

California Forest Carbon Plan Concept Paper: *Managing our Forest Landscapes in a Changing Climate*

Forest Climate Action Team¹

March 9, 2016

This concept paper provides an overview of the proposed goals and strategies of the under-development Forest Carbon Plan to provide a discussion document to foster interaction with and feedback from the public. In addition to furthering our work on the Forest Carbon Plan, the Air Resources Board will use the information developed in this process as the basis for goals for forest carbon sequestration and for reduction of greenhouse gas and black carbon emissions in the 2016 Scoping Plan Update. We have noted within this document the specific topics on which we are particularly interested in public comment at this time. Public workshops to discuss this concept paper will be held on March 23 in Sacramento and March 24 in City of Shasta Lake; details are available at <http://www.fire.ca.gov/fcat/>. Please submit your written comments by April 8, 2016 via email to fcat.calfire@fire.ca.gov.

Introduction

Vision Statement

The Forest Climate Action Team (FCAT) has developed a Vision Statement for its work:

The Forest Carbon Plan will provide forest carbon targets and an array of strategies to promote healthy wildland and urban forests that protect and enhance forest carbon and the broader range of forest environmental services for all forests in California. Our vision of forest protection, enhancement, and innovation includes:

- Sustainable forests that are net sinks of carbon.
- Healthy forests that are resilient to anticipated climate change effects, including 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.

¹ The Forest Climate Action Team (FCAT) was assembled in August of 2014 under the direction and leadership of Governor Edmund G. Brown Jr. for the primary purpose of developing a Forest Carbon Plan by the end of 2016. FCAT is comprised of executive level members from many of the State's natural resources and environmental agencies, state and federal forest land managers, and other key partners directly or indirectly involved in California forests. FCAT is under the leadership of CAL FIRE, CalEPA, and The Natural Resources Agency. The FCAT website is available [here](#).

- Forests that are protected from fragmentation and conversion, and that provide a diverse range of quality, interconnected habitat types for terrestrial and aquatic wildlife species, including listed and non-listed species.
- Forests that provide an abundance of outdoor recreational and tourism opportunities.
- Integrated carbon, restoration, and wildfire protection goals.
- Extensive, well-managed urban forests that sequester carbon; provide significant environmental, social and economic co-benefits to communities rich and poor; and yield wood products and biomass when trees must be removed.
- Collaborative, adaptive, and innovative planning and implementation.

This Vision Statement is an important part of the framing for the Forest Carbon Plan; we welcome your comments on it.

Purpose and Scope of the Forest Carbon Plan and this Concept Paper

Through the Forest Carbon Plan and other collaborative work, the FCAT aims to develop and implement plans to improve the health of California’s forests, increase their carbon storage, and reduce their emission of carbon to the atmosphere. FCAT will describe these goals and processes in an innovative forest conservation and restoration plan for the state’s 33 million acres of forestland and for the state’s extensive urban forests. While the Forest Carbon Plan targets carbon emissions and storage, it also acknowledges and targets improving and safeguarding interrelated ecosystem services, as well as social and economic considerations.

It is our intent that the Forest Carbon Plan:

- Summarize 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.
- Establish forest health and resiliency conditions needed to reach targets for carbon sequestration and net reductions in emissions of greenhouse gases (GHGs) and atmospheric black carbon;
- Develop near-, medium- and long-term targets for carbon sequestration and emissions reductions by region and ownership, through 2050 and beyond, based on goals and ecosystem potential.
- Develop implementation and investment strategies to achieve carbon sequestration targets;
- Provide a framework for managing California’s forested landscapes to increase carbon sequestration and reduce climate-warming emissions, alongside other values of healthy forests;
- Identify synergies and gaps in various federal and state mandates, policies, regulations, and programs related to forests;
- Address both wildland forests and urban forests.
- Be consistent with state and federal wildland fire management goals and strategies.

The purpose of this concept paper is to describe the framework and process that FCAT is employing to develop the Forest Carbon Plan. The FCAT further aims for this paper to foster public discussion of carbon sequestration and emission reduction goals and strategies, as well as related ecosystem, social, and economic considerations. Timely identification and discussion of forest carbon goals and targets will allow the FCAT to provide recommendations to the Air Resources Board (ARB) for inclusion in the anticipated spring 2016 release of the Scoping Plan Update Discussion Draft.

California's historic drought and unprecedented tree mortality have focused significant public attention on forests and the wildland-urban interface. Accordingly, there has been great public interest in the Forest Carbon Plan as a vehicle to deliver forest-based policies that will address concerns for forest health. This concept paper is intended to invite public engagement in developing forest health management strategies.

FCAT previously released the proposed outline of the Forest Carbon Plan (available [here](#) on the FCAT website) and plans to complete a document that substantively follows this outline by the end of 2016. The Forest Carbon Plan will use detailed data and analysis to take the mid- to high-level goals developed through this concept paper and public input processes to a higher level of specificity in terms of goal quantification, targets by region and land ownership class, co-benefits, strategies, investment needs, and recommended policies. An overview of these methods is provided in the section, "Analytical Approach." The Forest Carbon Plan will be the detailed implementation plan for the forest carbon goals developed in the Forest Carbon Concept Paper and embodied in the 2016 Scoping Plan Update.

On behalf of FCAT, the Natural Resources Agency has entered into an interagency agreement with the University of California, Berkeley, for a forest resources economics study to support analytical elements of the Forest Carbon Plan and its implementation.

Forests of California Today

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 the dominant, 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.
(Clark et al., 2016)

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 (Agee, 1996). 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. Under these conditions many western forests are overly dense and experiencing large and severe wildfires.

In the past several decades, increased burning has been linked to various aspects of climate change (Higuera, 2015). Weather and climate primarily determine the total acreage burned. The historical evidence spanning the past 3,200 years suggests that more acres burn during warm periods (Calder et al., 2015; Marlon et al., 2012; Power, 2012; Swetnam, Falk, Sutherland, Brown, & Brown, 2011). The wildfire problem today corresponds to a warmer, drier climate (Calder et al., 2015; Kitzberger et al., 2007; Marlon et al., 2012; Figure 1).

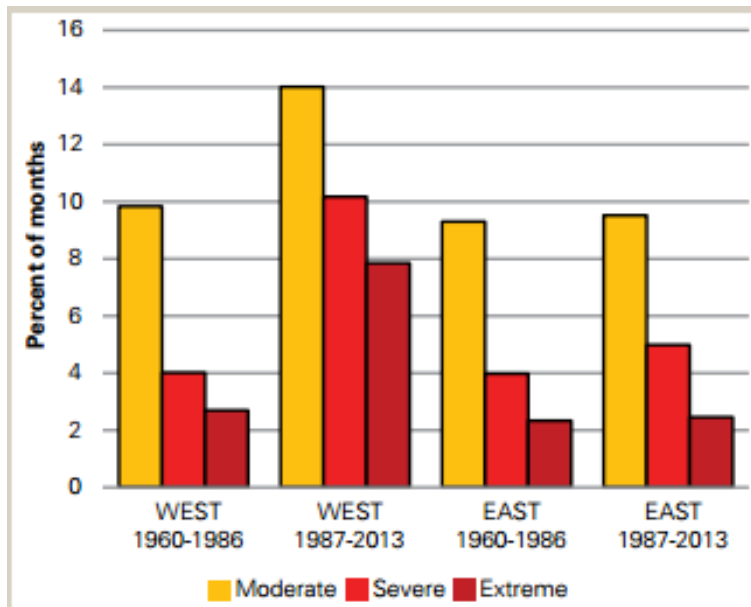


Figure 1. Drought for forested land of the conterminous United States for two 27-year periods from 1960 to 2013 (Source: USFS- GTR, WO-93b, 2016).

Since 1960, the four biggest wildfire seasons West wide have occurred in the last 10 years (Schoennagel et al., 2016). Past human activities, such as fire suppression and logging, influence acres burned, but the impacts are small when compared to drought, wind and temperature. A meta-analysis of over 1,200 studies and 3,200 years of evidence concluded that “managers will have to learn to work with, not against, the time-varying influence of climate on widespread fire years; recent experience suggests that it is unlikely that the forces that set up west-wide years can be resisted at the scale of individual forests or management units” (Swetnam et al., 2011).

The Forests of California

The Forest Carbon Plan focuses on forested ecosystems and associated ecological communities, as well as urban forests. California has a large forestland base (approximately 33 million acres, or almost one-third of the state) (CAL FIRE, 2010) that has the potential to significantly offset GHG emissions from the industrial, transportation, and built environment. The forest land base is divided between private and public management (see Table 1). Predominantly under federal government (over 57 percent), these forest resources also consist of state and private lands. Diverse land owners introduce several challenges, and coordination among state agencies, private land owners, and federal agencies is essential to the success of a comprehensive forest climate strategy in California. Strategies must address different objectives and the capacities of different forest landowner classes. Carbon storage strategies must also consider the broader range of environmental services that forests provide (e.g. clean water, water storage, clean air, soil productivity, nutrient cycling, wildlife habitat, forest products, and recreation). The inevitable element of risk in natural systems requires tradeoffs between priorities. Accumulating evidence suggests that in Mediterranean-climate forests the optimal 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 reflect the disturbance regime that it grows under (North and Hurteau, 2011; Collins et al., 2015). The risk of losing all the trees to severe wildfire suggests that redistributing the total carbon

storage among fewer, larger and more fire resilient trees has the highest chance of storing the most carbon in the long term.

Table 1. California forestland ownership.

Ownership Category	Acres of Forestland	Percentage of Total Forestland Area
Private	13,131,000	39.3 %
Federal	19,171,000	57.4 %
State	711,000	2.1 %
Local	374,000	1.1 %
Total	33,387,000	100 %

Source: CAL FIRE, 2010.

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. Of the nearly 33 million acres of forest, 17 million acres are timberland², 56 percent in public ownership and 44 percent in private ownership. Roughly 18 percent of public forest, including 3.7 million acres of timberland, is in a reserved status unavailable for timber harvest. On the private forestlands, landowners primarily engaged in timber production own about 4.5 million acres of forest (4.0 million acres of timberland) and non-industrial landowners own about 8 million acres of forest (CAL FIRE, 2010).

Forests in which trees are harvested regularly are referred to as “working forests”. California’s forested landscape consists of a mosaic of land covers including working forests, conservation reserves and human-dominated uses. This landscape functions at multiple scales to provide ecosystem services such as carbon sequestration, aesthetics, recreational opportunities, wildlife habitat, water quantity and quality. It may also provide economic opportunities to its residents and others who participate in timber harvesting and production and who provide recreation- or tourism-related services. Timber harvest volume has generally declined since the mid- to late-1980s, but has been trending upward in the last 5 years (data from the State Board of Equalization Timber Yield Tax Program:

<http://www.boe.ca.gov/proptaxes/timbertax.htm>). Recent data (Christensen et al., 2016) comparing change between the 2001–2006 and 2006–2010 periods indicate that large private ownerships primarily engaged in timber production are harvesting at sustainable levels where harvest is close to growth and tree mortality is at a minimum. When counting harvested wood products in use, these lands produce and store the greatest amounts of carbon. Federal ownerships have high tree mortality, low harvest levels, and low growth. Private non-industrial landowners are somewhere in the middle between these two conditions.

Forest Health

California forests are as diverse as their ecosystems. California has a wide variety of tree species including, but not limited to, many types of conifers (e.g. Douglas-fir, ponderosa pine, sugar pine, incense-cedar, Coast redwood, giant sequoia, etc.) and also many types of oaks (e.g. blue oak, coast live oak, etc.). Climate change threatens California forests with more frequent and severe wildfires, pests, disease, increased temperatures, and changing precipitation and water availability. As described below, these threats may decrease forest growth (and hence decrease rates of carbon sequestration), cause

² Forest is considered “timberland” if it is growing on ground that is capable of significant annual tree growth and considered available for timber management.

geographic shifts in tree distribution and forest types, and result in forest loss and tree mortality (and hence increase rates of GHG emissions).

These threats, coupled with the legacy of past land management, overlay traditional pressures for the conversion of forested lands to alternate land uses. In addition, past fire suppression activities and lack of fuels management have left California forests particularly vulnerable and weakened. Decades of conflict over the appropriate balance between active versus passive management and commodity production versus protecting or enhancing ecosystems has hindered progress on achieving a healthy forest landscape. Some of this conflict has been declining in recent years as more stakeholders now recognize needs for active management to achieve and/or sustain desired ecosystem conditions. Resolution of these conflicts has been assisted in part through multi-stakeholder collaborative efforts. At times, asymmetric distribution of forest products infrastructure—loggers, mills, biomass energy plants—throughout the state has contributed to low levels of active forest management.

Forest losses due to climate change not only threaten carbon storage and emissions from forests, but also threaten water resources, energy transmission, the survival of fish and wildlife, and human health. These losses also will negatively impact tourism, recreation opportunities, and the timber industry.

While historically wildfire has been a key component in ecosystem dynamics, a number of factors have disrupted the natural fire regime of many of California's ecosystems. Many cases, where the type of fire and the pattern of its occurrence have diverged from historical conditions, have resulted in changing ecosystem composition, structure and function. Factors such as fire suppression, timber management, grazing, land use, exotic invasive species and climate change all place stress on the interaction of fire with ecosystem health, function (such as biodiversity), and sustainability.

Using Stand Density Index (SDI) as an indicator of overly dense stands, results show approximately 42%, or 14 million acres forestland, are in need of treatment in California. SDI measures tree density per unit area as a measure a site's carrying capacity for living biomass. Trees in dense or "overstocked" stands (i.e., with high SDI values) are typically water-stressed, and have been shown to succumb more easily to disease, insect pests, and eventually mortality. Using Forest Inventory and Analysis (FIA) data as an alternative measure of overly dense stands yields approximately 1-2 million acres of overstocked forest land in California. The Forest Service estimates that 9 million acres of National Forest lands in the state are in need of restoration in California (<http://www.fs.usda.gov/detail/r5/landmanagement/?cid=stelprdb5409054>).

The Growing Forest Health Threat of Rising Temperatures and Changing Precipitation Regimes

Climate can greatly influence the dynamics of forest and range ecosystems, especially the type, mix, and productivity (including rates of carbon sequestration) of species. Future climate change scenarios predict increases in temperature, increases in atmospheric CO₂ concentrations, and changes in the amount and distribution of precipitation (Dale et al., 2001). Altering these fundamental drivers of climate can result in changes in tree growth, changes in the range and distribution of species, and alteration to disturbance regimes (e.g., wildfires, outbreaks of pests, invasive species). Relatively small changes in temperature and precipitation can affect reforestation success, growth, susceptibility to pests, and forest productivity.

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 (Dale et al., 2001). While disturbances occur regularly in nature, large changes in the patterns of disturbance could make forests less resilient. Vegetation types with restricted ranges may be more vulnerable than others, as may areas that are already under stress from land use changes (i.e., expanding wildland urban interface) and management (Foster, 2003).

The influence that climate has on disturbance regimes may already be affecting forests. Much of California is in the fourth year of a severe drought. Recent research has demonstrated that up to 27% of this drought can be ascribed to climate change-driven warming (Williams et al., 2015). The on-going drought in California is making many forests less resilient to wildfire and more susceptible to invasive bark beetles. In a cyclical fashion, increased beetle activity from climate change leaves behind greater tree mortality, which in turn contributes to more intense wildfires (Simard et al., 2010). Extended drought and earlier snowmelt may become the new norm, as Southern California is expected to see conditions up to 30% drier and 1-2 degrees (Fahrenheit) hotter than historical norms in the next 15 years (Krist et al., 2014). Additionally, increasing temperatures and decreasing precipitation exacerbated by climate change contribute to dry and hot conditions favorable for wildfires, thereby increasing the risk for wildfire even more. Fire seasons in the West have already increased by 78 days since the mid-1980s, so greater increases in fire seasons in coming years are likely (Westerling et al., 2006).

According to the U.S. Forest Service “National Insect and Disease Forest Risk Assessment, 2013-2027,” (Krist et al., 2012) California is at risk of losing at least 25% of standing live forest due to insects and disease over 5.7 million acres, or 12% 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 projected to lose 60% of basal area, lodgepole pine 40%). 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, and will increase the risk from already highly destructive pests such as mountain pine beetle.

Extensive tree mortality is already prevalent in California. As there is usually a lag time between drought years and tree mortality, we are now beginning to see a sharp rise in mortality from the past four years of drought. Field data from USFS, State and Private Forestry Aerial Detection Surveys in 2015, show elevated tree mortality associated with bark beetles primarily in the Southern Sierra Nevada and in Southern California mountains³:

- 2,910,000 total acres with some level of tree mortality were mapped in California, starkly higher compared to about 909,000 acres in 2014.
- 29.1 million dead trees, up from about 3.3 million dead trees in 2014, and an estimated additional 29 million dying trees (Wade Evans, 2016).
- Bark beetle-caused tree mortality was attributed to approximately 1.6 million acres, representing an estimated 16.5 million dead trees in the region.

³ More recently, there are reports from the field that increasing tree mortality also is being seen further north in the Sierra Nevada mountains.

Under authority provided under the 2013 Farm Bill, the Secretary of Agriculture and the Chief of the Forest Service have now designated 6.7 million acres of National Forest 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 processes.

Figure 2 illustrates the high level of drought and bark beetle tree mortality in the Southern Sierra Nevada foothills in mid-2015. In response to the very high levels of tree mortality concentrated there, Governor Jerry Brown issued an [Emergency Proclamation](#) on October 30, 2015.

Implications for Forest Carbon Sinks

Decades of fire suppression, coupled with limited forest management activity, have left many of California's forests with higher densities of small trees and fewer large trees on the landscape overall compared to historic forest conditions (Stephens et al., 2015; North, 2012). These conditions have detrimental implications for both the quality and quantity of forest carbon sinks. In dense stands, competition for scarce resources can stunt individual tree growth rates, and therefore sequestration rates. Stands that have reduced tree competition, whether by fire or treatment, can experience greater growth rates in the live trees that remain (Stephenson et al., 2014), allowing carbon sequestration rates to remain increasing over time. In dense stands, increased mortality also causes more carbon to shift from live to dead pools. As larger trees experience higher-than-expected levels of mortality due to increased density-dependent stressors (North et al., 2009), the loss of live carbon is compounded as larger trees store more carbon (Stephenson et al. 2014.) It is important to clarify that while this shift may not cause noticeable changes in the total amount of forest carbon (Wiechmann et al., 2015), as more carbon is shifted into dead material the overall sequestration rate of the stand is offset by emissions from decay increase over time.

These dense forests are also highly vulnerable to large, damaging wildfires. Severely burned forests have less ability post-fire to naturally restore their carbon-carrying capacity due to decreased survivorship of trees in general, especially large trees (North and Hurteau, 2011), and a diminished ability to regenerate which may lead to longer-term conversions to vegetation types with lower carbon carrying capacities (Ryan et al., 2010; Carlson et al., 2012; Roccaforte et al., 2012; Dore et al., 2012). Also, the short-term forest carbon emissions at the time of a severe fire are small relative to the long-term emissions from the dead carbon pool left to decay (Matchett et al., 2014; Hicke et al., 2013; Ryan et al., 2010; Campbell et al., 2009).

Recent observations suggest that unmanaged forests could be carbon neutral or even carbon emitters, without any interaction from fire, while treated forests continue to sequester carbon ([Wiechmann et al., 2015](#); [Dore et al. 2012](#)). With the addition of wildfire, between 2001 and 2010 high levels of pollution and greenhouse gases were released from California forests faster than they were being absorbed (Gonzalez et al., 2015; Wiechmann et al., 2015). These losses in forest carbon occurred during a time when the Sierra Nevada received an average amount of snowpack (averaged across all 10 years) and an average of 110,000 acres burned on the west slope. In the three to four years since the studies terminated, the snowpack has averaged less than 35% of normal and the fire seasons have averaged 220,000 acres.

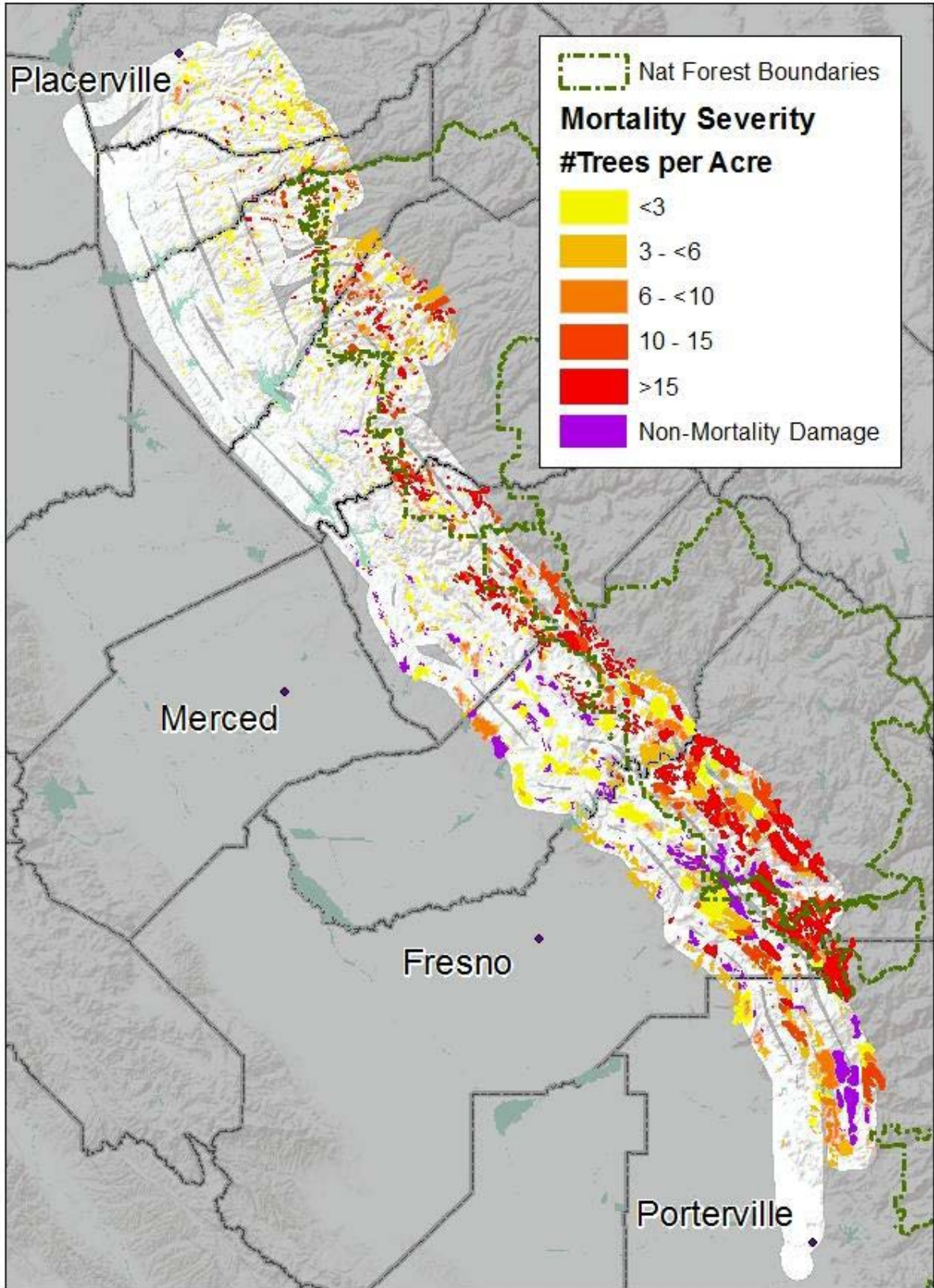


Figure 2. Tree Mortality and Other Damage in Southern Sierra Foothills, 2015 (USDA Forest Service, 2015).

In addition to wildfire, increased stress from drought can have a deleterious effect on forest carbon sinks. A study conducted by the Universities of California, Berkeley and Davis, and the U.S. Geological Survey found that the drought has contributed to denser forests with smaller trees, which has implications for the quality of those forest carbon sinks and their risk of loss due to severe wildfires (McIntyre et al., 2015). Additionally, not only is tree growth, and therefore carbon sequestration rates, stunted during drought periods, but growth rates can remain impacted for additional years after the drought has ended (Anderegg et al., 2015). However, Dore et al. (2012) found that when a drought hit their study site in the third year following implementation of their treatments, treated forests were able to sustain their carbon sequestration rates under significantly hotter and dryer conditions than the untreated stands, despite the fact that the treated site had fewer trees and leaf area. These findings have important implications for the benefits of forest treatments on the resiliency of forest carbon sinks in times of drought.

As climate change continues to exacerbate the potential for drought, wildfire, insects, and disease, California's overstocked forests remain at severe risk of loss in the absence of management activities that thin them to reduce competition or that introduce a mix of tree species that are adapted to the local environment to create forests more resilient to disturbances and less susceptible to forest pests. Forest treatments (e.g., understory thinning, surface fuel treatments, prescribed fire) can reduce stand densities and fuel loads, restoring the structure and composition of fire-excluded forest ecosystems and lowering the potential for damaging, high-severity fire (Stephens et al., 2009; Campbell et al., 2009; Hurteau and North, 2008; Hurteau and North, 2009; North et al., 2009). Although treatments result in short-term forest carbon losses through biomass removal, studies have shown that under certain circumstances, carbon can quickly be recovered to pre-treatment levels if large, fire-tolerant overstory trees are not removed in large quantities (Weichmann et al., 2015; Stephens et al., 2009; Hurteau and North, 2010). Treatments may also enhance the carbon sequestration ability of trees. Results from the Sierra Nevada Adaptive Management Project showed that leaves on trees in forests that have been thinned fixed more carbon per capita than leaves in untreated forests (Bales et al., 2015). These treatments can also lead to longer-term stability of the carbon sink and increased quality in terms of decreased risk of loss to catastrophic wildfire, increasing carbon sequestration rates over time rather than decreasing, and increased carbon stored in live biomass compared to dead.

Species Range Shift

As temperature and precipitation patterns change, the climatic conditions suitable for different types of tree species in any given region also will change, and climate change can lead to geographic shifts in tree distribution and forest types. In general, geographic shifts will tend to be northward and toward higher elevations as average temperatures rise. High-elevation tree species adapted narrowly to historical temperature ranges at those elevations will be particularly vulnerable to range contraction and extinction. Forest management and restoration practices undertaken today ideally should be informed by the expected future changes, and should be robust over a wide range of plausible future climate change outcomes.

Urban Forests

Urban forests are those comprised of native or introduced trees and other vegetation in the urban and near-urban areas, including, urban watersheds, soils, natural riparian habitats, and trees on private and public properties. The urban areas of California are home to nearly 95 percent of the state population.

The urban tree canopy is estimated to occupy 3,204 km², an average of 15% of the all urban area, and there is approximately 90 m² of tree canopy per person, although the urban canopy is not evenly distributed (Bjorkman et al., 2015).

Urban forests make up only a small percentage of the total forested area of California. However, the proximity to trees and their ecological benefits are important for human health. Some of the known benefits of urban forests include:

- Carbon storage and sequestration;
- Avoided emissions through reduced local energy use from canopy shading and cooling;
- Air pollution removal through dry deposition;
- Rainfall interception, reduction in flood risk and in water pollution;
- Increased property value through curb appeal and neighborhood charm;
- Improved human health through reducing air pollution, minimizing heat effects and reducing exposure to UV rays, and providing shady places for active transportation and recreation to occur;
- Improved quality of life through aesthetic value, noise reduction and reduction in stress.

Similar to wildland forests, urban forests also are showing climate impacts. For example, drought and water conservation efforts have been impacting urban trees as residents decrease watering. Urban tree selection needs to reflect not only appropriate species, but also changing climactic conditions, including rising temperatures and drought.

While urban areas represent only about 5% of the land area of California, almost 95% of the state's population resides in urban areas, which proportionally increases the benefits of urban trees and tree canopy to human populations. In addition, urban areas have on average approximately 35% of their land area in impervious surfaces (Bjorkman et al, 2015). Impervious surfaces combined with excessive heat can cause "heat island" effects, which can compound the effects of air pollution. Urban heat islands can affect human health by contributing to respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke and heat-related mortality. The effects of urban heat islands can be lessened with tree planting to increase shade, reduce energy use, and moderate air pollution. Areas with the greatest heat island effects and air pollution were identified as priority landscapes for tree planting (Bjorkman et al, 2015). In addition, the study identified areas with the highest amount of energy consumption and extreme heat for priority tree mitigation to help cool buildings through shade.

Another key finding from the Bjorkman et al, (2015) study is the large proportion (61%) of urban areas in California considered to have low tree canopy cover. In addition, 40% of urban areas ranked high for the percent of days over 90°F, and 15% of urban areas ranked high for impervious surfaces. Together, these effects mean much of the urban areas in California are subject to high urban heat threat (40%). The study found that while there is a considerable extent of canopy in California's urban areas, it tends to be concentrated in certain areas. This analysis provides the opportunity to identify urban areas that could benefit from tree planting, as well as from protecting or better managing tree canopy that already exists.

A Vision for California's Forests

We began this concept paper with the broad FCAT vision of healthy forests that protect and enhance forest carbon and the broader range of forest environmental services for all forests in California. FCAT has developed the following description of the attributes of healthy California forests:

- **Resilient**—Forests are able to regenerate after disturbance and adapt to changes in climate and precipitation regimes. Forest resiliency is characterized by:
 - **Dynamic growth and complexity** – Forest tree species diversity, basal area, and age class distribution maintain approximately equivalent forest ecosystem processes and productivity even under changing climate conditions.
 - **Diverse structure** – Forest stand structure is variable and may include open areas that reduce susceptibility to wildfire and environmental stressors (e.g., drought, over-crowding, air pollutants, insects, and disease).
 - **Healthy soils** – The fertility, structure, and productive capacity of the soil to support forest vegetation and soil carbon are maintained long-term.
 - **Endemic levels of insect and disease** – Levels exist that are associated with natural mortality.
 - **Carbon storage** – Functioning as a net carbon sink over time.
 - **Water** – High water quality and sustainable water supply exists.
- **Biodiverse** – All forests are able to sustain a wide range of habitat for wildlife and fish species.
- **Economically and Ecologically Sustainable** –Healthy forests are able to support ecosystem functions and processes while meeting current and future needs of people for aesthetics, recreation, health, products, and other ecosystem services.

Like the Vision Statement provided at the beginning of this document, the above description of healthy forest attributes is also an important part of the overall framing of the Forest Climate Plan. Thus, we encourage your comments on it.

While the main focus of FCAT is on adapting management of California's forests to contribute to sequestering carbon and reducing emissions of GHGs and black carbon, FCAT also recognizes the importance of the environmental, social, and economic co-benefits that flow from enhanced, holistic management. While co-benefits are addressed briefly in this concept paper, the Forest Carbon Plan and resource economics study conducted through the University of California Berkeley will comprehensively address them. See section III(e) of the [Forest Carbon Plan outline](#).

Strategies to achieve goals for forest carbon and health must be flexible and nimble enough to address the varying biophysical conditions or landowner goals and capacities for forest management throughout California. Goals and strategies must recognize bioregional and landowner class differences.

The majority of California's wildland forests, private and public, are "working forests" that provide some flow of woody materials for utilization over time. Working forests do not stand alone, but are connected to a harvesting, transportation, and processing infrastructure that produces lumber, veneer, other laminated wood products, biomass energy, wood shavings and chips, and other products. Pulp is not in the product mix as California currently does not have pulp or paper mills. For many private landowners, revenue-generating opportunities may be the deciding factor in continuing to hold their

forest as an unfragmented working forest as opposed to selling their forest property, resulting in land fragmentation, subdivision, development, or other conversion to a non-forest use.

California also has large areas of “reserved” forests that are not working forests, but are set aside for the protection and fostering of natural conditions and ecological processes. These areas are found in parks and National Forest wilderness areas, for example. Management goals and treatments, such as fuels reduction, on reserved forest areas will need to consider the specific purposes for which the lands are managed, as well as legal restrictions.

To provide optimal carbon, ecological, social, and economic benefits, urban forests must be healthy and widespread. Achieving such resilient urban forests can aid in job creation, support watershed health, reduce urban energy demand, and influence occurrence of urban heat islands.

The work to improve California’s forests is underway even as uncertainties exist for the future climate. The direction, pace, magnitude and variability of climate change in the near or long term future is uncertain. This uncertainty further highlights the need to foster forest resilience as a climate adaptation mechanism, and to embed flexibility in our goals and strategies.

The Carbon Storage Potential of California’s Forest Landscapes and Urban Forests

This section provides a general introduction to varieties of sources and methods available for estimating carbon contained in natural forests, urban forests, in wood products, and the land-atmosphere exchange of carbon. Measurement methods vary in their input data demands, robustness, and application scope. Some methods are designed for forest carbon accounting at fine scales or for sampled large areas, while other methods may be appropriate for purposes of monitoring for progress or for policy making. The approach for the Forest Carbon Plan has been to rely primarily on information from the Forest Service’s Forest Inventory and Analysis (FIA) Program. However, we seek comment on how best to use various approaches, and what combinations afford opportunities for gaining comprehensive understanding of overall land conditions, trends and progress. The introduction to methods is followed by estimates of carbon in California forests and wood products recently reported by the Forest Service FIA program, results from a statewide assessment of urban forests, other recent work, and emerging initiatives.

Introduction to Methods

Two general approaches are used to estimate the exchange of CO₂ and other gases between forests and the atmosphere. One approach is to estimate the net change in the amount of carbon contained in forests (carbon stocks) over time. This “stock-change” approach involves 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 overall estimates of carbon. Carbon is estimated for defined “pools” for example above- and below-ground live, understory, herbaceous/grass, shrub, standing dead, dead downed, litter/debris, duff, and soil carbon. In turn, statistical procedures are used to aggregate data from many plots, in order to generate estimates that are representative for a large area at a point in time. An example of this approach is the FIA program. Emerging applications augment plot-based approaches with spatially explicit data from

technologies such as Light Detection and Ranging (LiDAR) or Synthetic Aperture Radar (SAR). These technologies (typically mounted on aircraft or other platforms such as satellites) yield a snapshot of “wall to wall” information on the 3-D structure of forests. Other satellite-based instruments provide information using 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 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. They 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 5-year research project, or for large areas or regions and for long periods.

Both 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 may transpire before plots are re-measured. Depending on the density of plot deployment, disturbance events (such as fire) may or may not be detected in plot data in a timely manner. However, ground-based approaches provide statistically robust crucial information unavailable by other means. Airborne technologies such as LiDAR 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. The utility of these approaches likely depends on the scope and purpose of a given forest carbon monitoring effort.

Listed below are examples of programs and projects measuring forest attributes and processes.

- Forest Inventory and Analysis (FIA) Program <http://www.fia.fs.fed.us/>
- LandTrendr combines time series satellite data with plot data from the FIA 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 FIA 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/>
- LandfireC is the name of an approach developed at the 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 FIA and other sources. <http://www.landfire.gov/> ; <http://ucanr.edu/sites/forestry/files/212528.pdf>

- CarbonTracker is a CO₂ measurement system developed by the National Ocean and Atmospheric Administration (NOAA) 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 (CMS) 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 CO₂, water vapor, and energy exchange in forests and other lands. <http://ameriflux.lbl.gov/>
- Carnegie Airborne Observatory (CAO) is a research and applications program integrating satellite and aircraft-based remote sensing technologies (including LiDAR and multispectral imaging) with ground-based data to map forest carbon, monitor change and forest health. CAO gathered high spatial resolution LiDAR and multispectral data for California in the summer of 2015 to map 3-D forest structure, biomass, carbon, and to assess tree drought stress. <https://cao.carnegiescience.edu/> ; <https://cao.carnegiescience.edu/california-forests-in-drought>
- PlanetarySkin is a collaboration between NASA and Cisco to provide technical support for national and sub-national entities engaged in forestry and other natural resource management. <http://www.planetaryskin.org/>

Carbon Storage

The following information on carbon storage is based primarily on FIA data for California, which is collected under the [Resource Monitoring and Assessment Program](#) of U.S. Forest Service Pacific Northwest Research Station. The section provides summaries of FIA estimates for carbon stocks in above- and below-ground carbon pools. Estimates for above-ground forest carbon include live tree, understory vegetation, and standing dead trees. Below-ground carbon pools include roots, underground dead trees, 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 FIA (Table 2). Note that these estimates do not include down woody material. Trees store carbon as they grow 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 disturbances release carbon over different time horizons, the patterns of which can affect how and when the carbon moves between the various forest carbon pools. The Forest Service manages lands with the largest above-ground storage; the private lands (corporate and non-corporate) are the next highest.

The total amount of above-ground carbon stored is estimated at 4,283 million metric tons CO₂eq across all forest lands (Table 2). Above-ground carbon is stored predominately in live tree carbon pools, which represent 86% of the above ground carbon. Understory vegetation (4%) and dead standing vegetation (10%) make up the remaining fraction. Below-ground carbon is estimated at 3,148 million metric tons CO₂eq across all forest lands (Table 2). Soil organic carbon is the largest storage component (74%) of the belowground carbon pool; followed by belowground live (24%) and belowground dead plant material

(2%). Across ownership groups, approximately 60% of carbon storage is found on public lands, 35% on private forest land and the remaining 5% is State and Local forest land.

Table 2. Above- and Below-Ground Forest Carbon, 2014 (excludes down woody material and harvested wood products).

Units in 1,000 metric tons of CO₂eq. Source: Christensen et al. (2016).

Forest Owner	Above-Ground Carbon ¹	Below-Ground Carbon ²	Total
USDA Forest Service	2,292,436	1,584,415	3,876,851
Other Federal Ownerships ³	376,927	286,789	663,716
Local	45,753	32,977	78,730
State	161,260	80,832	242,092
Other Public	1,566	1,804	3,370
Private Corporate Forestland	618,036	510,102	1,128,138
Noncorporate Private	787,657	650,621	1,438,278
All owners - Total	4,283,635	3,147,540	7,431,176

¹Includes above-ground live tree, dead tree, and understory vegetation; excludes down woody material and harvested wood products.

²Includes roots, underground dead trees, and soil organic carbon.

³Includes National Parks, Bureau of Land Management and other federal agencies

Carbon Storage – Wood Products and Other Uses

Forest management activities can have net positive benefits on forest and other sector GHG emissions when they result in long-lived wood products, substitute for more energy intensive products, and off-set the use of fossil fuels for energy. Quantification of the movement of raw materials through these wood products pools is an important component of a forest carbon inventory. This section summarizes carbon contained in wood products and other utilization resulting from timber harvest.

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 (8.7 million metric tons CO₂eq) was processed into finished lumber and other products in 2012. Carbon sequestration varies with the lifespan of the product and end-uses. The analysis in their study of wood products details the many pathways that forest products are utilized and that shows less than 1% of the harvested material goes unused (Table 3).

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 the period examined, which ended in 2012 (McIver et al., 2015). Stewart and Sharma (2015) estimated that when carbon storage in wood products is included in forest carbon accounting, managed forests show substantial carbon sequestration benefits over unmanaged stands. In a related study, Stewart and Nakamura (2012) estimated that using revised

coefficients on mill and consumer wood utilization efficiencies substantially increases the estimates of climate benefits from harvested wood products.

Table 3. Harvested 2012 Carbon from California Forests by End-Use (metric tons CO₂eq).

Percent of Harvest*	Metric Tons CO ₂ eq	Product Category
26%	2,291,230	Finished lumber
10%	867,007	Landscaping products
4%	349,296	Veneer and other products
4%	361,772	Pulp and fiberboard products
54%	4,763,341	Residues combusted for energy
1%	108,118	Other
Total	8,740,764	

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

Percentages may not sum to 100 due to rounding. These product categories vary greatly in length of time that they sequester carbon.

Source: McIver et al., 2015.

Historically, timber harvesting in California has been on the decline since the mid-1980s. McIver et al. (2015) estimated that timber harvesting in California was 1,425 million board feet (MMBF) in 2012. This harvest level represents a decline of 18% from 2006 (1,733 MMBF) and a 37% decline from 2000 (2,250 MMBF). During 2012, 84% of harvesting by volume occurred on private timberlands, 14% on National Forest lands and 2% associated with other public lands. Nearly all of the wood from timber harvested was processed in California (i.e., 97%).

Carbon Sequestration Rates

The carbon contained in a forest represents the accumulated carbon dioxide uptake and carbon sequestration that has occurred over time. The difference in the amount of biomass contained in a forest at two different times represents the overall change in “in-forest” carbon stocks resulting from growth, mortality, harvest or other disturbances over time. Using data from FIA reports, changes in biomass were evaluated over two time periods, 1991-1994 and 2007-2010 (Christensen et al., 2016). These tables do not include sequestration rates from storage in wood products and other end uses. Changes in plot design, inventory methods, and plots revisited all can influence the estimate of carbon sequestration in the forest.

The net increase in carbon sequestration for private, state and local lands was estimated at 6.3 million metric tons CO₂e/year (Table 4; Christensen et al., 2016). The net increase in carbon dioxide sequestration for the two time periods was 3.3 million metric tons CO₂e/year for National Forests (Table 5). For this time period (1991-1994 and 2007-2010) growth exceeded mortality and removal for all ownership groupings except for reserve lands on National Forests. On these reserve lands mortality outpaced growth, and that pattern is consistent with more recent FIA data inventories. Combined, carbon sequestration was estimated at 9.6 million metric tons CO₂e/year across all forest lands, (excluding wood products).

Table 4. Growth, Mortality, and Removals on Nonfederal Forest Lands.
(Million Metric Tons CO₂eq/yr)

Land Ownership	Growth	Mortality	Harvest - Removal	Net Change
State and Local Government	0.2	0.0	-	0.2
Corporate	13.3	2.6	9.5	1.2
Non-corporate	10.0	2.7	2.5	4.8
Total	23.5	5.3	12.0	6.3

Source: FIA data tables (1991–1994 and 2007–2010)

Note: In FIA terminology, “non-corporate” includes nongovernmental organizations; unincorporated partnerships, associations, clubs; Native American, and individuals. The term “nonindustrial” also is often used for this category. Similarly, “corporate” and “industrial” are often used synonymously.

Table 5. Growth, Mortality, and Removals on Federal Forest Lands. (Million Metric Tons CO₂eq/yr)

Forest Land Class	Growth	Mortality	Harvest-Removal	Net Change
National Forest Lands				
Timberland	22.4	16.0	1.1	5.3
Reserve Forestland	5.4	8.1	0.0	(2.7)
Low Productivity Forestland	2.0	1.6	0.0	0.4
Other Federal Forests	0.4	0.1	0.0	0.3
Total	30.26	25.80	1.20	3.3

Source: FIA data tables (2001-2006 and 2007-2010)

Growth and Harvest by Ownership

According to the 2014 FIA analysis, the current level of harvest (“removals”) and mortality is generally less than growth on both private and public forestland. National Forests have substantial live tree inventories, but exhibit higher mortality rates. Private forests have lower live-tree inventories, but this is offset by storage in wood products, bio-energy, and lower mortality rates. The changes in growth, mortality, and removals among ownership groups reflect different approaches to forest management. This results in a carbon signature that is unique for each ownership group.

Forest Service – Reserve (wilderness). This ownership category is representative of unmanaged forests. Table 5 shows that while there is moderate growth, mortality is outpacing growth. There are no removals from harvest, but mortality from wildfire, pests, disease and other disturbance agents is high. Thus, these lands are net sources of carbon emissions.

Forest Service – Timberland. These forests tend to be more productive forests with higher per-acre levels of growth than reserve lands. They have a small amount of removals from harvest, which has greatly declined from previous decades, and have slightly lower levels of mortality per acre per year than “Forest Service – Reserved” lands. Growth currently exceeds mortality, but only by 9 percent because these lands show high rates of mortality.

Corporate Timberland. On private corporate timberlands (Table 4) growth is slightly exceeding removals and mortality. This illustrates a near perfect example of “sustained yield” as required by California’s Forest Practices Act. Forests are managed to create relatively little annual mortality and the harvested volume is slightly less than forest growth. There is less carbon stored in live tree inventories, but mortality is much lower. In addition to live tree inventories, climate benefits are achieved through long-lived building products and the utilization of non-lumber wood for renewable energy.

Noncorporate Timberland. This category illustrates a different forest management strategy. These forest lands show increasing inventories and harvest less per acre than corporate timberlands. Mortality rates are slightly higher than corporate, but much lower than federal lands. In addition, there are moderate levels of removal from harvesting and storage in wood products.

State and Local – Forestland. This category of ownership manages a much smaller fraction of the land base. However, it is characterized by higher levels of growth that greatly exceed mortality, and low levels of removal.

Summary of Forest Carbon Inventory Findings 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 2. Using a combination of FIA 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 or 3.083 metric tons CO₂eq (± 210 MMTC/771MMTCO₂eq) in the above-ground live pool. Other remote-sensing based assessments report above-ground live forest carbon stocks ranging from 970 MMTC/3,560 MMTCO₂eq (Kellndorfer et al., 2012) to 870 MMT/3,193 MMTCO₂eq (Wilson et al., 2013).

Urban Forests

Bjorkman et al. (2015) found that the estimated amount of CO₂ stored in urban forests in California totaled 103 million metric tons CO₂eq. Annually, the amount of CO₂ sequestered from urban forests is estimated at 7.2 million metric tons/year. The amount of CO₂ avoided was estimated to be 1.3 million metric tons/year. There are few studies in California estimating carbon sequestration rates in urban areas; particularly on a statewide basis. A U.S. Forest Service report, estimated that urban trees in California sequestered 4.3 million metric tons CO₂eq/year (Nowak and Greenfield, 2010). As such, the two studies provide a range of 4-7 million metric tons CO₂eq. Future studies are needed to refine estimates in urban areas.

Discussion

Forest carbon is stored in both forest ecosystems (native forests and urban trees) and in harvested wood products. The degree to which California forests operate as a sink and source of carbon is influenced by both land management and by a range of forest health issues (i.e., tree mortality from drought, pest and disease outbreaks, wildfire, and other agents of disturbance). For all forest lands, improving forest health and managing to reduce losses from mortality can greatly influence the carbon

balance on forest lands. On commercial and other actively managed lands the use of long-lasting wood products and utilization of residuals for energy can also enhance carbon storage.

National Forest Carbon Accounting Framework (FCAF)

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 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 (Woodall et al., 2015). 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 FCAF is designed to meet national scale monitoring needs, it is hoped through research partnerships with stakeholders, such as states, that valid downscaling techniques can be developed to disaggregate national results to smaller scales. For example, in order to use FCAF 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 data. To help downscale FCAF, strategic partners have the opportunity to increase the base intensity of FIA plots (1 plot/2,248 ha) through direct or in-kind contributions.

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

Last, efforts are underway to more directly incorporate harvested wood products through the Woodcarb II model within FCAF 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 sequestration and GHG emission accounting, 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 the statewide inventory, to county-scale or regional accounting used in some Climate Action Plans. These methods have been and will continue to be informed by field-based measurement, FIA and otherwise, as well as satellite imagery and spatial analysis. Advancements in the availability and quality of satellite imagery and other remote sensing products are rapid and may offer new methods for cost-effective statewide carbon stock analysis. As outlined in the inventory discussion above, California's accounting will need to include the lifecycle of wood products, which may necessitate new tracking and monitoring systems for wood intended for durable, long-term use and carbon storage.

While forest health will be pursued at the landscape scale, the Forest Carbon Plan will effectively be implemented at these scales across property boundaries and using different policy and incentive tools, so we need a method of tracking performance that can accommodate all of these. Moreover, as federal

climate policy develops, California's methods will need to be aligned with U.S. standards, and can serve to inform them. For example, California's forest practice rules and inclusion of sustainable harvest requirements in bioenergy production through Senate Bill 1122 can inform rules for the federal Clean Power Plan's bioenergy GHG accounting. In addition, carbon accounting methods should seek to incorporate impact or performance metrics for climate co-benefits cited as indicators of forest health, including water quality and wildlife habitat, for example. 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 sequestration and GHG emissions quantification, and integration of new data and methods as needed to fill gaps. This work will be accelerating in 2016 and 2017 to facilitate goal-setting and implementation for the Forest Carbon Plan and the 2016 Scoping Plan Update, 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 NGOs, the forest products industry, and academia in developing these quantification methods.

The quantification of forest carbon is still an evolving field. Public input on the best data and quantification methods to use, from the project to the landscape level, will be helpful to our work.

Goals and Management Strategies

The primary climate change objective for California forests is to preserve and enhance resilient carbon storage in all forests statewide, public and private, wildland and urban, while ensuring that these forests continue to provide other valuable goods and services, including ecosystem services. Carbon, ecological, social, and economic functions will be jointly addressed. Disadvantaged communities, urban and rural, should be given special consideration.

This concept paper includes initial analyses developed to quantify and understand forest carbon conditions. The Forest Carbon Plan will include more detailed analyses of forest carbon conditions today and those expected in the future. These analyses will inform the Forest Carbon Plan's finer-grained (e.g., bioregions, ownership classes) goal setting and implementation strategies. Once completed, the Forest Carbon Plan will be reviewed and adjusted periodically in an adaptive management fashion.

The strategies for achieving forest carbon sequestration and GHG emission reduction goals are organized around the concepts of (a) land protection, (b) enhancement of resilient carbon storage through active management and restoration, and (c) cross-sector innovation to promote GHG emission reductions in other sectors that support forest health. These categories of goals and strategies apply to both urban forests and wildland forests, but these are discussed separately to allow for clearer discussion of the conditions (ecological, jurisdictional, ownership, etc.) and goals unique to both areas. A similar conceptual framework is to be used for the Natural and Working Lands sector in the 2016 Scoping Plan Update.

The below discussion represents our first cut at laying out detailed proposed goals and management strategies for consideration for the 2016 Scoping Plan Update and the Forest Carbon plan. Hence, we strongly encourage stakeholders to consider them and provide FCAT with comments on them. The

FCAT will work internally and with external stakeholders throughout 2016 to improve these goals and strategies and to develop refined quantitative and/or qualitative regional scale and ownership class targets for each of the goals and strategies included below. The FCAT is seeking input from stakeholders to define the regional delineation and/or regional considerations that should be incorporated into applicable protection, enhancement, and innovation strategies. Likewise, input from stakeholders is needed to guide how goals, strategies, and their implementation are adjusted across ownership classes.

Wildland Forests

PROTECT

Goal: Increase protections on forested lands to reduce the rate of fragmentation and conversion to non-forest uses, to preserve forestland sequestration potential, and to promote infill and compact development.

Maximizing potential benefits from this objective will require coordinated efforts among conservation organizations and land use planners at the local, regional and state levels; participation from private and public land owners and managers; shared data on the market and non-market values of natural and working lands (including carbon sequestration and GHG emission benefits); and engagement with foundations and federal agencies.

Strategies:

1. Provide state funding for working forest and other conservation easements, delivering the funding through the California Forest Legacy Program (including both State and Federal components), Wildlife Conservation Board, and other forest conservation granting programs, and working in collaboration with land trusts and other related nongovernmental organizations.
2. Identify and pursue land use and tax incentives that would serve to support the economic viability of forest ownership while promoting utilization of best management practices to accumulate and effectively manage resilient carbon storage, while providing other important forest co-benefits.
3. Share best practices with private funders and federal agencies to ensure coordinated conservation strategies statewide.

ENHANCE

Goals: Increase all forest carbon storage pools and minimize GHG and black carbon emissions in a sustainable manner so that the carbon bank in living trees is resilient and grows over time, as ecological limits allow. These management and restoration objectives and strategies must be applied flexibly across National Parks, National Forests, other federal forests, State Forests, State Parks, County Parks, industrial timberlands, family forests, etc. The methods and intensity applied will have to be tailored to any given forest stand and related to conditions and management activities around it to maximize beneficial watershed or landscape-scale impacts.

California's high-level forest carbon goal is to progressively scale up to get an additional 500,000 acres/year of nonfederal forestlands and smaller federal forest lands under plans and appropriately managed to improve forest health, with performance assessment for carbon sequestration and

GHG/black carbon emissions to meet the State's 2030 and 2050 climate targets, watershed enhancement targets as laid out in the California Water Action Plan, and alignment with the State Wildlife Action Plan. This acreage target will include capture the carbon outcomes of commercial timber harvesting. This approach will align requirements of Assembly Bill 1504 (Skinner, 2010) with other, non-regulatory policies and incentive mechanisms undertaken to enhance forest carbon sequestration and carbon pollutant emission reductions. Analysis done as part of the Forest Carbon Plan work will help to identify priority areas for establishing plans and implementing projects.

The above commitment is a challenge match to the U.S. Forest Service, which is committed to restoring 500,000 acres/year of National Forest lands in California. Activities on both federal and nonfederal forest lands will be coordinated at the landscape or watershed level for maximum leverage. This shared commitment means that state, federal, and private-sector partners endeavor to work through the backlog of forestland that is below its ecological potential, in terms of carbon sequestration, water quality protection, and wildlife habitat, by 2030, including the areas of the state currently suffering from extraordinary levels of tree mortality. Given that uncharacteristically large and severe wildfires have driven GHG and black carbon emissions from California forests in recent years, and that the incidence and extent of wildfires is expected to increase as climate change advances (Westerling et al., 2011), particular focus should be given to strategies that reduce the incidence and extent of uncharacteristically large and severe wildfires through proactive forest management to improve stand health.

Strategies: Planning and implementation will be designed for effectiveness at the watershed or other regionally relevant large landscape scale. This approach will integrate forest management and restoration activities taking place through a number of existing statewide and regional programs and new or modified ones currently under development or recently proposed, such as the CAL FIRE GGRF-funded [Forest Health Program](#) and the Department of Fish and Wildlife GGRF-funded [Greenhouse Gas Emissions Reduction through Restoration Program](#), both currently proposed in the Governor's fiscal year 2016-17 budget. If these proposed programs are funded by the Legislature, coordination between them would help to ensure the programs are aligned and generating watershed benefits.

Forest treatments can reduce stand densities and fuel loads, restoring the structure and composition of fire-excluded forest ecosystems to better match functioning, fire-adapted ecosystem conditions. Although these treatments may result in short-term forest carbon losses through biomass removal, carbon can quickly be recovered through retention of larger trees that have the capacity to rapidly add volume. These treatments also can lead to longer-term stability of the carbon sink and increased quality in terms of:

- Decreased risk of loss to catastrophic wildfire;
- Increased carbon sequestration rates over time rather than decreasing; and
- Increased carbon stored in live biomass compared to dead.

Existing plans, their update processes, and their execution should be used as a mechanism for implementation of California's forest health and carbon management objectives, and supplemented as necessary to fill gaps, utilize shared science and management resources, and implement strategies. Successful execution of this Forest Carbon Plan will manifest as full implementation of these existing plans, modified through a collaborative process of adaptive management. Existing plans include but are not limited to the California Strategic Fire Plan, the Sierra Nevada Watershed Improvement Program,

State Wildlife Action Plan and its companion plan for forests and rangelands, the California Water Plan, the California Water Action Plan, the Region 5 Forest Service Ecological Restoration Plan, and National Forest, National Park Service, and Bureau of Land Management resource plans, and the new Community and Watershed Resilience Program. Many large private forestland managers have ownership-wide or watershed-wide management plans, habitat conservation plans, Nonindustrial Timber Management Plans, Program Timberland Environmental Impact Reports, sustained yield plans, or water quality permits that can serve as implementation mechanisms. At a smaller scale, forest stewardship plans prepared under the California Forest Improvement Program (CAL FIRE), Environmental Quality Incentives Program (Natural Resources Conservation Service), or American Tree Farm Program, along with associated cost-share incentives programs, can provide a mechanism for forest carbon planning and project implementation.

Management activities for forest enhancement include the full suite of silvicultural tools, including selective mechanical thinning, prescribed fire, and reforestation, utilized according to landscape conditions, landowner goals and capacities, and considering cost effectiveness. Specific management parameters and actions will include the following, where feasible and appropriate:

1. Align and or integrate cross-jurisdictional management goals to optimize carbon storage and stewardship efforts, including wildfire protection strategies and actions (e.g., location and management of fuel breaks).
2. Increase the pace and scale of the use prescribed fire for fuels reduction and restoration of ecological processes.⁴
3. Increase utilization of unintentional forest fire ignitions to allow ecologically desirable fire to occur.
4. Increase the pace and scale of mechanical and manual fuel reduction treatments.
5. Reforest and restore denuded areas or those with below-optimal stocking rates using species mixes and genotypes that are appropriate for future climate conditions.
6. Maintain resilient genetic forest stock through support, maintenance and expansion of seed banks; revitalization of state nurseries where private sector activities are insufficient; and research that will help to refine strategies for selecting genotypes or species and aid in development of decision support tools for selection.
7. Reduce the spread of forests pests and diseases through sanitation treatments, and through education and regulation (where needed) regarding the movement of infected materials.
8. Engage with local communities and public and private landowners to disseminate best practices to improve carbon sequestration rates and reduce the risk, extent and intensity of wildfire.

Sustaining this level of active management will require collaborative engagement of public and private sectors, and the development of sustainable financing mechanisms. These implementation and investment mechanisms are discussed in a section below.

INNOVATE

Goal: Optimize net GHG storage and carbon pollutant emission reduction contributions from forested lands while sustaining lands and rural economies. Consider as many ways as possible to derive products and resources from the forest that enhance long-term carbon stores, reduce emissions, provide financial

⁴ See, e.g., the recently signed *Memorandum of Understanding for the Purpose of Increasing the Use of Fire to Meet Ecological and Other Management Objectives* at the website:

<http://www.sierraforestlegacy.org/Resources/Community/PrescribedFire/FireMOUSigned.pdf>

mechanisms to support ongoing carbon- and ecosystem-sustaining management in forests, or some combination thereof.

Strategies:

1. Promote research and development of appropriate bioenergy, biofuels, product manufacturing and waste management technologies that serve to support sustainable resource management. Particular emphasis will be given to support existing and new facilities or infrastructure that provide utilization pathways for excess woody biomass removed from forest health treatments on private and public lands.
2. Support and grow wood products campuses, particularly those scaled to serve rural communities through environmental improvement and jobs creation and product development and scaling.
3. Match and support woody biomass disposal needs with utilization needs in the energy, fuels, agricultural, and residential landscaping markets, in partnership with the California Energy Commission, CalRecycle, the California Department of Food and Agriculture, the USDA Natural Resources Conservation Service, and other logistical and funding partners.
4. Reduce or subsidize the cost of removing low-value waste materials from the forest for use in wood products, bioenergy production, biofuels, or other uses.
5. Support the utilization of long-lasting, carbon-storing wood products (such as dimensional lumber, panel products, and cross-laminated timber) in the place of carbon-intensive building products like cement and steel.
6. Support reliable supply and markets for timber and other woody materials

Urban Forests

Urban forests provide carbon sequestration, water infiltration improvements, and increase energy efficiency—for buildings and transportation—of the built environment. For these reasons, there is a need to develop goals and strategies particularly for urban forests, apart from the wildland and wildland-urban interface forestland in California.

For disadvantaged urban communities with low levels of tree canopy and high levels of impervious surfaces, increasing the urban tree canopy and surface porosity can provide outsized benefits to disadvantaged communities. For many of these communities, accessing green spaces is difficult.

During the fiscal year 2014-15 GGRF grant cycle, the CAL FIRE Urban and Community Forestry Program grant funds provided substantial benefits to disadvantaged communities through directly investing the majority of its grant funds in disadvantaged communities. The remainder of its grants was invested in projects that provide benefits to disadvantaged communities.⁵

New urban forestry projects should consider changing social demographics at a more local level. As California's urbanizing regions pursue more compact, transit-oriented development to achieve climate goals with necessary investments such as transit improvements and parks, there is increasing concern that these new investments may lead to the displacement of disadvantaged community members. New urban forestry projects can create jobs for disadvantaged Californians through the adoption of local and targeted hiring policies.

⁵ Protecting and benefitting disadvantaged communities as a part of GGRF investment is specifically required by SB 535 (de León, Chapter 830, Statutes of 2012).

PROTECT

Goals: Protect greenspace and tree canopy in cities and towns throughout the state, particularly in areas that contribute significantly to or are heavily impacted by the urban heat island effect. Where opportunities exist, increase acreage of urban trees and greenspace.

Strategies:

1. Promote urban development and redevelopment that provide significant space for trees and other green infrastructure, including parks and greenways. These efforts should adopt effective anti-displacement policies and create adequate growing spaces for trees.
2. Significantly increase the percentage of people, particularly in disadvantaged communities, who live within ¼ to ½ mile of open spaces, community gardens, parks, green alleyways and other urban forestry and green infrastructure projects. Prioritize projects in areas accessible by transit to increase benefits to all city dwellers.
3. Identify, purchase, and improve 30 private properties within disadvantaged communities to provide public access to greenspace by 2030. By funding property acquisition by local stakeholders or requiring local community engagement in design of privately owned but publicly accessible greenspace, green infrastructure projects are community-led and the wide range of long-lasting benefits directly reach disadvantaged communities.
4. Protect Californians in urban areas from the urban heat island effect by encouraging adoption and implementation of quantitative goals at the local level to reduce this effect.
5. Work to coordinate with local planning agencies to integrate urban forests into long-range urban zoning plans.
6. Promote urban trees in areas at risk of development between urban and wildland or urban and agricultural interface areas.

ENHANCE

Goals: Increase statewide tree canopy in cities and towns by 5% by 2030 with strategic consideration to disadvantaged communities. By commencing early, projects can result in a projected 20% increase in urban tree canopy by 2050. Capture urban water runoff for groundwater infiltration and use in maintaining green infrastructure. Incentivize urban tree canopy maintenance and preservation programs to help projects achieve long-range climate, health and economic benefits.

Strategies: These tree canopy growth goals, particularly the 2050 goal, will require a significant increase in the pace and scale of tree planting. Many cities, particularly those outside of the major urban centers of the state, lack technical and financial resources for the inventory, planning, planting, and maintenance of urban forests. These strategies are aimed at supplementing local resources with state planning and investments.

1. Support federal, state, and local urban forestry and urban greening programs and nongovernmental organizations through the [CAL FIRE Urban and Community Forestry Strategic Forest Plan](#).
2. Support utilization of urban wood waste for uses including wood products, mulch, compost, biofuels, and bioenergy.

INNOVATE

Goals: Support innovative urban forestry and greening projects that reduce GHG emissions, increase carbon sequestration, and provide other environmental, health, social, and economic co-benefits.

Strategies:

1. Support local governments and nongovernmental organizations to inventory urban trees, develop urban forest management plans, and implement the management plans.
2. Update urban forestry project research with recommended anti-displacement strategies upon completion of the California Air Resources Board's anti-displacement study, including development of a new methodology for analyzing potential displacement, as necessary.⁶
3. Support the design and implementation of innovative, multi-function urban greening projects that provide a wide range of carbon, climate, environmental, social, and economics benefits.

We again reiterate that the goals and management strategies are critical elements for the 2016 Climate Scoping Plan Update and the Forest Carbon Plan itself. Thus, stakeholder comment on the goals and strategies proposed above is very important and is very much encouraged.

Analytical Approach

This section describes the proposed analysis methods that will be used to support decision-making under the Forest Carbon Plan. The methods will be finalized after incorporating public review and input.

Priority Areas

The objective of this part of the analysis is to lay the groundwork for subsequent analyses by identifying areas of high priority, characterized by unique resource values, high hazard areas, and other criteria such as high population levels. The amount of priority area by ownership group will be identified for each benefit and co-benefit. This represents an estimate of the amount of highly valued forest resources that have a high threat risk of loss from one or more types of disturbance. Examples of priority areas could include impacted forest lands, water resources, and wildlife habitat.

Management Actions

Possible management actions to achieve the goals and objectives of the Forest Carbon Plan will be developed as follows:

- Develop a matrix of management actions that can be applied to each co-benefit category;
- Estimate the proposed acres treated by each management action;
- Report annual treatment acres over a 10 year time horizon (e.g., 2005-2015) by management action and ownership group.

⁶ CARB website: http://www.arb.ca.gov/research/single-project.php?row_id=65188

Planning Targets

The objective of this part of the analysis is to set planning targets for climate (carbon storage and emissions avoidance) and other co-benefits. Information on priority area by ownership group and information from the FCAT Inventory Subcommittee will be used to estimate the magnitude of the area where management actions are most needed. Planning targets will likely be refined based on economic evaluation done as part of the resource economics study.

Level of Investment

This section will estimate the level of investment needed to meet planning targets for carbon storage or emissions avoidance and other co-benefits. The estimate is to be based on the planning target (i.e., percentage of the priority area to be treated) and the acreage to be treated by each management action. This can be done statewide and for each of the major ecological reporting units. Each ecological reporting unit will have a unique portfolio that consists of a range of investments and supporting management actions to reach planning targets. In addition, determine any major constraints or changes to policy and regulations that influence meeting planning targets.

The analytical approach is a crucial part of the Forest Carbon Plan. Thus, we invite public input on the process described above.

Implementation and Investment Mechanisms

Successful implementation of the Forest Carbon Plan will be dependent upon strong and productive collaboration with multiple federal, state, local, and private forest landowners. It will be essential to identify where resources (staff, funding, grants, streamlined regulatory processes, information, infrastructure, technical expertise, etc.) are available or lacking to help us do this work.

We provide here an outline of collaboration and investment opportunities. We invite stakeholder comments identifying other opportunities or providing recommendations on how we can best utilize the opportunities below.

Collaborative Opportunities

Collaboration of a wide range of players—land owners and managers, agencies at multiple levels of government, businesses, nongovernmental organizations, and stakeholders—is essential for implementation success, particularly for working at the landscape level. Some examples of collaborative approaches include:

- [Sierra Nevada Watershed Improvement Program](#) (Sierra Nevada Conservancy/Forest Service)
- [Good Neighbor Authority](#) (Forest Service and State)
- Collaborative Forest Landscape Restoration Act Projects (Forest Service and partners)
- [Memorandum of Understanding for the Purpose of Increasing the Use of Fire to Meet Ecological and Other Management Objectives](#)
- Cohesive Strategy Projects/Landscape Management Demonstration Areas (i.e., Fire-Adapted 50 Project)

- Landscape Conservation Cooperatives and Collaborative Climate Adaptation Committees in California.
- Joint Chiefs Joint Landscape Restoration Partnership Program (Forest Service and Natural Resources Conservation Service)
- California Headwaters Partnership
- Community wildfire protection plans
- California Urban Forest Council
- California ReLeaf
- California Urban Forest Advisory Committee
- Tuolumne Community and Watershed Resilience Program

One possibility for collaboration exists between owners and managers of California’s forested watersheds and the downstream beneficiaries of the great quantity of high quality water that these watersheds provide. On some watersheds in other parts of the country, this linkage has been specifically made and investments in the watersheds flow back upstream from the rates paid by residential and industrial water consumers. While this kind of connectivity has long been discussed in California, little to no direct investment connection has yet been made.

Investment Mechanisms

Federal

- Support increased federal investment on National Forests and other forest lands in California.
- Support alternatives to stop paying for the increasing costs of fighting National Forest fires with funding otherwise budgeted for forest fuels/forest health projects on National Forests and grants to state forestry agencies, such as Forest Stewardship grants (so-called “fire borrowing”).
- Seek federal matching funds for state Greenhouse Gas Reduction Funds that may be invested on federal lands.
- Continue federal forest health and urban forestry investments in nonfederal forestlands through Forest Stewardship and Urban and Community Forestry funding, and wildland-urban interface community assistance program funding provided to CAL FIRE and other California program partners.

State

- Support the Governor’s proposed FY 2016-17 budget allocation of Greenhouse Gas Reduction Funds:
 1. Funding to the Department of Forestry and Fire Protection of \$140 million for forest health, \$10 million for working forest conservation easements, and \$30 million for urban forests) and other state funds to meet the goals of the plan.
 2. Funding of \$20 million to the Natural Resources Agency for a green infrastructure grant program.
 3. Funding of \$60 million to the Department of Fish and Wildlife for wetlands restoration, including mountain meadows.
- Use existing programs (supported with current and potential new funding sources) to achieve forest health and forest carbon goals; for example:
 1. Department of Forestry and Fire Protection California Forest Improvement Program (GGRF, Timber Regulation and Forest Restoration Fund, U.S. Forest Service Forest Stewardship Funds)
 - a. Vegetation Management Program (SRA Fire Prevention Fund, GGRF)
 - b. Urban and Community Forestry Program (GGRF, U.S. Forest Service Forest Stewardship Funds)

- c. SRA Fire Prevention Fund Grant Program (SRA Fire Prevention Fund)
- 2. Sierra Nevada Conservancy
 - a. Watershed Improvement Program (Prop. 1)
- 3. California Conservation Corps
 - a. Public/private partnerships
 - b. State Responsibility Area Fire Prevention Fund fuels reduction projects
- Implementation of the Forest Practice Rules consistent with the California Environmental Quality Act requirements for consideration of climate change impacts and [AB 1504 implementation](#) by the Board of Forestry and Fire Protection
- Use the analytical components of the Forest Carbon Plan process and the resources economics study being done as a part of the Forest Carbon Plan to identify the most cost-effective investments for carbon storage, emissions reductions, and related co-benefits
- Coordinate and leverage other public and private investments, particularly through partnerships with the Forest Service, large private forest land owners, and local fire-safe councils.
- CAL FIRE and Board of Forestry and Fire Protection implementation of SRA Fire Protection Fee grant programs is conducted, when and where appropriate, in a fashion that supports the achievement of forest carbon goals.
- Build on the direction provided in SB 1122 and the Governor’s Emergency Proclamation on tree mortality for increasing opportunities to use forest waste materials for bioenergy production.
- Build on the directive in the Governor’s Emergency Proclamation on tree mortality regarding prescribed fire and the recent multi-party MOU on prescribed fire to expand opportunities for the use of prescribed fire as a tool for managing forest ecosystems and forest carbon emissions.
- Continue to seek federal grants such as the National Disaster Resiliency Competition.

[Local](#)

- Support local efforts to generate funding for fire prevention, forest health projects, the development of wood product and biomass facilities, and urban forest projects.
- Land use planning for forest protection and conservation in general plans.
- Support rural and disadvantaged communities with opportunities for training and jobs implementing forest (wildland and urban) management and treatment programs.

[Private](#)

- Support purchases of forest carbon offsets to improve forest health, maintain working forestlands, and establish urban forests.
- Support the establishment and care of urban forests.
- Support voluntary conservation easements and tax credits to protect important native forests facing pressures for conversion to non-forest land uses.
- Support strengthening of markets for forest products that provide carbon sequestration and emission displacement benefits
- Invest in infrastructure required for active management of forestlands and production of forest products and biomass energy.

Measuring Progress

Monitoring, Assessment, and Reporting

For each goal and strategy, monitor, assess and report results based on forest health resiliency performance measures, carbon storage, and GHG emission and black carbon reductions. In order to achieve this, FCAT will:

- Establish a technically sound and accurate baselines for forest carbon content, GHG emissions and black carbon emissions for both wildland and urban forests. The GHG reduction benefits will be estimated following Air Resources Board guidelines or other accepted methodologies. Monitoring will rely predominately on FIA and forest health data, supplemented with other data sets.
- Establish a monitoring system for tracking changes in the baselines listed above.
- Specify the reporting requirements for each project type. For CAL FIRE funded projects most activities will be captured in CalMAPPER.
- Track progress for each management strategy.
- Issue periodic reports to the public in order to provide transparency and opportunity for improvements to the strategies.
- Periodically report progress to the Legislature.

Research and Development

New information and tools will have a great impact as the strategies turn into action. Key studies already underway include the resource economics study being conducted by the University of California, Berkeley for FCAT and research being conducted to support the California Natural Resources Agency's Fourth Climate Change Assessment. One emerging research need is a workable, statewide GHG accounting framework for forestlands. This framework is in early stages of development though the Scoping Plan Natural and Working Lands program element using a process that will include stakeholder and academic partners. Research also is needed to provide better information on genetic selection of tree planting stock that can best thrive under changing climate conditions. As other gaps in knowledge emerge, key research priorities must be developed and funded in order to ensure that science-based, cost-effective strategies continue to be chosen.

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