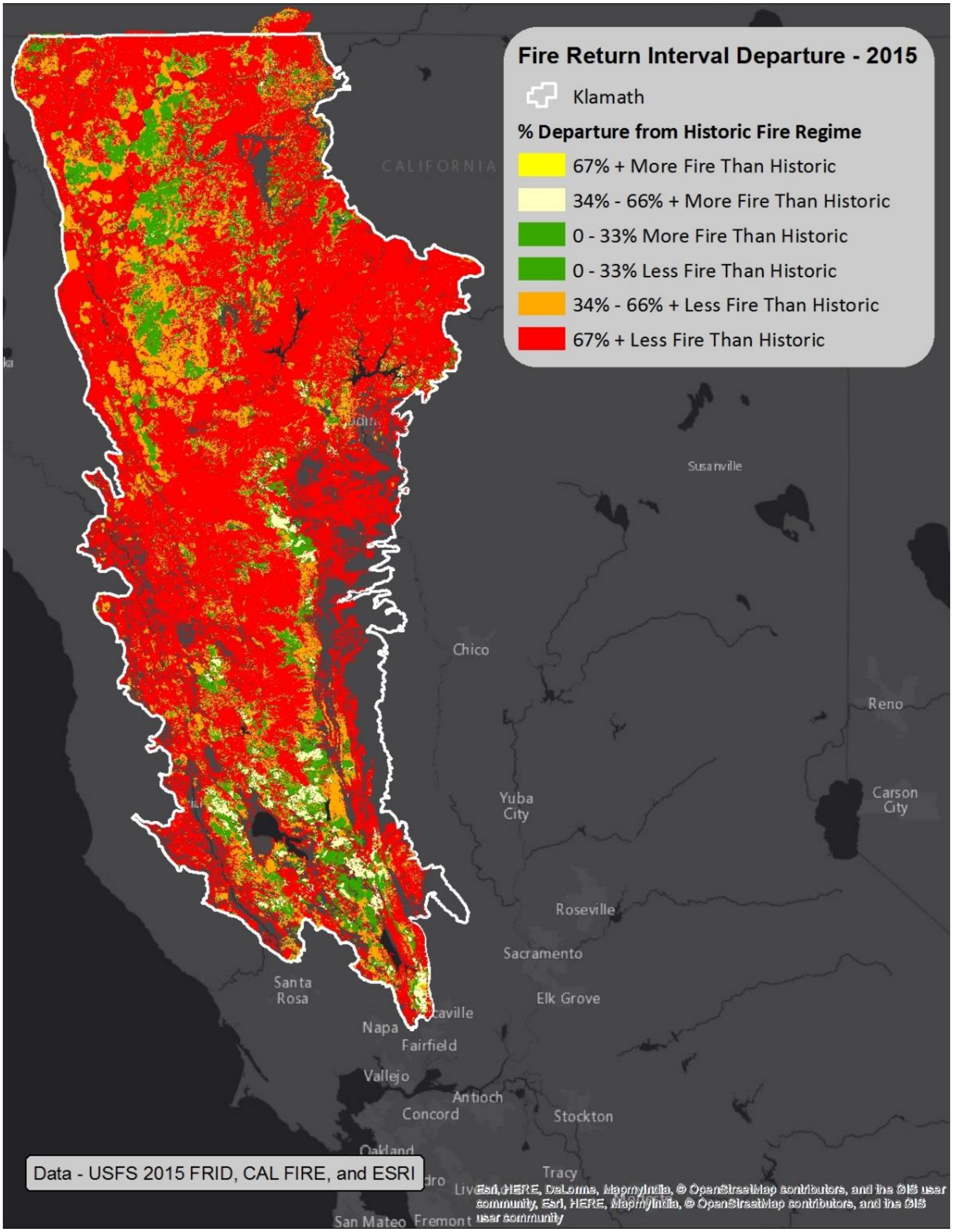

Figure 2. Fire Return Interval Departure for the Klamath/Interior Coast Ranges Ecoregion.

1.1.1.3 Forest Management

Figure 3 shows stylized management regimes for the forestlands of the ecoregion, identifying areas of high, medium, low timber, and no timber management emphasis by ownership class. The largest proportion of the area, 53 percent, is in no management emphasis, followed by medium (25 percent), low (14 percent), and high (9 percent). The areas of medium to high timber management emphasis may be the most promising areas for implementing forest treatments designed to improve forest health and address climate mitigation and adaptation.

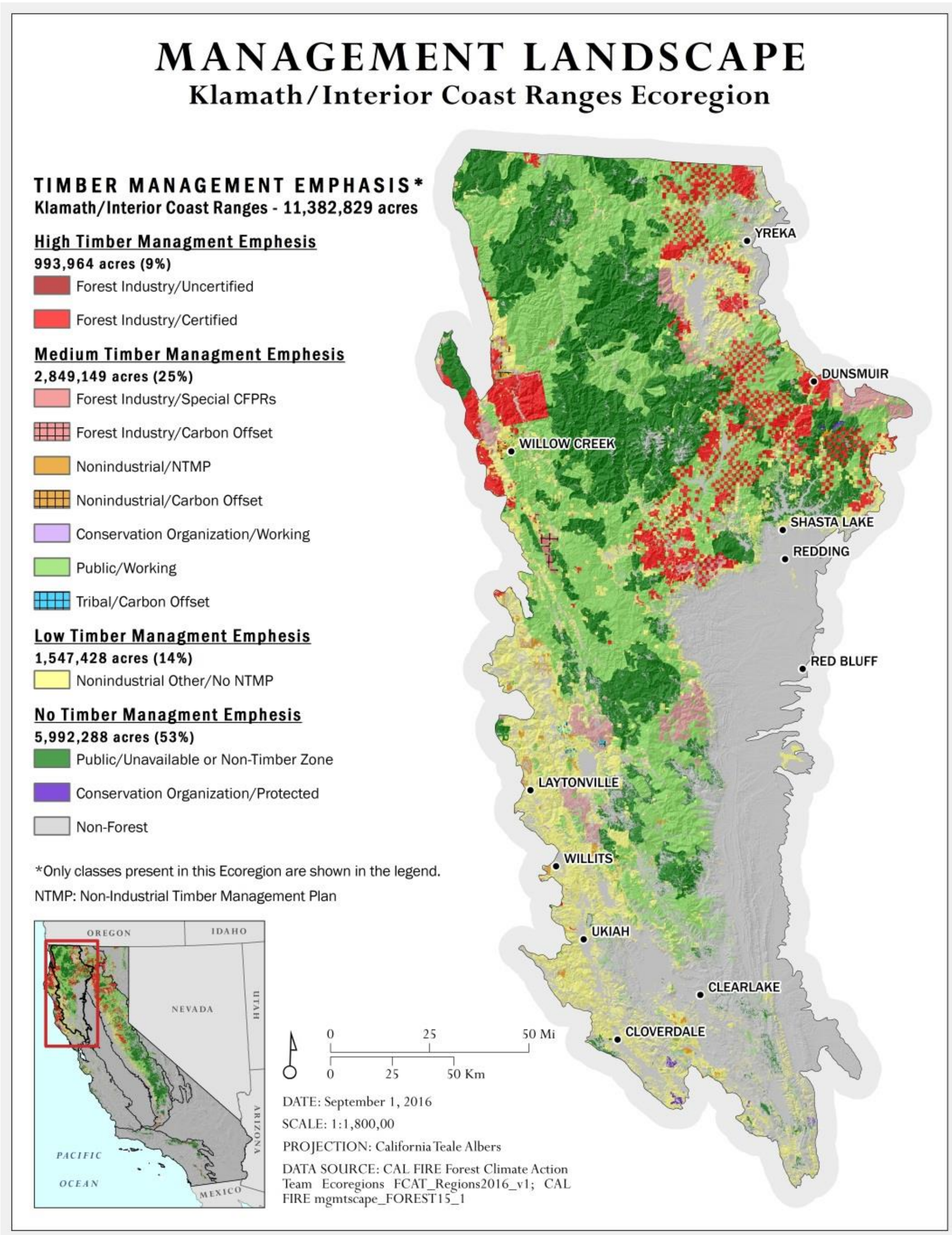

Figure 3. Management Landscape of the Klamath/Interior Coast Ranges Ecoregion.

Table 2, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report, takes a close look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation type in the table, it identifies 873,000 acres as suitable for wildland urban interface fuel treatments, 343,000 acres suitable for fuel breaks, and 1.4 million acres as suitable for ecological restoration treatments. This totals to 2.7 million acres.

Table 2. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the Klamath/Interior Coast Bioregion.

Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	**607,922**	**221,536**	**909,058**	**1,738,516**
Shrub Dominated	184,771	84,446	128,954	398,172
Grass Dominated	641,754	201,967	529,135	1,372,856
Total by Treatment	1,434,447	507,949	1,567,147	3,509,544

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report
Wildland-Urban Interface: projects would generally consist of fuel reduction to prevent the spread of fire (in either direction) between structures and wildlands.
Fuel Breaks: projects would consist of treating the vegetation to reduce fuel loads in strategically located areas to support fire control activities.
Ecological Restoration: projects would generally occur outside of the wildland-urban interface in areas that have departed from the natural fire regime and would generally consist of restoring the fire resiliency by promoting native fire-adapted plant communities.

1.1.2 Sierra-Cascades Ecoregion

1.1.2.1 Overview of the Ecoregion

The Sierra-Cascades ecoregion encompasses the Sierra Nevada mountain range and the southern portion of the Cascade Mountains. Though geologically distinct, these areas combine to form a near-continuous stretch of mountains and forests from the Tehachapi Mountains and Mojave Desert in the south, to the northern California border. The Sierra Nevada is a massive block mountain range which comprises the single longest uninterrupted range in North America, oriented generally along a south-southeast-north-northwest axis. The western slope rises gradually from the Central Valley to its crest, relative to the sharp and steep eastern escarpment bordering the more xeric Great Basin and Eastside Ecoregion.

The geologically younger Cascades are characterized generally by volcanic peaks such as Mt. Lassen and Mt. Shasta. Elevations range from 196 ft. near the northern Sacramento Valley to greater than 14,000 at the Sierra crest (Mt. Whitney) and at Mt. Shasta. In total the ecoregion covers 32,902 square miles, or approximately 21 percent of the land area of California. Major river systems include the Kern, Merced, Tuolumne, Mokelumne, American, Yuba and Feather in the Sierra, and the Klamath and Pit in the Cascades.

Weather patterns originating in the Pacific and moving eastward over the coast ranges and through the Central Valley combine with diverse soils and topography to create vegetation assemblages occurring roughly in elevational bands (Figure 4). These include foothill shrub and woodlands at lower elevations, more xeric lower montane conifer forests, mesic upper montane and subalpine forests, alpine meadows and shrublands, and barren peaks at the Sierra crest and highest elevations of the Cascades.[363] Climate of the region is Mediterranean, with warm and dry summers followed by cool, cold winters, and patterns of temperature and precipitation influenced by both latitude and elevation. Typical winters see a deep snowpack develop at upper elevations as weather systems drop moisture moving over the mountains, with 60 percent of precipitation falling as snow, which typically persists through early summer.[364,365]

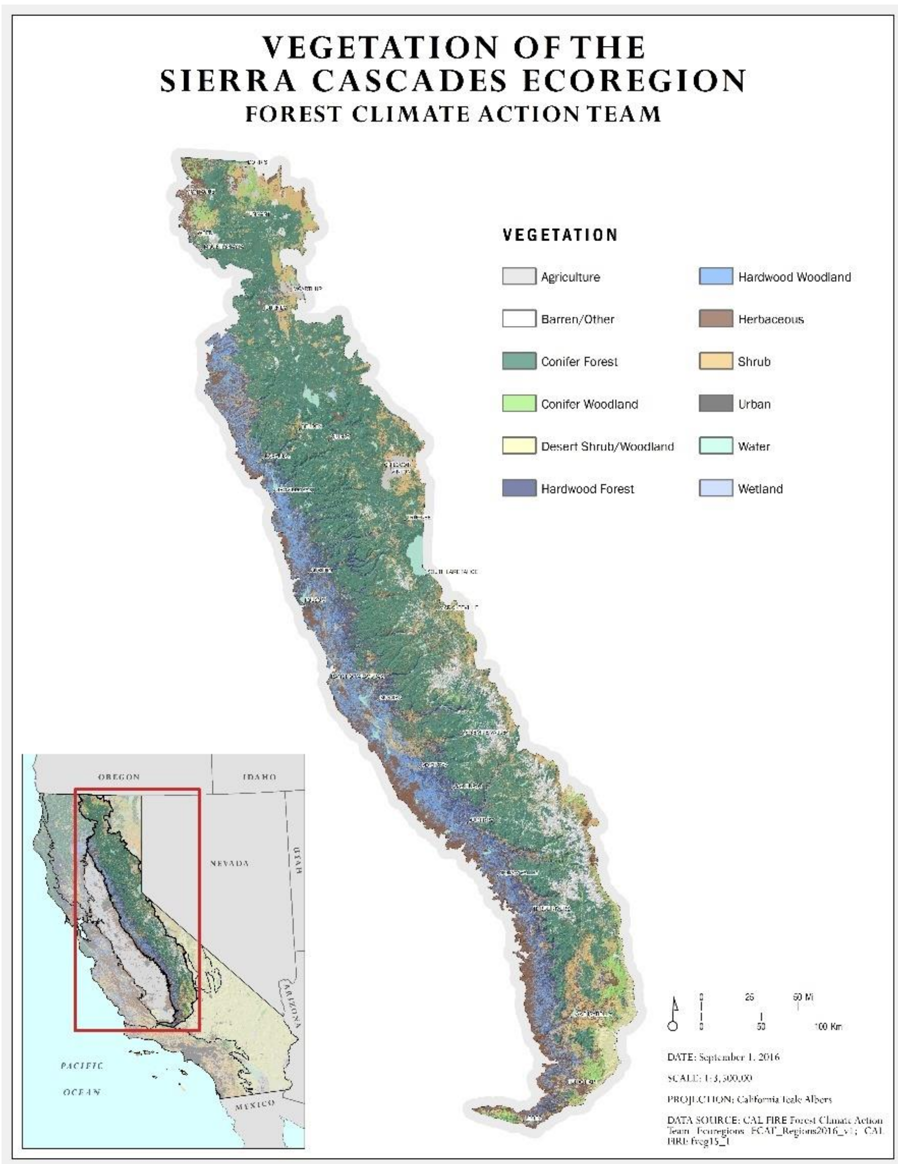

Figure 4. Vegetation of the Sierra-Cascades Ecoregion.

[363] California Department of Forestry and Fire Protection, 2015
[364] Van Wagtendonk & Fites-Kaufman, 2006
[365] Skinner & Taylor, 2006

There are approximately fifteen million acres of forestland in the Sierra-Cascades ecoregion[366] (Table 3). The federal government is responsible for 63 percent of the forestland in the region and private lands (35 percent) comprise the bulk of the remainder. Most of the forestlands are in unreserved status (79 percent), and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation. Reserved lands (21 percent) may be available and suitable for prescribed or managed fire.

Table 3. Area of sampled land by land status and ownership group, California 2005-2014; Sierra Cascades Region.

	Ownership group						
	National forest	BLM	NPS	Other federal	State and local govt.	Private	Total
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	5,430	81	--	--	59	2,980	8,550
Other unreserved forest land	814	253	--	16	72	2,303	3,458
Total, unreserved	6,244	334	--	16	131	5,283	12,008
Reserved forest land:							
Reserved productive forest land	1,249	90	865	--	75	--	2,279
Other reserved forest land	585	8	259	2	69	--	923
Total, reserved forest land	1,834	98	1,124	2	144	--	3,202
Total, forest land	8,078	432	1,124	18	275	5,283	15,210

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data

The ecoregion was inhabited by a number of Native American tribes for millennia prior to Euro-American settlement.[367] With the arrival of Spanish and Euro-American settlers in roughly 1820 began the decline of Native American land use. Discovery of gold and silver spurred settlement in the region beginning around 1849, with grazing and significant logging occurring in support of mining and developing cities. Establishment of the National Forest System and the designation of Yosemite, Sequoia, Kings, Canyon and Lassen National Parks formalized a significant portion of the region as being under federal control, particularly in the middle to upper elevations.[368] Logging continued in the region throughout the 20th century, peaking in the 1950s, but timber sales on federal land began to wane in the 1980s due to recession and cultural shifts in attitudes about public land management.[369] Private industrial and non-industrial timber management continues today, primarily in the northern and low to middle elevations of the ecoregion. Water competes with timber and recreation as the most significant resource, filling reservoirs that supply agricultural lands of the Central Valley and major metropolitan areas, from Sacramento to the Bay Area to Southern California.

[366] Christensen, 2016
[367] Anderson & Moratto, 1996
[368] Beesley, 1996
[369] Ruth, 1996

1.1.2.2 Disturbance Regimes

Fire has been and continues to be the most ubiquitous disturbance process in the Sierra-Cascades ecoregion.[370] In addition to lightning ignitions, Native Americans and early Euro-American settlers alike used fire for regularly for various other purposes. West-wide policies of wildfire suppression in the early 20th century helped spur a relatively fire-free era, before recognition of fire as an important ecosystem process, and the effects of the disruption of fire regimes in the early 1970s. Yosemite and Sequoia-Kings Canyon National Parks were among the first locations in the U.S. to attempt re-introduction of fire through human or natural ignitions.

When examined by vegetation types or ecological zones, pre-settlement fire regimes are believed to have ranged from relatively frequent (5-25 years), low intensity fires in woodlands and low-elevation conifer forests to relatively infrequent (>200 years) but severe fires in upper elevation forests .[371] Frequent fires in the low- to mid- elevations are believed to have maintained the pine and mixed conifer forests in a relatively open and heterogeneous state, with small patches of high-severity fire resulting in a relatively small component by land area. Middle elevations to upper montane forests were characterized by somewhat less frequent and more mixed severity fires, though characterization of fire regimes in this zone is the subject of some scientific investigation and debate today.[372,373] Recent decades have seen an increase in fire size and overall severity in the conifer forests of the Sierra-Cascades ecoregion, including the Rim Fire of 2013-- the largest fire in the region's history-- and the 2014 King Fire.[374,375,376,377] Despite recent efforts at restoration, much of the forested area remains departed from pre-settlement fire frequencies, with low- and middle-elevation vegetation types of oak woodland, yellow pine, and mixed conifer missing the most fire cycles.[378]

Figure 5 shows FRID on a percentage basis for the Sierra-Cascades Ecoregion based on 2015 data. As is evident from the figure, bulk of the ecoregion is highlighted in red, indicating that much of the area has seen 67% or greater departure from the historic fire interval (i.e., much lower fire frequency than historically). However, there are significant areas in the southeastern part of the ecoregion that are much more within the historic fire interval, as evidences by the green color. A significant portion of these areas are in National Parks that have been implementing very active ecological restoration, prescribed fire, and managed fire programs to shift these areas back closer to historical fire regimes.

[370] McKelvey et al. 1996
[371] Skinner & Chang, 1996
[372] Perry et al., 2011
[373] Hutto et al., 2016
[374] Miller & Safford, 2012
[375] Mallek et al., 2013
[376] Lydersen et al., 2014
[377] California Department of Forestry and Fire Protection, 2015
[378] Safford & Van de Water, 2014

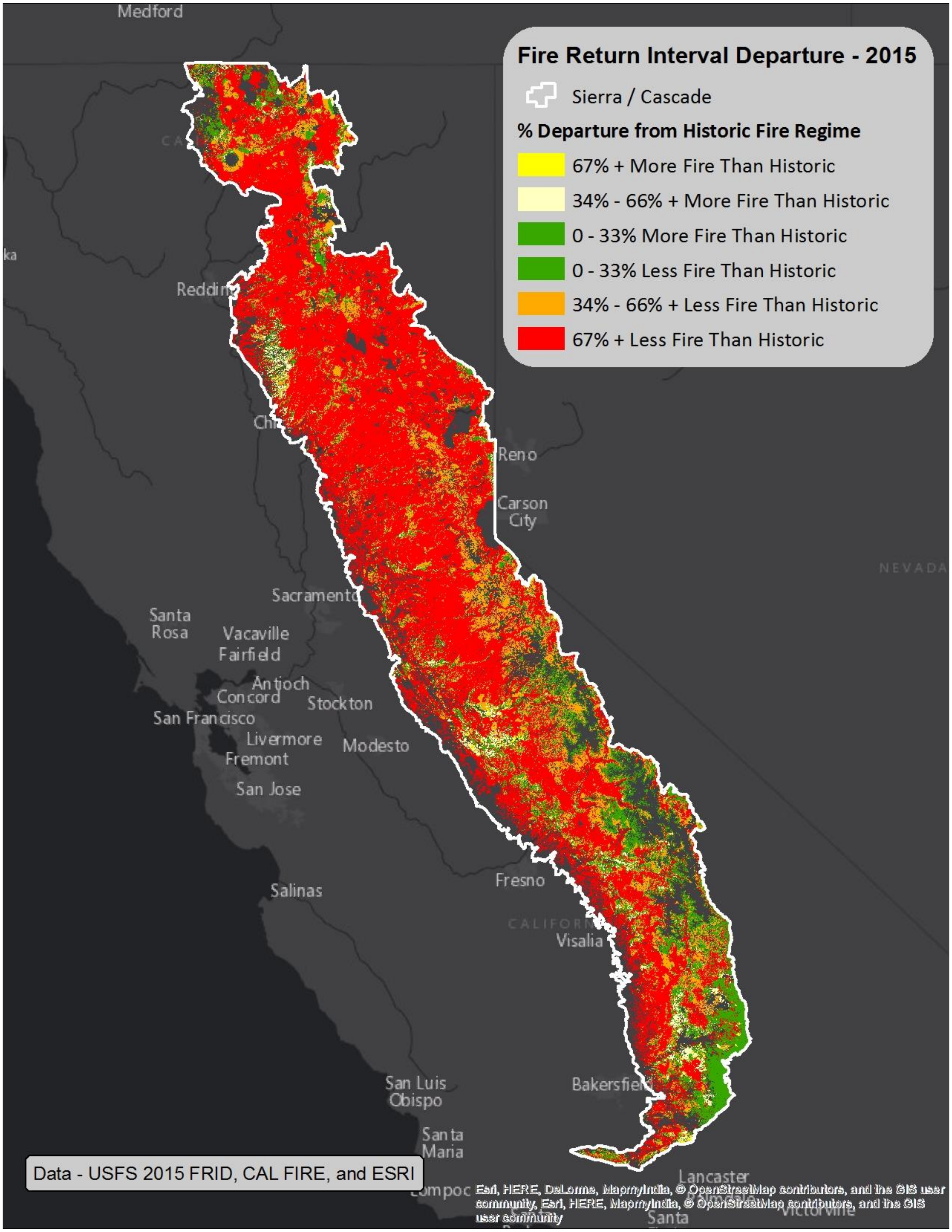

Figure 5. Fire Return Interval Departure for the Sierra/Cascade Ecoregion.

1.1.2.3 Forest Management

Figure 6 shows stylized management regimes for the forestlands of the ecoregion, identifying areas of high, medium, low timber, and no timber management emphasis by ownership class. The largest proportion of the area, (61 percent), is in no management emphasis, followed by medium (23 percent), low (eight percent), and high (nine percent). The areas of medium to high timber management emphasis may be the most promising areas for implementing forest treatments designed to improve forest health and address climate mitigation and adaptation.

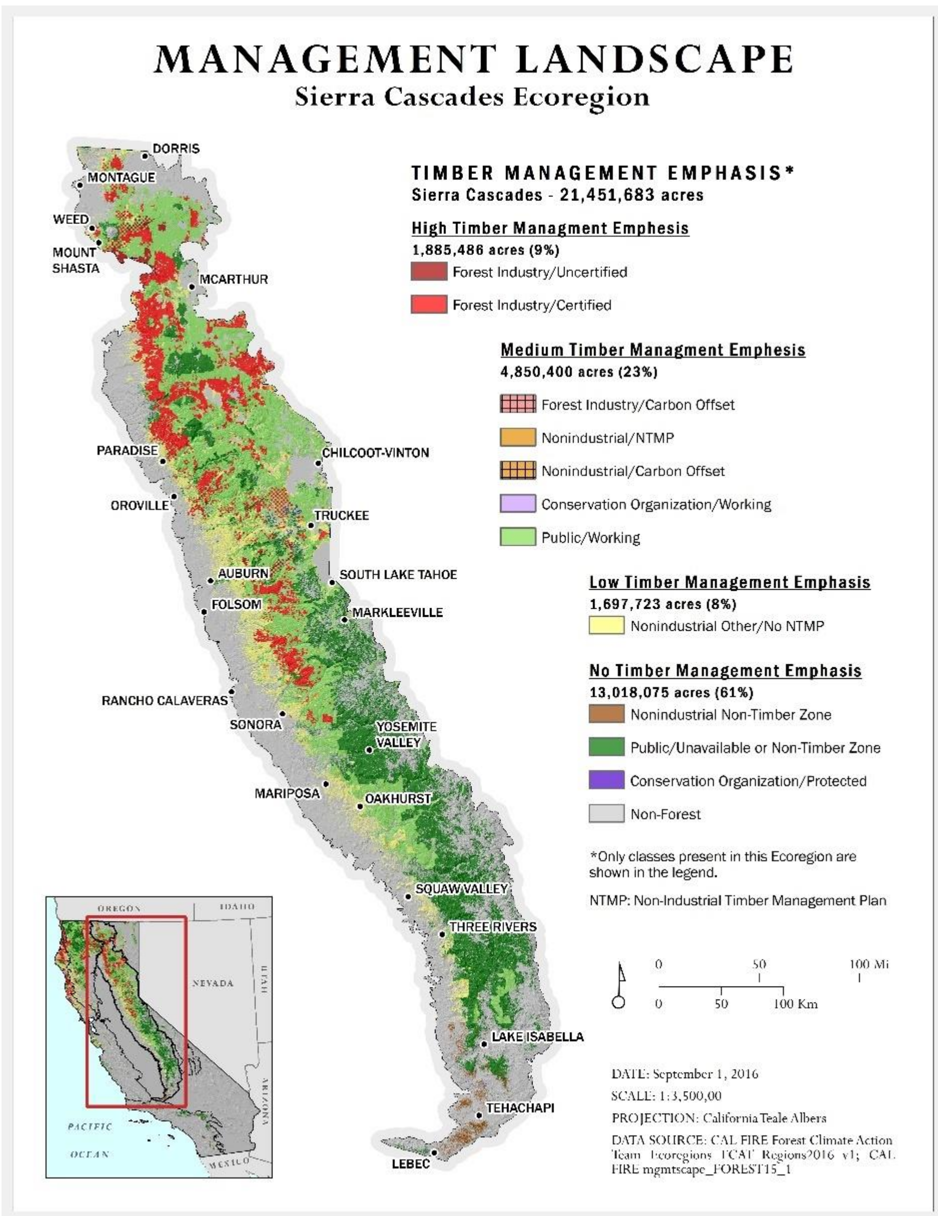

Figure 6. Management Landscape of the Sierra/Cascades Ecoregion.

Forest disturbance from insects and disease occurs as both an element of background tree mortality, and as episodic events related to drought, fire, and overly-dense stands.[379] The drought conditions of the past five years have resulted in significant conifer mortality, particularly at lower and middle elevations of the Southern Sierra. Of the 102 million trees USDA Forest Service aerial surveys found had died between 2010 and summer 2016, the majority is located in ten counties in the southern and central Sierra Nevada region.[380] While flood events can occur in warm winter precipitation events (such as the Merced River floods of 1997 in Yosemite National Park), downstream flooding is mediated by dams and reservoir systems that also support hydroelectric power and water supply to the Central Valley and metropolitan areas of the state. Wind events and avalanches can be significant perturbations on smaller scales.

Table 4, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report takes a close look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation type in the table, it identifies 1.091 million acres as suitable for wildland urban interface fuel treatments, 154,834 acres suitable for fuel breaks, and 722,877 acres as suitable for ecological restoration treatments. This totals to 2 million acres.

Table 4. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the Sierra-Cascades Ecoregion.

Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	**1,090,662**	**154,834**	**722,877**	**1,968,373**
Shrub Dominated	323,025	96,448	178,085	597,557
Grass Dominated	1,470,973	253,995	624,761	2,349,729
Total by Treatment	2,884,660	505,276	1,525,722	4,915,658

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report

1.1.3 Central Coast and Interior Ranges Ecoregion

1.1.3.1 Overview of the Ecoregion

The Central Coast and Interior Ranges Ecoregion is an ecologically diverse region stretching from the southern San Francisco Bay Area south to Santa Maria. It is bounded by the Pacific Ocean to the west and the Central Valley to the east, and encompasses several mountain ranges including the Santa Cruz, Gabilan, Diablo, Santa Lucia, San Rafael and Temblor Ranges. Elevation ranges from sea level to 5,096 ft. Rugged terrain, complex geology, topography, climatic variability, and disturbance history interact to create a complex vegetation mosaic that includes coastal prairies and sage-scrub, annual grassland, chaparral, montane- and mixed-hardwood forests, and conifer forests at the highest elevations (Figure 7). The Santa Cruz Mountains include significant areas of coast redwood-Douglas-fir and coast redwood-mixed evergreen forest. Climate is strongly Mediterranean, with 80 percent of rainfall occurring between

[379] Ferrell, 1996

[380] US Department of Agriculture News Release No. 0246.16, November 18, 2016.

November and March, and warm, dry summer seasons. Rainfall varies with latitude, decreasing as one moves from north to south, and is also influenced by topography as weather systems move from the Pacific eastward over the coast and interior ranges, resulting in the lowest rainfall at the eastern edge of the ecoregion. Lightning strikes are rare. Major valley and river systems include the Santa Clara, Salinas, and Santa Maria valleys.[381]

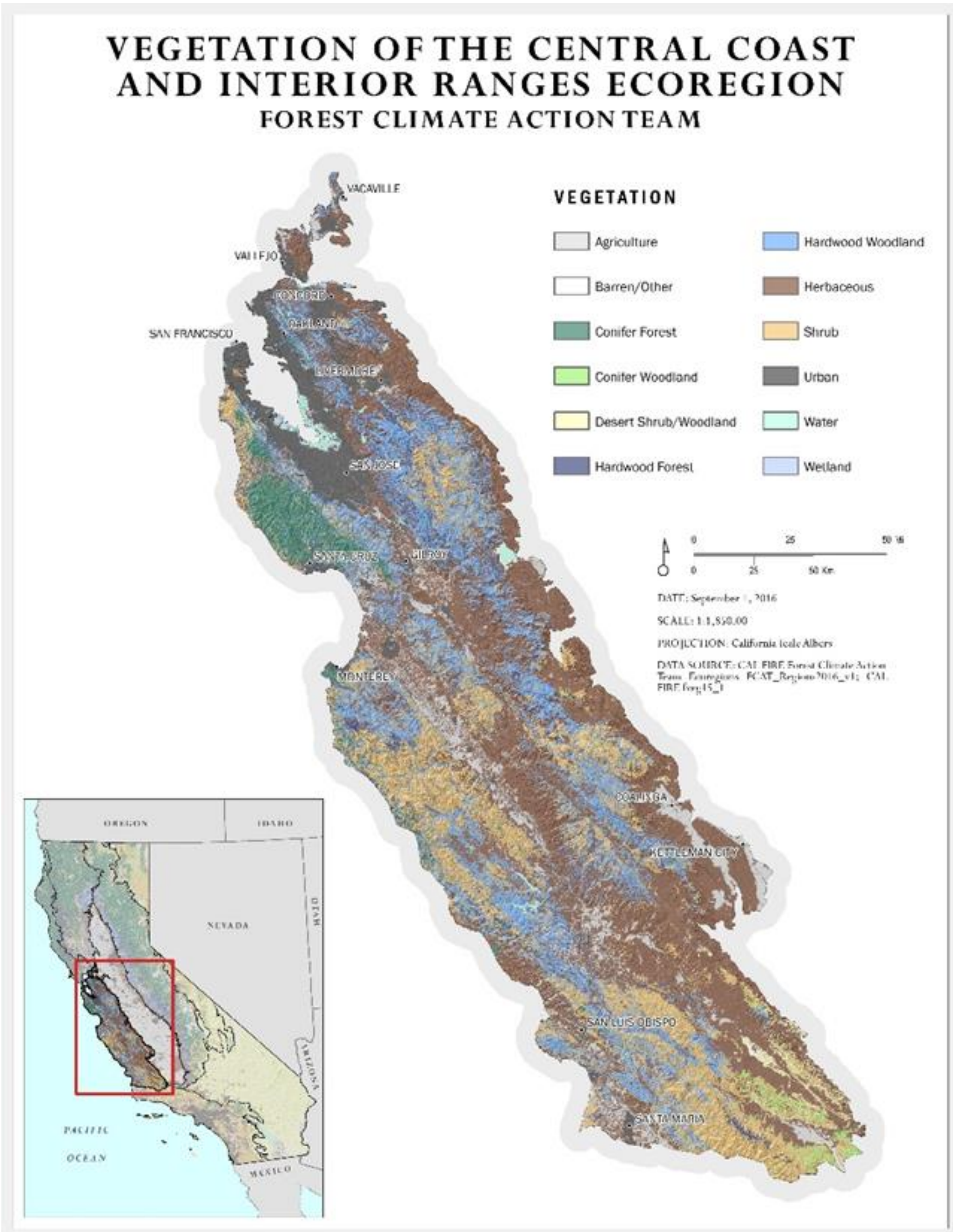

Figure 7. Vegetation of the Central Coast and Interior Range Ecoregion.

[381] Davis & Borchet 2006

There are approximately 1.8 million acres of forestland in Central Coast and Interior Ranges Ecoregion (Table 5).[382] Most forestland in the region is privately owned (60%), while state and local government own approximately 20% of forestland, which is an unusually high percentage for California. The federal government is responsible for 19% of the forestland in the region. Most of the forestlands are in unreserved status (73%), and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation. Reserved lands (27%) may be suitable and available for prescribed or managed fire.

Table 5. Area of Sampled Land by Land Status and Ownership Group, California 2005-2014; Central Coast and Interior Ranges.

	Ownership group						
	National forest	**BLM**	**NPS**	**Other federal**	**State and local govt.**	**Private**	**Total**
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	2	--	--	--	12	210	224
Other unreserved forest land	85	68	--	22	38	886	1,099
Total, unreserved	87	68	0	22	50	1,096	1,323
Reserved forest land:							
Reserved productive forest land	26	--	6	--	80	--	112
Other reserved forest land	128	11	4	--	243	--	386
Total, reserved forest land	157	11	10		323		498
Total, forest land	244	79	10	22	373	1,096	1,821

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data

1.1.3.2 Disturbance Regimes

Native Americans have occupied the Central Coast and Interior Ranges ecoregion since the early Holocene (9,700 BCE to today). Spanish settlement and mission construction from the late 18th century was followed by Mexican settlement in the early 1800s and gradual population increase of Euro-Americans through the 1940s. Native Americans exerted significant influence across the ecoregion on vegetation through the ignition and use of fire for various purposes. Relatively little is known about pre-settlement fire regimes in coast redwood forest in this region, in comparison to other forest types in the state. Greenlee and Langenheim (1990) estimate a mean fire return interval of 135 years from lightning, though aboriginal burning likely increased fire frequency. Some studies have suggested mean fire intervals as short as 8-12 years.[383,384]

Charcoal sediment studies in the Santa Barbara channel suggest large fire events occurred on average every 24 years over a 560-year period in the Santa Lucia Range.[385] Moritz (2003) suggests that fire hazard in the Santa Lucia Range is not significantly related to fuel age, but rather prevalence of extreme weather events. Several large fires have occured in the ecoregion in the modern era, including the Marble Cone Fire of 1977, the 1999 Kirk Complex, and the 2016 Soberanes Fire. Many forest and woodland species in the Santa Lucia and Interior Coast Ranges have developed life history strategies and fire-dependent adaptations, including serotiny in Bishop, Monterey, and knobcone pine. Extensive type conversion of

[382] Christensen, 2016
[383] Brown et al., 1999
[384] Stephens & Fry, 2005
[385] Mensing et al., 1999

shrublands to grasslands, and invasion of non-native species are other major agents of change in the region.[386]

Figure 8 shows FRID on a percentage basis for the Central Coast and Interior Ranges Ecoregion based on 2015 data. This ecoregion looks significantly different from the other ecoregions discussed this far, as a significant portion of the area has fire frequencies that are near historic levels or are more frequent than historic. Much of this area is in the Los Padres National Forest, which has many, large fires over the past several decades. Although not reflected in the data in Figure 8, these fires include the 2016 Soberanes Fire, which burned over 132,000 acres in this ecoregion, including almost 95,000 acres on the Los Padres National Forest.

[386] Keeley, 2000

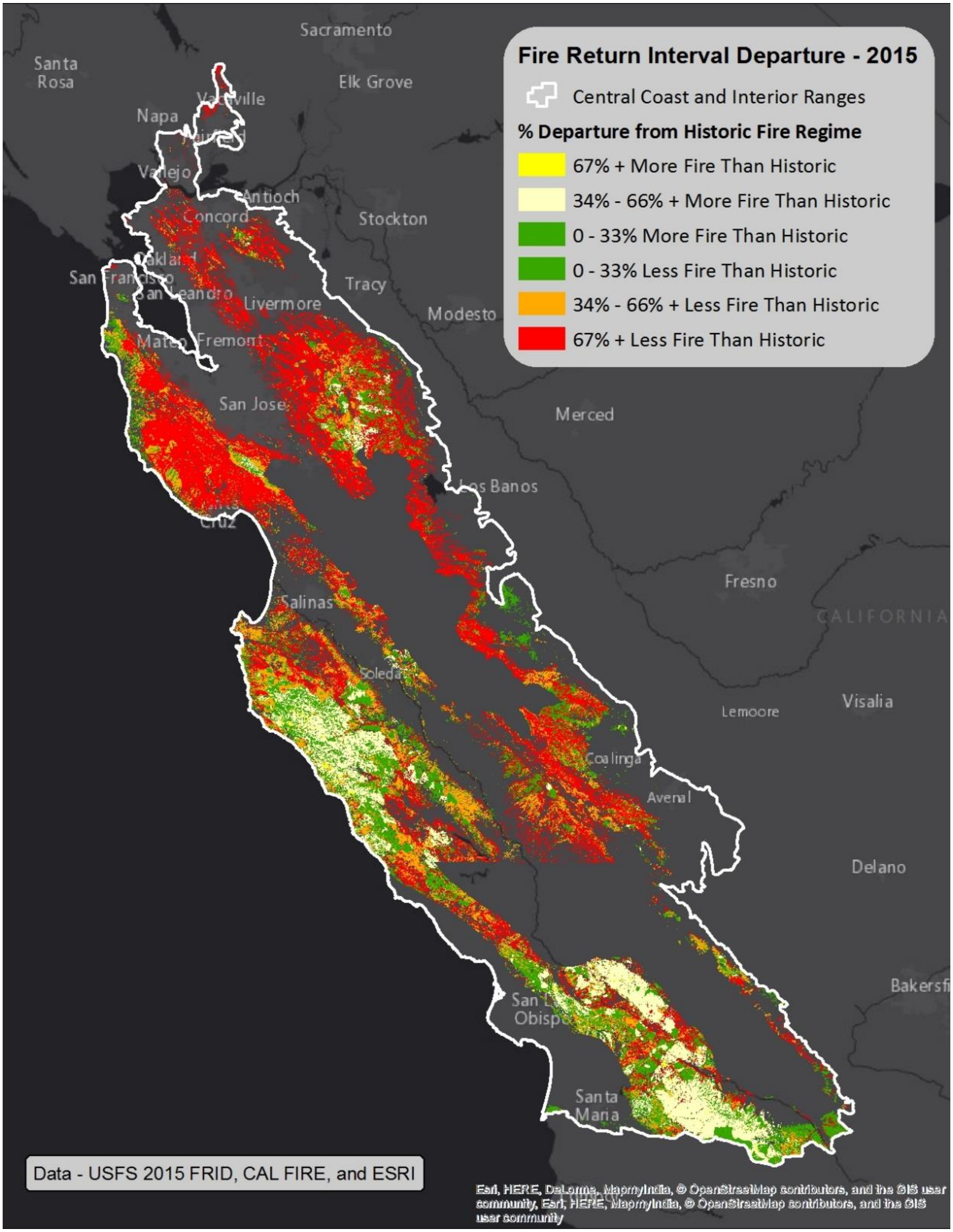

Figure 8. Fire Return Interval Departure for Central Coast and Interior Ranges Ecoregion.

1.1.3.3 Forest Management

Figure 9 shows stylized management regimes for the forestlands of the ecoregion, identifying areas of high, medium, low timber, and no timber management emphasis by ownership class. The largest proportion of the area, 97%, is in no management emphasis, followed by medium (1%), low (2%). The areas of medium timber management emphasis may be the most promising areas for implementing forest treatments designed to improve forest health and address climate mitigation and adaptation.

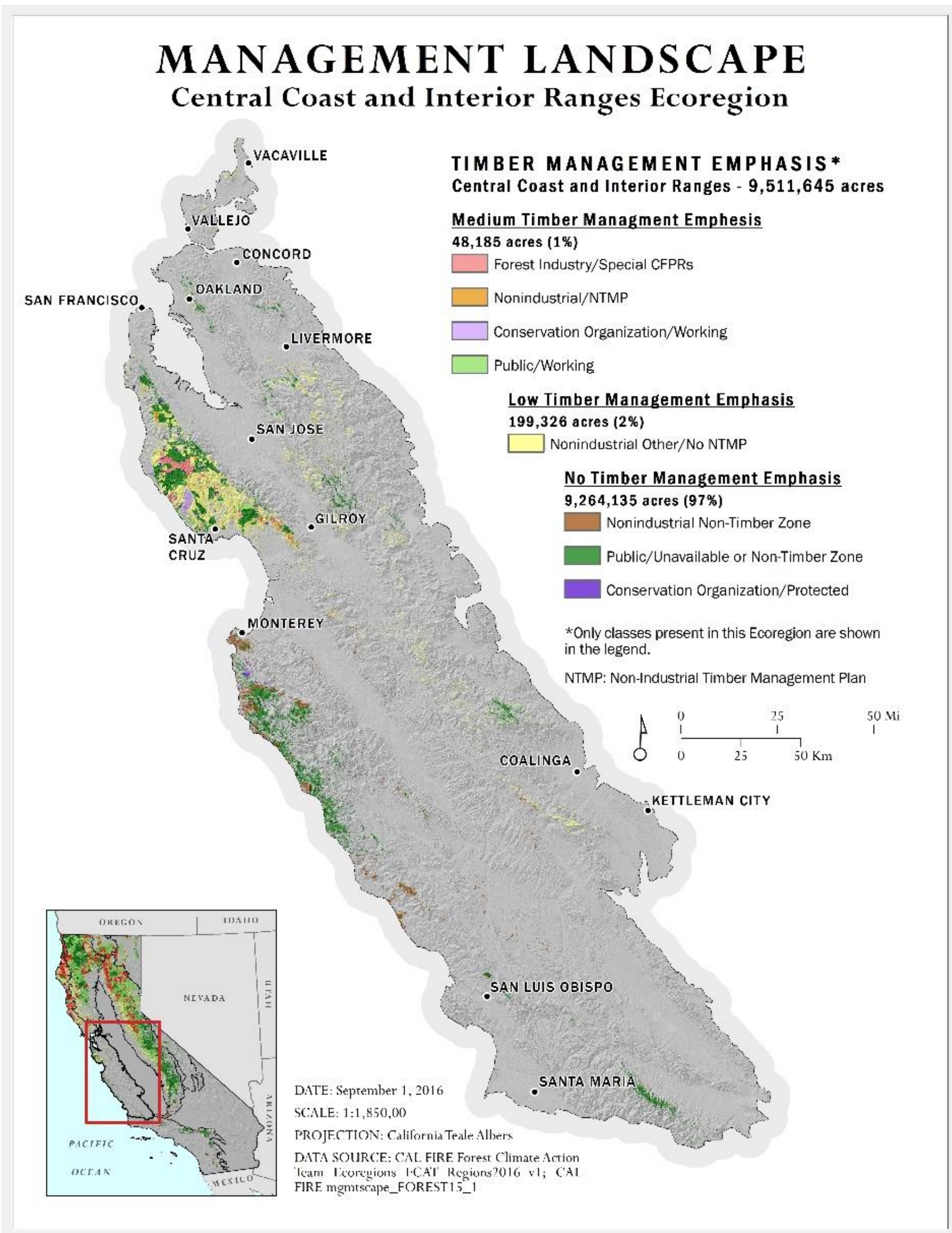

Figure 9. Management Landscape of Central Coast Interior Ranges Ecoregion.

Table 6, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report takes a close look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation type in the table, it identifies 53,893 acres as suitable for wildland urban interface fuel treatments, 12,248 acres suitable for fuel breaks, and 41,347 acres as suitable for ecological restoration treatments. This totals to 107,578 acres.

Table 6. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the Central Coast and Interior Ranges Ecoregion.

Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	53,983	12,248	41,347	107,578
Shrub Dominated	410,122	132,588	362,589	905,299
Grass Dominated	794,135	203,365	253,805	1,251,305
Total by Treatment	1,258,240	348,201	657,741	2,264,182

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report

1.1.4 South Coast and Mountains Ecoregion

1.1.4.1 Overview of the Ecoregion

The South Coast and Mountains ecoregion occupies the southwestern portion of the state to the Mexico border (Figure 10). It is bounded to the north by the southern reaches of the Central Coast, Central Valley and Sierra Nevada ecoregions, and to the northeast and east by the Mojave and Colorado Desert ecoregion. The Pacific Ocean forms its southwestern edge. The Transverse Ranges (Santa Ynez, Santa Monica, San Gabriel Mountains, and others) and the Peninsular Ranges (San Jacinto, Santa Ana, Laguna Mountains, and others) bound coastal plains and basins occupied by major metropolitan areas such as Santa Barbara, San Diego and the Los Angeles Basin, which is an extensive alluvial floodplain. The Transverse Ranges are one of the few east-west ranges in western North America. Topographic variation among these ranges is great, with elevations ranging from sea level to 11,489 feet at San Gorgonio Mountain.

Climate in the South Coast and Mountains ecoregion is Mediterranean, with two thirds of precipitation falling between November and April, strongly influenced by elevation as storm systems pass from the west or southwest to the east, and accompanied by lightning in autumn storms. Santa Ana winds are an important element of regional weather and climate. These occur during periods in which high pressure cells in the Great Basin are coupled with troughs of low pressure off the coast, resulting in warm, dry winds moving towards the coast. Because these conditions most often occur in the fall when fuel moisture is naturally low and can last days or weeks, Santa Ana winds support rapid fire spread under the worst fire weather conditions in the country[387],[388], however recent fire history such as the 2013 Silver Fire has also

[387] Keeley, 2006
[388] Moritz et al., 2010

shown large fire potential under non-Santa Ana conditions, thereby ranking the region as having the highest burn probabilities in the state.

Vegetation in the low-to mid-elevations of the region is dominated by a variety of shrub types, including mixed chaparral, coastal scrub, chemise-redshank chaparral, and desert scrub. Annual or non-native grasslands are interspersed. Conifer forest and woodlands, including pine species and mixed-conifer hardwood types play a more dominant role in the mid- to upper-elevation montane portions of the mountain ranges, especially the San Gabriel and San Bernardino ranges. Patches and populations of oak woodlands, closed cone cypress, big cone Douglas-fir, pinyon-juniper woodlands, and riparian forest are also interspersed throughout. Urban and agricultural areas comprise over 23% of the ecoregion, and 56% of the state's population lives within its margins.[389]

[389] Keeley, 2006

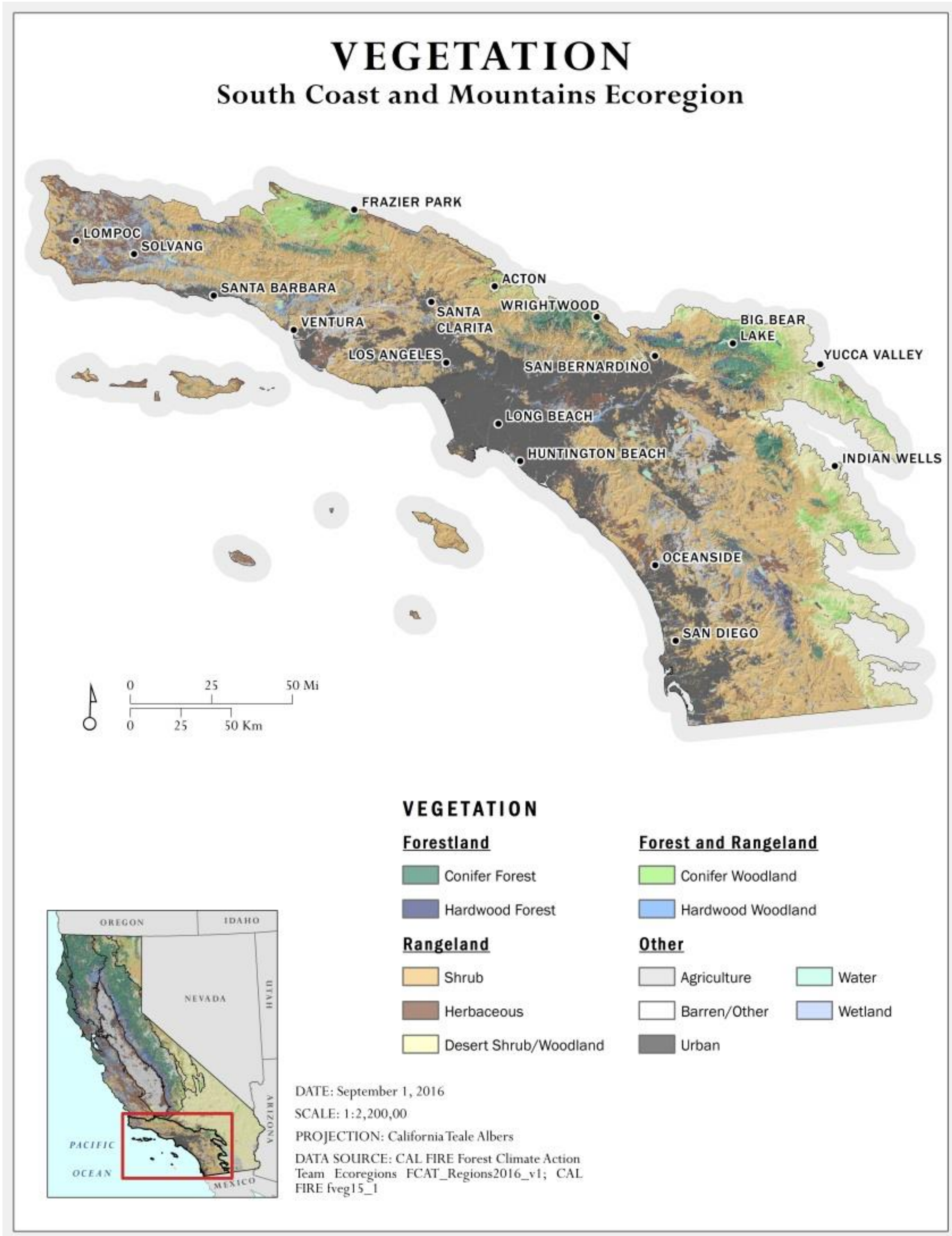

Figure 10. Vegetation of the South Coast and Mountains Ecoregion.

There are approximately 1.4 million acres of forestland in South Coast and Mountains Ecoregion (Table 7).[390] The federal government is responsible for 72 percent of the forestland in the region and private landowners 21 percent. State and local government own approximately seven percent of forestland. Most of the forestlands are in unreserved status (66 percent), and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation. Reserve lands (34%) may be available and suitable for prescribed and managed fire.

Table 7. Area of sampled land by land status and ownership group, California 2005-2014; South Coast and Mountains Ecoregion.

	Ownership group						
	National forest	BLM	NPS	Other federal	State and local govt.	Private	Total
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	148	--	--	--	--	39	187
Other unreserved forest land	366	45	--	53	25	265	754
Total, unreserved	514	45	--	53	25	304	941
Reserved forest land:							
Reserved productive forest land	134	--	--	--	11	--	145
Other reserved forest land	143	39	83	11	58	--	334
Total, reserved forest land	277	39	83	11	69		479
Total, forest land	791	84	83	64	94	304	1,420

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data

1.1.4.2 Disturbance Regimes

As in other portions of the state, fire was an integral tool for the many Native American groups in the ecoregion. Native Americans converted areas from shrubland to grassland, a practice that was maintained or enhanced upon Euro-American settlement. This conversion is believed to have maintained habitable areas in what would otherwise be dense shrub.[391] By acreage, contemporary fires in shrublands of this region have been dominated by large fire events – notable examples include the 2003 and 2007 Southern California fire complexes and the 2009 Station Complex. Box 1A describes restoration activities underway at Cuyamaca Rancho State Park east of San Diego following the 2003 Cedar Fire, which destroyed the forest's seed base and cone-producing canopy. As noted above, Santa Ana winds play an important role in driving fire patterns in the region, and humans account for the vast majority of ignitions. Some debate has occurred regarding the extent to which twentieth century fire suppression has influenced fire size and extent.[392,393,394]

[390] Christensen, 2016
[391] Keeley, 2002
[392] Minnich & Chou 1997
[393] Keeley, 2002
[394] Moritz et al., 2010

Box 1A: Reforestation at Cuyamaca Rancho State Park Reforestation Project

In 2003, the catastrophic Cedar Fire burned over 24,000 acres of the 24,768-acre Cuyamaca Rancho State Park (CRSP), resulting in widespread destruction of the mixed conifer forest's seed bank and cone-producing canopy. Little natural regeneration has been observed in the years following the fire; this threatens the long-term survival of this unique Southern California "sky island" forest ecosystem.

The CRSP Reforestation Project is designed to restore the park's diverse native forest. It consists of planting approximately 10% of the park lands and has become an opportunity to restore a mixed conifer forest that is more resilient to climate impacts. A multi-agency, multi-disciplinary team guides the effort, which includes a mosaic of reforested areas with patches at various elevations, stand compositions and densities. This design is intended to be successful across a diverse range of future fire and climate scenarios. As the forest stands mature, they will become centers for seed dispersal and are expected to speed further recovery of the larger pre-fire mixed conifer forest.

Image: Chuck Fazio

The project provides carbon mitigation benefits and is the first reforestation project and first project on public lands to be registered with the Climate Action Reserve. The active restoration of the 2,530 acres of forest in the park is expected to result in a net storage of 300,000 metric tons of CO_2e over the first 100 years of the project. Further storage may occur once seedlings mature and become seed sources for regeneration outside of the project area.

Other benefits provided by this project include:

- Watershed protection: the restored forest is located at the headwaters of two San Diego county watersheds;
- Restoration of a vanishing forest type: over 51% of this ecosystem in San Diego County was burned in high intensity fires over a course of 10 years;
- Habitat restoration for species under pressure, such as bald eagles, the California spotted owl, and the purple martin;
- Youth education: over 16,000 youth visitors per year may learn about the restoration project and the role of fire in maintaining healthy ecosystems;
- Economic benefits to the local community, which provides food and lodging for forestry crews in the short term. Long term benefits may occur as the forest matures and visitors to the park increase in the coming years; and v
- Recreation and rejuvenation: the park is located within an hour's drive of 3 million people who may visit to seek respite from the demands of urban stressors.

Project activities are being conducted by the California Department of Parks and Recreation in partnership with CAL FIRE.

Recent analysis of fire regimes in the shrub dominated region suggests that frequency has increased and may be driving some fire mediated type conversion from shrub to herbaceous types.[395] The pre-settlement fire regime of montane mixed conifer forests was similar to comparable to that of forests in the Sierra Nevada, with short to moderate return intervals and low- to mixed-severity effects. Drought events in recent decades have resulted in significant mortality to conifer forests of the San Gabriel and San Bernardino ranges. Invasive species are also considered a major disturbance factor in the region, with establishment of non-native grasslands beginning with early Spanish settlement which continue to thrive today. Managing vegetation, habitat, and people in the region continues to challenge managers due to high likelihood of high intensity fires and widespread wildland-urban interface, along with other competing interests such as agriculture and recreation demands from open space.

Figure 11 shows FRID on a percentage basis for the South Coast and Mountains Ecoregion based on 2015 data. Compared to the FRID maps for the other ecoregions, this ecoregion has a significant proportion of areas that are seeing more frequent fire than they have historically. This observation comports with USDA Forest Service findings that National Forests in Southern California have large areas that have been burning at higher frequencies than under presettlement conditions.[396]

[395] Safford & Van de Water, 2014
[396] Safford & Van de Water, 2014

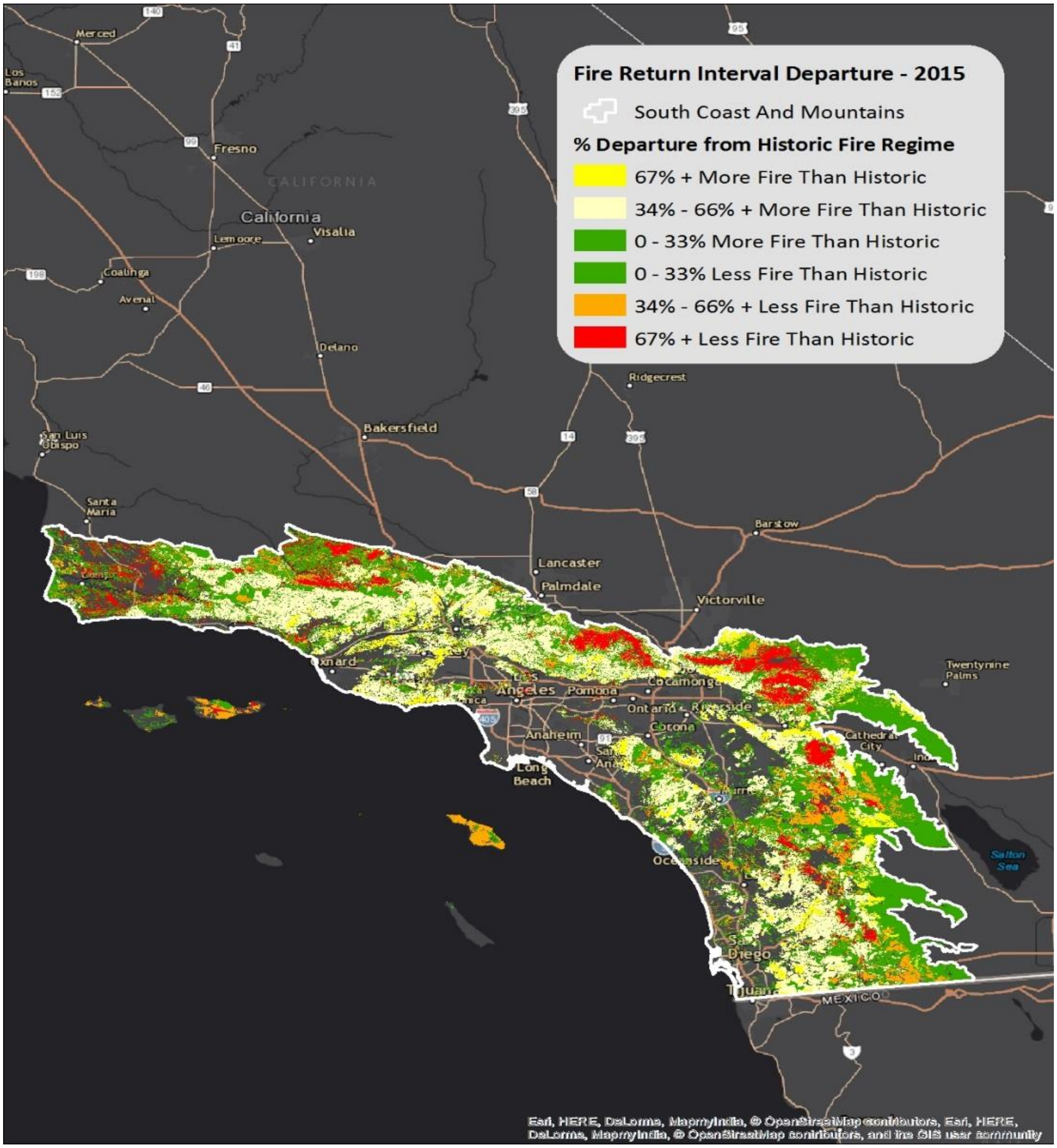

Figure 11. Fire Return Interval Departure for the South Coast and Mountains Ecoregion.

1.1.4.3 Forest Management

Figure 12 presents the management landscape for the ecoregion and indicates that there are no areas of timber management emphasis, which is unique to this ecoregion. This condition has implications for the amount of active land management that might be expected to occur to improve forest health resilience, other than fuels reduction and prescribed and managed fire.

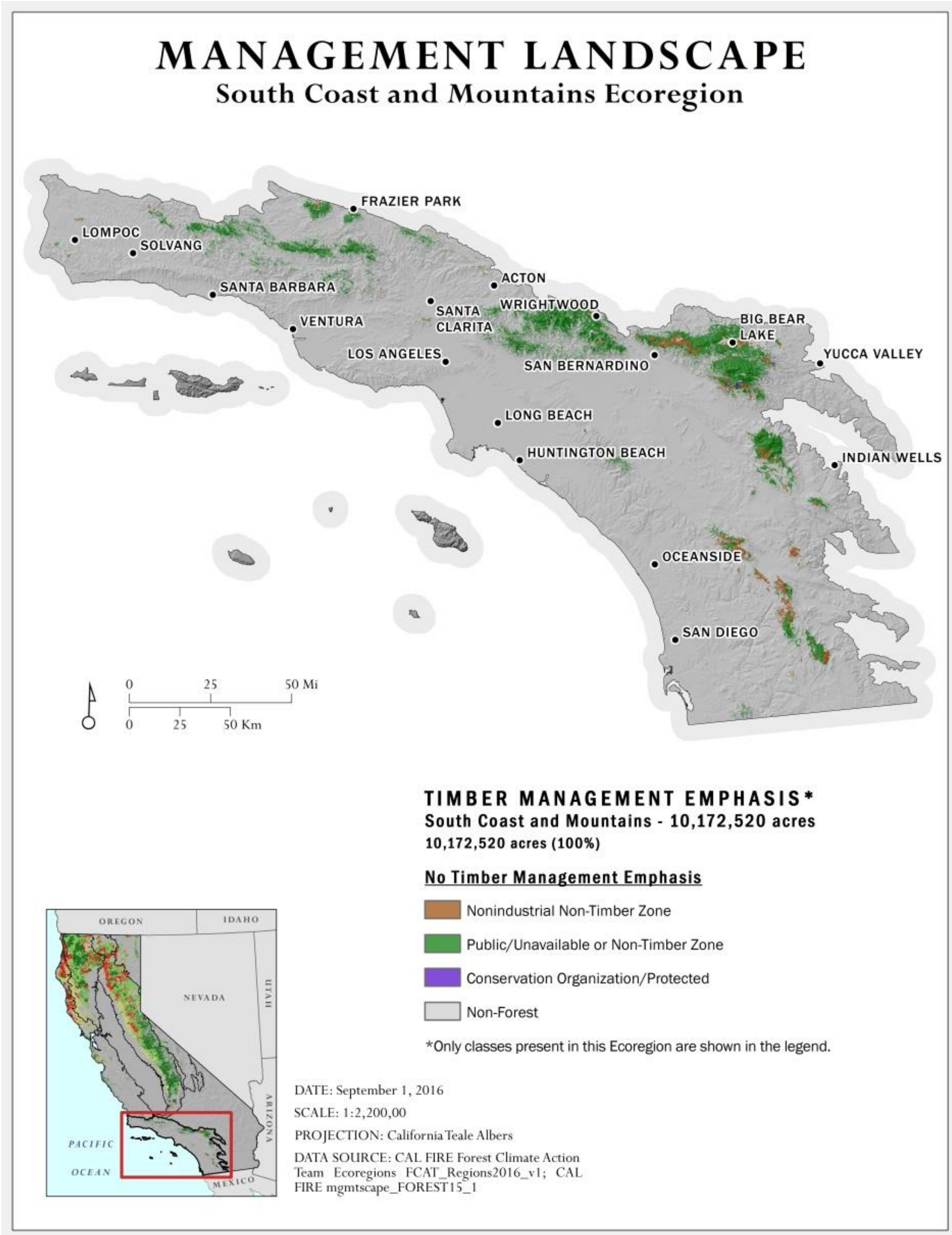

Figure 12. Management Landscape of the South Coast and Mountains Ecoregion

Table 8, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report takes a closer look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation types in the table, it identifies

101,424 acres as suitable for wildland urban interface fuel treatments, 25,248 acres suitable for fuel breaks, and 22,850 acres as suitable for ecological restoration treatments. This totals to 149,523 acres.

Table 8. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the South Coast Bioregion.

Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	101,424	25,248	22,850	149,523
Shrub Dominated	958,039	252,806	157,476	1,368,321
Grass Dominated	284,868	68,969	35,875	389,712
Total by Treatment	1,344,331	347,023	216,201	1,907,556

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report

1.1.5 North Coast Ecoregion

1.1.5.1 Overview of the Ecoregion

The North Coast ecoregion (Figure 13) represents a relatively narrow band of coastal land stretching from the northern California border south to Marin County and the San Francisco Bay. It is bounded by the Pacific Ocean to the west and the Klamath-Interior Coast Range ecoregion to the east, and is distinguished by the significant influence that the coastal temperate maritime climate has on its ecosystems. From sea level, elevation ranges to 5,400 feet, with significant topographic variability created by the generally northwest-southeast trending North Coast ranges, including the King and Mendocino, which are geologically distinct from the Klamath Range to the east. The Smith, Klamath, Mad, Eel, and Russian rivers empty into the Pacific Ocean along the region's coastline.

Temperature is moderated by proximity to the coast, though this effect diminishes as one moves toward the east and south. Although the region's climate is Mediterranean, with the bulk of annual precipitation falling largely between October and April, summer fog plays a significant role in providing moisture for coastal forests, especially redwood forests.[397]

The region includes portions of Del Norte, Humboldt, Mendocino, Sonoma, and Marin counties. Ownership of forested portions of the region is a mix of primarily private industrial and non-industrial timberland owners, but state and federal entities and non-governmental organizations own or manage several significant areas such as Redwood National and State Parks, the King Range National Conservation Area, Humboldt Redwoods State Park, Jackson Demonstration State Forest, and Point Reyes National Seashore.

Montane conifer and hardwood forests cover approximately 64% of the region, including redwood (22%) and Douglas-fir (13%) dominated forest types. Annual and perennial grasslands cover approximately 12% of the region, with an additional 5% in shrub-dominated vegetation. Some unique forest and vegetation assemblages exist in the region, such as those found on marine terraces of various geologic ages. Common

[397] Dawson, 1998

associates of redwood and Douglas-fir include tanoak, California bay-laurel, and Pacific madrone. In the more mesic northern end of the region, forests more closely resemble the highly productive temperate rainforests of the Pacific Northwest, with vast alluvial deposits supporting the tallest trees on the planet. Redwood and Douglas-fir can both exceed 1200 years in age, and the tallest tree in the world, a 380-foot redwood, resides in Redwood National Park. Beyond their great physical stature, redwoods and redwood forests are renowned for a variety of other features, including their productivity and structural complexity, ability to withstand fire and insect disturbance, and capacity for vegetative reproduction or sprouting.[398]

The unique and grand nature of these North Coast forests creates considerable aesthetic, economic, and recreational value, but has also resulted in many of the seminal conflicts in California forest management since settlement of Euro-Americans. Early use of redwood for structural lumber began in Santa Cruz, San Mateo and Marin counties, but the gold rush sparked significant expansion of timber industry in California ca. 1850. By 1856, nine sawmills operated near Humboldt Bay. Introduction of tractor logging and power saws in the 1930s contributed to significant increases in harvest, with Del Norte County producing 300 MMBF of redwood and Douglas-fir by 1946. Concern and conflict over unsustainable harvest levels and significant impacts from road building in the region led to the eventual establishment of state and national parks and reserves, and played a significant role in development of the California Forest Practice Rules in 1973.[399] Outside of reserves, timber production continues today in second- or young-growth forests. Due to the high productivity of these forests, the region has seen the development of several early "carbon projects" under the California Cap-and-Trade market in recent years, designed to protect or enhance storage and sequestration of carbon in forest vegetation.

There are approximately 2.7 million acres of forestland in the North Coast and Ecoregion (Table 9).[400] Private landowners responsible for the bulk of the ecoregion's forestland (85%), followed by state and local governments (10%). The federal government is responsible for only 5% of the forestland in the region. Most of the forestlands (90%) are in unreserved status, and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation. The area in reserved status (10%) may be available and suitable for prescribed fire and managed fire treatments.

[398] Mooney & Dawson 2016
[399] Stuart & Stephens 2006
[400] Christensen, 2016

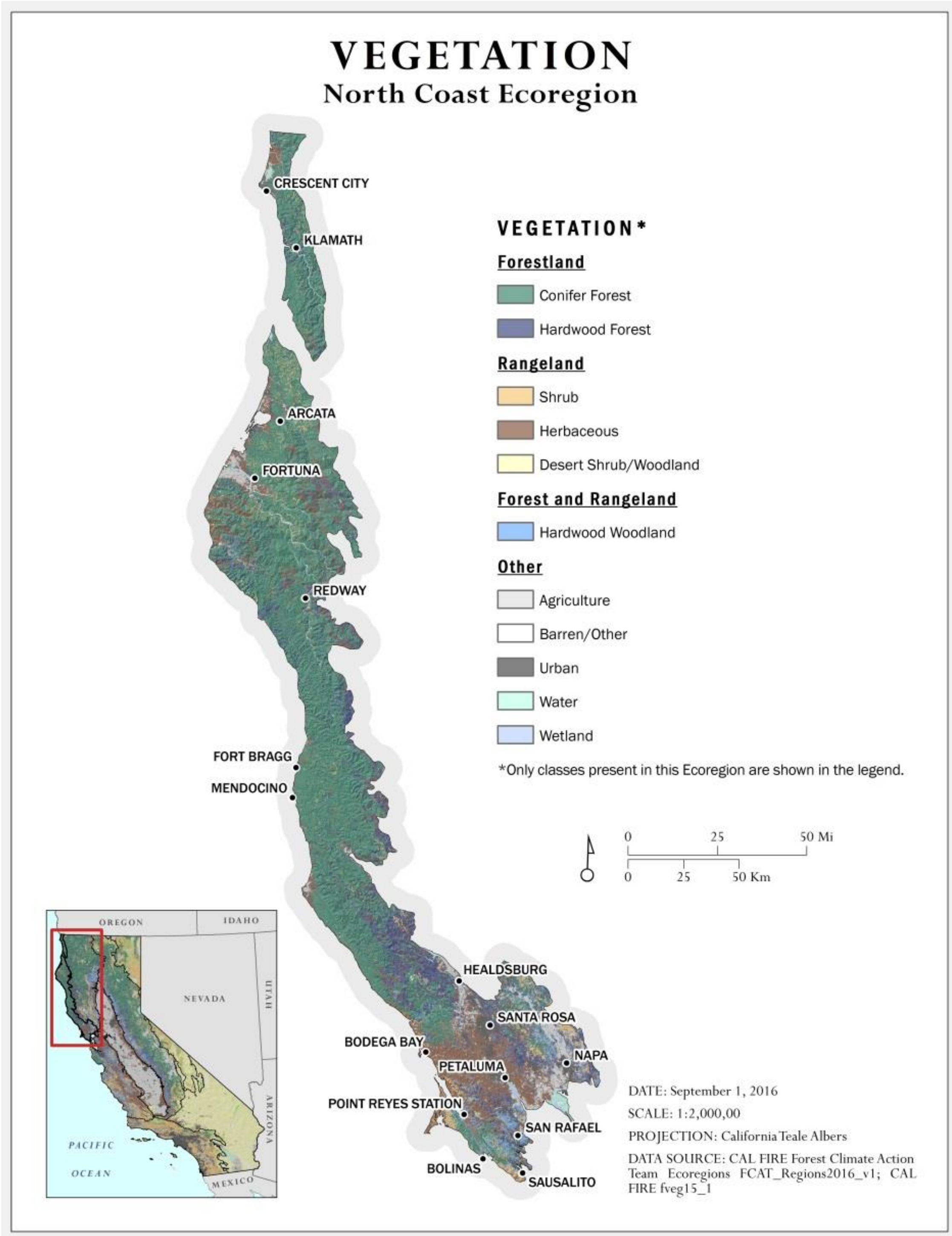

Figure 13. Vegetation of the North Coast Ecoregion.

Table 9. Area of Sampled Land by Land Status and Ownership Group, California 2005 – 2014, North Coast Ecoregion.

	Ownership group						
	National forest	**BLM**	**NPS**	**Other federal**	**State and local govt.**	**Private**	**Total**
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	23	54	--	0	52	2,045	
Other unreserved forest land	7		--	2	5	214	
Total, unreserved	30	54	--	2	57	2,259	2,402
Reserved forest land:							
Reserved productive forest land	0		43	--	150	--	193
Other reserved forest land			11		49	--	60
Total, reserved forest land	0	0	54		199	--	253
Total, forest land	30	54	54	2	256	2,259	2,655

Source: USDA Forest Service FIA – *November 22, 2016 update*

1.1.5.2 Disturbance Regimes

As with other ecoregions, fire was utilized by Native Americans in the North Coast region for millennia. Generally, anthropogenic ignitions were contained to mostly near settlements and in more xeric grasslands and woodlands. Natural and human ignited fire was less frequent in the more mesic coastal forests, owing as much to fuel conditions as to lower lightning strike density near the coast. However, fire history studies suggest fire-free intervals for north coastal forests may have been longer in the wetter portions of the region in the north and west and shorter on drier or more southern sites.[401,402,403]

Fires generally occurred in the North Coast region in summer or fall, were small to medium in size, and low to moderate in intensity. Redwood is a fire enhanced facultative sprouter, with seedling establishment being problematic in the absence of fire or other ground disturbance. Douglas-fir-tanoak regeneration may be enhanced by fire if followed by a large seed crop. Several populations of fire-dependent species exist in the region, including Bishop pine.[404] Disruption of pre-settlement fire regimes occurred later in this region than in others. Anthropogenic ignitions associated with logging slash continued into the early 20th century, but by mid-century fire suppression became much more effective, and along with changes in logging practices resulted in declining cumulative area burned. In the most recent decades, the Mendocino Lightning Complex of 2008 resulted in the most significant burned area in the region.

Figure 14 shows FRID on a percentage basis for the North Coast Ecoregion based on 2015 data. As is evident from the figure, the bulk of the ecoregion is highlighted in red, indicating that much of the area has seen 67% or greater departure from the historic fire interval (i.e., much lower fire frequency than historically). The figure indicates that a very substantial proportion of the area would need to be treated

[401] Veirs, 1982
[402] Mahony, 2000
[403] Brown & Baxter, 2003
[404] Stuart & Stephens 2006

for ecological restoration, fuels reduction, certain fire or habitat management practices, or other activities to bring the effective fire return interval back closer the historical level.

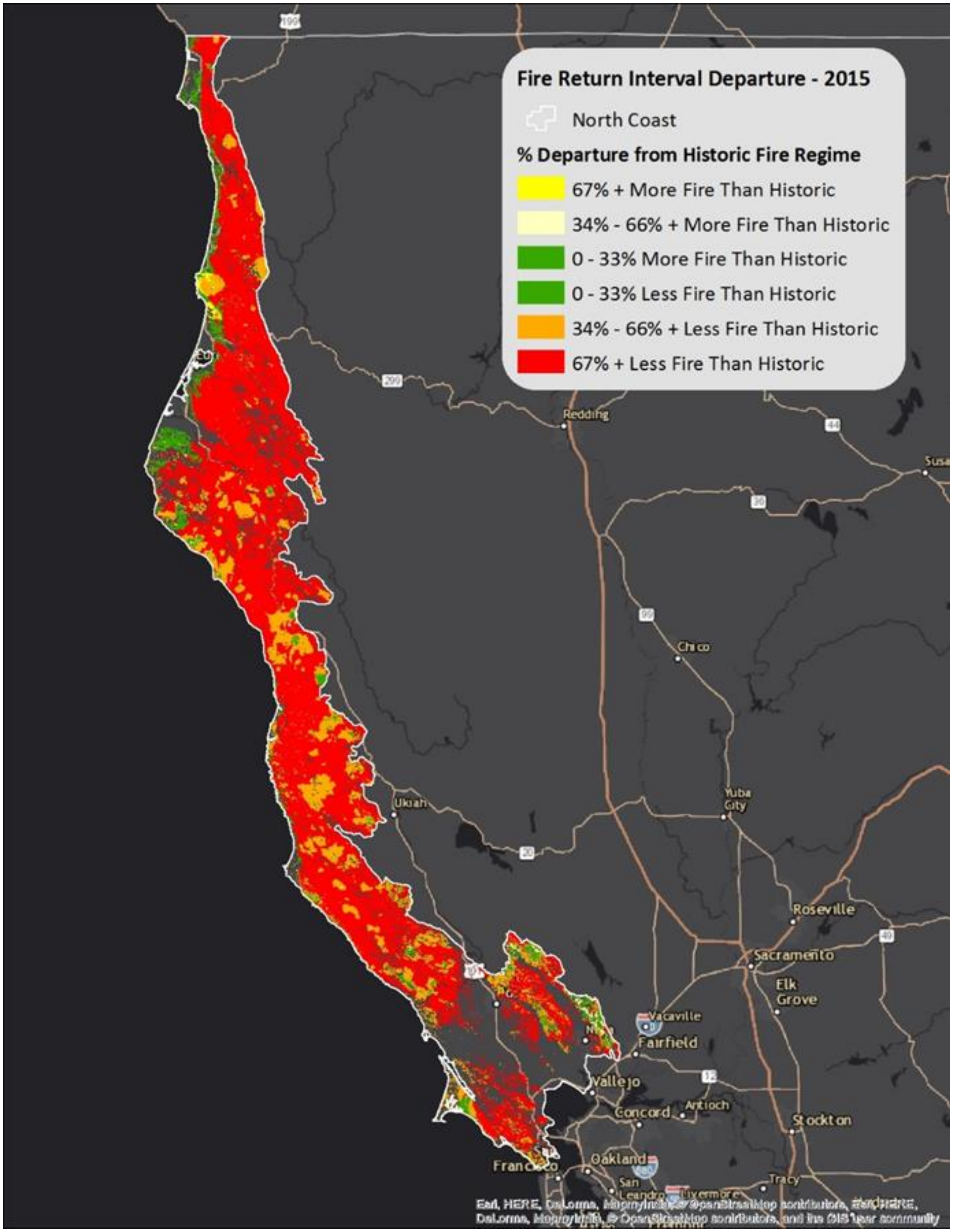

Figure 14. Fire Return Interval Departure for the North Coast Ecoregion.

Arguably, timber harvest represents the most significant disturbance agent in the region over the last century. Climate change may be the most significant driver of change during the next, as long-term weather patterns including reduction of summer fog days reduce or rearrange suitable habitat for redwood and other coastal forest species.

1.1.5.3 Forest Management

Figure 15 shows stylized management regimes for the forestlands of the ecoregion, identifying areas of high, medium, low timber, and no timber management emphasis by ownership class. The largest proportion of the area, (39 percent), is in no management emphasis, followed by low (27 percent), high (23 percent) and medium management emphasis (11 percent). The areas of high and medium timber management emphasis may be the most promising areas for implementing forest treatments designed to improve forest health and address climate mitigation and adaptation.

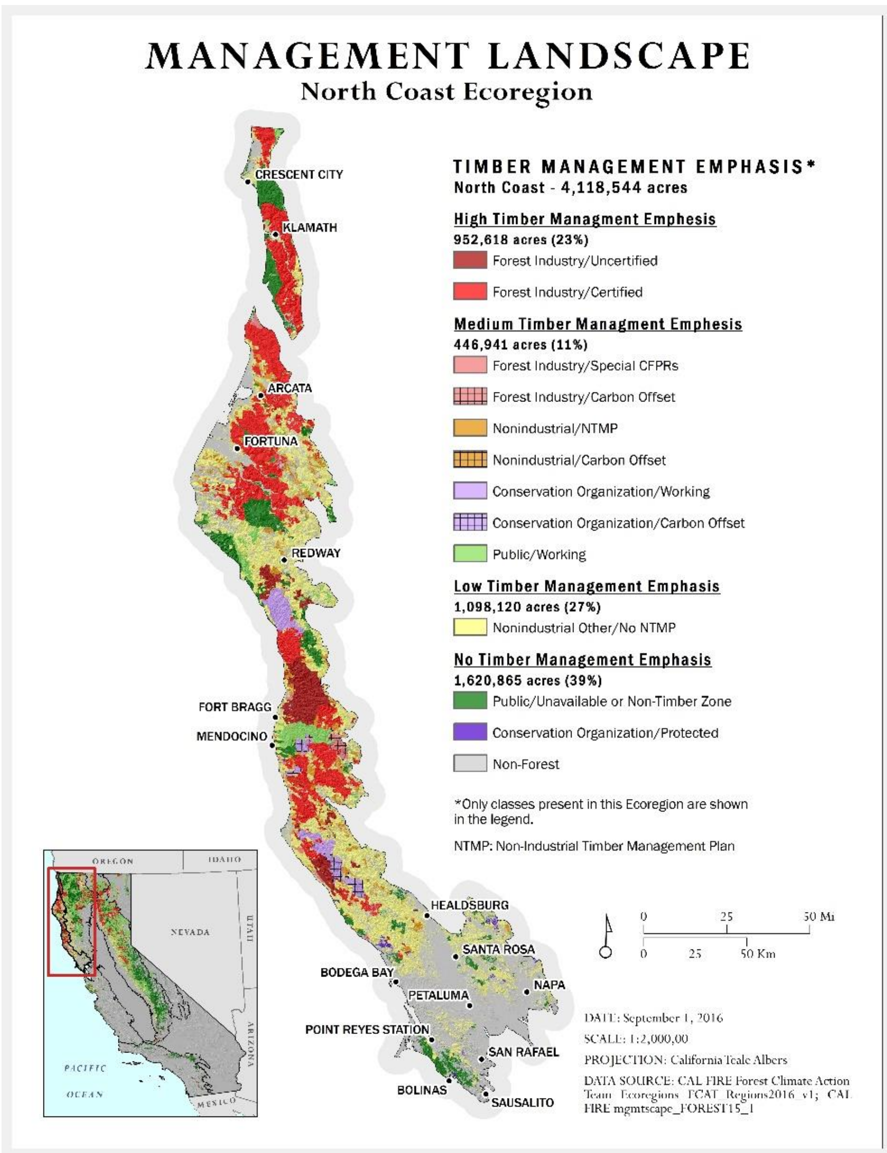

Figure 15. Management Landscape of North Coast Ecoregion.

Table 10, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report takes a closer look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation types in the table, it identifies 441,462 acres as suitable for wildland urban interface fuel treatments, 123,464 acres suitable for fuel breaks, and 484,760 acres as suitable for ecological restoration treatments. This totals to 1,049,686 acres.

Table 10. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the North Coast.

Ecoregion Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	441,462	123,464	484,760	1,049,686
Shrub Dominated	68,037	27,424	34,161	129,623
Grass Dominated	294,078	73,132	57,242	424,453
Total by Treatment	803,577	224,021	576,163	1,603,761

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report

1.1.6 Eastside Ecoregion

1.1.6.1 Overview of the Ecoregion

The Eastside ecoregion occupies the area between the Sierra Cascade Ecoregion and the eastern California border, excluding the Mojave and Colorado desert regions in the southeastern part of the state. Because of the shape of the border, the region encompasses two disjoint areas, including portions of the Modoc Plateau in the northern section, and the Mono Basin Owens Valley, and White and Inyo Mountains in the south. Together, these sections represent California's portion of the vast Great Basin region of western North America. Ecologically the Eastside ecoregion is influenced greatly by its position within the rain shadow of the Sierra Nevada and southern Cascades, which buffers it from Pacific storms. Elevations range from less than 1,200 feet in Saline Valley to over 14,000 feet in the White Mountains, but much of the ecoregion is characterized by large areas of flat, high-elevation desert steppe. Precipitation mainly falls as snow between November and April, and lightning strikes are most common from July through August, often accompanying summer thunderstorms.

Vegetation here is dominated by high-elevation desert and woodland types, sharing characteristics with the Oregon high desert or the basin-and-range country of Nevada. By area, sagebrush types (35%) and desert scrub types (23%) are the most common, with pinyon-juniper woodlands covering an additional 12%. Coniferous forests occupy approximately 10% of the region, including ponderosa and Jeffrey pine at lower elevations (sometimes classified regionally as "Eastside pine"), with some white fir and subalpine forests at higher elevations. Groves of aspen are also a notable vegetation type in this region.

Land ownership in the region is largely federal, shared between the USDA Forest Service (Inyo NF, Modoc NF, White Mountains) and the BLM. Proportionally more private ownership exists in the northern section, while The National Park Service (Death Valley NP), Department of Defense, and City of Los Angeles (Owens Valley) manage significant tracts in the southern section. The region is rural by large measure, with only 0.2% urban area.

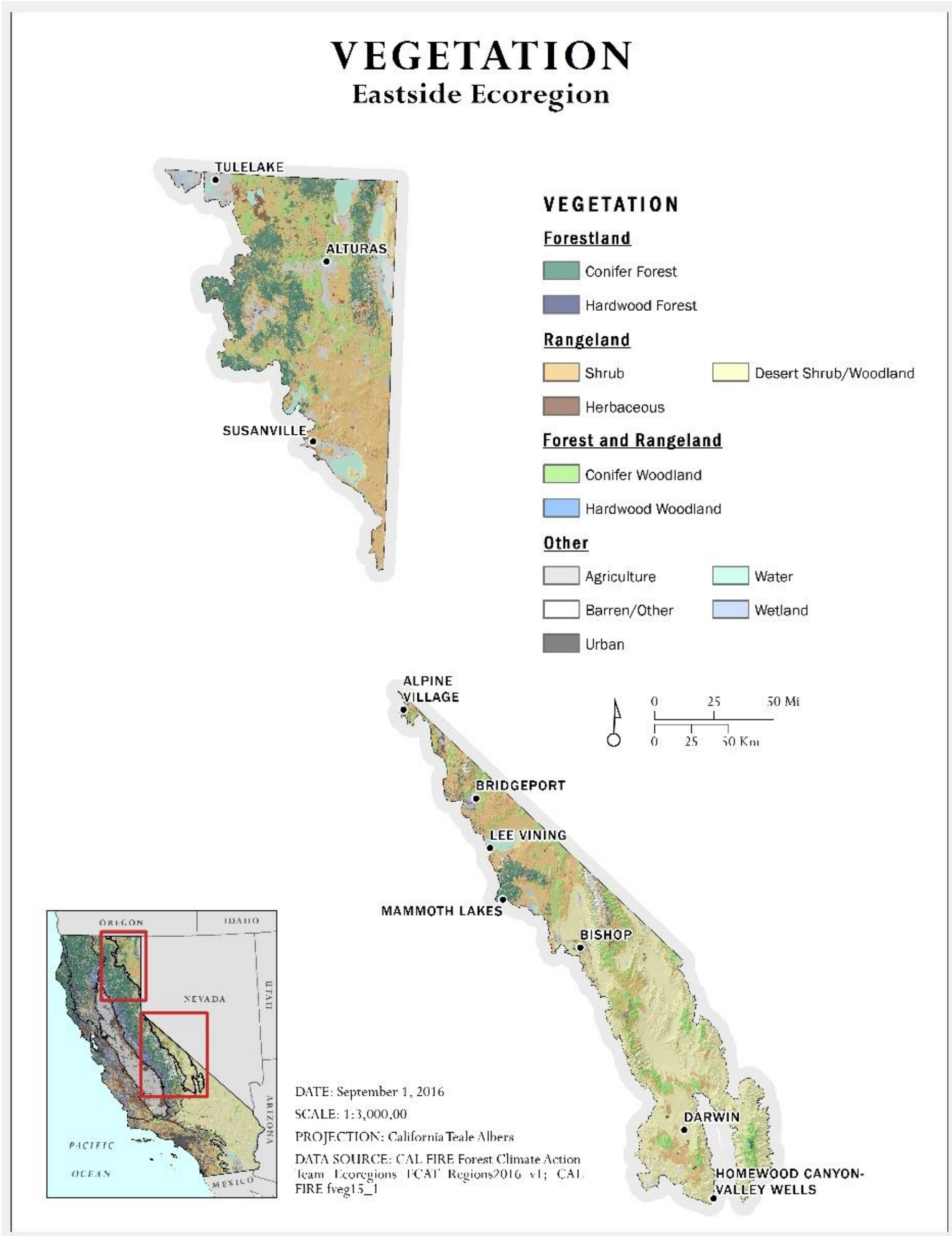

Figure 16. Vegetation of the Eastside Ecoregion.

There are approximately 2.9 million acres of forestland in the Eastside Ecoregion[405] (Table 11). The federal government is responsible for 80 percent of the forestland in the region, while private landowners hold 19 percent of the forestland. Most of the forestlands are in unreserved status (78 percent), and thus potentially available for a broad range of management options that may help to address climate adaptation and mitigation.

[405] Christensen, 2016

Table 11. Area of Sampled Land by Land Status and Ownership Group, California 2005-2014; Eastside Ecoregion.

	Ownership group						
	National forest	**BLM**	**NPS**	**Other federal**	**State and local govt.**	**Private**	**Total**
Land status							
	Thousand acres						
Unreserved forest land:							
Timberland	702	41	--	--	--	309	1,052
Other unreserved forest land	854	449	--	6	6	230	1,545
Total, unreserved	1,556	490	--	6	6	539	2,597
Reserved forest land:							
Reserved productive forest land	54	--	--	--	6	--	60
Other reserved forest land	81	54	66	--	9	--	210
Total, reserved forest land	135	54	66	--	15		270
Total, forest land	1,691	544	66	6	21	539	2,867

Source: Forest Inventory Analysis (FIA) Program, Christensen 2016 unpublished data

1.1.6.2 Disturbance Regimes

Relatively little is known about pre-settlement fire history in the sagebrush-steppe communities of this region, but fire was (and continues to be) likely driven largely by fuel characteristics and amounts. Where sagebrush is continuous, surface fuel loads are generally high, but replaced by high crown fuel loads in the pinon-juniper woodlands. On drier and more desert-like sites, discontinuous fuels likely resulted in patchy burns and long fire-free intervals. Lower and upper montane sites hosting eastside pine and other coniferous forest types are believed to have been subject to low-moderate intensity surface fires with relatively short fire-free intervals.[406],[407],[408],[409]

Early and continued grazing, along with logging of pine in forested areas have altered fire regimes in the forests of this region. Non-native plant invasion, especially cheatgrass, is another important element of disturbance, and may actually be causing increases in fire frequency in some areas because it provides such a light, flashy fuel.

Figure 17 shows FRID on a percentage basis for the Eastside Ecoregion based on 2015 data. As is evident from the figure, the bulk of the ecoregion is highlighted in red or orange, indicating that much of the area has seen substantial departure from the historic fire interval (i.e., much lower fire frequency than historically). The figure indicates that a very significant proportion of the area would need to be treated for ecological restoration, fuels reduction, certain fire or habitat management practices, or other activities to bring the effective fire return interval back closer the historical level.

[406] Smith, 1994
[407] Stephens, 2001
[408] Brooks & Minnich, 2006
[409] Riegel et al., 2006

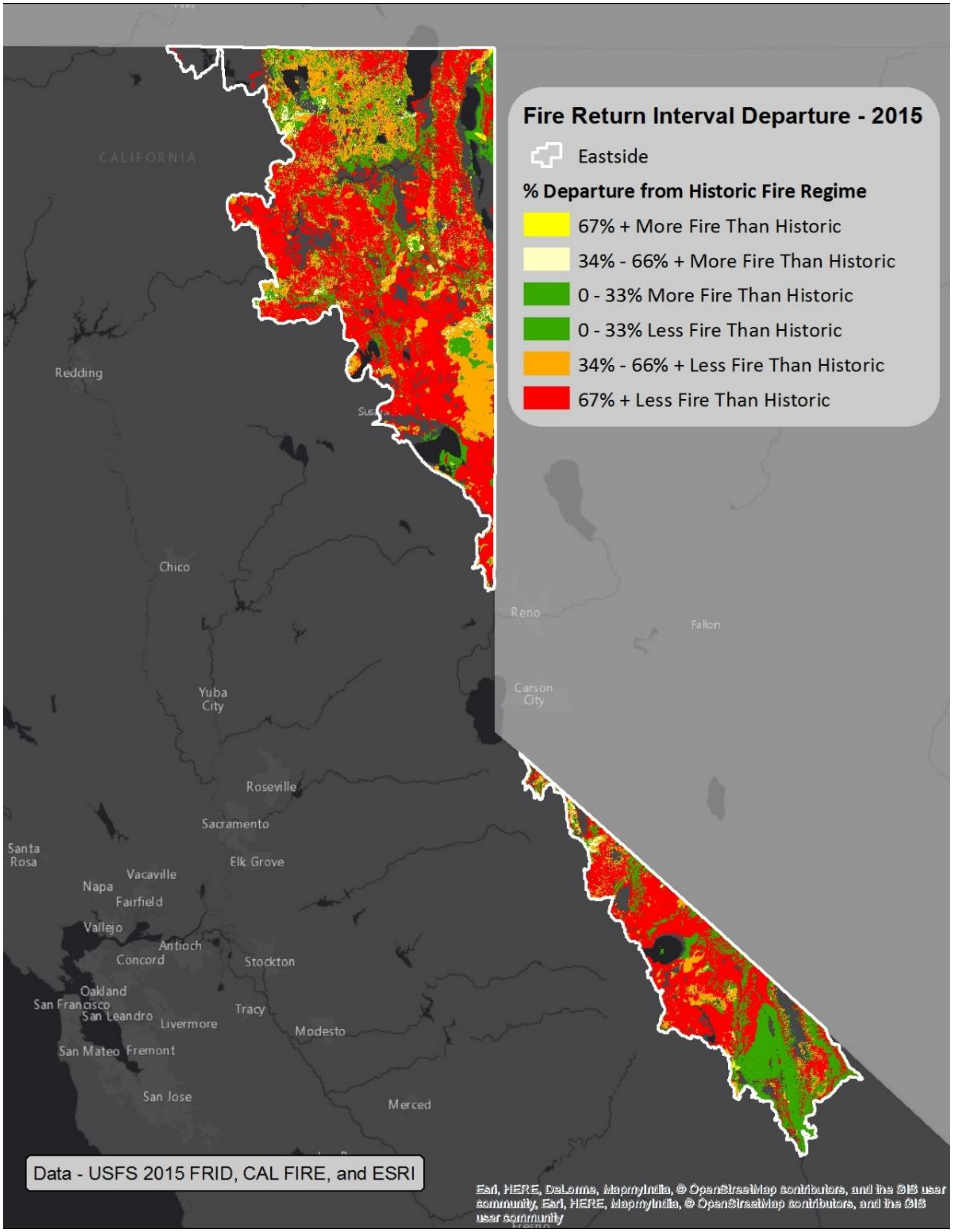

Figure 17. Fire Return Interval Departure for the Eastside Ecoregion.

1.1.6.3 Forest Management

Figure 18 shows stylized management regimes for forestlands of the ecoregion, identifying areas of high, medium, low, and no timber management emphasis by ownership class. The largest proportion of the area (90%) is in no timber management emphasis, followed by medium (7%), high (2), and low (1). The areas of medium and high timber management emphasis, though limited in extend, may be the most promising areas for implementing forest treatments designed to improve forest health and address climate mitigation and adaptation.

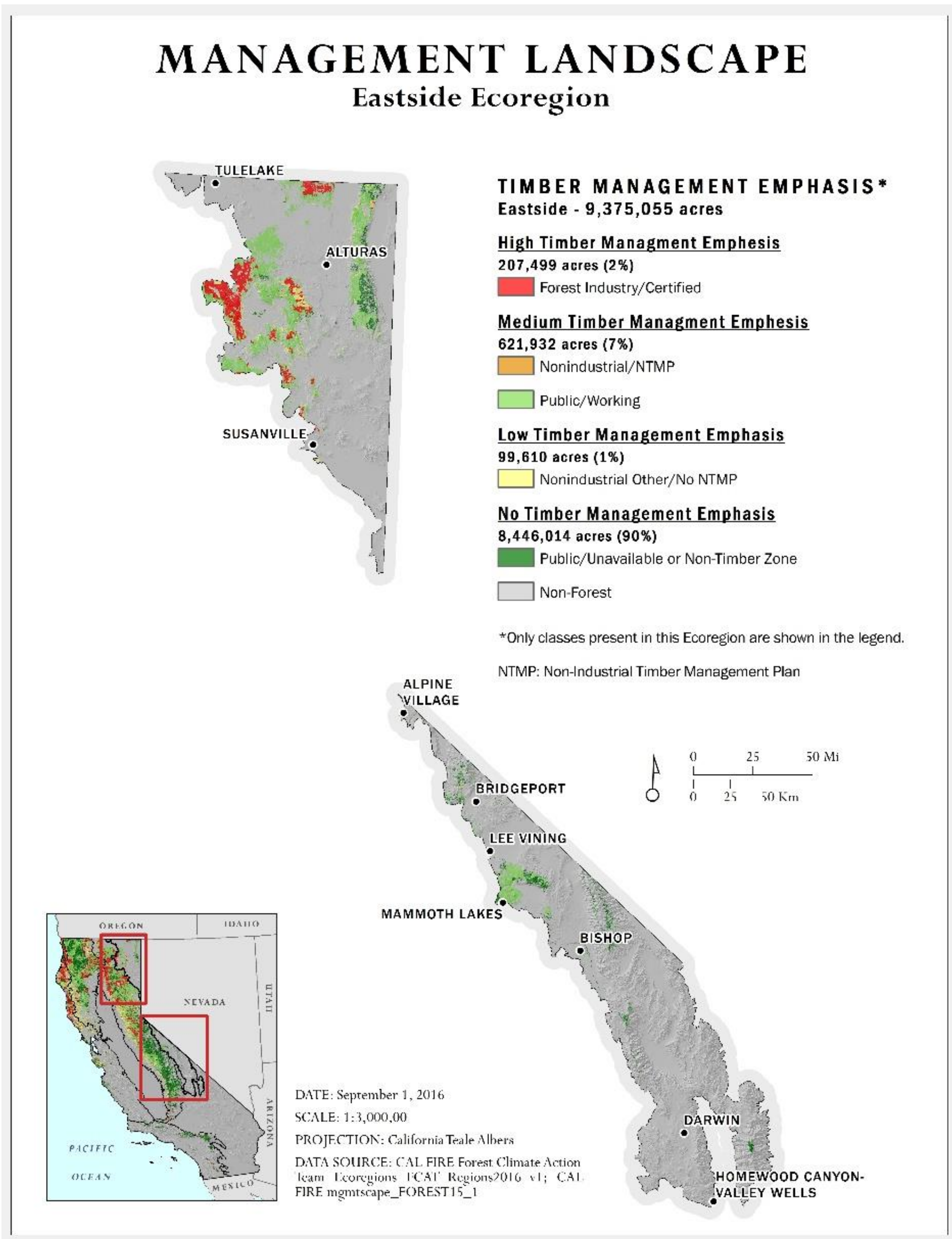

Figure 18. Management Landscape of the Eastside Ecoregion.

Table 12, drawn from Board of Forestry and Fire Protection's Vegetation Treatment Program Draft Environmental Impact Report (VTP-EIR) takes a close look at management potentials on non-federal State and Local Responsibility Area lands. Focusing on the tree-dominated vegetation type, the table identifies 377,423 acres as suitable for wildland urban interface fuel treatments, 199,676 acres suitable for fuel breaks, and 827,087 acres as suitable for ecological restoration treatments. This totals to approximately 1.4 million acres.

Table 12. Treatable Acres by Dominant Vegetation Type and Treatment Alternative within the Eastside Ecoregion.

Dominant Vegetation Type	WUI	Fuel Breaks	Ecological Restoration	Total by Dominant Vegetation Type
Tree-Dominated	377,423	199,678	827,087	1,404,189
Shrub Dominated	235,956	154,778	538,995	929,729
Grass Dominated	120,292	51,095	124,530	295,917
Total by Treatment	733,671	405,551	1,490,612	2,629,835

Source: CAL FIRE's Vegetation Treatment Program Draft Environmental Impact Report