Appendix A

Carbon Stock Data, Tools, Inventory, and Forecast

Memo

455 Capitol Mall, Suite 300
Sacramento, CA 95814
916.444.7301

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To: Amaury Berteaud, Gina Schmidt, and Will Condon (AMBAG)

From: Liz Luck, Brenda Hom, Hannah Kornfeld, and Poonam Boparai (Ascent)

Subject: **Monterey Bay Natural and Working Lands Climate Mitigation and Resiliency Study – Existing Tools, Data, and Literature Final Technical Memorandum**

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1 INTRODUCTION

The Association of Monterey Bay Area Governments (AMBAG) is developing a Monterey Bay Natural and Working Lands Climate Mitigation and Resiliency Study (Study), a carbon model of the Monterey Bay Natural and Working Lands, and conducting a scenario-based study to explore the impact of different climate change and land use scenarios, as well as the implementation of different climate adaptation and mitigation strategies. The goal of the Study is to create a geospatial carbon sequestration model for the counties of Santa Cruz, Monterey, and San Benito. This technical memorandum outlines the tools and data that could support the creation of the carbon stock inventory and development of carbon sequestration strategies.

The data and methods discussed in this technical memorandum are evaluated for their accuracy relative to the local context, consistency with statewide inventory protocols, and their ability to be updated into the future. The quantification of carbon stock and sequestration values is an evolving area as statewide efforts are focusing more on carbon sinks to meet the goal of carbon neutrality by 2045. There is no readily available tool that precisely estimates the carbon stock and sequestration potential at a local level. Instead, and as part of the Study, a variety of existing tools, datasets, and methods for quantifying carbon stock from natural and working lands are available and will be used in combination to develop a carbon model for the Monterey Bay Area.

1.1 ORGANIZATION OF THIS MEMORANDUM

This technical memorandum includes five sections:

- **Section 1: Introduction** provides the background and key words for this technical memorandum.
- **Section 2: Carbon Stock Methodology Overview** describes the components of a carbon stock inventory and compares geospatial data types used in carbon stock quantification tools.
- **Section 3: Comparison of Existing Tools, Data, and Literature** compares available information on mapping resources, existing carbon inventories, and models, as well as how they can be used in conjunction with one another.

- **Section 4: Data Gaps** outlines the considerations that should be accounted for with the available data sources, tools, and models.
- **Section 5: Recommendations** includes recommendations for data resources and tools to use in the creation of a carbon stock and sequestration inventory tool.

1.2 KEY TERMS

The following key terms are used throughout this technical memorandum and are defined as such:

- **Carbon Pool:** A system which has the capacity to accumulate or release carbon, considered to be a reservoir. Examples include forest biomass, wood products, soils, and the atmosphere (Intergovernmental Panel on Climate Change [IPCC] 2000).
- **Carbon Sequestration:** The process of increasing the carbon content of a carbon pool other than the atmosphere (IPCC 2000).
- **Carbon Stock:** The absolute quantity of carbon held within a pool at a specified time (IPCC 2000).
- **Soil Carbon:** Included inorganic and organic carbon, it constitutes 75 percent of terrestrial carbon (Ecological Society of America 2000).
- **Soil Inorganic Carbon:** Mineral forms of carbon, either from weathering of parent materials, or from a reaction of soil minerals with atmospheric carbon (Haque et al. 2020).
- **Soil Organic Carbon:** The amount of carbon within the organic compounds of soil. Soil organic carbon accounts for 58 percent of soil organic matter (Ecological Society of America 2000).
- **Soil Organic Matter:** A mixture of carbon compounds consisting of decomposing plant and animal tissue and carbon associated with soil minerals and microbes (Ecological Society of America 2000).
- **Natural Lands:** Lands consisting of forests, grasslands, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas, watersheds, wildlands, or wildlife habitats, or lands used for recreational purposes such as parks, urban and community forests, greenbelts, trails, and other similar open-space lands. For purposes of this paragraph, "parks" includes, but is not limited to, areas that provide public green space (California Public Resources Code 9001.5).
- **Working Lands:** Lands used for farming, grazing, or the production of forest products (California Public Resources Code 9001.5).

2 CARBON STOCK METHODOLOGY OVERVIEW

2.1 ANATOMY OF A CARBON STOCK INVENTORY

A carbon stock inventory represents the amount of carbon stored in natural (e.g., forests, wetlands, grasslands) and working lands (e.g., cropland) at a specified time. The Study aims to develop a data-driven carbon inventory to provide a baseline of carbon stock in Monterey, Santa Cruz, and San Benito counties. To quantify the carbon stock and sequestration potential of an area, both aboveground and belowground data sources of carbon pools must be assessed. The types and sources of carbon that will be evaluated in the Study are described below and depicted in Figure 1.

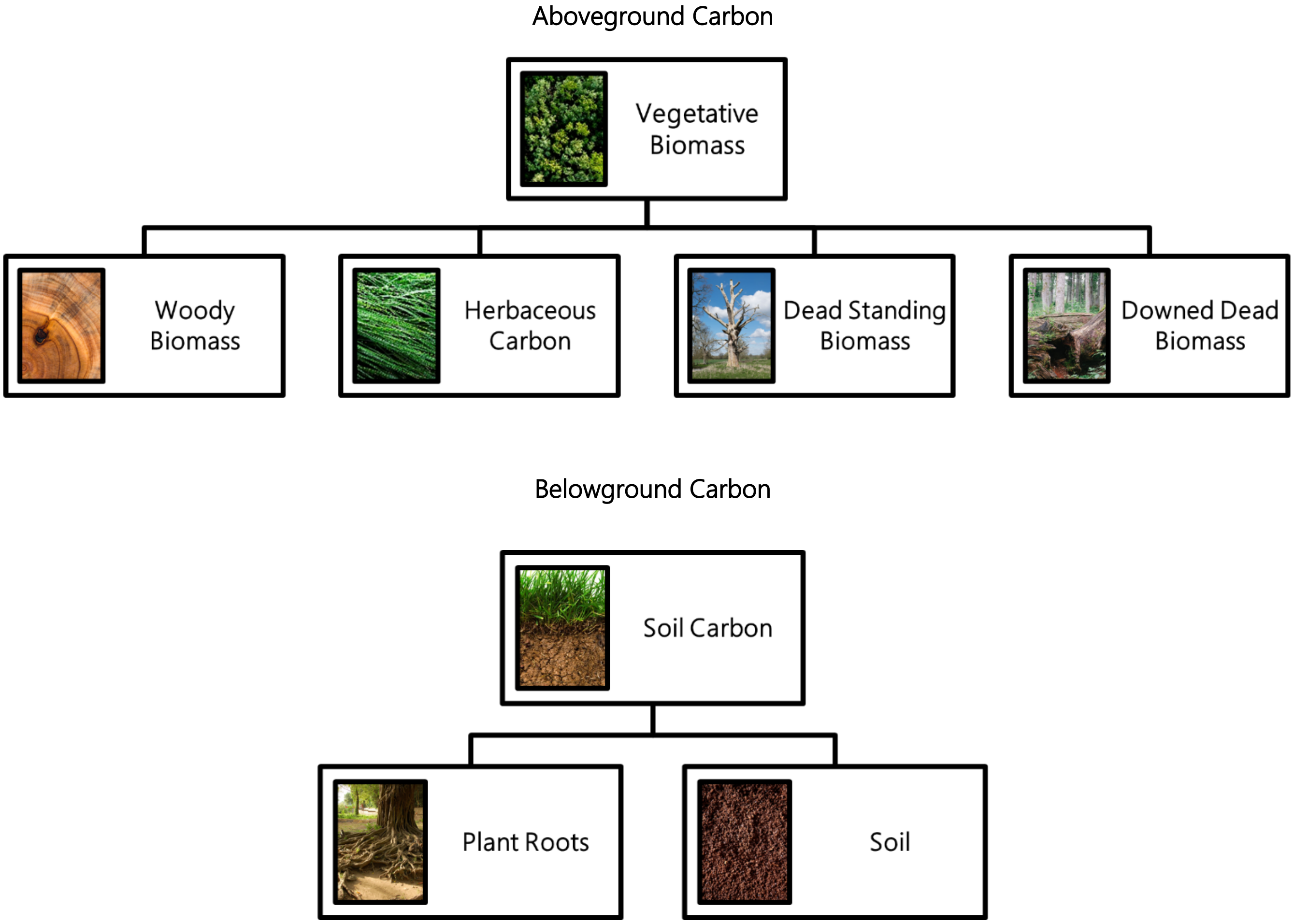

Figure 1 Types and Sources of Carbon included in a Carbon Stock Inventory
Source: Ascent Environmental 2022

2.1.1 ABOVEGROUND CARBON

Aboveground carbon is the amount of carbon stored within vegetative biomass that is above the soil. Vegetation utilizes photosynthesis to take carbon dioxide out of the atmosphere and incorporate the carbon into biomass. Aboveground carbon includes woody biomass in trunks, branches, and shoots as well as herbaceous carbon in leaves, flowers, fruiting bodies, and grasses. Additionally, aboveground carbon includes the carbon in leaf litter, dead standing biomass, and downed dead biomass. Approximately 45-50 percent of the dry biomass weight of the vegetation is equivalent to its carbon stock (McGroddy et al. 2004; Schlesinger 1991). An example of estimating aboveground carbon stock in forests is described in the *California Forest and Rangeland Greenhouse Gas Inventory Development Final Report* (hereafter referred to as the Forest and Rangeland Report) (Battles et al. 2013). As discussed in the Forest and Rangeland Report, the US Forest Service's (USFS's) Forest Inventory and Analysis Program (FIA) calculated forest biomass using decadal data on tree height and diameter sampled by FIA. Forest biomass was estimated using volume-to-biomass models for individual tree species and was then converted to carbon stock using a 47 percent conversion rate (a median factor of the 45-50 percent range presented above). For other vegetation types included in a forest (aside from trees), scientific literature provided estimates of average biomass using similar sampling methods and was also converted to carbon stock using the 47 percent conversion rate (Battles et al. 2013).

2.1.2 BELOWGROUND CARBON

Belowground carbon is the carbon stored within plant roots and soil. Plant root carbon stock is estimated the same way as aboveground carbon: estimating biomass by using the dry weight of the materials and converting the biomass to carbon. In soil, carbon is primarily stored as soil organic matter (SOM). SOM is a mixture of carbon compounds consisting of decomposing plant and animal tissue and carbon associated with soil minerals, and microbes. Within SOM, approximately 58 percent is soil organic carbon (SOC) which represents the distinct carbon pool in the soil (Lal 2004). Overall, soil carbon (i.e., organic and inorganic carbon) constitutes approximately 75 percent of the carbon in terrestrial environments, which is three times the amount stored in living plants and animals. Soils represent a massive sink potential for carbon dioxide from the atmosphere, although soil carbon can either be stored in the soil for millennia or can be quickly released back into the environment due to decomposition. Decomposition of organic matter in the soil by microbial activity can release carbon dioxide as a byproduct, causing the soil to also be a source of atmospheric carbon. The length of time that carbon is stored in soils can be affected by a variety of factors such as vegetation type, climatic conditions, and soil properties such as texture and type. Further, management practices can affect a soil's potential to be either a source or a sink of carbon. For example, conservation farming practices such as reduced tillage, cover cropping, and crop rotation can be used to increase soil carbon compared to conventional practices (Ecological Society of America 2000).

One way to measure the more long-lasting pools of soil carbon is to take soil samples to analyze SOC (Lal 2004). As described by IPCC's *Guidelines for National Greenhouse Gas Inventories*, "over time, soil organic carbon reaches a spatially-averaged, stable value specific to the soil, climate, and land-use and management practices" (IPCC 2006:2.29). To quantify SOC in undisturbed soils, SOC values from soil samples with different soil types, climates, land uses, and management practices can be averaged spatially.

2.2 GIS DATA

To create a carbon stock inventory and forecasts, different types of geographic information system (GIS) databases can be used. GIS databases use one of two methods to store data: raster or vector. Raster datasets are continuous geographic data that use a matrix of cells which each contain an attribute value and a coordinate location. Each cell is the same size and represents an area on the map, which is the spatial resolution of a raster dataset. Raster data sources can be remotely sensed data, satellite imagery, aerial imagery, and shaded or topographic data. Examples of raster datasets are digital elevation models, slope, or rainfall (GIS Lounge 2022). Vector data represents geographic data that are symbolized as points, lines, and polygons. Polygon data is the most applicable in delineating carbon stock values based on geographic area because it can be specifically created around a land use boundary, as opposed to a square cell in a raster. Polygon data requires manual creation, which can be accomplished by using surveyed data points that have been linked to geographic coordinates through georeferencing, by drawing it by hand, or other methods (GIS Lounge 2022).

2.2.1 RASTER-BASED APPROACH: TERRACOUNT EXAMPLE

TerraCount, a model created by the California Department of Conservation, uses raster datasets to quantify carbon stock on a spatial scale. TerraCount tiers from and adds to the statewide greenhouse gas (GHG) and carbon sequestration inventory developed by the California Air Resources Board (CARB). TerraCount is based on a methodology that quantifies aboveground and belowground carbon stock in GIS using US Department of Agriculture's (USDA's) and the US Department of the Interior's Landscape Fire and Resource Management Planning Tools (LANDFIRE). LANDFIRE is remotely sensed data for the US, which has a spatial resolution of 30 meters (m) by 30 m.

Aboveground Carbon

To estimate aboveground carbon stock, TerraCount overlays existing vegetation cover (EVC), existing vegetation height (EVH), and existing vegetation type (EVT) raster datasets on a geographical area. Each cell of the raster is then linked to a unique carbon density value, created by CARB, based on the combination of three raster layers (i.e., vegetation type, vegetation height, vegetation canopy cover) (Battles et al. 2013; CARB 2018; Gonzalez et al. 2015; Saah et al. 2016). In the methodology used to develop TerraCount, the LANDFIRE remotely sensed land cover classes were not found to be accurate, so custom land cover classes were created using a coded model, as noted in TerraCount Appendix C (DOC n.d.). Some external data sources were used to distinguish land cover classes; for example, raster data from the USDA's Cropland Data Layer (CDL) was used for crops. Further classification like water and the urban forests were delineated into polygons using US Census Bureau data and visual georeferencing.

Belowground Carbon

To assess soil carbon stock using TerraCount, an IPCC Tier 2 method was used (i.e., a baseline carbon stock was estimated and the carbon stock was adjusted up or down if agricultural management practices are applied). First, polygon data was overlaid on IPCC defined climate zones and soil zones (based on Soil Survey Geographic database for the state of California). Then, the combination of the climate zone and soil zone vectors was further distinguished by crop type and was linked to a unique inventory value for soil carbon stock. The baseline carbon stock values were adjusted with carbon sequestration rates based on agricultural management practices, which were given by the USDA's COMET-Planner tool.

2.2.2 VECTOR-BASED APPROACH: MONTEREY COUNTY EXAMPLE

Vector datasets can be used to quantify carbon stock on smaller spatial scales that are more precise for the area of study. For example, in quantifying the carbon stock and carbon sequestration potential of natural and working lands in unincorporated Monterey County as part of the Community Climate Action and Adaptation Plan (CCAAP), a vector-based approach was used.

Aboveground Carbon

For the CCAAP, land cover types were obtained through the USFS's Classification and Assessment with Landstat of Visible Ecological Groupings (CALVEG) for California's Central Coast (which includes the Monterey Bay Area). CALVEG includes vector data for ecosystems such as Blue Oak Woodland, Juniper, Eucalyptus, Montane Chapparal, among others. The US Fish and Wildlife Service's National Wetlands Inventory (NWI) polygons were then overlaid in GIS, and in instances where the CALVEG wetland layer overlapped, the CALVEG data was removed because NWI data is more precise to wetlands. Finally, raster data from the USDA's CDL database was overlaid to provide definitive types of crops for carbon quantification. This raster data was converted into polygons that aggregated crop types to conduct the analysis. CALVEG, NWI, and CDL informed the area's land cover types, which were then converted to carbon values by using GIS acreage and carbon sequestration rates provided at a statewide level (Battles et al. 2013; CARB 2018; Gonzalez et al. 2015; Saah et al. 2016).

Belowground Carbon

Soil carbon stock and vegetative carbon stock inventory data was incorporated from the US Geological Survey's (USGS's) *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States* (referred to hereafter as USGS Report) (USGS 2012). The USGS Report provides carbon density estimates for the carbon stock baseline by providing SOC, live biomass, and dead biomass by ecoregion, which is classified as the Central Coast and interior ranges for the CCAAP (USGS 2012:55).

2.2.3 CONSIDERATIONS FOR GIS DATA TYPES

The benefit of using raster data is that the remotely sensed geospatial data can be updated with less manual entry when compared to a vector dataset. The resulting carbon density values are also based on the distinct measurable vegetation characteristics within each cell such as EVH and EVC. However, cell size and resolution are coarse and can overgeneralize land use types for an area that has many different land uses, as well as an area with heterogenous vegetation height and cover. In the Forest and Rangeland Report, the EVT raster dataset has been noted to result in stratification problems with regards to carbon density values because the land use types are averages of the area and are not specific compared to vector-defined land use types (Battles et al. 2013, Saah et al. 2016). Another limitation of raster data is that there are no raster datasets that quantify soil carbon that would be at the same resolution as the LANDFIRE aboveground carbon raster dataset. Remote sensing or satellite data of soil properties are not capable of penetrating the vegetation cover; therefore, soil maps are typically based on soil surveys that are transferred into vector datasets.

Overall, with GIS analysis, translating between raster and vector data is possible but can be a time-intensive process with large datasets. In the TerraCount methodology, every 30 m raster would need to be converted into a separate polygon for the Study. The polygons created would likely cover multiple land use types in the Study area but would be averaged to represent the majority in each 30 m cell, resulting in overestimation or underestimation of carbon stock depending on the dominant land use. On the other hand, when using vector boundaries, land use can be designated with finer resolution, which will better integrate with AMBAG's Land Use Model. Further, carbon quantification can be assessed by using statewide or locally specific sequestration rates for different vegetation types that will pair better with specific vector land use type polygons.

3 COMPARISON OF EXISTING TOOLS, DATA, AND LITERATURE

A variety of land cover databases, carbon stock, and sequestration factors were evaluated for use in the Study. Each resource is described separately in the sections below.

3.1 LAND COVER DATABASES

3.1.1 LANDSCAPE FIRE AND RESOURCE MANAGEMENT PLANNING TOOLS

LANDFIRE is a series of raster GIS data that represents vegetation, fuel, disturbance, and fire regime geospatial data products for the US. It is a shared program between the wildland fire management programs of the US Department of the Interior and USFS. LANDFIRE is consistent, standardized, and comprehensive; the data are updated every 2 years and made available publicly (LANDFIRE n.d.). The three vegetation rasters that are useful in creating carbon density values, as described in the TerraCount methodology, are EVT, EVC, and EVH. Specific carbon densities can be evaluated for each raster cell depending on the combination of vegetation type, cover, and height that it contains by using the inventory 'lookup tables' outlined in the *Technical Improvements to the Greenhouse Gas (GHG) Inventory for California Forests and Other Lands* Report (referred to hereafter as the GHG Forest Report) (Saah et al. 2016).

3.1.2 CALIFORNIA PROTECTED AREAS DATABASE AND CALIFORNIA CONSERVATION EASEMENT DATABASE

California's Protected Areas Database (CPAD) and the California Conservation Easement Database (CCED) are created and frequently updated by the GreenInfo Network and are funded by the California Natural Resource Agency and the California Department of Water Resources. CPAD is a GIS vector dataset that depicts lands that are owned in fee and protected for open space purposes by over 1,000 public agencies or nonprofit organizations. CCED is a GIS vector dataset that contains lands protected under conservation easements and deed restrictions on private land. These restrictions limit land uses to those compatible with maintaining it as open spaces (i.e., natural habitat, farming, or forestry). CCED and CPAD were used in the Monterey County CCAAP carbon storage and sequestration estimate because land ownership type, combined with land use and location, are linked to carbon sequestration rates in the California Natural and Working Lands Carbon and Greenhouse Gas Model (CALAND) inventory (CARB 2018).

Cropland Data Layer

CDL is a GIS raster database that is crop-specific with georeferenced land cover that is annually updated by the USDA's National Agricultural Statistics Service (NASS). The raster data for the continental US uses moderate resolution satellite imagery and extensive agricultural ground truthing by the USDA's Farm Service Agency. The Farm Service Agency collects data from 41,000 farms that are visited annually, representing 11,000 area segments, which provides a statistically robust dataset of acreage and crop types that can be used to build a regression model estimate USDA n.d. A). By utilizing crop layers within CDL data, a geospatial carbon stock with distinct carbon sequestration rates can be paired with crop types (USDA n.d. B).

Classification and Assessment with Landstat of Visible Ecological Groupings

CALVEG is created by USFS and the USDA. Land type categories are based on forest, woodland, chaparral, shrubs, and herbaceous vegetation in addition to non-vegetated units. CALVEG can provide more locally specific vegetation indices compared to nationally created indices such as LANDFIRE. Vegetation vectors from this data can then be paired with inventory values based on scientific literature for the given species (USDA n.d. C).

National Wetlands Inventory

NWI is a vector dataset created by the US Fish and Wildlife Service. The geospatial data provided by NWI is on deep-water habitats and wetlands. The trends and changes of wetland habitats through time are also provided in this dataset. NWI covers the change in wetland habitats from the 1700s to 2009 and the data is produced on a 10-year basis. Wetland polygons can be added to delineate these habitats with special characteristics, such as montane riparian, freshwater emergent wetland, etc., which can then be assigned wetland carbon sequestration rates based on locally specific scientific literature or inventories (US Fish and Wildlife Service n.d.).

3.2 CARBON STOCK AND SEQUESTRATION FACTORS

3.2.1 CALIFORNIA NATURAL AND WORKING LANDS CARBON AND GREENHOUSE GAS MODEL

CALAND is a model created by CARB that quantifies the impacts of land use and management strategies on GHG emissions and carbon stock in California. CALAND uses a carbon inventory with carbon sequestration rates that are based on the land type, region, and land ownership of the area (CARB 2018). The carbon sequestration rates within the inventory are based on scientific literature specialized to types of ecosystems, land ownership, and locations within California. These inventory values are dependent on the CARB inventories, which are the same sources that the TerraCount methodology relies upon. The soil carbon sequestration rates are based on the USDA's Natural Resources

Conservation Service's (NRCS's) Gridded Soil Survey Geographic Database (gSSURGO), which uses soil survey data to estimate the carbon density of the soil for 0-150 centimeters depth (CARB 2018). To quantify carbon sequestration geospatially, the values in CALAND's inventory can be linked to vector datasets such as CPAD, CCED, CALVEG, and CDL.

Land Use and Carbon Scenario Simulator Model

USGS's Land Use and Carbon Scenario Simulator Model (LUCAS) is designed to track changes in land cover, land use, land management, and disturbance, and the associated impacts on ecosystem carbon stock and flux. Within the model there is the Stock and Flow Model, the State-and-Transition Model, and the Linkage to the Integrated Biosphere Simulator (IBIS). The State-and-Transition Model simulates changes in land use across a range of geographic scales such as land cover class change due to urbanization, wildfire, agricultural expansion, among others. The Stock and Flow Model tracks the movement of carbon between different carbon pools including interactions between the land and atmosphere which includes carbon from growth, emissions, and mortality. The IBIS is a dynamic global vegetation model that represents a wide range of terrestrial processes including canopy physiology, vegetation dynamics and competition, plant phenology, land surface physics, and carbon and nutrient cycling. USGS is still developing the LUCAS model, but the latest code is available for R studio with the download of SyncoSim Software (USGS 2018).

Carbon in Riparian Ecosystems Estimator for California

The Carbon in Riparian Ecosystems Estimator for California (CREEC) is a web-based tool created by the California Department of Conservation that predicts carbon dynamics in California's riparian forests from their start into year 100 of growth. It can be used for riparian forest restoration and other conservation projects. The user inputs into CREEC the previous land use, intended forest community, the geographic location, and type of restoration approach for proposed riparian projects. Carbon stock in biomass and in soil is output at an interval of 5 to 10 years. Carbon stocks are modeled based on statistical relationships between age and live tree biomass. Soil carbon is modeled by using recovery from a depleted amount of SOC to an expected mean value for forest type; the initial depletion is dependent on the previous land use and degree of soil disturbance with sampling preparation (California Department of Conservation 2018). In Mediterranean climate systems, uncertainties were noted to be high and soil carbon underestimation is likely. The model also relies upon field surveys for biomass estimation that are limited because production forestry systems are surveyed, which is not representative of natural systems (Matzek et al. 2018).

Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States

The USGS Report provides inventories of carbon stocks (USGS 2012). The carbon sequestration rates are based on remote sensing, soils, and land management variables and are specific to ecoregions (e.g., California's Central Coast and interior ranges) in Western United States, as defined by the US Environmental Protection Agency. The carbon stocks for soil, live biomass, and dead biomass have been used to assess carbon stock by using the ecoregion vector data, the ecosystem type (such as forest or agriculture), and the acreage to get an estimate on the soil stock (USGS 2012:55).

Soil Survey Geographic Database

NRCS's gSSURGO provides vector soil data and information produced by the National Cooperative Soil Survey (NCSS). The NCSS is a nationwide partnership of state, local, regional, private, and federal agencies that works to investigate, inventory, document, classify, interpret, disseminate, and publish information about soils. NRCS provides soil maps and data available online for more than 95 percent of counties in the US. The soil dataset, called the Soil Survey Geographic Database (SSURGO), is updated and maintained online through the USGS. Soil characteristics can be used to quantify SOM for a given polygon. Each polygon's SOM can then be linked to a SOC amount present in the soil (USDA 2019).

4 DATA GAPS

To create a geospatial carbon stock inventory, there are two primary options: 1) using a raster-based approach that relies upon the TerraCount methodology or 2) using a vector-based approach that relies upon previously published carbon stock inventories.

The benefits of using the TerraCount methodology include simplifying data sources by relying on LANDFIRE rasters, however, there have been noted challenges with the land cover type designations given by LANDFIRE. Specifically, the land cover types are more accurate at a coarse scale but can overgeneralize land use types. The TerraCount methodology includes more specification on land cover types by using a coded model, as well as vector data inputs to assess soil carbon values. The LANDFIRE datasets are frequently updated, but in past updates land cover values have been reassigned, meaning that future carbon values would need to be manually updated. Further, the exact combinations of EVH, EVC, and EVT are linked to carbon sequestration inventory values based on carbon density in 'lookup tables' as indicated in the GHG Forest Report. The lookup tables that link raster data cells values for EVH, EVC, and EVT to carbon values are not available to the public.

The benefits of using vector-based datasets to link to published carbon inventory values for both carbon sequestration rates and carbon stock values include being able to provide more defined land use types to link specified carbon stock or sequestration rates. Using a vector-based approach means there are more inventories that are publicly available such as the CALAND inventory and the USGS Report, whereas the carbon density values used in the TerraCount methodology are not available. Further, data gaps in relating carbon values to vector data can be bridged by scientific literature carbon sequestration values which can provide more locally accurate values. Additionally, the use of vector data allows for an easier integration with AMBAG's Land Use Model that is currently in development.

However, this approach also has several challenges. For example, in using the CALAND inventory outlined by CARB, sequestration rates for cropland are not provided. Land use types can either be aggregated to higher levels to match the CALAND inventory values, or different inventories and scientific literature can be added to assign carbon sequestration rates to more specialized land use types. In using many different inventories and data, the consistency of the data source is not the same throughout different land use types. However, carbon sequestration rates can be derived based on unique combinations of area, management practices, and vegetation types. Updating geospatial carbon stocks for future use based on many vector datasets would be more difficult than updating the three raster datasets, as used in the TerraCount methodology. This is because carbon sequestration rate updates for statewide inventories and scientific literature values would need to be continually provided. The tradeoff is that with more vector datasets and inventory values, more specificity in carbon values can be included in the Study.

5 RECOMMENDATIONS

5.1 GIS DATA TYPE RECOMMENDATION

Based on the availability of data and the accuracy of more specific carbon sequestration values, it is recommended that the Study apply a vector-based approach to estimate baseline carbon stock estimates and forecasted carbon sequestration potential of natural and working lands in the Monterey Bay Area. Vector datasets that link to carbon inventory values should be used to represent the existing carbon stock and sequestration rates of Santa Cruz, San Benito, and Monterey counties. Using this methodology allows for the continued addition of vector datasets that can be specified to the Monterey Bay Area.

5.2 ABOVEGROUND CARBON METHOD RECOMMENDATION

In the Study, it is recommended that CALVEG, CDL, and NWI vector datasets be used to create polygons for land use cover designations that are more specific than LANDFIRE's to link to carbon inventory values. These polygons can be processed in GIS to find the acreage of each land cover type, then using CPAD and CCED polygons for ownership type, areas can be linked to carbon sequestration rates derived from the CALAND inventory. Using the CALAND inventory will ensure that carbon inventory values are consistent with those used by CARB. Further, the CALAND inventory includes the carbon sequestration values provided in the Forest and Rangeland Report and the GHG Forest Report, which are also used in TerraCount, allowing for consistency with both statewide models. The CALAND inventory carbon sequestration values, in tons of carbon per hectare, are comparable to the carbon sequestration results that would be found in TerraCount.

Carbon stock factors from the USGS Report can link soil, live biomass, and dead biomass carbon stock to specific land use types with vector data like CALVEG, CDL, and NWI. The statewide inventories such as CALAND, the Forest and Rangeland Report, and the GHG Forest Report also provide the opportunity for values (based on local scientific literature) to be supplemented when useful and allows for continuous updates to be made. These values can replace individual factors in an Excel workbook to be integrated into the geospatial model that will support the carbon stock inventory.

5.3 BELOWGROUND CARBON METHOD RECOMMENDATION

In the Study, it is recommended that the SSURGO database be used to assess soil carbon stock. The SSURGO database is made of vectors that are associated with soil surveys that are taken in the Monterey Bay Area, meaning that it is field verified to the greatest degree of any of the soil data publicly available and specific to geographic areas (Data.gov 2022). The soil characteristics in the SSURGO database can be related to carbon stock values based on the amount of SOM in the soil. Specifically, carbon stock can be quantified based on an approximation of 58 percent of the SOM. The carbon sequestration rates can be linked to the CALAND inventory using the same process as the aboveground carbon methodology recommended above. These carbon sequestration rates for soil are specific to land use, region, and ownership. CALAND and the SSURGO database provide region-specific inventory values that are consistent with statewide values with the ability to be updated in the future.

5.4 NEXT STEPS

All of the databases and resources required to conduct the carbon stock and sequestration inventory are publicly available and free to use. The CALVEG, NWI, CDL, CPAD, SSURGO, and CCED databases are all available to download and will be added to a GIS map. Layers will be geoprocessed to include only the attributes within the Monterey Bay

Area (i.e., Santa Cruz, San Benito, and Monterey counties), at which point the CDL data will be converted from a raster format to vector data with polygons based on each crop. Each layer will then be calculated into specific acreage values for each polygon. This data will be input into an Excel workbook that will tie the land use values to specific carbon sequestration rates from CALAND and carbon stock values from the USGS Report. In addition to the USGS Report's carbon stock values, values for carbon stock based on specific land cover types and regionally specific values will be used when available from scientific literature. For example, the California Department of Forestry and Fire Protection, the California Natural Resources Agency, and California Environmental Protection Agency published the California Forest Carbon Plan, which includes carbon values for specific types of forests such as Coast Redwood and Douglas Fir. These values will be used when these specific forest types are identified through GIS analysis. Values from the California Forest Carbon Plan will supersede the generalized forest values included in the USGS Report.

Once all areas have been assigned carbon stock and sequestration values, the data will be imported back into GIS to define carbon value per grid cell for integration into AMBAG's Land Use Model. Integration into AMBAG's Land Use Model will require that carbon values for grid cell areas be averaged to the land cover polygons that are represented within each cell. These grid cells will reflect parcel-scale carbon values. Each Assessor's parcel number will be tied to a land cover category and carbon value. This will integrate into the Land Use Model to inform the carbon losses associated with land use changes.

Separately, the carbon values linked with land cover polygons created from this process will also be published as an ArcGIS Online map. This map will allow local agencies, organizations, and members of the public to utilize this tool to see carbon stock and sequestration values associated with specific areas and how these values may change over time due to the impacts of climate change (e.g., biomass lost from wildfires). This map will provide the land cover type with polygon boundaries, providing more specificity to map users of the carbon potential of a specified area. This tool can help inform conservation efforts and management practices to enhance carbon stock and sequestration.

Further, COMET-Farm and COMET-Planner will be evaluated for their ability to provide carbon sequestration rates for specific land management practices (e.g., regenerative agricultural practices). These specific land management associated rates will be added to the Excel workbook to be integrated into the map. These values will highlight how management practices on natural and working lands can impact carbon stock and sequestration. This will be helpful for agencies to understand their current and potential carbon stock values to support conservation efforts in natural and working lands.

6 REFERENCES

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Memo

1230 Columbia Street, Suite 440
San Diego, CA 92101
619.219.8000

Date: July 19, 2023

To: Amaury Berteaud, Gina Schmidt, and Will Condon (AMBAG)

From: Liz Luck, Hannah Kornfeld, Fred Hochberg, and Poonam Boparai (Ascent)

Subject: **Monterey Bay Natural and Working Lands Climate Mitigation and Resiliency Study – Carbon Stock Inventory Final Technical Memorandum**

This technical memorandum (memo) presents an estimate of existing carbon stock in Santa Cruz, Monterey, and San Benito counties to support the development of the Monterey Bay Natural and Working Lands Climate Mitigation and Resilience Study (hereafter referred to as "study"). The carbon stock analysis includes an inventory of existing carbon stored in vegetation and soils on natural (e.g., grasslands, forests) and working (i.e., agricultural) lands within Santa Cruz, Monterey, and San Benito counties (hereafter referred to as the "study area"). The inventory is referred to as a "baseline" throughout this memo. Carbon stock values are presented in terms of metric tons of carbon (MT C).

This memo includes the following sections:

- **Section 1: Overview of Carbon Stock** provides an overview of carbon stock and other concepts referenced in this memo.
- **Section 2: Methods to Estimate Baseline Carbon Stock in the Study Area** describes the data, sources, and methodology used to estimate existing carbon stock that serves as the baseline for the study.
- **Section 3: Summary of Estimated Baseline Carbon Stock in the Study Area** presents the estimated existing carbon stock of all land cover types in the study area.
- **Section 4: Comparison to Other Studies** describes the results of this study in comparison to similar efforts conducted in other regions of California.

1 OVERVIEW OF CARBON STOCK

Natural and working lands hold a prominent place in California's path toward carbon neutrality. While understanding the quantification of carbon stock values is an evolving area, understanding the magnitude and nature of existing carbon stock and potential future sequestration opportunities from natural and working lands will be an important advancement in climate mitigation and resilience planning in the study area.

Land use changes have direct impacts on the amount of carbon that is stored and sequestered within vegetation and soils in the study area. New development that converts grasslands, forests, shrublands, or other natural land covers to urban land uses reduces the carbon sequestration potential of such lands. Reforesting or afforesting barren, unproductive lands to preserve them from development and enhance their quality will have the opposite effect, increasing the lands' carbon sequestration potential. This inextricable link between land use and carbon stock highlights the need for thoughtful land use planning that minimizes losses to current carbon stock and maximizes preservation/enhancements.

Natural and working lands in the study area provide benefits to the region through arable lands that produce food, wine, recreational amenities, tourism, and provide wildlife habitat. Historically, land has been converted from natural and working lands into developed land uses within the study area. The consequences of converted natural lands and their impacts on current carbon stock have not been evaluated. This memorandum provides a baseline estimate for the carbon that is already stored in the study area's vast natural and working lands exclusive of land uses prior to 2015. Future tasks under this study will evaluate carbon sequestration potential associated with land management practices that enhance soil and vegetative carbon uptake.

1.3 KEY TERMS

The following key terms are used throughout this memo and are defined as such:

- **Carbon Pool:** A system which has the capacity to accumulate or release carbon, considered to be a reservoir. Examples include forest biomass, wood products, soils, and the atmosphere (Intergovernmental Panel on Climate Change [IPCC] 2000).
- **Carbon Sequestration:** The process of increasing the carbon content of a carbon pool other than the atmosphere (IPCC 2000).
- **Carbon Stock:** The absolute quantity of carbon held within a pool at a specified time (IPCC 2000).
- **Soil Carbon:** Included inorganic and organic carbon, it constitutes 75 percent of terrestrial carbon (Ecological Society of America 2000).
- **Soil Organic Carbon:** The amount of carbon within the organic compounds of soil. Soil organic carbon accounts for 58 percent of soil organic matter (Ecological Society of America 2000).
- **Natural Lands:** Lands consisting of forests, grasslands, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas, watersheds, wildlands, or wildlife habitats, or lands used for recreational purposes such as parks, urban and community forests, greenbelts, trails, and other similar open-space lands. For purposes of this paragraph, "parks" includes, but is not limited to, areas that provide public green space (California Public Resources Code 9001.5).
- **Working Lands:** Lands used for farming, grazing, or the production of forest products (California Public Resources Code 9001.5).

1.4 ANATOMY OF A CARBON STOCK INVENTORY

A carbon stock inventory represents the amount of carbon stored in natural (e.g., forests, wetlands, grasslands) and working lands (e.g., cropland) at a specified time. The study aims to develop a data-driven carbon inventory to provide a baseline of carbon stock in Monterey, Santa Cruz, and San Benito counties. To quantify the carbon stock and sequestration potential of an area, both aboveground and belowground data sources of carbon pools must be assessed. The types and sources of carbon that will be evaluated in the study are described below and depicted in Figure 1.

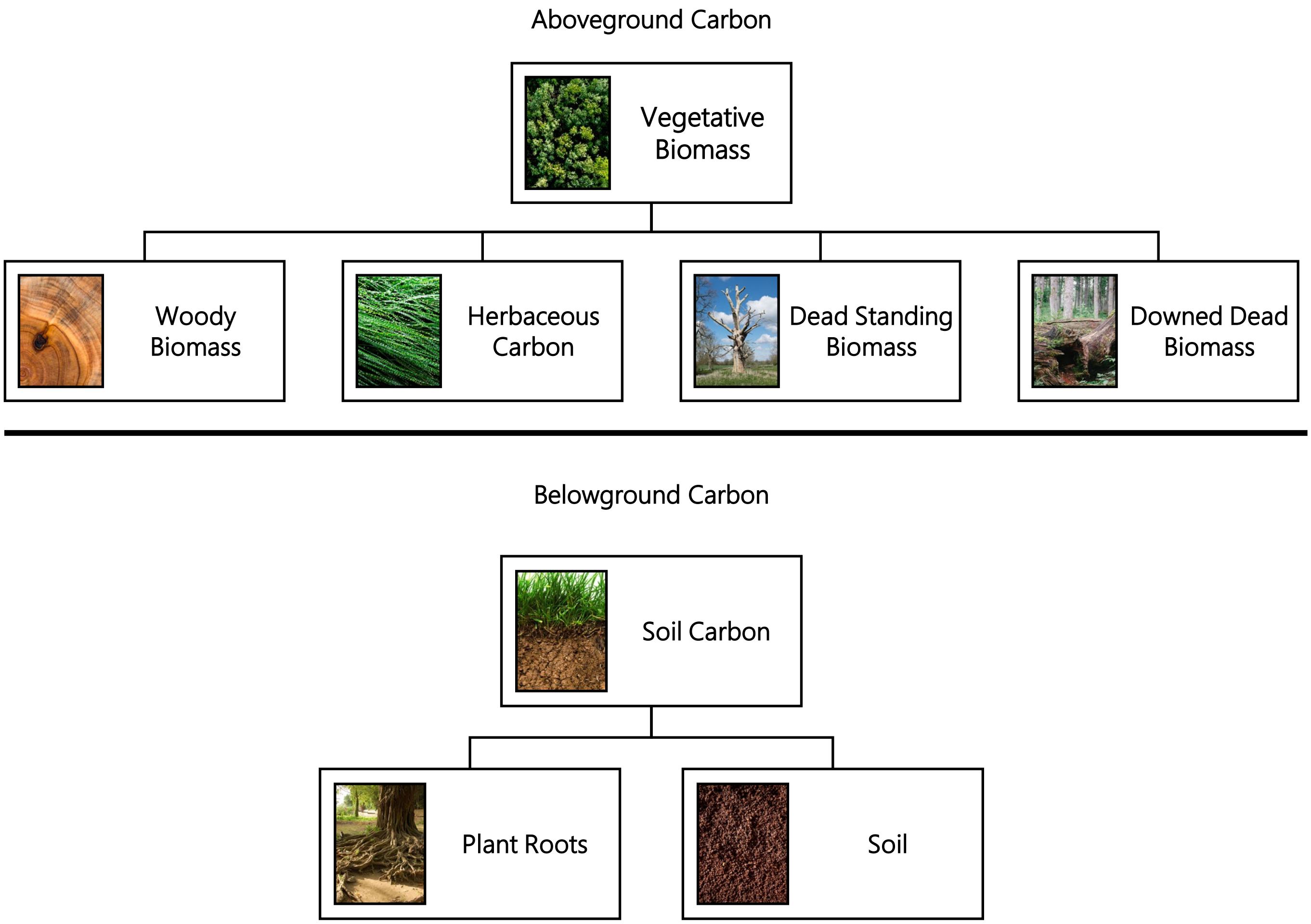


Figure 1 Types and Sources of Carbon included in a Carbon Stock Inventory
Source: Prepared by Ascent in 2023.

2 METHODS TO ESTIMATE BASELINE CARBON STOCK IN THE STUDY AREA

This section describes the data and methods used to estimate existing carbon stock in the study area.

2.3 LAND COVER ANALYSIS

To assess the carbon stock in the study area, a GIS-based analysis was performed using the best available data for land cover (i.e., vegetation), ownership types, and soil. The data sources for each land cover type are shown in Table 1. The California Department of Forestry and Fire Protection (CAL FIRE) Fire and Resource Assessment Program (FRAP) vegetation layer was used to assess land cover types, which is the most regionally specific for this analysis. The CAL FIRE FRAP vegetation layer is a vector-based spatial distribution of habitat types within California created in coordination with the California Department of Fish and Wildlife VegCamp Program and the US Department of Agriculture’s (USDA’s) Forest Service Remote Sensing Laboratory data. These data were then intersected with the California Department of Water Resources’ statewide crop mapping. This layer was used to identify the vineyards, orchards, and other croplands within the study area. This agricultural layer superseded the CAL FIRE FRAP vegetation layer to provide more specific crop types within the study area.

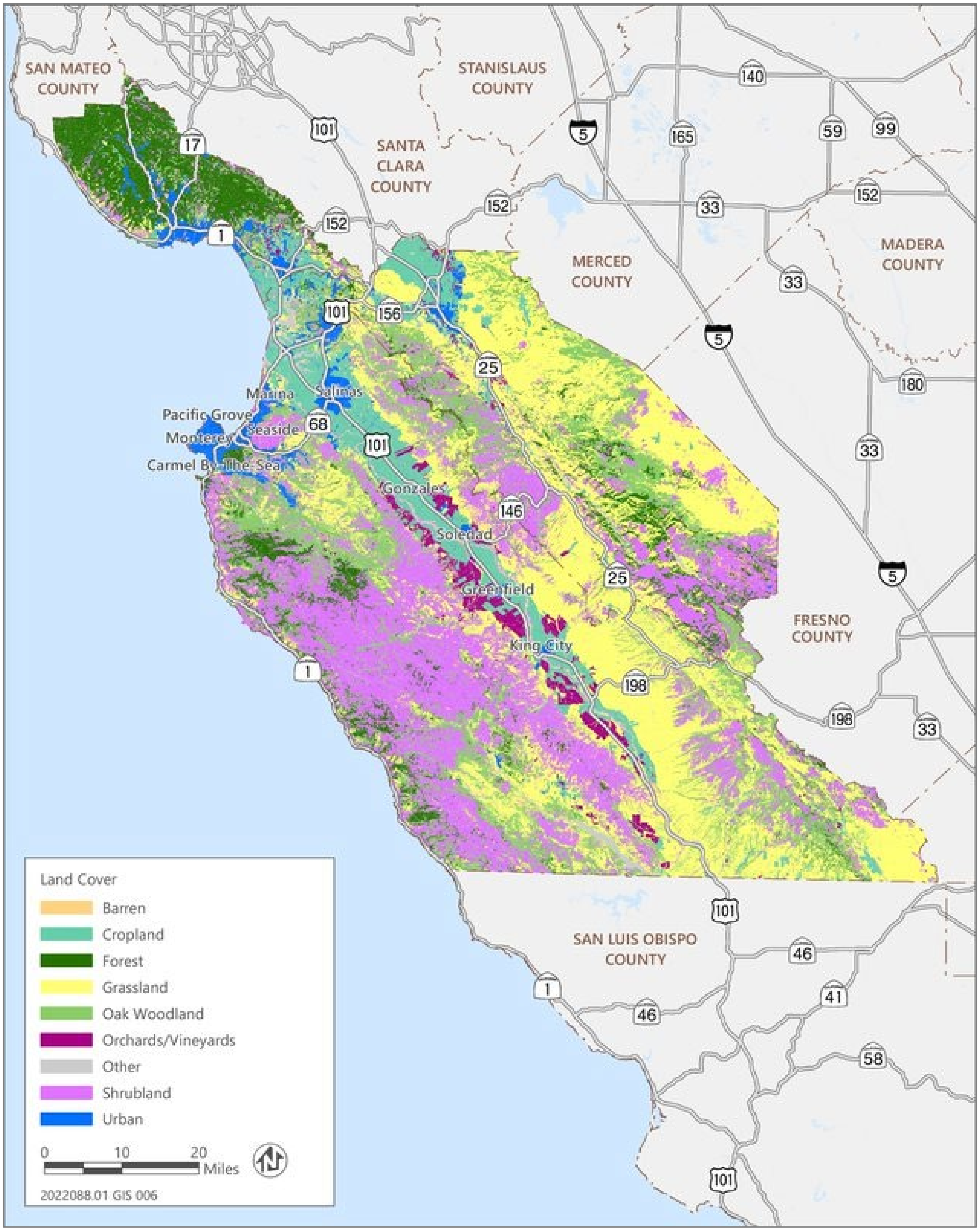
Next, the GIS layers were intersected with the US Fish and Wildlife Service’s (USFWS’s) National Wetlands Inventory (NWI). The NWI contains more than 35 million wetlands and deepwater features for all of the US. Wetlands are identified using aerial imagery based on vegetation, visible hydrology, and geography. NWI provides information on the status, extent, characteristics, and functions of wetland, riparian and deepwater habitats. In the areas where the NWI layer overlapped with the CAL FIRE FRAP layer or the agricultural layer, the CAL FIRE FRAP layers were removed because NWI is considered the most specific for this land cover type and is updated twice per year. The land cover types in the study area are identified in Figure 2.

Table 1 Spatial Data Sources

Land Cover Type	Source	Source Year
Forest	CAL FIRE FRAP	2015
Fresh Marsh	National Wetland Inventory	2015
Oak Woodland	CAL FIRE FRAP	2015
Urban	CAL FIRE FRAP	2015
Cropland	Department of Water Resources	2016
Orchards/Vineyards	Department of Water Resources	2016
Shrubland	CAL FIRE FRAP	2015
Grassland	CAL FIRE FRAP	2015
Wetland	Department of Water Resources	2016
Other	CAL FIRE FRAP	2015
Barren	CAL FIRE FRAP	2015
Water	National Wetland Inventory	2015
Soil	SSURGO	2022

Notes: CAL FIRE = California Department of Fire Protection and Forestry; FRAP = Fire and Resource Assessment Program; SSURGO = Soil Survey Geographic Database.

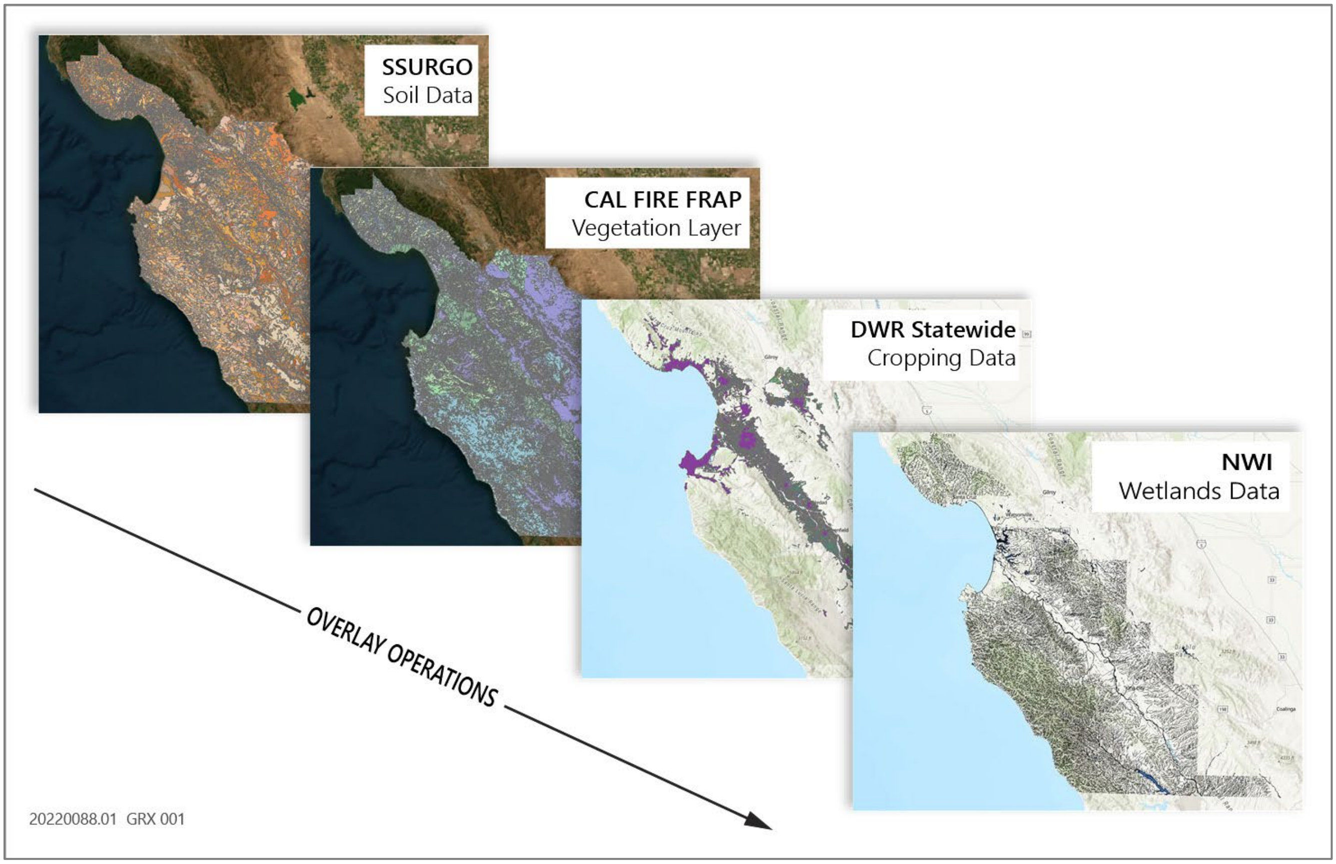
Source: Compiled by Ascent in 2023.



Source: Prepared by Ascent in 2023.

Figure 2 Land Cover Types Identified in the Study Area

The GIS attribute tables of land cover types and acreages were exported into a comma-separated values file. Using a Python script, the data were summarized and pivoted into a Microsoft Excel workbook with the total acreages for each land cover and soil type combination for quantification analysis. There were 1,439 unique combinations of land cover data and soil data in the study area. Figure 3 shows the overlay operations of the GIS layers used to conduct the analysis.



Notes: CAL FIRE FRAP = California Department of Forestry and Fire Protection Fire and Resource Assessment Program; DWR = California Department of Water Resources; NWI = National Wetlands Inventory; SSURGO = Soil Survey Geographic Database.

Source: Prepared by Ascent in 2023.

Figure 3 Data Sources Overlaid for GIS Analysis

2.4 ABOVEGROUND CARBON QUANTIFICATION

The resulting total acreages of each land cover type from the GIS, Microsoft Excel, and Python script analysis described above were linked to carbon stock values found in scientific literature. These carbon stock values, in metric tons per acre for a given vegetation type, were multiplied by the acreage of each land cover type found in GIS. Where possible, literature values that were regionally specific were used. In instances where regionally specific values were not available, statewide carbon stock values were used. Further, where values for carbon stock could not be found for specific land cover types, land cover types were combined into more general categories. For example, non-vineyard and non-orchard crops' aboveground carbon values were assigned the value for "cropland" in the US Geologic Survey's *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States* (hereafter referred to as "USGS Report"), because more specific data was not available for these types. In contrast, vineyard carbon stock was provided in a UC Merced report (Williams 2020), and avocado and almond orchards were given a specific carbon stock value found in the literature. [1] Additionally, riverine, freshwater emergent wetland, and freshwater forested/shrub wetland were combined into a more general category of "wetlands" because more specific carbon stock values could not be found.

Carbon stock values for urban forestry land cover types, which were specific to counties within California, were used from scientific reports prepared for the California Air Resources Board (CARB) and the California Environmental Protection Agency (Saah et al. 2016). Carbon stock values for forest land cover types were provided by the *California Forest Carbon Plan* (Forest Climate Action Team 2018) and oak woodland carbon stock values were provided by *An Inventory of Carbon and California Oaks* (Gaman 2008). Grassland and shrubland carbon values were published in a final report prepared for the California Energy Commission (Brown 2004). Carbon values for California's chaparral and Coastal Sage Scrub are from a scientific report produced by UC Davis staff (Bohlman et al. 2018). Where more specific carbon values could not be found the USGS Report, carbon stock values for general ecosystems in specific regions, including Mediterranean California, were used (USGS 2012). Aboveground carbon stock values by land cover type can be found in Attachment A.

2.5 SOIL CARBON QUANTIFICATION

Soil carbon stock was estimated using the USDA's Natural Resources Conservation Service's (NRCS's) Soil Survey Geographic Database (SSURGO) dataset, which provides soil type data throughout the state, inclusive of the study area. SSURGO provides data on the quantity of soil carbon at the depths of 5, 20, 50, 100, and 150 centimeters (cm). Data are collected from soil surveys performed throughout Monterey, Santa Cruz, and San Benito counties, and therefore is specific to the area of this analysis.

The following steps were performed for this analysis: First, SSURGO data were uploaded into GIS for the study area. Next, using the Soil Data Development Toolbox (a Python-scripted GIS toolbox used by the NRCS to create soil maps and reports), a soil map was created and the attributes that represent soil carbon were extracted. These attributes were then joined to the land cover data layers, as outlined above, to specify the soil carbon stored within each land cover type. Soil carbon was calculated to a depth of 50 cm. This depth was chosen due to the 96 percent availability of soil carbon data from SSURGO at this depth (deeper depths have lower data availability—for example, at the next depth of 100 cm, only 86 percent of the data was available). The SSURGO data used in this analysis was published in 2023, so it represents the most up-to-date soil carbon data collected. Figure 4 shows the soil organic carbon stock, estimated in metric tons of carbon per acre at depths of up to 50 cm for the study area.

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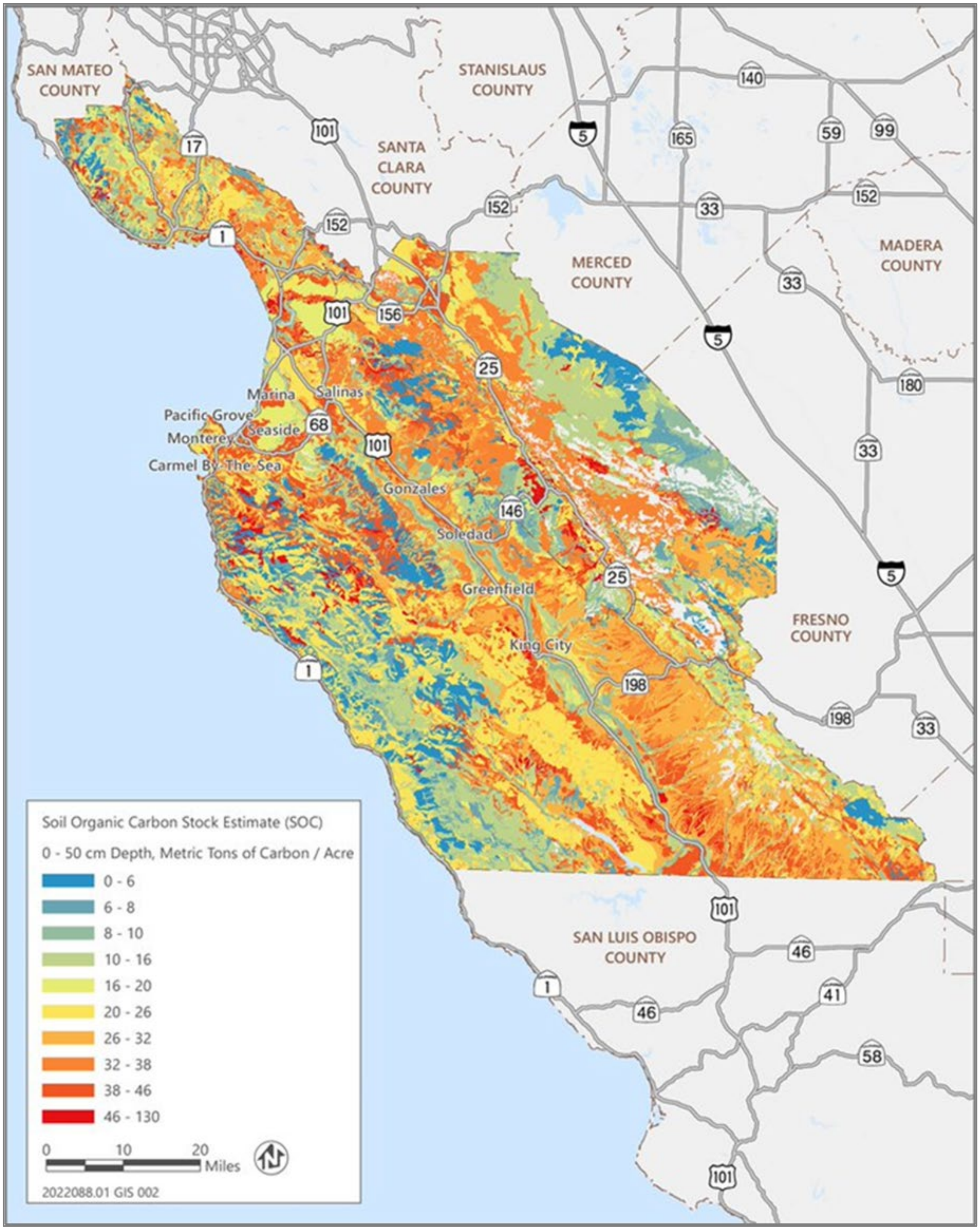
[1] Aboveground carbon stock data was available for defruited avocado trees (Saah et al. 2016: 17), but not for olive and apple trees. As a proxy, olive and apple trees were assumed to have the same aboveground carbon stock as defruited avocado trees. The carbon value for defruited trees was used because the fruit of these trees is harvested, and thus the carbon stored in the fruit does not remain in the vegetation or soil.



Source: Prepared by Ascent in 2023.

Figure 4 Soil Organic Carbon Stock within the Study Area (Metric Tons of Carbon per Acre)

3 SUMMARY OF ESTIMATED BASELINE CARBON STOCK IN THE STUDY AREA

Total baseline carbon stock in the study area was estimated to be approximately 117 million metric tons of carbon (MMT C). As shown in Table 2 and Figure 5, 51 percent of the carbon is stored in grasslands and forests, with the rest being stored in woodland, urban (developed) areas, shrublands, orchards, barren lands, row crops, and wetlands. While some ecosystems hold more carbon in their aboveground vegetation, such as forests, other ecosystems hold more in their soil, such as in grasslands.

Among the three counties in the study area, Monterey County has the most stored carbon in both aboveground and soil ecosystems. Monterey County's baseline carbon stock was estimated to be approximately 68 MMT C, while Santa Cruz County was estimated to be approximately 26 MMT C, and San Benito County was estimated to be approximately 23 MMT C. Additional baseline carbon stock information is available for each jurisdiction by land cover type in Attachment A.

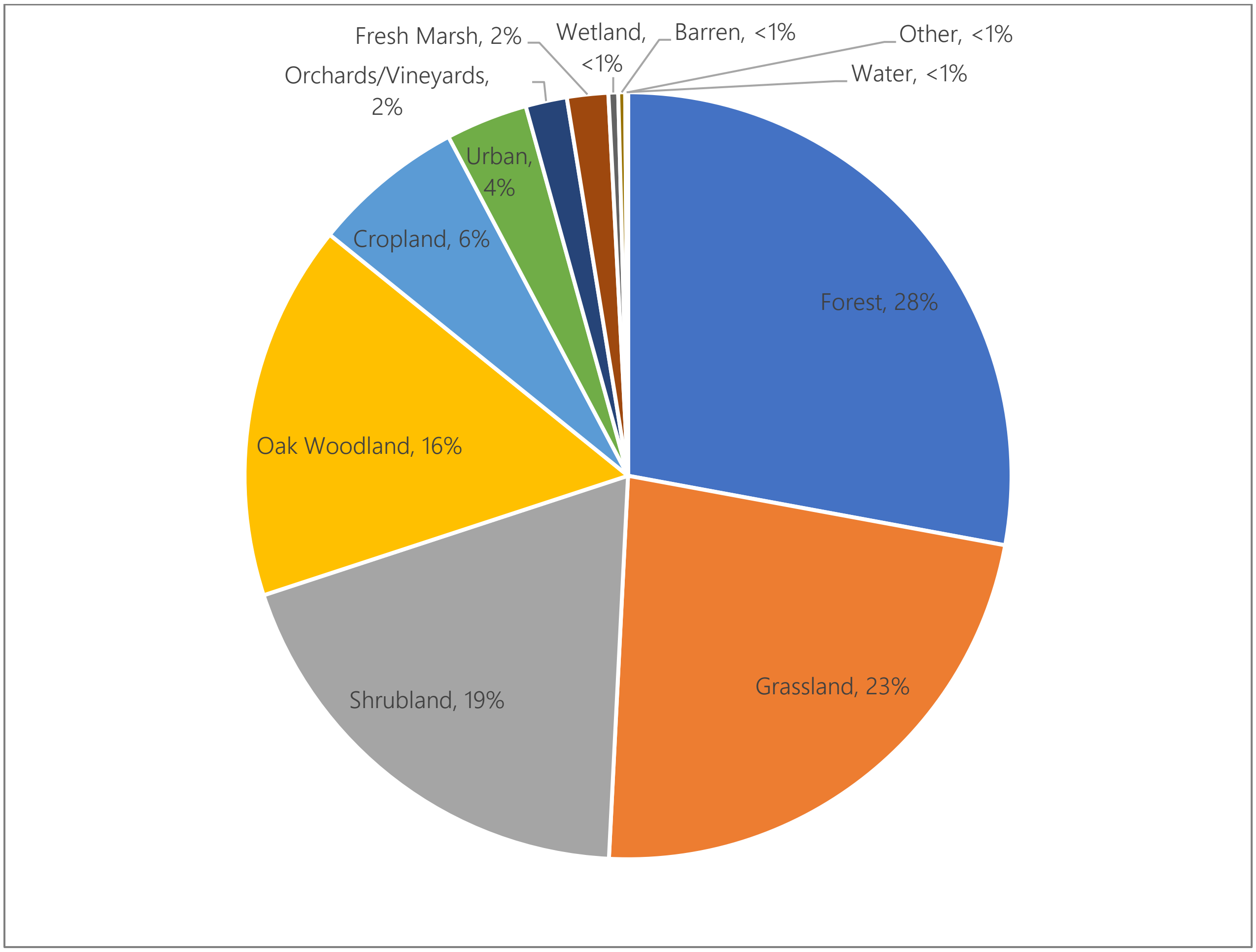
Table 2 Baseline Aboveground and Soil Carbon by Jurisdiction

	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Santa Cruz County			
Capitola	14,921	30,103	45,025
Santa Cruz	174,731	162,882	337,614
Scotts Valley	111,695	71,290	182,985
Unincorporated Santa Cruz County	19,074,575	5,976,604	25,051,179
Watsonville	49,577	103,255	152,832
Santa Cruz County Subtotal	**19,425,500**	**6,344,134**	**25,769,634**
Monterey County			
Carmel By-The-Sea	3,931	19,510	23,441
Del Rey Oaks	4,786	25,758	30,543
Gonzales	5,339	32,040	37,379
Greenfield	8,012	44,465	52,477
King City	13,663	63,185	76,848
Marina	33,574	174,228	207,802
Monterey	36,125	152,677	188,803
Pacific Grove	9,747	45,326	55,073
Salinas	73,653	435,732	509,386
Sand City	1,219	6,032	7,251
Seaside	41,784	180,773	222,557
Soledad	13,896	78,370	92,266
Unincorporated Monterey County	18,334,806	48,033,984	66,368,790
Monterey County Subtotal	**18,580,535**	**49,292,081**	**67,872,615**
San Benito County			
Hollister	8,887	163,699	172,586
San Juan Bautista	893	13,496	14,389
Unincorporated San Benito County	5,447,113	17,535,143	22,982,257
San Benito County Subtotal	**5,456,893**	**17,712,339**	**23,169,231**
Total	**43,462,927**	**73,348,553**	**116,811,480**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Prepared by Ascent in 2023.



Notes: All values are rounded to the nearest percent.

Source: Prepared by Ascent in 2023.

Figure 5 Total Carbon Stock by Land Cover Type in Study Area

Average carbon stock values are shown by more general land cover type in Table 3 and Figure 6. Table 3 represents a high-level summary of the results of using individual carbon values as described in Section 2. For example, for redwoods, Douglas firs, Sierran mixed coniferous, and other specific forest types, metric tons of carbon per acre values for each of these specific types were obtained using the methods in Section 2, multiplied by the appropriate acreage, and then summarized to produce the table below. Forests have the highest aboveground carbon values per acre, while croplands, grasslands, orchards, and vineyards have the highest soil carbon values per acre.

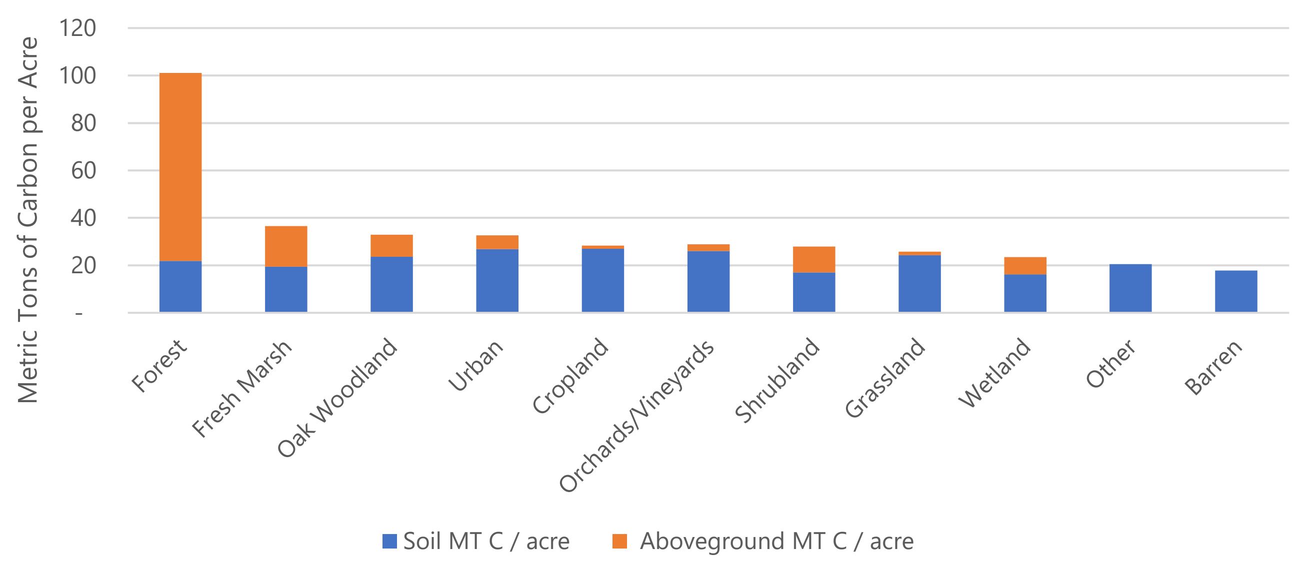
Table 3 Average Aboveground and Soil Carbon Stock Rates per Acre by Land Cover Type

Land Cover Type	Acres	Aboveground Carbon (MT C /acre)	Soil Carbon (MT C /acre)	Total Carbon (MT C /acre)
Forest	322,437	79	22	101
Fresh Marsh	55,500	17	19	37
Oak Woodland	563,980	9	24	33
Urban	119,422	7	27	34
Cropland	265,179	1	27	28
Orchards/Vineyards	70,438	3	26	29
Shrubland	803,213	11	17	28
Grassland	1,039,070	1	24	26
Wetland	20,373	7	16	24
Other	201	0	20	20
Barren	19,031	0	18	18
Water	13,145	0	10	10
Total[1] (MT C)	**3,291,989**	**13**	**22**	**35**

Notes: Totals may not sum exactly due to independent rounding. C = carbon; MT = metric tons.

[1] Total carbon stock is shown for the total acres of each land cover type. The total row at the bottom of the table is not a sum of carbon stock rates. Aboveground carbon, soil carbon, and total carbon rates in the columns are reported as averages because they represent per acre values.

Source: Prepared by Ascent in 2023.

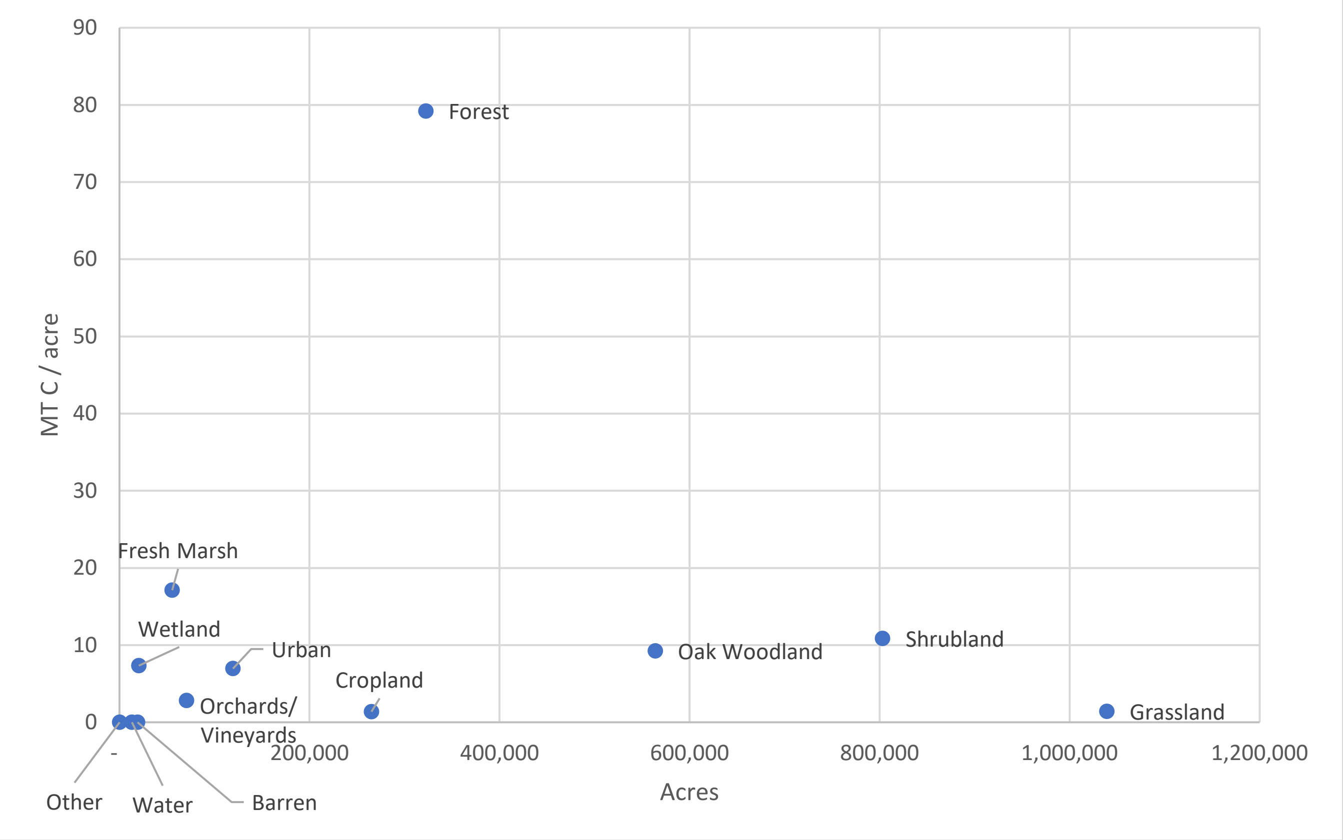


Notes: C = carbon; MT = metric tons.

Source: Prepared by Ascent in 2023.

Figure 6 Carbon Stock Rates by Land Cover Type (MT C/acre)

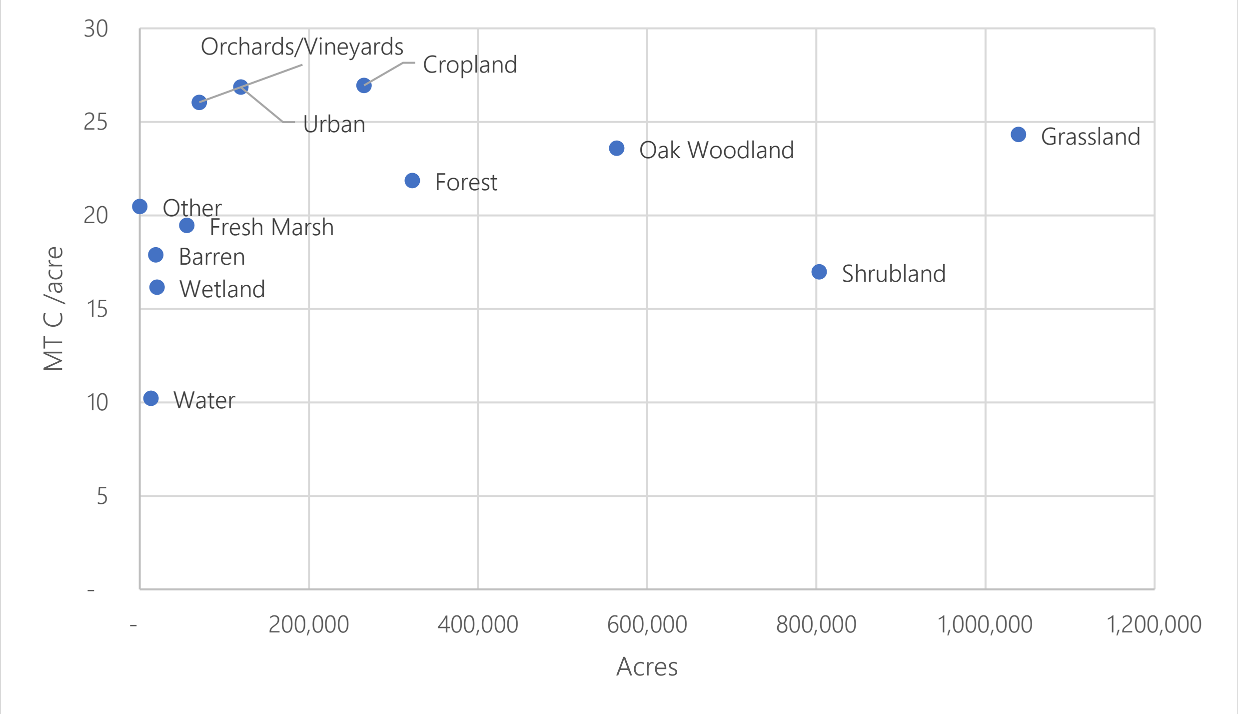
Land cover types are shown by the total acreage and the metric tons of carbon per acre (Figure 7 and 8).



Notes: C = carbon; MT = metric tons.

Source: Prepared by Ascent in 2023.

Figure 7 Aboveground Carbon Stock Rates by Land Cover Type (MT C/acre)



Notes: C = carbon; MT = metric tons.

Source: Prepared by Ascent in 2023.

Figure 8 Soil Carbon Stock Rates by Land Cover Type (MT C/acre)

4 COMPARISON TO OTHER STUDIES

Carbon stock inventories are a dynamic and rapidly changing field of study. In the last decade, cities and counties in California have taken on the challenge of quantifying the carbon stock within their jurisdictions with limited guidance, unlike anthropogenic greenhouse gas emissions quantification. Counties such as Merced, Sonoma, Santa Barbara, San Diego, and Calaveras have all conducted geospatial analyses by identifying land cover types and connecting them to carbon values. Some of the variability in results can be attributed to the different GIS layers used in the land cover type classification, while other variability is in the carbon stock values per land cover type. Table 4 shows the difference in MT C per acre (defined as total metric tons of carbon divided by total acres in a given region) between this study and studies that have been conducted across the state, as well as a comparison between CARB's two statewide carbon inventories.

Table 4 Carbon Stock Analyses Conducted Across California

Region	Analysis Year	Acres Evaluated	Carbon Stock Rate (MT C/Acre)	Total Carbon Stock (MMT C)
Monterey Bay Area (This Study)	2023	3,291,989	35	117
Sonoma County	2016	1,016,781	62	63
Santa Barbara County	2020	1,632,162	31	51
Merced County	2019	1,265,303	11	14
San Diego County	2022	2,727,116	24	65
Calaveras County	2021	662,838	31	20
Statewide[1]	2018	105,000,000	51	5,340
Statewide[1]	2022	105,000,000	29	3,117

Notes: C = carbon; MT = metric tons; MMT = million metric tons.

[1] Both statewide analyses have been conducted by the California Air Resources Board and show vastly different results for the same acreage area of study, demonstrating the evolving nature of this type of analysis.

Source: Compiled by Ascent in 2023.

CARB has a longstanding history of quantifying both greenhouse gas emissions and carbon stock. In 2007, CARB first included an estimate of carbon sequestration in forests and rangelands in its statewide greenhouse gas inventory. In 2016, CARB published the Forestry & Other Natural Lands Inventory, followed by the publication of CARB's Ecosystem Carbon in California's Natural and Working Lands (NWL Inventory) in 2018. The NWL Inventory estimated the amount of carbon in natural and working lands but expressed uncertainty in the estimates, with a margin of error for soil carbon of 90 percent. In 2019, Merced County was the first local jurisdiction to release a spatially based carbon stock inventory using the TerraCount method, funded by the California Department of Conservation. This method used LANDFIRE datasets to assess the vegetation height, cover, and type to convert into carbon density values. In 2020, CARB refined the 2018 NWL Inventory and, in 2022, CARB published a new NWL inventory and projections included in the 2022 Scoping Plan for Achieving Carbon Neutrality.

5 DATA GAPS

As carbon stock and sequestration research is rapidly evolving, this memo highlights several data gaps in developing carbon stock analyses. First, the GIS layers used in this analysis were sourced from different years because they were produced by various federal and state agencies. The CAL FIRE FRAP vegetation layer and NWI layer were produced in 2015, however, the Department of Water Resources' statewide cropping layer was produced in 2016. These data layers, used to represent aboveground carbon, and years were selected to represent a more uniform baseline year. The CAL FIRE FRAP vegetation layer has not been updated with newer data since the 2015 layer was produced. However, the SSURGO soil carbon data that was used was produced in 2022 because previous years' data are not publicly available. Therefore, the aboveground sources and soil sources do not allow for a truly uniform baseline of carbon stock in the study area. However, the data layers used in this memo are specific to the study area.

Second, based on the availability and granularity of the spatial data, there is a margin of error in the acreage estimates of land covers. The land cover acreage estimates from the GIS analysis do not match exactly the acres provided in the crop reports produced by the agricultural commissioners of the three counties included in the study. This is due to different methodologies to collect crop-specific data conducted by local agencies versus state agencies.

Lastly, carbon stock rates specific to each vegetation species represented in each land cover type are limited due to the lack of studies evaluating carbon stock, particularly those specific to the Monterey Bay Area. For example, while specific aboveground carbon stock values are available for forest species like Redwoods, specific aboveground carbon stock values for every crop produced in the study area are not available. In cases like these, land cover types are aggregated into more broad categories (refer to Attachment A).

6 REFERENCES

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Attachment A

Carbon Stock Rates by Land Cover Type and Associated Sources

Land Cover in GIS	Aggregated Land Cover Type	MT C/acre	Total Acres in GIS in Study Area	Source / Assumption
Annual Grassland	Grassland	1.42	1,036,271	Brown et al. 2004
Mixed Chaparral	Shrubland	14.01	417,725	Bolhman et al. 2018
Blue Oak Woodland	Oak Woodland	6.07	282,922	Gaman 2008
Coastal Oak Woodland	Oak Woodland	12.55	270,860	Gaman 2008
Chamise-Redshank Chaparral	Shrubland	8.56	200,298	Bolhman et al. 2018
Coastal Scrub	Shrubland	6.41	183,519	Bolhman et al. 2018
Urban (Santa Cruz County)	Urban	11.3	34,245	Saah et al. 2016 (Table 11)
Urban (San Benito County)	Urban	1.3	73,439	Saah et al. 2016 (Table 11)
Urban (Monterey Monterey)	Urban	5.8	11,738	Saah et al. 2016 (Table 11)
Redwood	Forest	122.40	93,061	Forest Climate Action Team 2018
Montane Hardwood-Conifer	Forest	120.21	83,668	Forest Climate Action Team 2018, Gaman 2008 Calculated the average of canyon oaks and mixed conifers
Miscellaneous Truck Crops	Cropland	2.10	80,255	USGS 2012
Montane Hardwood	Forest	29.95	65,152	Gaman 2008
Grapes	Orchards/Vineyards	2.63	58,057	Williams et al. 2020
Blue Oak-Foothill Pine	Forest	13.86	53,604	Gaman 2008 Blue Oaks averaged for other regions
Lettuce/Leafy Greens	Cropland	-	43,236	Assumed to be zero because herbaceous material is harvested
Cole Crops	Cropland	-	33,279	Assumed to be zero because herbaceous material is harvested
Riverine	Fresh Marsh	7.34	30,250	USGS 2012
Pasture	Cropland	2.10	23,165	USGS 2012
Miscellaneous Grain and Hay	Cropland	2.10	19,134	USGS 2012
Barren	Barren	-	18,827	Assumed to be zero
Freshwater Forested/Shrub Wetland	Wetland	7.34	16,219	USGS 2012
Strawberries	Cropland	-	14,832	Assumed to be zero because herbaceous material is harvested
Closed-Cone Pine-Cypress	Forest	50.96	14,215	USGS 2012
Valley Foothill Riparian	Fresh Marsh	45.72	14,141	Dybala et al. 2018
Idle	Cropland	2.10	12,161	USGS 2012
Cropland	Cropland	2.10	11,508	USGS 2012
Freshwater Emergent Wetland	Fresh Marsh	7.34	11,109	USGS 2012
Valley Oak Woodland	Oak Woodland	10.12	10,198	Gaman 2008
Mixed Pasture	Cropland	2.10	8,497	USGS 2012
Lake	Water	-	7,279	Assumed to be zero
Vineyard	Orchards/Vineyards	2.63	5,961	Williams et al. 2020
Bush Berries	Cropland	2.10	5,417	USGS 2012

Land Cover in GIS	Aggregated Land Cover Type	MT C/acre	Total Acres in GIS in Study Area	Source / Assumption
Freshwater Pond	Water	-	4,338	Assumed to be zero
Dryland Grain Crops	Cropland	2.10	4,164	USGS 2012
Eucalyptus	Forest	50.96	3,944	USGS 2012
Sierran Mixed Conifer	Forest	50.96	3,772	USGS 2012
Estuarine and Marine Wetland	Wetland	7.34	3,281	USGS 2012
Flowers, Nursery and Christmas Tree Farms	Cropland	2.10	2,671	USGS 2012
Walnuts	Orchards/Vineyards	4.82	2,156	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Apples	Orchards/Vineyards	4.82	1,951	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Juniper	Forest	50.96	1,905	USGS 2012
Ponderosa Pine	Forest	50.96	1,811	USGS 2012
Alkali Desert Scrub	Shrubland	-	1,633	Assumed to be zero
Miscellaneous Grasses	Grassland	1.42	1,518	Brown et al. 2004
Citrus	Cropland	2.10	1,364	USGS 2012
Perennial Grassland	Grassland	1.42	1,281	Brown et al. 2004
Douglas Fir	Forest	72.10	1,193	Forest Climate Action Team 2018
Irrigated Hayfield	Cropland	2.10	957	USGS 2012
Alfalfa and Alfalfa Mixtures	Cropland	2.10	954	USGS 2012
Estuarine and Marine Deepwater	Water	-	789	Assumed to be zero
Lacustrine	Water	-	738	Assumed to be zero
Deciduous Orchard	Orchards/Vineyards	4.82	676	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Orchard - Vineyard	Orchards/Vineyards	2.63	540	Williams et al. 2020
Beans (Dry)	Cropland	2.10	473	USGS 2012
Greenhouse	Cropland	2.10	472	USGS 2012
Miscellaneous Subtropical Fruits	Cropland	2.10	458	USGS 2012
Cherries	Orchards/Vineyards	4.82	364	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Onions and Garlic	Cropland	2.10	348	USGS 2012
Saline Emergent Wetland	Wetland	7.34	337	USGS 2012
Young Perennials	Cropland	2.10	331	USGS 2012
Irrigated Row and Field Crops	Cropland	2.10	315	USGS 2012
Carrots	Cropland	2.10	308	USGS 2012
Tomatoes	Cropland	2.10	268	USGS 2012
Olives	Orchards/Vineyards	4.82	228	Saah et al. 2016 (Table 7) Assumed defruited avocado values

Land Cover in GIS	Aggregated Land Cover Type	MT C/acre	Total Acres in GIS in Study Area	Source / Assumption
Avocados	Orchards/Vineyards	4.82	223	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Miscellaneous Deciduous	Cropland	2.10	217	USGS 2012
Peppers	Cropland	2.10	207	USGS 2012
Other	Other	-	201	Assumed to be zero
Wet Meadow	Wetland	7.34	193	USGS 2012
Evergreen Orchard	Orchards/Vineyards	4.82	149	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Fresh Emergent Wetland	Wetland	7.34	135	USGS 2012
Plums, Prunes and Apricots	Orchards/Vineyards	4.82	131	Saah et al. 2016 (Table 7) Assumed defruited avocado values
Desert Wash	Barren		117	Assumed to be zero
Montane Riparian	Forest	45.72	109	Dybala et al. 2018
Marsh	Wetland	7.34	97	USGS 2012
Melons, Squash and Cucumbers	Cropland	-	92	Assumed to be zero because herbaceous material is harvested
Managed Wetland	Wetland	7.34	89	USGS 2012
Desert Riparian	Barren	-	87	Assumed to be zero
Irrigated Grain Crops	Cropland	2.10	72	USGS 2012
Montane Chaparral	Shrubland	14.01	37	Bolhman et al. 2018 Assumed to be mixed chaparral
Estuarine	Wetland	7.34	22	USGS 2012
Rice	Cropland	2.10	19	USGS 2012
Corn, Sorghum and Sudan	Cropland	2.10	4	USGS 2012
Jeffrey Pine	Forest	57.40	3	Forest Climate Action Team 2018 Assumed to be mixed conifer
Almonds	Orchards/Vineyards	11.83	3	Saah et al. 2016 (Table 7)
Pomegranates	Cropland	2.10	1	USGS 2012

Notes: C = carbon; MT = metric tons; USGS = US Geological Survey.

Source: Prepared by Ascent in 2023.

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Attachment B

Baseline Carbon Stock Estimates by Jurisdiction

Capitola

Table A-1 Capitola Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Forest	4,779	792	5,571
Fresh Marsh	29	46	76
Oak Woodland	104	86	189
Urban	9,987	29,146	39,133
Wetland	22	33	55
Capitola Total	14,921	30,103	45,025

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Carmel-By-The-Sea

Table A-2 Carmel-By-The-Sea Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Fresh Marsh	17	82	99
Oak Woodland	2	6	8
Urban	3,768	19,326	23,095
Wetland	143	96	239
Carmel By-The-Sea Total	3,931	19,510	23,441

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Del Rey Oaks

Table A-3 Del Rey Oaks Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	148	148
Forest	213	72	286
Fresh Marsh	234	1,005	1,239
Grassland	23	658	681
Oak Woodland	536	1,609	2,146
Shrubland	2,092	9,666	11,758
Urban	1,566	11,228	12,794
Water	0	104	104
Wetland	120	1,267	1,388
Del Rey Oaks Total	4,786	25,758	30,543

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Gonzales

Table A-4 Gonzales Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	441	441
Cropland	155	9,189	9,344
Fresh Marsh	389	576	965
Grassland	26	540	566
Oak Woodland	5	6	10
Orchards/Vineyards	32	276	308
Shrubland	52	78	130
Urban	4,615	20,405	25,020
Water	0	424	424
Wetland	66	106	172
Gonzales Total	**5,339**	**32,040**	**37,379**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Greenfield

Table A-5 Greenfield Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	641	641
Cropland	438	11,499	11,937
Forest	210	115	325
Fresh Marsh	149	436	586
Grassland	241	3,764	4,005
Orchards/Vineyards	18	142	160
Shrubland	110	145	255
Urban	6,842	27,508	34,350
Water	0	211	211
Wetland	3	4	7
Greenfield Total	**8,012**	**44,465**	**52,477**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Hollister

Table A-6 Hollister Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	2,887	2,887
Cropland	2,325	37,248	39,574
Forest	59	35	94
Fresh Marsh	1,260	147	1,407
Grassland	122	2,091	2,213
Orchards/Vineyards	252	2,798	3,051
Other	0	67	67
Urban	4,811	115,827	120,638
Water	0	2,581	2,581
Wetland	57	17	74
Hollister Total	8,887	163,699	172,586

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

King City

Table A-7 King City Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	1,178	1,178
Cropland	1,037	11,078	12,115
Fresh Marsh	3,247	1,135	4,382
Grassland	354	5,666	6,020
Oak Woodland	8	48	56
Orchards/Vineyards	9	59	68
Shrubland	414	614	1,028
Urban	7,981	42,045	50,026
Water	0	633	633
Wetland	614	729	1,343
King City Total	13,663	63,185	76,848

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Marina

Table A-8 Marina Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	2,870	2,870
Cropland	0	2	3
Forest	2,408	1,720	4,128
Fresh Marsh	1,156	591	1,747
Grassland	1,363	19,369	20,732
Oak Woodland	3,156	9,606	12,762
Shrubland	7,169	29,083	36,252
Urban	17,643	109,867	127,509
Water	0	320	320
Wetland	679	801	1,480
Marina Total	**33,574**	**174,228**	**207,802**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Monterey

Table A-9 Monterey Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	117	117
Forest	4,146	2,204	6,350
Fresh Marsh	255	959	1,214
Grassland	137	3,799	3,936
Oak Woodland	1,550	4,607	6,157
Shrubland	1,279	2,705	3,984
Urban	28,464	137,232	165,696
Water	0	273	273
Wetland	294	783	1,077
Monterey Total	**36,125**	**152,677**	**188,803**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Pacific Grove

Table A-10 Pacific Grove Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	53	53
Forest	28	18	46
Fresh Marsh	7	22	29
Grassland	2	26	28
Oak Woodland	4	11	15
Shrubland	43	128	171
Urban	9,601	44,958	54,558
Water	0	56	56
Wetland	63	54	117
Pacific Grove Total	**9,747**	**45,326**	**55,073**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Salinas

Table A-11 Salinas Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	2,802	2,802
Cropland	2,030	79,303	81,333
Forest	93	43	136
Fresh Marsh	4,356	12,397	16,753
Grassland	308	5,788	6,096
Oak Woodland	91	240	330
Orchards/Vineyards	26	273	299
Shrubland	60	174	234
Urban	66,163	332,203	398,367
Water	0	639	639
Wetland	527	1,869	2,396
Salinas Total	**73,653**	**435,732**	**509,386**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

San Juan Bautista

Table A-12 San Juan Bautista Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Cropland	227	3,258	3,484
Fresh Marsh	103	314	418
Grassland	63	1,444	1,507
Oak Woodland	1	2	3
Orchards/Vineyards	51	445	497
Urban	388	7,757	8,146
Water	0	43	43
Wetland	59	232	291
San Juan Bautista Total	**893**	**13,496**	**14,389**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Sand City

Table A-13 Sand City Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	235	235
Forest	0	0	1
Grassland	8	82	90
Shrubland	303	707	1,010
Urban	908	5,008	5,916
Sand City Total	**1,219**	**6,032**	**7,251**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Santa Cruz

Table A-14 Santa Cruz Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	161	161
Cropland	376	3,849	4,225
Forest	104,436	23,271	127,707
Fresh Marsh	3,035	2,108	5,143
Grassland	925	17,992	18,918
Oak Woodland	3,319	4,938	8,258
Other	0	52	52
Shrubland	917	3,974	4,891
Urban	61,424	105,612	167,035
Water	0	334	334
Wetland	299	591	889
Santa Cruz Total	**174,731**	**162,882**	**337,614**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Scotts Valley

Table A-15 Scotts Valley Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	92	92
Forest	88,332	15,796	104,128
Fresh Marsh	93	282	375
Grassland	218	2,953	3,170
Oak Woodland	1,583	2,710	4,293
Shrubland	316	930	1,245
Urban	21,116	48,293	69,409
Water	0	113	113
Wetland	39	120	159
Scotts Valley Total	**111,695**	**71,290**	**182,985**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Seaside

Table A-16 Seaside Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	1,054	1,054
Forest	5,720	1,990	7,710
Fresh Marsh	240	839	1,080
Grassland	254	6,525	6,779
Oak Woodland	3,942	7,731	11,673
Shrubland	10,190	47,400	57,591
Urban	21,367	114,142	135,509
Water	0	201	201
Wetland	71	890	961
Seaside Total	**41,784**	**180,773**	**222,557**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Soledad

Table A-17 Soledad Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	289	289
Cropland	389	6,630	7,019
Forest	15	4	20
Fresh Marsh	1,704	921	2,625
Grassland	955	17,573	18,528
Oak Woodland	3	2	6
Orchards/Vineyards	21	258	279
Shrubland	266	353	618
Urban	9,883	49,859	59,742
Water	0	1,698	1,698
Wetland	659	783	1,442
Soledad Total	**13,896**	**78,370**	**92,266**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Unincorporated Monterey County

Table A-18 Unincorporated Monterey County Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	224,237	224,237
Cropland	213,820	4,795,906	5,009,727
Forest	5,587,727	2,304,989	7,892,716
Fresh Marsh	680,961	839,079	1,520,040
Grassland	860,471	16,801,646	17,662,117
Oak Woodland	3,627,257	9,653,895	13,281,153
Orchards/Vineyards	161,017	1,534,960	1,695,977
Other	0	761	761
Shrubland	6,838,058	10,416,808	17,254,866
Urban	247,585	1,115,654	1,363,239
Water	0	79,895	79,895
Wetland	117,909	266,152	384,061
Unincorporated Monterey County Total	**18,334,806**	**48,033,984**	**66,368,790**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Unincorporated San Benito County

Table A-19 Unincorporated San Benito County Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	88,997	88,997
Cropland	107,710	1,600,659	1,708,369
Forest	1,551,474	1,385,745	2,937,219
Fresh Marsh	168,366	145,703	314,069
Grassland	586,348	8,061,176	8,647,525
Oak Woodland	1,254,115	3,026,150	4,280,265
Orchards/Vineyards	25,878	224,523	250,401
Other	0	2,830	2,830
Shrubland	1,722,884	2,734,776	4,457,659
Urban	10,347	187,930	198,277
Water	0	40,145	40,145
Wetland	19,992	36,509	56,501
Unincorporated San Benito County Total	**5,447,113**	**17,535,143**	**22,982,257**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Unincorporated Santa Cruz County

Table A-20 Unincorporated Santa Cruz County Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	14,127	14,127
Cropland	35,178	583,960	619,138
Forest	18,185,709	3,314,237	21,499,946
Fresh Marsh	82,852	70,453	153,305
Grassland	19,560	314,148	333,708
Oak Woodland	322,521	594,841	917,361
Orchards/Vineyards	10,953	70,988	81,941
Other	0	372	372
Shrubland	155,727	392,276	548,003
Urban	254,597	597,530	852,127
Water	0	6,546	6,546
Wetland	7,478	17,127	24,605
Unincorporated Santa Cruz County Total	**19,074,575**	**5,976,604**	**25,051,179**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Watsonville

Table A-21 Watsonville Baseline Aboveground and Soil Carbon

Land Cover Type	Aboveground Carbon (MT C)	Soil Carbon[1] (MT C)	Total Carbon (MT C)
Barren	0	17	17
Cropland	319	3,802	4,121
Forest	5,046	721	5,766
Fresh Marsh	1,539	3,046	4,585
Grassland	359	5,275	5,635
Oak Woodland	408	725	1,133
Other	0	31	31
Shrubland	604	2,876	3,480
Urban	40,901	85,369	126,270
Water	0	220	220
Wetland	401	1,172	1,573
Watsonville Total	**49,577**	**103,255**	**152,832**

Notes: C = carbon; MT = metric tons.

[1] Soil carbon includes carbon held up to 50 centimeters deep.

Source: Analysis completed by Ascent in 2023.

Memo

1230 Columbia Street, Suite 440
San Diego, CA 92101
619.219.8000

Date: November 16, 2023

To: Amaury Berteaud, Gina Schmidt, and Will Condon (AMBAG)

From: Fred Hochberg, Hannah Kornfeld, and Poonam Boparai (Ascent)

Subject: **Monterey Bay Natural and Working Lands Climate Mitigation and Resiliency Study – Carbon Stock Scenario Forecast Technical Memorandum**

INTRODUCTION

This technical memorandum (memo) presents the methodology and results for the forecast of 2045 carbon stock in the natural and working lands (NWL) of Santa Cruz, Monterey, and San Benito Counties (collectively referred to as the "Study Area"). All carbon stock values in this memo are presented in terms of metric tons of carbon (MT C) or million metric tons of carbon (MMT C).

METHODOLOGY

The data underlying the *Monterey Bay Natural and Working Lands Climate Mitigation and Resiliency Study – Carbon Stock Inventory Final Technical Memorandum* (see Association of Monterey Bay Area Governments [AMBAG] 2023: 9-11) was used as a baseline of carbon stock estimates. Table 1 below shows a summary of these data. "Study Area Land Cover Type" refers to the categories of land cover that were used for the purposes of this analysis. A full description of the more specific types of land cover that "roll up" to these categories can be found in AMBAG (2023: A-1 through A-3). The stocks of carbon shown in Table 1 were assumed to represent existing conditions in the study area as of 2020, which is the baseline year of the AMBAG Land Use Model that is currently in development.

Table 1 Estimated Baseline Carbon Stock in Study Area NWL as of 2020 (MMT C)

Study Area Land Cover Type	Soil Carbon	Aboveground Carbon	Total Carbon
Forest	7.1	25.5	32.6
Fresh Marsh	1.1	0.9	2.0
Oak Woodland	13.3	5.2	18.5
Urban	3.2	0.8	4.0
Cropland	7.1	0.4	7.5
Orchards/Vineyards	1.8	0.2	2.0
Shrubland	13.6	8.7	22.4
Grassland	25.3	1.5	26.7
Wetland	0.3	0.1	0.5
Other	0.0	0.0	0.0
Barren	0.3	0.0	0.3
Water	0.1	0.0	0.1

Study Area Land Cover Type	Soil Carbon	Aboveground Carbon	Total Carbon
Total	73.3	43.5	116.8

Notes: MMT C = million metric tons of carbon; NWL = natural and working lands. Totals may not sum exactly due to independent rounding.

Source: Data compiled and analyzed by Ascent Environmental in 2023.

Next, a percent change in carbon stock by 2045 relative to the 2020 baseline was estimated. The California Air Resource Board's (CARB's) NWL carbon stock projections were used as the basis of this analysis (CARB 2022a). CARB generated these projections as part of the 2022 Scoping Plan for Achieving Carbon Neutrality (referred to hereafter as the 2022 Scoping Plan), the statewide plan to achieve carbon neutrality no later than 2045. The projections comprise five forecast scenarios of the quantity of statewide carbon stock for different land cover types; each scenario differs in the type and extent of land use practices that it implements, though all account for future climate change and wildfires (CARB 2022b: 14-18 and 29-31). Of these five, the following two were selected for the analysis in this memo:

1) The business-as-usual (BAU) scenario, which assumes that the land management practices in place from 2001 through 2014 continue through 2045 (CARB 2022b: 39). In this period, statewide forests, shrublands, and grasslands receive land management actions such as clearcutting, harvesting, mastication, and prescribed burning at a rate of 250,000 acres per year (CARB 2022b: 15-19). CARB chose the 2001-2014 timeframe because 2014 represented the latest available carbon data before CARB's Climate Investments (such as conservation and land restoration—see CARB [2023a: 34-35]) were fully implemented on the landscape (CARB 2022b:41-46). Thus, the 2001-2014 period represents a baseline against which the carbon storage effects of additional land management actions can be measured.
2) The Scoping Plan scenario, which is the scenario that CARB selected to achieve carbon neutrality by 2045 per its mandate in Assembly Bill 1279, the California Climate Crisis Act (CARB 2023b). The Scoping Plan scenario assumes that the creation of climate-resilient carbon stocks is prioritized, resulting in 2.3 million acres treated statewide per year (CARB 2022b: 16). This rate of treatment is approximately 9 times greater than the rate in the BAU scenario described above. The increased treatment is anticipated to, for example, reduce wildfire fuel availability, which will decrease wildfire severity and create more climate-resilient carbon stocks. Table 2 below summarizes the extent of the actions in the Scoping Plan Scenario.

Table 2 Level of Statewide Action on NWL in 2022 Scoping Plan Scenario

Description of Action	Level of Action
Forest, shrubland, and grassland fuel reduction and restoration	2,300,000 acres per year
Regenerative agriculture and cropland conservation above BAU	150,000 acres per year
Urban Forest investment increase above current investment	200 percent annual increase
Defensible space establishment in wildland urban interface	50,000 properties per year
Delta wetland restoration	60,000 total acres by 2045
Desert conservation above current conservation	15,000 acres per year

Notes: BAU = business-as-usual; NWL = natural and working lands.

Source: CARB 2022b: 18.

Both the BAU and Scoping Plan scenarios show substantial fluctuation in carbon stock from year to year that may not be indicative of overall long-term trends. For example, land may absorb carbon one year and emit it in the next due to wildfire. Therefore, comparing any two individual years to calculate the trend in carbon stocks between them is misleading, because it could be caused by short-term "noise" rather than real long-term effects. To account for this phenomenon, data from the individual years of 2020 and 2045 was not used to calculate the percent change in carbon stock. Instead, an average annual stock across the 10 years encompassing these individual years was used (i.e., the annual average from 2015 to 2024 [representing 2020, the midpoint of this range] was compared to the annual average from 2040 to 2049 [representing 2045]). This approach "smooths out" short-term fluctuations, and thus better indicates the likely overall trajectory of carbon over the 25 years between 2020 and 2045. The exceptions to this approach were Delta, Wildland-Urban Interface lands, and Desert lands, which do not have carbon stock data after 2045. Therefore, for these land cover types, only the year 2045 was used as an estimate of future carbon storage, not an average from 2040 to 2049. Collectively, these land cover types only represent approximately 2 percent of the total carbon stock in the Study Area, so these missing data have a minimal impact on the overall result.

Table 3 below shows the results of this analysis by each land cover type for which CARB presented data. A negative percent change indicates that statewide carbon stock is expected to decrease from 2020 to 2045 (i.e., carbon is released from the land into the atmosphere, due to decomposition of organic matter, wildfire, or human-caused disturbances); a positive change indicates that statewide carbon stock increases (plants use photosynthesis to draw carbon from the atmosphere into the land).

Table 3 Statewide 2020 and 2045 Carbon Stock by CARB Scenario

CARB Land Cover Type	MMT C 2020	MMT C 2045 (BAU)	MMT C 2045 (Scoping Plan)	Change relative to 2020 2045 (BAU)	Change relative to 2020 2045 (Scoping Plan)
Forests	1,245.8	1,184.6	1,178.5	-4.9%	-5.4%
Shrubs	631.7	584.5	588.6	-7.5%	-6.8%
Grasslands	124.1	129.1	134.4	4.1%	8.3%
Annual Croplands	39.8	39.0	40.1	-1.9%	1.0%
Perennial Croplands	38.6	49.7	49.7	28.6%	28.7%
Delta	916.8	910.2	913.4	-0.7%	-0.4%
Wildland-Urban Interface	18.5	18.5	14.2	0.0%	-22.9%
Urban Forests	27.7	28.4	35.6	2.2%	28.4%
Deserts	>0.1	>0.1	>0.1	-0.2%	-0.1%
Total	**3,043.0**	**2,943.9**	**2,954.6**	**-3.3%**	**-2.9%**

Notes: BAU = business-as-usual; CARB = California Air Resources Board; MMT C = million metric tons of carbon. Percent values are rounded to the nearest tenth of a percent; totals may not sum exactly due to independent rounding.

Source: Data compiled and analyzed by Ascent Environmental in 2023 based on data from CARB 2022a.

To calculate 2045 carbon stocks, the percent changes shown in the two rightmost columns of Table 3 were applied to the 2020 Study Area carbon estimates, as appropriate. Because the land cover types used by CARB and the Study Area did not match exactly, the nearest analogous land cover type was chosen in order to perform this calculation. For example, CARB had no specific carbon estimates for orchards and vineyards, so the rate of carbon sequestration in perennial croplands from CARB data was assigned to the Study Area's orchards and vineyards as a proxy. Due to the lack of vegetation on "other" land types, barren lands, and water, these lands were assumed not to sequester carbon.

Additionally, while the carbon stock percent changes shown in Table 3 were applied to all aboveground carbon in the Study Area, they were not applied to all soil carbon estimates. Specifically, soil carbon stocks were assumed to change from 2020 to 2045 for Study Area land cover types mapping to annual croplands and Delta wetlands but remain at 2020 levels for all other land cover types. This is because the CARB carbon stock data only included estimates of soil carbon for annual croplands and Delta wetlands; it did not include soil carbon stock data for the rest of the land cover types (CARB 2022b: 7).

Table 4 below summarizes the results of these steps. It shows how land cover types from the 2022 Scoping Plan were mapped to the land cover types in the Study Area. It also shows which land cover types were assumed to change their carbon stock per the percentages in Table 3, and which were not.

Table 4 Methodology for Applying Carbon Stock Changes from 2022 Scoping Plan Data to Study Area

Study Area Land Cover Type	Corresponding CARB Land Cover Type	Change in Soil Carbon Stock, 2020 - 2045	Change in Aboveground Carbon Stock, 2020 - 2045
Forest	Forests	No	Yes
Fresh Marsh	Delta	Yes	Yes
Oak Woodland	Forests	No	Yes
Urban	Urban Forests	No	Yes
Cropland	Annual Croplands	Yes	Yes
Orchards/Vineyards	Perennial Croplands	No	Yes
Shrubland	Shrubs	No	Yes
Grassland	Grasslands	No	Yes
Wetland	Delta	Yes	Yes
Other	NA	NA	NA
Barren	NA	NA	NA

Notes: CARB = California Air Resources Board; NA = not applicable.

Source: Prepared by Ascent Environmental in 2023.

RESULTS FOR STUDY AREA AND CONCLUSION

Tables 5 and 6 below show the forecast results by Study Area land cover type and jurisdiction, respectively; see AMBAG (2023: 4-9 and Appendix B-1 through B-10) for a description of the Geographic Information Systems analysis that apportioned the carbon stocks to different jurisdictions. Both results show a loss of carbon in the land in the Study Area. These results are consistent with CARB's results in the 2022 Scoping Plan, which states that under all land management levels, forests and shrublands are expected to lose carbon over the next two decades due to climate change, drought stress, and wildfire (CARB 2023c: 251).

Specifically, Tables 5 and 6 show that, from 2020 to 2045, there is a decrease in carbon stored in the Study Area of approximately 2.2 MMT, or 1.9 percent, in the BAU scenario, and a decrease of 1.8 MMT, or 1.5 percent, in the Scoping Plan scenario. The decrease is smaller in the Scoping Plan scenario than in the BAU scenario by approximately 0.4 MMT. This difference is due to the land management activities detailed in Table 2, which creates more climate-resilient carbon stocks.

This implies that the land management actions listed in Table 2 could, if implemented in the Study Area, mitigate up to 0.4 MMT of carbon loss. This is an approximation; the exact amount would depend on the timing, specific areas, and extent to which these practices were implemented, as well as the Study Area's current level of land management activities. Decisions on additional land management activities would need to be evaluated in the local context of the Study Area, accounting for feasibility, cost, and acceptability to land managers and owners.

Table 5 Study Area Current and Forecasted Carbon Stock by Land Type (MMT C)

Study Area Land Cover Type	2020 Soil	2020 Aboveground	2045 BAU Soil	2045 BAU Aboveground	2045 Scoping Plan Soil	2045 Scoping Plan Aboveground
Forest	7.1	25.5	7.1	24.3	7.1	24.2
Fresh Marsh	1.1	0.9	1.1	0.9	1.1	0.9
Oak Woodland	13.3	5.2	13.3	5.0	13.3	4.9
Urban	3.2	0.8	3.2	0.8	3.2	1.1
Cropland	7.1	0.4	7.0	0.4	7.2	0.4
Orchards/Vineyards	1.8	0.2	1.8	0.3	1.8	0.3
Shrubland	13.6	8.7	13.6	8.1	13.6	8.1
Grassland	25.3	1.5	25.3	1.5	25.3	1.6
Wetland	0.3	0.1	0.3	0.1	0.3	0.1
Other	0.0	0.0	0.0	0.0	0.0	0.0
Barren	0.3	0.0	0.3	0.0	0.3	0.0
Water	0.1	0.0	0.1	0.0	0.1	0.0
Total	**73.3**	**43.5**	**73.2**	**41.4**	**73.4**	**41.6**

Notes: BAU = business-as-usual; MMT C = million metric tons of carbon. Totals may not sum exactly due to independent rounding.

Source: Analysis conducted by Ascent Environmental in 2023.

Table 6 Study Area Current and Forecast Total Carbon Stock by Jurisdiction, Including Soil and Aboveground (MT C)

	2020	2045 BAU Forecast	2045 Scoping Plan Forecast
Santa Cruz County			
Capitola	45,025	45,008	47,593
Santa Cruz	337,614	333,545	349,249
Scotts Valley	182,985	179,025	184,115
Unincorporated Santa Cruz County	25,051,179	24,127,124	24,123,888
Watsonville	152,832	153,328	164,141
Santa Cruz County Total	**25,769,634**	**24,838,030**	**24,868,986**
Monterey County			
Carmel By-The-Sea	23,441	23,523	24,508
Del Rey Oaks	30,543	30,367	30,797
Gonzales	37,379	37,301	38,780
Greenfield	52,477	52,395	54,536
King City	76,848	76,740	79,209
Marina	207,802	207,421	212,117
Monterey	188,803	189,055	196,483
Pacific Grove	55,073	55,283	57,791
Salinas	509,386	509,182	528,872
Sand City	7,251	7,249	7,488
Seaside	222,557	221,797	227,414
Soledad	92,266	92,348	95,186
Unincorporated Monterey County	66,368,790	65,382,496	65,633,881
Monterey County Total	**67,872,615**	**66,885,157**	**67,187,061**
San Benito County			
Hollister	172,586	172,000	174,402
San Juan Bautista	14,389	14,343	14,549
Unincorporated San Benito County	22,982,257	22,711,875	22,787,304
San Benito County Total	**23,169,231**	**22,898,217**	**22,976,255**
Grand Total	**116,811,480**	**114,621,404**	**115,032,302**

Notes: BAU = business-as-usual; MT C = metric tons of carbon. Totals may not sum exactly due to independent rounding.

Source: Analysis conducted by Ascent Environmental in 2023.

REFERENCES

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