Appendix C - Focus Group Working Papers

Natural and Working Lands Working Paper

Natural and Working Lands Sector can be a source of emissions, for instance when such lands are converted to other uses or are subject to fires, disease and pests, but the sector also can actively remove carbon dioxide from the atmosphere. Plants absorb carbon from the atmosphere and through photosynthesis it is stored in plant material and roots. Soils may also store carbon. Natural and working lands can be protected, restored, and managed to reduce GHG emissions and maintain and increase carbon storage. Such actions often provide other important environmental and economic benefits, including benefits to human health and opportunities for revitalizing rural economies. The 2050 Vision for the Natural and Working Lands Sector is to reduce GHG emissions and maintain and enhance the capacity of natural and working lands to store carbon. Work to achieve the 2050 Vision may encompass: policy efforts, strategic investments, continued research, conservation, restoration, improved management practices, and a commitment to monitoring, evaluating and adapting strategies over time in light of changing conditions and improved information. Achieving the 2050 Vision for natural and working lands will help create a more resilient California that is better prepared for climate risks such as more frequent and severe wildfires, changing water availability, and stressors on species and natural communities.

California is one of the most biologically diverse areas on Earth and features a wide variety of natural resources and landscape types such as forests, desert, grasslands, oak woodlands, wet meadows, and tidal marshes. This section of the Appendix describes in further detail opportunities to avoid emissions and maintain or enhance carbon sequestration associated with forests (including urban forests and greening programs), rangelands/grazed lands, and wetlands.

This paper does not encompass all the ways in which natural and working lands can help to reduce GHG emissions in the state. For instance, natural and working lands support renewable energy development including solar, wind, geothermal and hydroelectric projects; and reducing the carbon content of energy is a critical component of reducing GHG emissions in the state. Natural and working lands also offer opportunities to increase climate literacy that can catalyze actions to reduce GHGs. For instance, California Parks draw tens of millions of visitors annually and interpretive programs may offer opportunities to help convey climate risks and opportunities. GHG benefits that agricultural croplands may offer are otherwise discussed in the Agriculture section of this Appendix. Finally, GHG issues associated with oceans are not included in this discussion. Oceans have absorbed about one-third of the GHG emissions produced by humans in the industrial era, and this is leading to acidification of the ocean.[1] Current measurements of ocean acidification are larger in magnitude and more rapid than anything in the fossil record of the past 65 million years[2] leading to significant implications for ocean biodiversity, fishing, and food security. It is unclear whether the

[1] http://centerforoceansolutions.org/climate/impacts/ocean-acidification/

[2] Ridgewell, Andy and Schmidt, Daniela N., Past constraints on the vulnerability of marine calcifiers to massive carbon dioxide release, Nature Geoscience 2010 Vol: 3(3):196-200. DOI: 10.1038/NGEO755

ocean's capacity to store GHG emissions will diminish over time.[3] Oceans play a key role in the global climate system - as oceans store and move heat, absorb GHG emissions, and function as part of the global water cycle. Climate models predict more extreme weather - due, in part, to climate impacts on oceans; and some weather changes will in turn increase GHG emissions (e.g. from wildfires or increased energy demand).

Jurisdiction over California's natural and working lands is divided between federal ownership, state ownership, and both industrial-scale and smaller-scale private ownership. Differing ownership and jurisdictional types have significant implications for managing lands for GHG purposes and other benefits. These issues are further discussed in the subsections below on forests, rangelands/grazed lands, and wetlands. Coordination across ownership and jurisdictional boundaries will be necessary in order to reduce emissions and maintain or enhance carbon sequestration on natural and working lands in California.

There are several common issues and opportunities associated with managing forests, rangelands/grazed lands, and wetlands for GHG purposes: 1) timing elements, 2) maintenance and monitoring requirements, 3) continuing research needs and the need to refine strategies over time, and 4) associated other benefits ("co-benefits"). These issues and opportunities are further discussed below.

There are issues and opportunities to consider with respect to timing of activities to prevent emissions and maintain or enhance carbon storage associated with forests, rangelands and wetlands. Forests, rangelands, and wetlands are dynamic, natural systems that experience carbon fluctuations; plant and soil respiration (including the decomposition of dead plant material) releases carbon into the atmosphere.[4] In order to capture significant, long-term carbon trends associated with natural systems, it may be necessary to look at longer time frame, decadal data and projections in order to craft strategies for preventing emissions and maintaining or enhancing carbon storage capability. Activities to enhance carbon storage, such as reforestation or restoration activities, may require some time to fully realize carbon benefits. There may also be additional benefits beyond carbon that can only be realized if actions are taken relatively early with respect to the actualization of expected climate impacts; for instance, in some cases, restoring tidal wetland can offer flood protection that is able to keep pace with sea level rise through the growth of root mass over time - but such naturally growing flood protection enhancements are only possible if restoration activities are initiated early enough.[5]

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[3] McKinley, Galen , Fay, Amanda, Takahashi, Taro, and Metzl, Nicolas. Convergence of atmospheric and North Atlantic CO2 trends on multidecadal timescales . Available from Nature Precedings <http://hdl.handle.net/10101/npre.2011.5993.1> (2011).

[4] IPCC Fourth Assessment Report: Climate Change 2007, Overview of the Global Carbon Cycle, Section 7.3.1. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7-3.html

[5] *See* Green Infrastructure for the Global Warming Era: The Horizontal Levee Nature's Low Cost Defense Against Sea Level Rise, 2013. This report concludes that in the San Francisco Bay Area, a hybrid tidal marsh-flood protection system can be constructed to keep pace with sea level rise for several decades in

Activities to reduce GHG emissions and maintain or enhance carbon storage associated with forests, rangelands/grazed lands, and wetlands will require on-going maintenance and monitoring. Dynamic, living systems must be maintained over time, and programs or investments to support carbon activities associated with natural and working lands must include a maintenance component. Furthermore, monitoring to quantify GHG benefits and other performance metrics is important to verify program success, and to refine management techniques, the accuracy of carbon models, and any criteria that may be used for the strategic prioritization of various activities related to carbon and natural and working lands.

Climate science and management responses to address climate change are both rapidly evolving as new information and experience is gathered. This section of the Appendix describes some continuing research needs relating to natural and working lands that would support efforts to reduce emissions and enhance or maintain carbon storage. As noted above, and is the case with efforts to address climate change in most sectors, an iterative process that refines management techniques, models and strategies over time is recommended.

Efforts to avoid carbon emissions and maintain and enhance carbon storage in forests, rangelands/grazed lands, and wetlands may offer a wide range of additional environmental and economic benefits ("co-benefits") for the state. These co-benefits may include, but are not limited to: functioning to enhance water quality and quantity; potentially providing safeguards against risks like flood and erosion; providing habitat, refugia and corridors for species and natural communities that are increasingly stressed by climate change; offering enhanced recreational opportunities and tourism revenue; supporting bioenergy development; offering waste diversion opportunities; helping to reduce energy demand as a result of shading; improving air quality; and/or supporting job creation in rural communities. In order to prioritize among the many opportunities to enhance carbon benefits associated with California's natural and working lands, it may be appropriate to try to maximize associated co-benefits that support AB32 and other state policy goals. Since carbon storage is only one of many products and ecosystem services which California natural and working lands provide, activities to reduce GHG emissions and maintain and enhance carbon storage should be undertaken in a manner consistent with sustainable and ecologically sound practices in order to continue to safeguard California's natural heritage.

More specific discussions relating to forests, rangelands/grazed lands, and wetlands are included below.

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critical locations if construction begins immediately.
http://www.bay.org/assets/SLR%20Executive%20Summary_web2.pdf

FOREST SECTOR

INTRODUCTION

California has a vast forest land base (approximately 33 million acres, or almost one-third of the state) that has the potential to significantly offset GHG emissions (Figure 1). California's forests are diverse and have evolved under varying ecological conditions and adapted to a fire prone environment. The diversity of tree species includes many types of conifers (e.g. Douglas-fir, incense-cedar, white fir, coast redwood, giant sequoia) and also many types of oaks (e.g. blue oak, coast live oak, etc.) Coast redwood and giant sequoia, for example, are some of the largest and fastest growing trees on Earth and have tremendous potential to store carbon and offset GHG emissions (Figure 3).

The state's forests also include urban trees. Trees in urban environments, or 'urban forests', sequester carbon dioxide through growth, while also providing significant shading and other cooling benefits that reduce urban temperatures and energy needs. Urban forests can also help filter air pollutants and can help absorb rainfall which would otherwise run over streets and wash pollutants into nearby waterways that are already under increasing stress from climate threats.

The forest land base is divided between private and public management. Predominantly held by the federal government (over 57 percent), these forest resources are located on state, federal, and private lands (Table 1). This diverse mix of land owners means that coordination among the state, private land owners, and federal agencies will be important to the success of any comprehensive forest climate strategy in California. In addition to carbon storage this strategy must consider the broader range of environmental services that forests provide (e.g. clean water, clean air, soil productivity, nutrient cycling, wildlife habitat, forest products, and recreation). Actions taken to address forest health concerns or to reduce wildfire risks may result in temporary reductions in carbon sequestration, but are necessary to maintain healthy forests that are efficient at GHG sequestration and more resilient to future climate conditions.

<u>Federal Lands</u>
Over half of the forest land base (approximately 19 million acres) and a substantial portion of the carbon sequestered in California's forests is on federal lands [1]. These lands support a range of management objectives and related environmental services. Forests on federal lands in recent decades have had less active management and tend to have a higher proportion of stands in older age classes. Previous research by USFS suggests that there could be substantial declines in carbon storage beginning in 2050 assuming the status quo for land management [2]. The decrease in carbon storage is a function of declining forest health; expect pest outbreaks, and losses from wildfire. To change the status quo state climate change strategies need to consider federal lands and broader forest health issues that extend beyond ownership boundaries. Since federal forests represent such a large and unfragmented part of the land base the

management choices for these lands are critical and represent an enormous opportunity to enhance climate benefits from a public resource.

Private and NGO Lands

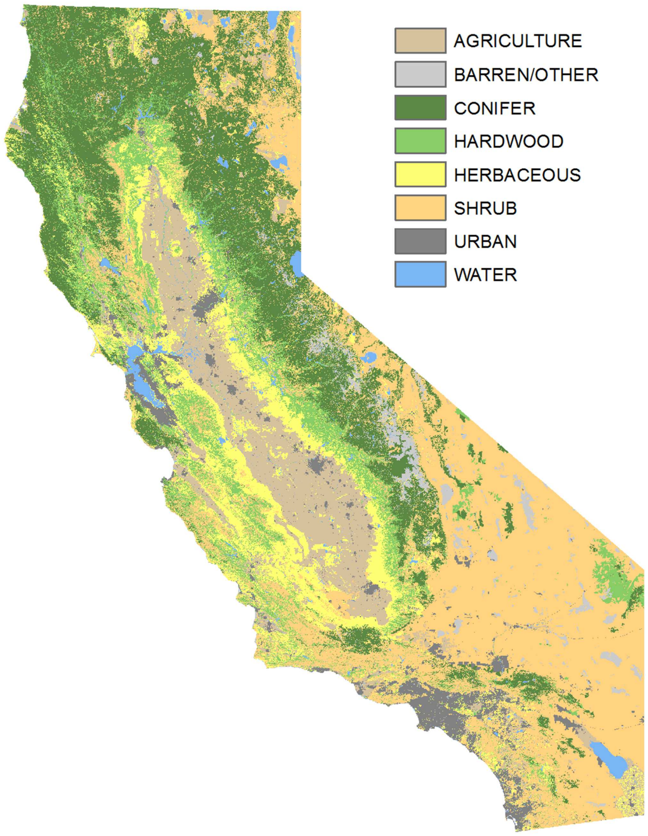
Private lands are also managed for different objectives, but can largely be categorized by commercial timberlands, non-industrial, and NGO lands. Private timberland owners have more actively managed stands. Through timber harvesting forest stands on these lands may show periodic reductions in carbon stored in aboveground biomass. However, depending on the silvicultural prescriptions and resulting wood products private timberlands can maintain healthy forest stands that provide sustained climate benefits.

Private Non-Industrial forests have much broader management objectives. They tend to have less active management and owners manage smaller tracts of land. A recent landowner survey found that owners value their lands for natural amenities as well as a financial investment [3]. Larger landowners (e.g. > 500 acres) were much more likely to manage the land to produce income, but also more interested in environmental improvements.

There is a small but growing group of forest managed by non-government organizations (NGOs). Management tends to have a conservation objective that provides climate benefits and other co-benefits. Lands managed by NGOs have begun to utilize existing forest protocols that create additional revenue streams for lands managed to create additional climate benefits.

CLIMATE CHANGE – Environmental Effects on Forests

Climate can greatly influence the dynamics of forest and range ecosystems. Climate influences the type, mix and productivity of species. Future climate change scenarios predict increases in temperature, increases in atmospheric CO2 concentrations, and changes in the amount and distribution of precipitation [4]. 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).



. Acres of Forestland by Landowner [1]		
ership egory	Acres of Forestland	Percentage
rivate	13,01,000	39.3 %
NGO	115,000	< 1%
ederal	19,171,000	57.4 %
State	711,000	2.1 %
Local	374,000	1.1 %
Total	**33,387,000**	**100 %**

Figure 1. Land cover map of California. Conifer and hardwood forest combined comprise approximately 33 million acres across the state. The corresponding table (Table 1) shows forest land ownership [1]

Given the long lifespan of trees in a forest stand, from decades to thousands of years, the effects of climate change on disturbance regimes may become apparent prior to noticeable changes in forests. These include changes in the timing, frequency and magnitude of wildfires; pest infestations; and other agents of disturbance (Table2) [5]. 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 well as areas that are already under stress from land use (i.e., expanding wildland urban interface) and management [6].

The influence that climate has on disturbance regimes may already be having an effect on forests. In California, extended drought and earlier snowmelt are leading to longer and drier summers with more pronounced fire activity. Relatively small changes in temperature and precipitation can affect reforestation success, growth, susceptibility to pests, and forest productivity.

Table 2. Climate change impacts in the forest sector [1]

FACTOR	DESCRIPTION
Hydrologic	Changes in temperature, precipitation, and hydrologic processes (i.e. decreased snow pack, earlier spring runoff, lower summer base flows).
Fire	Changes in the extent and frequency of disturbances from wildfires, pests, and disease outbreaks.
Biologic	Conditions may favor the spread of invasive species.
Biologic	Tree species expected to move northward or to higher altitudes.
Biologic	Changes in reforestation and regeneration success.
Biologic	Changes in forest productivity affecting growth and carbon storage. The effect of additional CO_2 on forest productivity is uncertain.
Economic	Economic impacts from increased fire damage and fire suppression costs.

<u>Climate Change Effects on Wildfire</u>

Most forest species in California have evolved in fire prone landscapes and as such, wildfire plays a critical role in maintaining ecosystem health. However, wildfires can also be destructive and pose significant threats to life, property, public health, infrastructure, and water quality. One outcome from decades of fire suppression has been that many forest stands have not burned as frequently as they had historically and resulted in substantial acreage across the state in a high fire threat condition (Figure 2).

Prior to Western settlement wildfires were thought to be much more extensive; burning 4.5% - 12% of the land base annually [7]. Based on historical fire records an average of 320,000 acres burned annually; though, average annual acreage burned has increased to 598,000 acres between 2000 and 2010 [1]. Wildfires represent a source of GHG emissions. Current estimates on average annual emissions from wildfire are 24 million metric tons CO_2/year [8].

Research has provided estimates of expected changes in wildfire activity resulting from climate change [9]. Results from this research predict an extended fire season with a substantial increase in wildfire acres burned. Early studies [10] showed only a modest increase in wildfire acres burned (9 – 15%) under a range of future climate scenarios. However, more recent modeling showed that the expected wildfire-burned forested area for Northern California, under a high emissions scenario, increased in excess of 100% [11]. The increased activity in number and extent of wildfires would likely result in significant increases in emissions from wildfire. In addition, research predicted outcomes that varied with fire regimes; where expected increases in temperature promoted greater large fire frequency in wetter forested areas [12].

Insects and Disease

Insects have been part of forest ecosystems through evolutionary history. Occasionally individual species populations will surge into sizeable outbreaks that can result in forest damage and tree mortality. Dead trees left from forest pests lose their ability to sequester carbon and can become prone to wildfires that increase carbon emissions and even further reduce the effectiveness of forests as carbon sequestration agents. The increase in fire hazard is mainly due to large volumes of surface woody fuels that accumulate as the trees fall apart over time, in conjunction with the understory vegetation growth that is stimulated by new sunlight making its way to the forest floor.

Climate change is expected to dramatically increase pest outbreaks across the state. Insect life history and distribution is largely defined by temperature and precipitation, and the current and predicted upward trend in temperatures particularly favors forest insects. In recent history we have seen these patterns when bark beetle outbreaks occurred during periods of drought. Foliar pathogen outbreaks, such as Sudden Oak Death, have occurred during years when precipitation has been high and late in the season [13]. Insects also have the ability to travel into new ranges which will give them an advantage in changing climate conditions over their more slowly distributing tree hosts.

Based on the USFS Forest Health Monitoring Program predictive potential risk model of insect and disease related forest mortality, nearly 5 million acres are at high risk. The USFS 2011 mapping efforts surveyed 42 million acres across the state, and over half a million acres showed mortality [13].

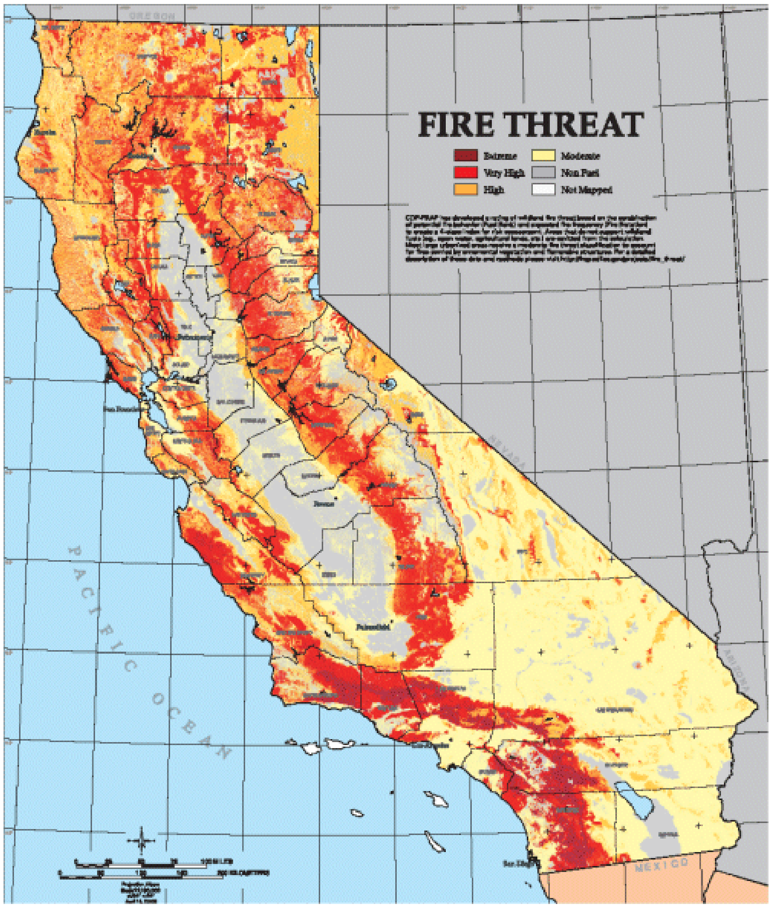


Figure 2. Map of fire threat. Areas of orange and red represent high and very high fire threat respectively [1].

<u>Forest Health – Restoration Needs</u>

Following decades of fire suppression many forest stands, particularly across the Sierra, are overstocked with small trees and high fuel loads that are at risk to high severity fire and insect/disease outbreaks. Stand improvement and forest fuel reduction treatments are intended to compensate for historic disturbance cycles and make these forests more resilient. Recent study estimates that almost 3 million acres across the Sierra would benefit from fuel reduction treatments [14].

FOREST CARBON ACCOUNTING

There is much interest in the role that forests (natural and urban) can play in offsetting GHG emissions. Forest ecosystems are a major part of the carbon cycle; taking in carbon dioxide (CO2), storing carbon as part of its woody biomass (including long after harvest in certain forest products), and releasing oxygen back into the atmosphere. Given the diversity of tree species there is great variability in carbon sequestration among different forest types. Mixed conifer forests, found broadly across the Sierra and Cascades, have been estimated to store 60 tons of carbon per acre [15]. In addition, redwood forests are unique to California; their high growth rates and large size have great potential for biomass and carbon sequestration (Figure 3). Carbon storage for

Redwood forests have been estimated at approximately 150 tons per acre [16]. Through wildfire, mortality, and other forms of disturbance there is a natural cycling of carbon between forests and the atmosphere. Given enough time, healthy forests are resilient and will recover and regain carbon lost through disturbance. Understanding how forest carbon pools are affected by land management and natural disturbance regimes is an emerging field of science, requiring extensive data collection and complex modeling approaches [17] [18]. Our current capacity to comprehensively measure all pools of carbon is limited [19] [20] [21]. Although some studies have been done it is an area where additional research is needed to refine methods and fill data gaps [22]. The breakdown of carbon stock (i.e. pools) include quantification of living biomass (above and below ground), dead organic matter (litter and debris), soil organic matter, and wood products (Figure 4).

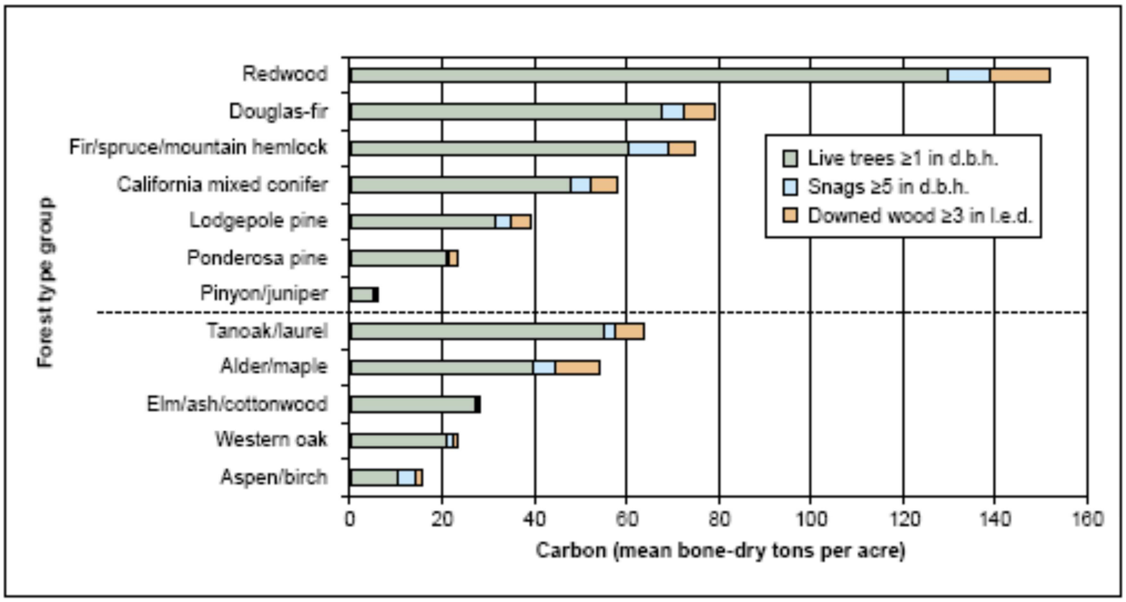


Figure 3. Estimates of carbon storage by forest trees in California [16]

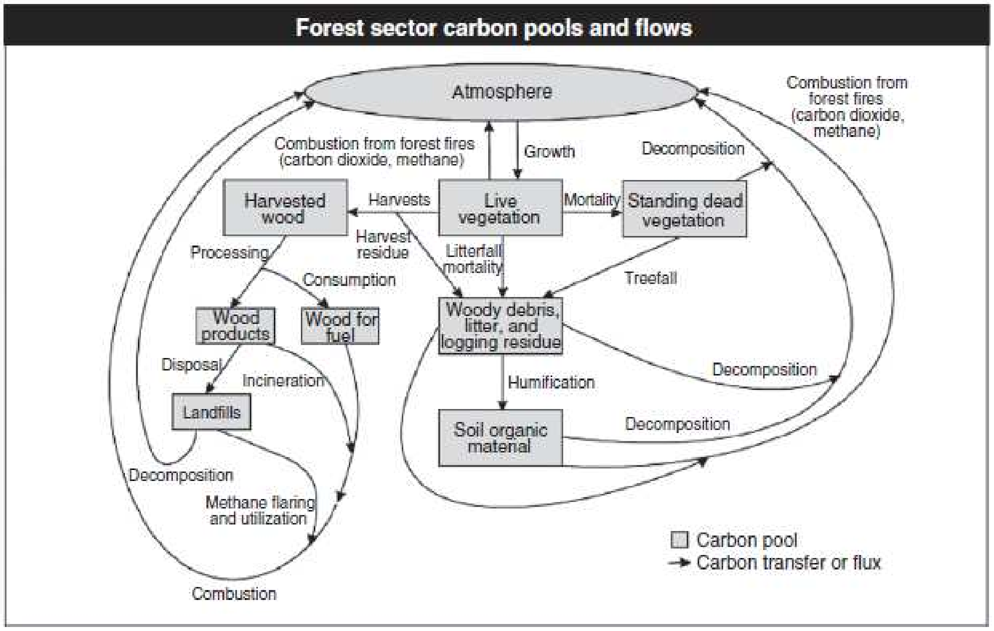


Figure 4. Forest carbon sequestration cycle. Heath et al. 2003 [23] cited in Sedjo and Sohngen 2012 [24].

Urban forests are an important part of the forest sector and like wildland forests, urban forests are also contributors to carbon sequestration and storage. There are around five million acres of urban area in California, which is around 5% of California's land base, and urban area is projected to increase to 15% by 2050 [25]. Within that urban area, average tree cover throughout California's urban area varies greatly between counties, cities and communities. The average tree cover for a California urban area has been estimated at 6.7%, yet there is likely to be substantial variability[25]. For example, Sacramento has an estimated tree cover of 13.2% [26]. Previous Air Resources Board (ARB) estimates of CO2 sequestration have not included urban tree canopy in their estimates. CALFIRE is currently working with UC Davis to create a statewide source of information for estimating CO2 sequestration in California's urban areas that will utilize existing tree inventories and canopy data to support the AB32 scoping report and other resource assessments.

Past and Current Studies

Previous studies have mostly estimated forests in California to be operating as a carbon sink [27]; but are predicted to slow over the next century [28], [29] [30]. This pattern of slowing carbon storage is similar to a trend shown nationally (figure 5). Methods for estimating forest carbon and emissions are still relatively new and are an active area of research. This is reflected in the broad estimates that range from an annual sink of 66.4 MMT CO2eq to a potential source of 55 MMT CO2eq for studies evaluating conditions between 1990 and 2010.

Initial estimates reported in the 2008 AB32 Scoping Plan estimated annual forest sequestration at 5 MMT CO2eq [31]. In 2010, CALFIRE estimated net forests carbon sequestration at 30 MMT CO2eq (Table 3) [1]. National estimates for California's forests have been even higher. USDA estimates 66.4 MMT CO2eq/yr sequestered by CA forests in 2008. This finding is based on GHG inventory data from 1990 – 2008

[32]. Between 1994-2000 California Energy Commission funded a study that estimated that forests and rangelands in a limited study area were sequestering 7.55 $MMTCO_2eq/yr$ [33]. Using a vegetation dynamics model NASA researchers estimated that in above average precipitation years (1990-2004) forest carbon pools may offset between 52and 86 MMT CO2eq/yr ; and estimated that forests could be a source of up to 55 MMT CO2eq/yr in a dry year [27]. An additional study that looked at the impact of climate change on California ecosystem services also founds forests to operate in a similar range of 13 $MMTCO_2eq/yr$ [34]. There have been limited studies to estimate carbon sequestration of forests in urban area. California urban forests contain about 36 MMT of carbon, and remove about 4.4 MMT CO2 from the atmosphere annually.[25].

Given the wide range of carbon estimates and consistent with the emphasis of this Scoping Plan Update to include all natural landscapes, ARB is currently working with University of California researchers to refine the carbon emission inventory for California forest, shrub, grassland, wetland, and desert vegetation land types. The deliverables will include an updated inventory utilizing FIA and other data sources in combination with remote sensing tools to expand, revise and update the carbon inventory. Consistent with the existing inventory elements, the new inventory will also include improved methods to account for carbon storage and emissions in wood products in use and in landfills. These sources of stored carbon need to be assessed relative to natural (e.g., wildfire, decomposition of dead material) and management-based emission sources.

In addition to development of an updated inventory, the University of California research team will also deliver a system tool to allow ARB staff to utilize the most current data and information to update the Sector Greenhouse Gas inventory. To assist with these efforts, CALFIRE, USFS, and other agencies have made substantial investments in collecting information on vegetation, wildfires, and management activities that, over time, can be used to assist ARB staff in refinement and improved accuracy of the GHG inventory.

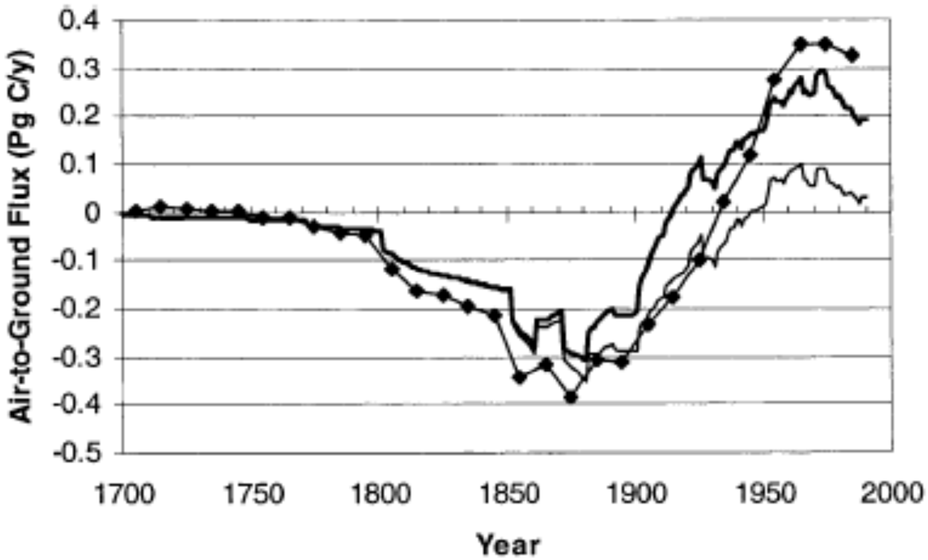


Figure 5. adopted from [28] this figure shows estimated average annual air to ground net flux in Pg•y^{-1} from 1700 to 1990. Positive values indicate a land sink and negative values indicate a source to the atmosphere. Light line, ref. 6 without fire suppression. Dark line, ref. 6 with fire suppression. Dark line with dots is the results from a mechanistic ecosystem demography model.

Monitoring Challenges

Given the complexity of forest ecosystems and inter-annual variability in carbon fluxes there is an on-going need to invest in monitoring to refine baseline and future estimates for forest carbon. The most critical component of monitoring forest carbon in California is the continued long-term commitment to collect forest inventory plot data through FIA (Forest Inventory Analysis). FIA is a federal U.S. Forest Service program that provides a statistically rigorous sampling of forest stands across the country that can be used as a core part of a forest carbon inventory. However, FIA was initially developed to track changes in commercial timber resources and has only in recent years been refined to provide additional measurements for estimating forest carbon [18]. Carbon monitoring has brought an additional level of complexity to commonly measured variables since below ground and forest floor variables are of interest and are spatially heterogeneous [35]. Estimation of all of these variables occurs amidst the backdrop of natural ecosystem dynamics/disturbances, and human caused disturbances.

USFS FIA was traditionally limited to lands with undisturbed understories, which excluded urban areas. However, the USFS recognizes the critical role that urban forests play, and have a pilot project to include urban forests in the National FIA program, and California is included in the project. These data will be helpful in measuring carbon storage in areas that have traditionally been overlooked because of urban challenges including a wide variation in species, climate, tree diameter and density, and different irrigation regiments. These variations occur widely across single communities and counties, adding potential error to statewide urban canopy carbon estimates. These estimates can improve through further field data collection; increasing the density of FIA plots and expanding monitoring of all carbon pools [26].

In addition to field inventory data (e.g. FIA) recent carbon accounting methods are being developed to link plot data to vegetation maps derived from remote sensing. This is a promising area of research to provide a detailed spatially based estimate of forest carbon. LiDAR data in particular has shown to provide extensive information on tree height, canopy, and other structural elements. However, there are ongoing challenges associated with both data and methods that require additional refinements to improve the accuracy of carbon estimates.

There are also challenges associated with estimating emissions from wildfire, tree mortality from pests and other forest health issues. Ongoing investments both in monitoring data and analysis procedures are needed.

MITIGATION STRATEGIES & CO-BENEFITS

The recommendations herein are consistent with the 2008 AB 32 Climate Change Scoping Plan, which identified the following forestry sector opportunities for additional greenhouse gas (GHG) reductions:

- Afforestation and Reforestation
- Forest Management
- Urban Forestry
- Forest Conservation
- Fuels Management
- Forest Materials & Bioenergy

The following section provides a brief description and examples of these strategies and highlights the many co-benefits associated with forest sector strategies.

An analysis by CAL FIRE [1] indicated that status quo management of forestlands in the state would sequester over 30 MMCO2E (net) over a ten-year period. Investments in additional forestry sector projects have the potential to assure that this level of net sequestration is attained (e.g., through reduction of fire threat and addressing forests pests) or exceeded (e.g., through projects that will increase the rate of net sequestration). While more work is needed to refine quantification of the GHG benefits and costs of forest sector projects, it is clear that these projects have significant potential to sequester carbon and reduce emissions. Further, forest sector projects provide multiple and substantial co-benefits.

Investment opportunities in the forest sector generally fall into one of the 6 categories detailed below. In some cases there are a number of entities with established programs and expertise to deliver on-the-ground GHG reduction projects, though current program funding is in most cases significantly below historic levels and is a barrier to achieving the potential levels of GHG reductions. See Enabling Programs, below, for implementation.

<u>Forest Conservation</u> – Tools available to prevent or mitigate conversion of forestlands to more developed uses include land use planning, conservation easements, and mitigation banking. Working Forest Conservation Easements (WFCEs) are an important legal tool to secure existing and future forest carbon stocks from loss due to development. Specifically, WCFEs prevent the conversion of forests to other uses (thereby avoiding the release of sequestered carbon). They also require maintaining or increasing carbon stocks over time while guiding management to improve wildlife habitat and watershed health. Furthermore, WFCEs help ensure that our forests will always be a source of logs for California's lumber mills and woody materials for bioenergy—thereby helping maintain forest sector employment.

The co-benefits of WFCEs include:
- Improved forest management, including site-specific conservation prescriptions, and support for adaptation;
- Watershed conservation to maintain water sources;
- Retention of actively managed timberland to sustain the forest-products industry in perpetuity.

<u>Forest Management</u>– Many of California's forests, notably those held by smaller forestland owners and lands managed by the US Forest Service and other public agencies, are unnaturally dense due to decades of fire exclusion and minimal levels of management. Hundreds of thousands of acres of forest are in need of thinning and removal of fire-prone vegetation, or in need of treatment to address insect and disease conditions. These areas would accumulate carbon more quickly and be more resilient to disturbance factors of fire and pests if they were returned to a healthier, natural condition.

The co-benefits of improved forest management include:
- Accelerating the creation of older forest conditions;
- Creating renewable energy through biomass utilization;
- Reducing the near-term intensity of wildfires and the corresponding property damage and carbon emissions;
- Reducing fire suppression risks and costs, and;
- Creating immediate jobs in the woods in in rural parts of the state that have long faced economic disadvantages.

<u>Fuels Management</u>— Large portions of California have forests that are at very high risk of wildfire, and many of these forests are at increased risk because of high fuel loads resulting from past management actions and a legacy of fire suppression. Investments in fuel reduction projects can help reduce the intensity of fires, making forest carbon stores more stable by increasing the resiliency of the forest to the inevitable wildfire. The near-term carbon emissions associated with the thinning can be reduced if the waste material is used at a local biomass facility to generate energy.

Fuel treatments have a proven track record of reducing costs and losses associated with wildland fires. These include wildland fire suppression costs to federal, state, and local governments.

Reforestation and Afforestation – Replanting areas that were formerly forested or are currently under-stocked offer significant carbon sequestration opportunities, especially over a longer time horizon. Areas of opportunity include conifer forests not reforested after severe fire, as well as riparian hardwood reforestation at lower elevations. Opportunities are present on both private and public forestlands.

The co-benefits of reforestation include:
- Improved watershed health; and
- Significant employment opportunities.

Urban Forestry – More than 94% of Californians live in an urban area and depend on the multiple ecosystem, social, and economic benefits of urban forests. Urban forests reduce atmospheric carbon by locking up CO2 in their roots, trunks, stems and leaves while they grow and by reducing heating and air conditioning demands reducing emissions associated with power production [36]. Maintaining existing urban forests sustains current carbon sequestration benefits while planting more trees offers significant new GHG reduction opportunities that will increase over time. Urban forests also improve air and water quality, provide local jobs, reduce residential energy consumption, and benefit disadvantaged communities.

The co-benefits of urban forestry include:
- Increasing shade that reduces heat island effect, lowers cooling bills, and saves energy;
- Strengthening property values;
- Improving air and water quality;
- Creating jobs planting and maintaining trees; and
- Improved water quality and reduced stormwater runoff.

Forest Bioenergy -- Converting forest biomass to energy presents both challenges and opportunities. If produced in a sustainable and efficient manner, wood fuel can be a renewable, at least partially carbon neutral source of energy. Some of the potential benefits of utilizing woody biomass fuel include improved forest health, reduced risk for wildfires, enhanced silvicultural opportunities, avoidance of GHG emissions, and diversion of urban wood waste from landfills. Forest biomass conversion to energy is compatible with a variety of land management objectives that include wildfire control, forest health and commercial timber management. While the bulk of industrial fuel wood today comes from residues left over from commercial harvest operations, additional supply could come from noncommercial thinning, post-fire salvage, fuels reduction residues, and urban forest materials. Currently, throughout California biomass energy provides 2.4 percent of all electricity used [37]. Approximately half, or 1.2 percent, comes from forestlands.

The co-benefits forest bioenergy include:
- Forest health can be improved by the timing and intensity of thinning, stand spacing, rotation length, and site preparation [38]
- Fuel treatments can reduce wildfire intensity and likelihood in residential communities [39].
- Selling low quality wood and fostering better quality higher grade timber provides enhanced silvicultural opportunities [40].
- Provide alternatives to pile burning which releases carbon and other air pollutants directly into the atmosphere without the benefit of capturing the energy [41].
- Potential additional terrestrial carbon created which reduces emissions and provides climate benefits [42, 43].

RESEARCH NEEDS FOR WILDLAND AND URBAN FORESTS RELATED TO CLIMATE CHANGE

The fundamental focus of the research needs discussed in this section is to enhance monitoring and develop a better understanding of forest and woodland ecosystem dynamics. Further, the proposed research needs are intended to promote research that leads to managing forests in a sustainable manner that enhances forest carbon and related ecosystem services. See the Climate Research Needs report and the State Adaptation Plan for additional information on research needs for the forest sector.
- Improved tools and on-going research for monitoring and modeling and to better understand baseline conditions, processes, and projected trends in forest resources, carbon flux and climate related changes.
- Continue and enhance FIA plot data collection. Develop analytical tools to integrate the urban FIA data results into planning and policy decisions.
- Track human related and natural forest disturbances and create and maintain a central, accessible database.
- Utilize public forest lands for a weather station network and conduct long-term monitoring to better understand the relationship between climate and forests.
- Utilize paleoecology to better model and understand climate and vegetation dynamics.
- Reduce uncertainties in forest climate modeling and increase understanding of threats to forest carbon, including those posed by fire, insects, disease and invasive pests.
- Benefit-cost analysis on actions to maintain or enhance forest carbon and other ecosystem services.
- Further research to assess the influence on climate change on forest health and productivity.

FOREST SECTOR – POLICY FRAMEWORK

<u>Interagency Forest Working Group (IFWG)</u>

Pursuant to the initial Scoping Plan,the California Natural Resources Agency (CNRA) through the Board of Forestry and Fire Protection established the Interagency Forestry Working Group (IFWG) to address a broad range of climate change issues. The purpose of the interagency committee was to provide recommendations and technical information to assist the Board in achieving the Board's goals and objectives as outlined in the Board's report to the Air Resources Board on AB32 and in relation to the climate adaptation strategies. Three primary tasks were identified by IFWG:

1. Update the California GHG inventory for the forest sector (ARB lead)
2. Evaluate adequacy of existing forest regulations and programs to achieve Scoping Plan forest sector GHG targets (CALFIRE and USFS lead)
3. Define biomass sustainability for biomass and biofuel utilization (CEC lead)

The Board of Forestry and the California Natural Resources Agency co-chaired the IFWG with participation from seven other departments and agencies including:

California Environmental Protection Agency
Air Resources Board
California Department of Fish and Wildlife
California Energy Commission
Department of Water Resources
CAL FIRE
U.S. Forest Service

There has been significant work on the GHG emissions inventory for forests since the initial Scoping Plan. Preliminary results show that healthy forests can be an important source of sequestration; however, loss of forests through fire and conversion to other uses can release significant CO2. California forests must be managed to ensure that they provide net carbon storage even in the face of increased threats from wildfire, pests, disease, and conversion pressures. Planning targets for ensuring net carbon sequestration, must also ensure forest resilience, health, and continued ecosystem services. Developing such planning targets may require a resource economics study, and funding for such a study will be needed. Implementation of forest climate planning targets will require adequate and sustainable funding sources that will need to be identified.

ENABLING PROGRAMS

CAL FIRE's programs involve collaboration with many other government entities (federal, state, local), private land owners, and nongovernmental organizations. The following programs are established to enhance the range of environmental services that forests provide, including climate benefits:

- Urban and Community Forestry Program
- California Forest Improvement Program
- Vegetation Management Program
- Forest Legacy Program
- Forest Pest Management Program
- Reforestation Services Program

More information on these programs is available at:
http://calfire.ca.gov/resource_mgt/resource_mgt.php

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RANGELAND/GRAZED LAND

Introduction

In California, there are about 33.6 million acres of grazed land (19.2 million acres of privately held and 14.5 million acres of publicly owned grazed forest and rangeland), comprising about one third of the land in the state (Table 1; Figure 1). Additional grazing occurs on extensive desert shrub land. Unless otherwise noted, desert shrub land is not the focus of this discussion. Eight of California's 12 major drainage basins are dominated by vegetation types that are commonly grazed rangeland. This represents roughly twenty ecosystems in California, and a rich diversity of species. Rangeland plays a key role in ensuring watershed function in California. The location of rangeland, between the forested areas and major river systems, means that almost all surface water in California passes through rangeland. Two-thirds of the major reservoirs in the state are located on public and private rangeland. As such, grazed land "green" infrastructure is a cost-effective way of protecting and maintaining healthy watersheds in California. This is accomplished through rangeland conservation programs that aim to secure beneficial land uses through conservation easements and best management practices, in order to protect both water supplies and water quality. Another important set of benefits of rangeland include the natural ability to sequester and store carbon in the plant material and soil.

While rangeland in California is, overall, close to neutral with respect to GHG emissions, a significant mass of carbon is sequestered in rangeland soils throughout the seasonal flux (Kroeger, T., et al. 2009. An Economic Analysis of the Benefits of Habitat Conservation on California Rangelands. Defenders of Wildlife. 91pp.) (USDA. Technical Bulletin 1930.2011.USDA Agriculture and Forestry Greenhouse Gas Inventory: 1990-2008.115pp.). In addition, there is considerable potential to increase sequestration through simple, well known land management practices (Kroeger, T. et al. 2009.). For annual grassland, the greatest benefits in sequestration enhancement are associated with restoration of riparian corridors, restoration of perennial grassland, and control of invasive plant species. For oak-woodland/savanna type rangeland, the greatest benefits in sequestration are associated with restoration of woody species. Finally, for chaparral rangeland, the greatest benefits are associated with control of invasive plant species and management of expanding shrubs and trees (USDA. 2011). These enhanced management approaches, while beneficial for a variety of other ecosystem services, such as species richness and water quality protection, are not generally of significant economic benefit to land managers producing food and fiber through animal grazing. To realize the greatest benefits, incentives or cost shares are often necessary, to induce management practices with multiple social/environmental benefits.

Grazed land soils emit both nitrous oxide and methane, which result from increased available nitrogen and manure off-gassing (USDA.2011.). Rainfall, soil moisture, and intensity of grazing all have an influence on the variability of GHG flux and net capacity in a given timeframe. However, since grazed land is, in general, not plowed, there is still little net emission of GHGs from rangeland. USDA calculated that in 2008, nationwide, 96% of GHG emissions from grazed land were nitrous oxide, methane making up the other 4%. Conversely, grazed lands were a sink for carbon. In some years, the mass balance trends toward carbon sequestration, while in other years the mass of nitrous oxide and methane emissions exceeds that of carbon sequestration (ibid).

In California, between 1984 and 2008, an average of 16,105 acres of rangelands was converted every year, primarily to urban and irrigated agriculture uses (California Department of Conservation. 2011. California Farmland Conversion Report 2006-2008. State of California. 108pp.). Climate change will pose a new threat to rangelands by changing water availability and species distributions. Climate modeling scenarios showed that a loss of rangelands will lead to loss of biodiversity, impaired water quality, less carbon sequestration, less groundwater recharge, and in some cases, less input to food production (Kroeger, T., et al. 2009.). Ecosystem services (resources and processes supplied by natural ecosystems) provided by rangelands include wildlife habitat, groundwater recharge, and carbon sequestration. Recent studies have attempted to assess potential threats to rangeland ecosystems services and to quantify the economic costs and benefits. The key threats for ranching in the future include limited availability of grazing land for lease, fragmentation of grazing land, declining forage quality and quantity, and high start-up investment cost. The expanse of rangeland in California offers significant potential for increased carbon sequestration. While recent publications have begun to address the specifics of carbon sequestration in California landscapes (Silver, W., R. Ryals, and V. Eviner. 2010. Soil Carbon Pools in California's Annual Grassland Ecosystems. Rangeland Ecol Manage 63:128-136.) (Silver, W., M. DeLonge, and J. Owen. 2013. Climate Change Mitigation Potential of California's Rangeland Ecosystems. DESPM, University of California, Berkeley. 30pp.) most of the studies of rangeland carbon sequestration have been conducted outside California. A comprehensive assessment of such opportunities needs to be conducted (PIER. 2003. California Energy Commission Contractor/Consultant Report. Attachment IV – Carbon Sequestration in California's Terrestrial Ecosystems and Geological Formations. 48pp.)

Table I. Area of land cover by owner group (acres in thousands) (From FRAP 2010)

WHR Vegetation Type	Private	USFS	BLM	NPS	Other Public	NGO	Total[1]
Forestland							
Conifer Forest	6653	10762	346	1106	434	34	19335
Hardwood Forest	2828	1305	194	104	151	12	4594
Forest and Rangeland							
Conifer Woodland	466	989	469	317	137	21	2399
Hardwood Woodland	4296	284	193	19	456	45	5295
Rangeland[2]							
Shrub	4842	5806	2353	282	1180	60	14522
Herbaceous[3]	9525	376	433	82	831	159	11407
Desert	3540	137	10450	4772	4325	27	23251
Total Forest and Rangeland	**32151**	**19658**	**14438**	**6682**	**7512**	**358**	**80799**
Other							
Agriculture	11336	3	39	1	237	24	11639
Barren/Other	358	841	428	760	324	3	2714
Urban	3897	6	27	5	221	3	4159
Water[4]							1916
All							
Total	**47742**	**20508**	**14932**	**7449**	**8294**	**387**	**101227**

1 Totals may not add up due to rounding
2 Rangeland refers to “primary” rangeland, and does not include conifer forest, which has rangeland forage potential and is often grazed by livestock
3 Includes wetlands
4 Areas classified as water are not assigned an ownership
USFS – United States Forest Service, Department of Agriculture
BLM – Bureau of Lands Management, Department of the Interior
NPS – National Park Service, Department of the Interior
NGO – non-governmental organizations (e.g., The Nature Conservancy)
Data Sources: California Protected Areas Database, GreenInfo Network (2009); Statewide Land Use / Land Cover Mosaic, FRAP (2006)

(California Department of Forestry and Fire Protection Fire and Resource Assessment Program. 2010. California’s Forests and Rangelands: 2010 Assessment. Sacramento, California.341pp.)

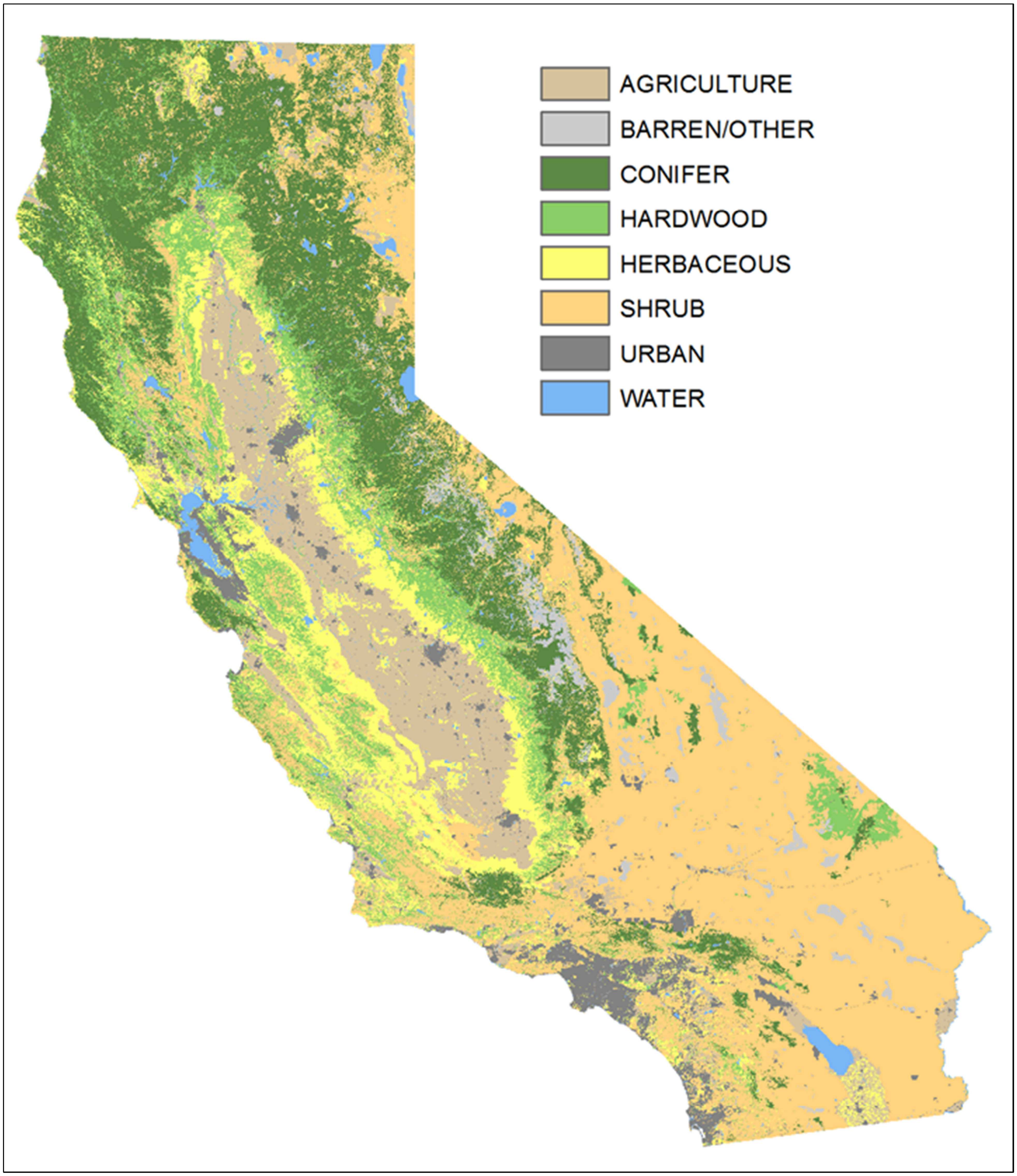

Figure I. Distribution of land cover by type (Derived from CDFFP FRAP 2010)
(CDFFP FRAP. 2010.)

Issues and Opportunities

Grasslands, globally, account for about one-third of stored soil carbon (Silver, W., et al. 2013). Carbon sequestration in rangeland results primarily from forage vegetation growth (ibid). Additional soil carbon sequestration can occur through additions of manure and compost, with a related increase in emission of nitrous oxide and methane (ibid). Rates of carbon sequestration are sensitive to precipitation, with higher precipitation leading to greater soil moisture, increased plant growth, and increased levels of soil carbon (ibid). California precipitation is temporally and spatially highly variable, with modeled future scenarios showing a likelihood of increased variability (ibid). This underscores the need for more complete and ongoing assessment of statewide potential for enhanced management of rangelands for increased sequestration of atmospheric CO_2, where feasible.

Recent publications estimate that there is significant potential to increase annual rates of carbon sequestration in California rangelands through soil amendment, perennial grass enhancement, and tree planting, particularly within the savannah woodland systems (Silver, W., et al. 2013) (Ryals, R. and W. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecological Applications, 23(1), 2013, pp. 46 – 59.) (Silver, W., et al. 2010) Silver et al have calculated that rangeland management carbon sequestration projects implemented on about 28 million acres of the existing rangeland in California could yield increased carbon sequestration of between 21 and 42 million metric tons per year. For comparison, commercial and residential sourced GHGs are calculated to contribute about 42 million metric tons per year. While enhanced carbon sequestration is a promising potential future outcome, maintaining existing rangelands intact is also an important part of meeting future GHG emission targets.

In a recently published study of Yolo County prepared for the California Energy Commission's California Climate Change Center, researchers at the University of California, Davis, calculated relative contributions of GHG emissions from agricultural and non-agricultural land uses (Jackson, L., et al. 2012. Adaptation Strategies for Agricultural Sustainability in Yolo County, California. California Energy Commission. Sacramento. 189pp.) Conversion of agricultural land to other developed uses has been shown to increase GHG emissions by up to seventy times, compared to current emissions. For rangeland, conversion to urban uses is calculated to result in GHG emissions up to 217 times, compared to current emissions. Conversely, conversion of cultivated agricultural land to grazing land will result in an immediate, significant, permanent decrease in GHG emissions by a factor of about 66% per acre fallowed (Jackson, L., et al. 2012).

Conclusions

When rangeland is converted to developed uses, CO_2 emissions can be expected to increase significantly. Depending on the type of development, the increase in CO_2 emissions may be up to two hundred ten times that calculated to occur from average rangelands (Jackson, L., et al. 2012). Existing sequestration rates exhibit a relatively neutral flux of GHG sequestration/emission, while showing reasonably significant potential for modified management activities, and resultant increased rates of sequestration. One of the greatest issues to consider when adding rangeland management to the GHG sequestration toolbox is the marginal financial returns to the land owner. There are not a lot of funds available within existing economics of livestock grazing to fund additional studies, to perform modified management for enhanced carbon sequestration, nor to measure and validate sequestration rates over the long-term. The state must take leadership in developing incentives and cost shares, to protect and enhance the extensive rangelands of California for the greatest benefit of current and future generations.

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WETLANDS

Introduction

The process of carbon capture and storage (sequestration) in the terrestrial biosphere, underground, or in the oceans is a mechanism to reduce the buildup of carbon dioxide (CO2) and other greenhouse gases (GHG) in the atmosphere for the purpose of reducing or slowing GHG-induced climate change. Reducing or slowing GHG emission is the central feature of California's landmark efforts to address global warming. A proven method of carbon sequestration is the use of land and water-based ecological systems to enhance the natural uptake of atmospheric carbon in plants and soil. Acquisition of land through voluntary transactions and the restoration of that land will help protect and expand carbon sequestration potential while working to meet our conservation goals for the state. Sound conservation and management efforts will not only provide direct sequestration benefits but will safeguard long-term sequestration investments.

Wetlands are prime candidates for these mitigation practices for a number of reasons. Wetlands, especially tidal wetlands, have great potential for carbon sequestration due to high levels of net primary productivity and low decomposition rates, meaning that a large amount of organic matter is accumulated annually (Miller et al., 2008). Wetlands can also serve as perpetual long-term sinks for carbon because they continually grow larger from deposition of organic matter and sediments and are therefore relatively self-sustaining over time. Additionally, wetlands have among the most efficient sequestration rates per unit area of all habitat types. That being the case, when wetlands are either converted or degraded they will emit large amounts of previously sequestered carbon (stored carbon), adding to existing GHG emission levels. For example, it was recently determined that global tidal marsh degradation/conversion has led to the release of up to 0.24 billion metric tons of CO2 per year at an estimated cost of 9.7 billion dollars (Pendleton et al., 2012). In the Sacramento-San Joaquin Delta (Delta), a recent study found that approximately 175–299 g-C m^{-2} yr^{-1} were emitted as CO2 and 3.3 g-C m^{-2} yr^{-1} were emitted as CH4 from a grazed degraded peatland (Hatala et al., 2012). Degraded wetlands also have lower sequestration rates than healthy systems (Danone Fund for Nature, 2010). Therefore, restoring and conserving wetland habitats will increase the sequestration potential of our California landscape and reduce future GHG emissions.

WETLAND TYPES AND PRIORITIZATION

California is home to approximately half a million acres of wetlands (see Figure 1 below). Within the state there are many different types of wetlands (e.g. freshwater wetlands, salt marshes, freshwater forested and scrub wetlands, etc.), however not all wetlands are created equal in terms of carbon sequestration potential. To prioritize wetlands for possible acquisition or restoration efforts, a number of different factors must be considered. Assessing these factors for the various wetland types will allow us to identify wetland areas with the highest opportunity for climate change mitigation.

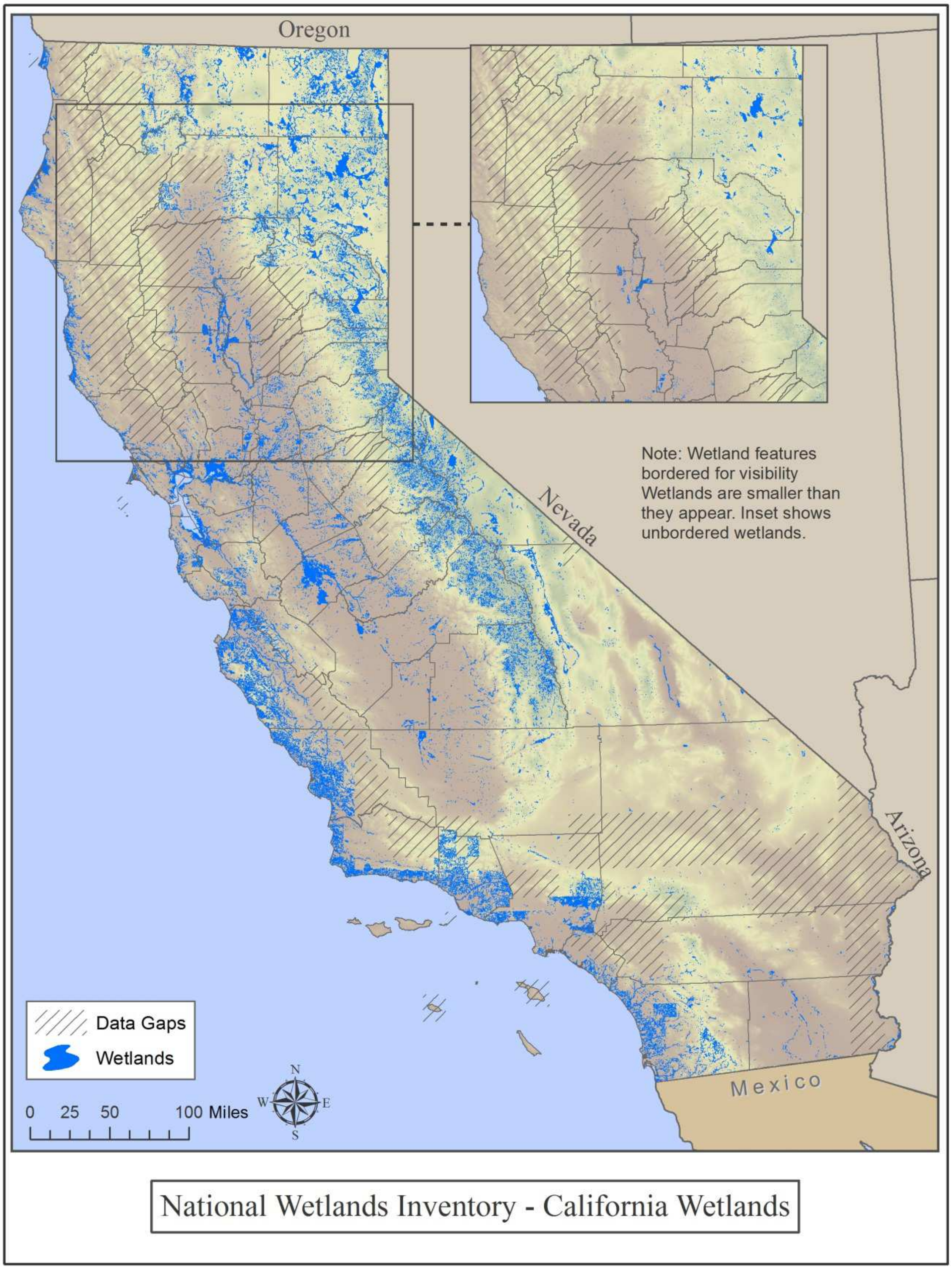

Figure 1: Wetlands in California based on the National Wetlands Inventory.

Important prioritization criteria may include factors such as sequestration rate and stability of sequestration, GHG storage capacity, longevity of sequestration potential, GHG emissions from the wetland, potential release of stored GHGs through degradation or conversion, and other important co-benefits for climate change adaptation and overall ecosystem health and function.

Generally, tidal wetlands, including both freshwater and saline wetlands, are thought to have substantial potential for carbon sequestration now and into the future (Crooks et al., 2009). Freshwater mineral-soil wetlands in the conterminous U.S. were found to have a net carbon balance of approximately 9.8 Mt C per year, with carbon sequestration outweighing carbon loss due to drainage of wetlands (U.S. Climate Change Science Program, 2008). Freshwater tidal wetlands in particular have among the highest sequestration rates of all wetland types including brackish tidal wetlands and salt marshes (Crooks et al., 2009) (see Figure 2). However, freshwater wetlands also emit greenhouse gases such as methane that can potentially offset the sequestration benefits associated with this wetland type.

Comparatively, salt marshes also have high sequestration rates but without the high level of methane emissions; methane emissions are found to generally decrease along a wetland salinity gradient (Poffenbarger et al., 2011). Carbon sequestration in salt marshes may therefore have a greater impact in reducing atmospheric GHG concentrations. However, salt marshes may provide less stability as long-term sequestration investments compared to freshwater tidal wetlands; freshwater wetlands accumulate soil at a faster rate and are therefore more likely to keep pace with sea level rise (Crooks et al., 2009). If a salt marsh cannot rebuild faster than the relative sea level rise in a specific location, the salt marsh may drown thereby deteriorating or eliminating its ability to sequester carbon; stored carbon however, would not be released once submerged.

Given the complexity of wetland carbon and methane fluxes and storage capacities, local knowledge of the wetland type and characteristics (such as vegetation, depth of wetland soils, size, etc.) will be an important input to the prioritization exercise. For example, carbon capture projects carried out by the California Department of Water Resources demonstrate how local factors can influence sequestration at a given location. Twitchell Island, a permanently flooded, managed wetland, is comprised of carbon-rich peat soils commonly found in the Delta. Tule and rice growth on Twitchell Island has not only stopped the peat soils from subsiding, but reversed subsidence by increasing root structure (accretion) which eventually yields soil production. Subsidence reversal in the project area has protected the large carbon stores in the soil that would be otherwise lost through subsidence, while also sequestering additional carbon from plant decay. Although some methane is emitted in the process, these conditions have created a net carbon sink in the project area, with a positive GHG flux of approximately 2.3 tons/acre CO2-eq as measured from May 2012 through April 2013.

Other information, such as the decision-support tool in Figure 3, may also be used to inform the prioritization process. This particular tool examines such factors as carbon storage per unit area, sequestration rates, and GHG emissions (e.g. methane and nitrous oxide) in order to compare carbon offset potential of different wetland habitats. For example, using the tool to examine the prioritization criteria suggests that forested riparian areas also have generally high carbon storage and sequestration rates and low to medium emissions, which might make that community a viable option for restoration as well. Other useful information sources include comprehensive reports such as “Greenhouse Gas Mitigation Typology Issues Paper: Tidal Wetlands Restoration” (Crooks et. al, 2009), where sequestration rates are identified for multiple wetland types (Figure 2). Additionally, scientific articles and research on specific types of wetlands will provide valuable information to the process. Multiple resources will likely be needed to assess not only the sequestration potential of the wetland, but the feasibility of restoration and available management options to implement the desired actions.

Wetland Type	**Carbon Sequestration Potential ($gC\ m^{-2}\ yr^{-1}$, $gCO_2e\ m^{-2}\ yr^{-1}$)**	**Methane Production Potential ($gCH_4\ m^{-2}\ yr^{-1}$, $gCO_2e\ m^{-2}\ yr^{-1}$)**	**Net Balance**
Mudflat (saline)	Low (<50, 184)	Low (<2, 50)	Low C sequestration
Salt Marsh	High (50-250, 184-917)	Low (<2, 50)	High C sequestration
Mangrove	High (50-250, 184-917)	Low – High	Depends on salinity
Brackish Tidal Marsh	High (250-450, 183.3-1650)	High (5-100, 125-2,500)	Unclear[48]
Freshwater Tidal Marsh	Very High (500-1000, 1,833-3700)	High - Very High (40-100+, 1,000-2,500+)	Unclear – potential very high C [49]
Estuarine Forest	High (100-250, 366.7-	Low (<10, 250)	High C sequestration

Figure 2: Summary of carbon sequestration and methane production across the salinity interface (from Crooks et al., 2009). Note: $1gC \equiv 3.67\ gCO_2e$; $1gCH_4 \equiv 25\ gCO_2e$

		Carbon storage / unit area	Global total carbon storage	Sequestration rates	Carbon fluxes/area (3 high)	$N2_0/CH_4$ emissions (3 high)	Net CO_2 equivalent seq. (3 net cooling)
Riverine	River, waterfalls, wadi	0	0	0	3	0	0
	Forested riparian /alluvial	2-3	2	? - 3	3	1-2	1-2
	Non-forested marshes / deltas	1-2	1	?	2-3	3	1
	Permanent: depressional wetland, oases, ponds, karst, marshes, prairie pothole	1-2	1	1-2	1	3	1

Mineral soil flats &	Seasonal wet non-forested: meadows, salt pans, dambos	1	1	1	1	0-1	0-1
	Seasonal wet forested: swamps	2-3	2	1	2-3	0-1	0-1
Organic soil flats	Temperate, alpine and boreal forested wetlands	3	3+	0-2	1-2	1-3	1-2
	Temperate, alpine and boreal non-forested wetlands	3	3+	0-2	1-2	1-3	1-2
	Tropical non-forested peatland	3	1	0-3	2	2-3	1
	Rice paddies	2-3	2	0-1	?-2	1-3	1
	Tundra	2	2-3	0-1	1	1	0-1
	Tropical peat swamp forests	3+	1	0-3	2	1	2-3
Slope	Mineral soil: freshwater springs, fens, oases	1-2	1	0-1	2	1-3	1
	Peat soil: freshwater springs, fens, sloping bogs/mires, oases	3	1	0-3	2-3	1-3	1-2
Lacustrine	Natural: lakes, glacial lakes	1-2	1-2	1-2	1-2	1-2	?
	Human made: reservoirs and dams, post mineral extraction sites (gravel, mine), aquaculture ponds, treatment ponds	1-2	1-2	1-3	2-3	1-3	1
	Marsh wetlands	1-2	1	2-3	2	3	1
Estuarine &coastal fringe	Salt marsh	2-3	1	3+	3	1	3
	Saline / coastal lagoons	1-2	1	2	3	1	2
	Mangroves	2-3	1-2	3+	3	1	3
	Nearshore: seagrass, kelp, macro-algal complexes	1-2	1	?-2	3	1	?-2
	Coral reefs	2	1	0-1	3	0	1-2
	Shellfish reefs	2	1	0-1	3	0	1-2
	Mudflats, tidal flats, beaches	1-2	1-2	0-2	3	1	0-2
	Coastal aquaculture / mariculture	1	1	?	?-2	?	?
Other	Caves	0	0	0	?	0	0
	Treatment wetlands	1	0	0	3+	3	1

Figure 3: Carbon storage and sequestration potential (naturally functioning wetlands, including artificial wetlands). From “Achieving Carbon Offsets through Mangroves and Other Wetlands” (Danone Fund for Nature, 2010)

CLIMATE CHANGE ADAPTATION CO-BENEFITS

In addition to sequestration rates and capacity, adaptation co-benefits should be part of the prioritization process. Generally, wetland restoration and conservation to promote carbon sequestration also provide an opportunity to meet some of the climate change adaptation objectives identified for natural resources in the state. For example, preserving these ecological communities with an eye towards increasing connectivity can help to create a large-scale, well connected, sustainable system of conservation areas that will be necessary for allowing species movement and persistence into the future. Sequestration activities will also restore and enhance ecosystem function to conserve both species and habitats in a changing climate, and provide an opportunity to manage endemic and priority species populations. These are all important adaptation actions identified in the 2009 California Climate Adaptation Strategy (CAS 2009) for the biodiversity and habitats sector. Other co-benefits, the extent of which will vary by wetland type, include reducing land subsidence, providing habitat for fish and wildlife, and supporting esthetic, recreational and commercial uses. Certain co-benefits are also linked to other sectors. For example, wetland restoration and avoided degradation can reduce fire potential, serve as a buffer to flooding events by increasing flood capacity, restore ground water recharge and reduce the need for pumping, protect water quality and provide water supply reliability, etc.

Restoration can be considered a nature-based solution for addressing climate change by increasing sequestration and preventing future emissions while also protecting ecosystem services, which can have additional cost-benefits for the community. For example, projected sea-level rise is estimated to put approximately $100 billion worth of assets at risk in California, about two-thirds of which are concentrated in the San Francisco Bay Area (Heberger et al., 2011). Restoring San Francisco Bay's tidal marshes is one way to protect valuable shoreline development from sea level rise. "Tidal marshes can provide significant flood protection benefits by attenuating wave energy during storms, and at significantly lower cost than traditional flood risk management structures. By using tidal marshes in combination with earthen levees, construction and maintenance costs can be reduced by almost 50%" (ESA PWA, 2013).

ACTIONS

Actions can be taken now to undertake efforts to reduce future GHG emissions through wetland restoration. The following actions have been identified as important to effectively manage wetlands for sequestration in the future:

- Develop funding mechanisms to support efforts to restore, conserve, and protect wetlands.
- Restore, conserve, and maintain existing wetlands in addition to creating new areas that were not previously sequestering carbon.
- Avoid wetland degradation and conversion that could potentially reduce sequestration benefit and increase emissions
- Develop actionable policies and measures that conserve wetland resources that provide high sequestration benefit
- Pursue research related to measuring carbon sequestration potential that will inform and support management actions that maximize sequestration longevity

There are some challenges and issues we can expect to face when pursuing these actions. Cost of restoration activities, development in high priority wetland areas (especially in coastal locations), and jurisdiction over lands will impact the location and scale of restoration efforts. Once an area has been identified, there are other challenges related to GHG measurement and monitoring that will affect our ability to take these actions. For example, varying methodologies for GHG quantification and the need for vigilant monitoring could be seen as barriers. There is also scientific uncertainty surrounding "wetland gas exchange rates (including CO_2, CH_4, and N_2O), wetland interactions with the surrounding landscape (specifically carbon budgets), and carbon accumulation rates in the soil and litter column of wetlands" (Crooks et al., 2009). GHG accounting is also inherently difficult within a defined boundary when working with dynamic systems such as tidal wetlands. A comprehensive discussion of potential challenges and possible solutions can be found in the 2009 PWA report (Crooks et al., 2009).

ENABLING PROGRAMS

Many existing programs will support the implementation of the actions described above. A sampling of enabling programs and how they may aid in implementation are presented in Table 1 and described below.

California Department of Fish and Wildlife	
	Climate Science Program
	Resource Assessment Program
	Fisheries Restoration Grant Program
	Natural Community Conservation Planning Program
	Inland wetlands conservation program
	Riparian habitat conservation program
	Conservation Reserve Program
	Environmental Quality Incentives Program
	Wildlife Habitat Incentives Program
	Comprehensive Wetland Habitat Program
	California Waterfowl Habitat Program
	California Landowner Incentive Program
California Department of Water Resources	
	West Delta Program
	Central Valley Flood System Conservation Strategy

Table 1: Programs within the California Department of Fish & Wildlife and the California Department of Water Resources that will enable the identification of priority wetland areas for sequestration and help facilitate acquisition and restoration efforts.

<u>Climate Science Program:</u> The Climate Science Program at the Department facilitates the integration of climate change into all policies and programs at the Department as appropriate to lead to climate adaptation and mitigation actions on the ground. The program also coordinates with partners at a national, regional, and state-wide level on climate change research, projects, guidance, strategies, and more.

<u>Natural Community Conservation Planning Program:</u> Conservation planning tools, such as landscape-scale Natural Community Conservation Plans (NCCP), provide a regulatory framework for conserving biologically important landscapes. Many of these NCCPs already exist and many more are in development throughout California (e.g. the Bay-Delta Conservation Plan). There is tremendous potential through future land

acquisitions and habitat restoration in both existing and future NCCP plans to sequester even more carbon, benefitting the conservation plans and meeting the state's mandated reductions under AB 32.

Resource Assessment Program: One of the Department's most valuable assets is the wealth of scientific data collected under the Resource Assessment Program, including information on the distribution and abundance of fish, wildlife, native plant species, and the natural communities and habitats in which they live. The Department's Resource Assessment Program is well positioned to develop and implement a long-term and strategic inventory and monitoring program that could inform implementation and evaluation of projects that support AB 32 emissions reduction targets. Already the Department is working with other state, federal, and conservation partners to develop a statewide, long-term monitoring effort to evaluate the effects of climate change on indicator species, populations, communities and ecosystems. Currently, almost all data collection and monitoring is done in conjunction with partners in the UC and CSU system. Many studies to gather baseline data also include information from industry representatives and contributions from citizen scientists. Variables related to the distribution and abundance of priority species, habitats, and natural communities in California provide insight into ecosystem health and function, which could have direct ties to the ecosystem's ability to sequester carbon. Measuring these indicators could also contribute to a cost/benefit analysis of mitigation and adaptation projects to inform state actions to reach emissions reduction goals. In addition to species and habitat data, the RAP could begin to develop GHG emissions and storage data. Effectively monitoring species, habitat, and GHG data will be crucial to establishing a baseline from which to measure change and assess the efficacy of our efforts to reduce GHG emissions.

Fish Restoration Grant Program: The Fisheries Restoration Grant Program (FRGP) was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California. This competitive grant program has invested millions of dollars to support projects from sediment reduction to watershed education throughout coastal California. Contributing partners include federal and local governments, tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners.

Wildlife Conservation Board Programs: The primary responsibilities of WCB is to select, authorize and allocate funds for the purchase of land and waters suitable for recreation purposes and the preservation, protection and restoration of wildlife habitat. WCB approves and funds projects that set aside lands within the State for such purposes, through acquisition or other means, to meet these objectives. WCB's three main functions are land acquisition, habitat restoration and development of wildlife oriented public access facilities, which are carried out through its programs.

Wildlife Branch Programs: The Comprehensive Wetland Habitat Program (CWHP) was established in 1990 in response to the nationwide groundswell of interest in wetland preservation, restoration, and enhancement. The CWHP provides coordination, direction, and funding for many of the Department's wetland habitat programs and activities. Although the responsibilities of the CWHP extend statewide, the program is focused primarily on the Central Valley.

DWR West Delta Program: The objective of the West Delta Program is to implement different land-use management strategies to reverse subsidence, while maintaining economic viability on Sherman and Twitchell islands and decreasing the stresses on the levee systems. These management strategies often also provide diverse habitat for wildlife and waterfowl. The Department is also conducting work to benefit species of wildlife that occupy wetland, upland, and riparian habitats and to provide recreational opportunities for hunting and viewing. In addition, property acquired and habitat developed through the Department's efforts will be available as mitigation for impacts associated with ongoing Delta flood management programs.

Central Valley Flood System Conservation Strategy (CVFSCS): The CVFSCS, an integral part of the Central Valley Flood Protection Plan, outlines processes to increase and improve the quantity, diversity, quality, and connectivity of riverine habitats in the flood management system. Ultimately the lands converted to wetland, riparian, and upland habitats will increase the opportunities for sequestering carbon within the flood system.

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