County of Sonoma

Carbon Inventory and Sequestration Potential Study

October 2023

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These organizations participated in collaborative project scoping, design, and draft-editing sessions. The time and expertise they dedicated brought needed insight into the carbon stock inventory analysis and informed the study regarding on-going, local carbon sequestration activities.

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GLOSSARY

C

CALIFORNIA AIR RESOURCES BOARD (CARB) –
CARB is charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change. CARB's mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. CARB is the lead agency for climate change programs and oversees all air pollution control efforts in California to attain and maintain health-based air quality standards.

CALIFORNIA AIR RESOURCES BOARD (CARB) LAND RESTORATION BENEFITS CALCULATOR –
A tool to estimate the net greenhouse gas benefit and selected co-benefits of each proposed Land Restoration project type used by Programs funded by the Greenhouse Gas Reduction Fund.

CALIFORNIA AIR RESOURCES BOARD (CARB) SCOPING PLAN – Lays out a path to achieve targets for carbon neutrality and reduce anthropogenic greenhouse gas emissions by 85 percent below 1990 levels no later than 2045, as directed by Assembly Bill 1279.

CARBON NEUTRALITY – A state of net-zero carbon emissions, achieved by balancing total carbon dioxide emissions with equal removal of atmospheric carbon.

CARBON or CARBON DIOXIDE (CO_2) – A natural occurring atmospheric gas, also produced by burning fossil fuels, through land-use changes, and industrial processes.

CO_2e – Carbon dioxide equivalent. Greenhouse gases trap heat in the earth's atmosphere at different rates (see Global Warming Potential). Using a greenhouse gases' global warming potential, gases other than CO_2 are translated into CO_2 equivalents (CO_2e) so all greenhouse gases may be summed together.

CARBON SEQUESTRATION – Process of capturing, securing, and storing carbon from the atmosphere, for example in vegetation such as grasslands or forest, as well as in soils and oceans. This process occurs naturally and can also be facilitated by human activities.

CARBON SINK – A natural environment, such as a forest or ocean, recognized for its ability to absorb and store carbon dioxide from the atmosphere.

CARBON STOCK – The quantity of carbon contained in a "pool" or reservoir (such as vegetation, soil, rock, etc.) that accumulates or releases carbon.

CLIMATE CHANGE – A shift in local and global climate patterns, most acutely attributed to changes since the late twentieth century and increased levels of greenhouse gases, produced by the use of fossil fuels, emitted into the atmosphere.

CLIMATE SMART LAND MANAGEMENT (CLIMATE SMART PRACTICES) – Managing lands to deliver climate benefits. Specific actions or practices may be called climate smart practices, and in the case of agricultural practices may be referred to as climate smart agriculture.

CO-BENEFITS – Positive benefits related to climate mitigating actions (e.g., reduced air pollution).

COMET-PLANNER – An evaluation tool designed to provide estimates of the net greenhouse gas reductions for specific agricultural management conservation practices included in the California Department of Food and Agriculture Healthy Soils Program and is intended for initial planning purposes.

COMMUNITY-BASED ORGANIZATION (CBO) – A community-based organization is typically a non-profit organization that represents a serves a community or segment of the community. A CBO often works to identify, prioritize, and address the needs or objectives of the community, and can assist the community in taking action and collaboration with government entities or other organizations.

F

FOREST – is an area of land dominated by trees. In this report, the term "forest" term is used to encompass woodlands that occur in Sonoma County, such as oak woodlands and redwood forests.

G

GLOBAL WARMING POTENTIAL (GWP) – The measure of how much energy the emissions of one ton of a gas will absorb, relative to the emissions of one ton of carbon dioxide. Global warming potential was developed to allow comparisons of global warming impacts of different greenhouse gases.

GREENHOUSE GAS(ES) (GHGs) – Gases that trap heat in the atmosphere (e.g., CO_2, methane, nitrous oxide, and ozone).

H

HEALTHY SOILS PROGRAM (HSP) – The Healthy Soils Program stems from the California Healthy Soils Initiative, a collaboration of state agencies and departments to promote the development of healthy soils on California's farmlands and ranchlands. The Healthy Soils Program has two grant programs:
1) the HSP Incentives Program which provides financial assistance for implementation of conservation management that improves soil health, sequesters carbon, and reduces greenhouse gas emissions, and
2) the HSP Demonstration Projects which showcase California farmers and ranchers' implementation of Health Soils Program practices.

I

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) – Created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP), the IPCC is an organization of governments that are members of the UN or WMO tasked with providing government at all levels with regular assessments of the scientific basis of climate change, its impacts and future risk, and options for adaptation and mitigation. Hundreds of experts review thousands of research papers to produce the assessment reports which serve as comprehensive summaries of what is known about climate change.

IPCC ASSESSMENT REPORT 5 (IPCC AR5) – provides the state of knowledge concerning the science of climate change. IPCC AR5 was developed by climate change experts and government representatives. The Special Report on Climate Change and Land addresses greenhouse gas fluxes in land-based ecosystems, land use and sustainable management in relation to climate change adaptation and mitigation, desertification, land degradation, and food security.

L

LAND COVER – The physical land type at a location (i.e., forest, open water).

LANDFIRE – (also known as Landscape Fire and Resource Management Planning Tools), is an interagency vegetation, fire, and fuel characteristics mapping program, sponsored by the United States Department of the Interior (DOI) and the United States Department of Agriculture, Forest Service. LANDFIRE produces a comprehensive, consistent, scientifically credible suite of geo-spatial data layers for the entire United States.

N

NATURAL AND WORKING LANDS – Natural and working lands include forests, grasslands, shrublands/chaparral, croplands, urban green spaces, and wetlands.

NATURE-BASED SOLUTIONS (NBS) BENEFITS EXPLORER – A web-based tool developed to serve as a key starting point for organizations looking to invest in nature-based solutions, and for those who want to learn more about benefit identification and accounting.

NATURAL RESOURCES CONSERVATION SERVICE (NRCS) GHG AND CARBON SEQUESTRATION RANKING TOOL – A tool that provides a qualitative ranking of the benefits of a variety of agricultural practices for greenhouse gas emission reduction and carbon sequestration.

O

ORGANIC CARBON OR BIOSPHERIC CARBON – Produced by and found in living organisms including plants and soils, whereas inorganic carbon is present in minerals, rocks, and non-biologic sediments.

P

PERMIT SONOMA – Sonoma County's consolidated land use planning and development permitting agency, which includes land development or construction that takes place in the unincorporated areas of Sonoma County (outside the nine incorporated cities).

R

RESOURCE CONSERVATION DISTRICTS (RCDs) – RCDs are non-governmental special districts of the State of California, set up to be locally governed agencies with their own locally appointed or elected, independent boards of directors. California RCDs implement projects on public and private lands and educate landowners and the public about resource conservation. RCDs are go-to hubs for natural resource conservation and agriculture on public and private lands at local, regional, state, tribal, and federal levels. The Gold Ridge RCD and Sonoma RCD both serve Sonoma County.

S

SOIL ORGANIC CARBON – Soil carbon refers to solid carbon stored in soils, existing in organic and inorganic forms. Soil organic carbon is present within soil organic matter, such as plant and animal waste, microbes, and microbial byproducts. The total amount of organic carbon present in soil is one of the primary indicators of soil health.

SONOMA COUNTY AGRICULTURAL PRESERVATION AND OPEN SPACE DISTRICT (AG + OPEN SPACE) – a community-created taxpayer-funded agency to create lasting protections (e.g. conservation easements) for agricultural and natural lands in Sonoma County.

SONOMA COUNTY BOARD OF SUPERVISORS – the governing board of Sonoma County and of special jurisdictions including the Sonoma County Water Agency and Ag + Open Space. The Board is composed of five supervisors elected from supervisorial districts for four year terms.

SONOMA COUNTY REGIONAL CLIMATE PROTECTION AUTHORITY (RCPA) – coordinates countywide climate protection efforts among Sonoma County's nine incorporated jurisdictions, and across multiple countywide agencies.

SONOMA COUNTY REGIONAL PARKS – local agency stewarding more than 50 parks and beaches in Sonoma County, delivering the mission of connecting people with nature.

SONOMA COUNTY VEGETATION MAPPING AND LIDAR PROGRAM (SONOMA VEG MAP) – 5-year program to map Sonoma County's topography, physical and biotic features, and plant communities and habitats. The resulting products include a suite of fine scale data products, like countywide LiDAR data.

SONOMA WATER – independent special district directed by the Sonoma County Board of Supervisors to provide water supply, flood protection, and wastewater services.

T

TERRACOUNT – A scenario analysis tool, which was piloted for the Resilient Merced project to develop scenarios of change in land use and land management and evaluate future impacts on carbon stocks.

ES.
EXECUTIVE SUMMARY

Climate change has harmful, sometimes catastrophic effects on public health, natural resources, infrastructure, and emergency response. Sonoma County has already felt the effects of climate change at the local level, through lives and homes tragically lost to wildfire including the Nuns, and Pocket Fires and Kincade fires, which burned 143,388 acres of Sonoma County between 2017 and 2019 (CAL FIRE, 2017, 2019). The LNU Lightning Complex, and Glass Fires of 2020 also burned significant acreage across Sonoma County. Natural and working lands have been recognized as a powerful tool to address climate change, allowing the County of Sonoma to make progress towards its greenhouse gas (GHG) reduction goals, while increasing resiliency to future climate impacts. Natural and working lands, which include the iconic redwood forests, oak woodlands, vineyards, and pasturelands found across Sonoma County, can be a powerful engine for mitigating climate change and increasing resilience to climate impacts through climate smart land management practices (climate smart practices).

The purpose of this Carbon Inventory and Sequestration Potential Study (Study) is to establish the first detailed quantitative estimate of Sonoma County's historical and existing carbon stocks and changes over time. This is a critical first step in meeting local, State, and national climate goals as it identifies baseline conditions, and methods for identifying changes in carbon stocks over time. It should be noted that new programs are being undertaken to assess carbon sequestration on working lands, which will be described further in ***Section 2 Regional Efforts***. The Study also assesses the potential impact of climate smart practices, and ultimately identifies a set of measures and actions for the County and key stakeholders to consider for implementation across Sonoma County's rich and varied landscapes.

HOW THIS STUDY ADVANCES SONOMA COUNTY'S CLIMATE GOALS

The County of Sonoma has developed specific goals to decrease net greenhouse gas (GHG) emissions and achieve carbon neutrality by 2030 through decarbonization and sequestration and develop policies to optimize carbon sequestration while minimizing the loss of natural carbon sinks. This direction comes from the County of Sonoma 5-year Strategic Plan, which was approved by the Board of Supervisors on March 2, 2021. This Study implements the County's 5-Year Strategic Plan by assessing the carbon sequestration potential of climate smart practices while considering the climate change impact on carbon stocks. There are numerous policies and plans developed by the County of Sonoma and other local agencies to address climate smart practices on natural and working lands.

- Sonoma County Board of Supervisors Climate Change Action Resolution (18-0166)
- Sonoma County 5-Year Strategic Plan 2021-2026 Climate Action and Resiliency: Goal 5
- Sonoma County General Plan
- Sonoma County Climate Resilient Lands Strategy
- Sonoma County Integrated Parks Plan
- Regional Parks Sonoma County Strategic Plan 2023-2025
- Sonoma County Ag + Open Space 2021 Vital Lands Initiative
- Sonoma County Ag + Open Space Healthy Lands and Healthy Economies
- Community Grazing Collaboratives
- Sonoma Water Climate Adaptation Plan
- Sonoma Climate Mobilization Strategy, Regional Climate Protection Authority
- Climate Action 2020 and Beyond, Regional Climate Protection Authority

This Study is intended to provide a starting point for further analysis informed by local climate smart practice planning and implementation activities. The County, along with many regional partners, has embarked on the Sonoma-Marin Ag and County Climate Coalition (SMACCC) project, funded by the USDA Climate Smart Commodities grant program. SMACCC project implementation and monitoring efforts within the Sonoma County will be led by the Gold Ridge Resource Conservation District and the Sonoma Resource Conservation District (RCDs). The RCDs will leverage their local expertise and ongoing relationships with the agricultural community to increase the pace and scale of carbon farm planning and climate smart practice implementation. Data gathered from these efforts will be used to refine the sequestration and co-benefits analysis, further localized climate smart agricultural planning, and evaluate realistic adoption targets for practices given the sequestration potential, logistics, costs, and numerous co-benefits associated with each practice. Future planning for climate smart practice implementation should incorporate RCD data based on local implementation activities as much as possible and be guided by the work of the SMACCC project. Additionally, future analysis could elaborate on how the land use categories utilized for the purposes of this Study equate to local zoning designations, to aid decision makers in incorporating these findings into general plan policies and goals.

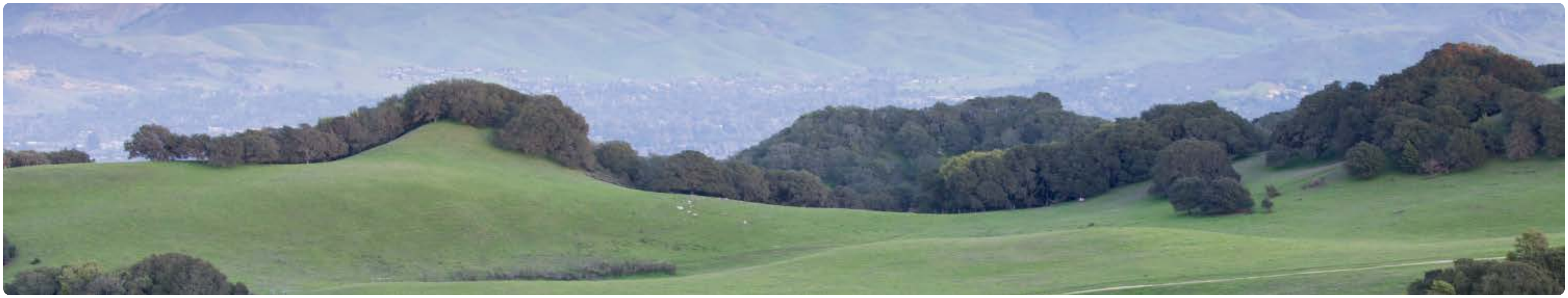
WHAT IS CARBON SEQUESTRATION AND WHY IS IT IMPORTANT?

Carbon sequestration is the removal and storage of carbon from the atmosphere. This process occurs naturally through plant photosynthesis, where carbon is drawn from the atmosphere and into plants and soil. Both natural and working lands can be carbon sinks, where plants and soils take in more carbon than they release. Conserving these carbon sinks can help move the county closer to achieving the objectives of carbon neutrality, land conservation, and carbon sequestration (County of Sonoma, 2021). Carbon sequestration is not the only benefit of conserving, restoring, and strategically managing natural and working lands. Natural and working lands also provide numerous social, economic, and ecosystem benefits to wildlife and the wider community. In most cases, the co-benefits of climate smart practices (e.g., habitat creation and water quality) motivate implementation while carbon sequestration is an added benefit, not often quantified until recently. The focus of this Study is to consider the potential impacts of increasing the pace and scale of implementing climate smart practices that increase the overall health of natural and working lands, while providing additional, social, economic, and ecosystem benefits.

APPROACH

This Study includes land-based carbon inventories for 2013 and 2022. The land-based carbon inventories quantify the amount of carbon stored across different land cover classes, establishing a baseline to assess the existing carbon stock and sequestration potential of natural and working lands. This snapshot of existing carbon stock and sequestration by land cover class demonstrates what could be lost if carbon stocks across Sonoma County are not stabilized (e.g., if forests are lost to wildfire) or what could be built upon through optimizing climate smart land management practices. The land-based carbon inventory also allows for the modeling of future carbon sequestration potential and GHG reduction of different land-management activities, which can serve as the basis to inform selecting and prioritization of climate smart practices for County of Sonoma.

This land-based carbon inventory is calculated by first assessing the type of land cover classes across Sonoma County by acre, and then by quantifying the amount of carbon stored in the different land cover classes. Inventories provide a snapshot of the carbon stock in a region's land-based ecosystems at a given moment in time. Comparing land cover and carbon inventory values between years can help identify trends in land cover change and estimate increases or decreases in carbon stocks. Carbon stock assessments described in this Study account for land-cover based changes between years, and do not account for changes in land management practices. This analysis also includes a description of carbon stock by landownership, as implementing climate-smart solutions across public and private ownership will require different degrees of coordination, and different stakeholder-tailored strategies.



SONOMA COUNTY CARBON STOCK INVENTORIES

Sonoma County's diverse landscapes held approximately 117,593,161 MT CO_2e in 2013 and 105,365,590 MT CO_2e in 2022, providing critical co-benefits like healthy ecosystems and watersheds, recreation areas, and local food production. Carbon stocks and emission potential varies by land cover. For example, in croplands carbon stocks are relatively stable to fire risks because they are generally irrigated and heavily managed landscapes, while shrubland and forests may be more susceptible to losses from wildfire. Land conversion (e.g., development conversions of wildland or agricultural to other uses), can result in carbon stock losses. This Study captures carbon stock changes based on vegetation type, cover, and height. The results of the Sonoma County Carbon Inventories are provided in ***Table ES-1***. The sources, methodology, and further detail on this analysis are described in ***Section 3 Land Cover and Carbon Stock Analysis*** and ***Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***.

Table ES-1. 2013 and 2022 Sonoma County Total Carbon Stock

Land Cover Class	2013 Total Carbon Stock (MT CO_2e)	2022 Total Carbon Stock (MT CO_2e)	Percent Change between 2013 and 2022 (MT CO_2e)
Barren	440,119	367,468	-17
Cultivated and Field Crops	100,577	101,027	0
Development	6,962,559	7,749,627	11
Forest	78,034,944	61,578,011	-21
Grassland/Herbaceous	18,109,720	17,988,852	-1
Open Water	675,920	1,303,822	93
Orchard	239,362	202,396	-15
Pasture and Hay	2,396,328	3,944,917	65
Shrub/Scrub	4,094,253	5,196,075	27
Vineyard	3,593,475	4,582,317	28
Wetland	2,945,905	2,354,039	-20
Total	**117,593,161**	**105,365,950**	**-10**

CLIMATE SMART PRACTICES TO INCREASE CARBON SEQUESTRATION

Evaluating carbon sequestration potential on the regional level helps us understand what climate smart practices could potentially achieve the greatest amount of carbon sequestration and work towards meeting climate goals. This Study estimated the following for each climate smart practice (see *Table ES-2*):

- Estimated implementation acreage
- Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan
- Annual Carbon Sequestration – 100 Percent Adoption Scenario

For further discussion see *Section 4 Climate Smart Practices and Analysis* and for a full description of the methodology please refer to *Appendix C Carbon Sequestration Analysis of Climate Smart Practices*.

Table ES-2. Estimated Implementation Acreages for All Climate Smart Practices

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 Percent Adoption Scenario (MT CO_2e)
NATURAL LANDS				
Forest				
Forest Slash Treatment (CPS 384)	414,591	NA	NA	NA
Fuel Reduction	399,044	20	7,980,870	399,044
Improved Forest Management Thinning from Below	15,548	50	1,399,284	27,986
Riparian Restoration	970	45	296,602	6,591
Grasslands				
Native Grassland Restoration	132,077	50	3,957,357	79,147
Oak Woodland Restoration	11,889	50	861,953	17,239
Riparian Restoration	339	45	103,658	2,304
URBAN FOREST				
Development				
Urban Forestry	5,266	50	35,056,040	701,121

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 Percent Adoption Scenario (MT CO_2e)
URBAN FARMS				
Cultivated and Field Crops Orchards and Vineyards				
Biochar Application (CPS 336)	59	NA	NA	NA
Cultivated and Field Crops				
Compost Application and Nutrient Management (CPS 590)	7.1	6	87	14
Conservation Crop Rotation (CPS 328)	24.0	1	5	5
Cover Cropping (CPS 340)	5.3	1	2	2
Field Border (CPS 386)	6.7	20	165	8
Hedgerow Planting (CPS 422)	0.4	34	121	4
Mulching (CPS 484)	7.7	5	12	2
Residue and Tillage Management - No Till (CPS 329)	24.0	1	5	5
Residue and Tillage Management - Reduced Till (CPS 345)	24.0	1	3	3
Windbreak/Shelterbelt Establishment (CPS 380)	1.6	80	1,048	13
Orchard and Vineyard				
Compost Application and Nutrient Management (CPS 590)	51.8	6	482	80
Cover Cropping (CPS 340)	38.8	1	64	64
Hedgerow Planting (CPS 422)	3.1	34	864	25
Mulching (CPS 484)	56.1	5	95	19
Residue and Tillage Management - No Till (CPS 329)	114.4	1	40	40
Residue and Tillage Management - Reduced Till (CPS 345)	114.4	1	14	14
Windbreak/Shelterbelt Establishment (CPS 380)	11.4	80	7,493	94

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 Percent Adoption Scenario (MT CO_2e)
WORKING LANDS				
All Agricultural Land Covers				
Riparian Forest Buffer (CPS 391)	4,503	45	1,835,873	40,797
Riparian Herbaceous Cover (CPS 390)	4,503	10	9,456	946
Cultivated and Field Crops				
Alley Cropping (CPS 311)	1,210	15	31,581	2,105
Biochar Application (CPS 336)	849	NA	NA	NA
Compost Application (CPS 808) - Compost C/N </= 11, 3 tons per acre	849	6	10,545	1,758
Compost Application (CPS 808) - Compost C/N > 11, 6 tons per acre	849	6	22,109	3,685
Compost Application (CPS 808) and Nutrient Management (CPS 590)	849	6	10,443	1,741
Conservation Cover (CPS 327)	61	1	38	38
Conservation Crop Rotation (CPS 328)	1,210	1	266	266
Cover Cropping (CPS 340)	849	1	340	340
Field Border (CPS 386)	109	20	2,679	134
Filter Strip (CPS 393)	17	10	215	21
Hedgerow Planting (CPS 422)	23	34	6,539	192
Mulching (CPS 484)	551	5	882	176
Nutrient Management (CPS 590)	849	1	-17	-17
Pasture and Hay Planting (CPS 512)	121	5	738	148
Residue and Tillage Management - No Till (CPS 329)	1,210	1	266	266
Residue And Tillage Management - Reduced Till (CPS 345)	1,210	1	145	145
Windbreak/Shelterbelt Establishment (CPS 380)	33	80	21,899	274
Orchard				
Biochar Application (CPS 336)	2,313	NA	NA	NA
Compost Application (CPS 808)	2,264	6	21,056	3,509

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 Percent Adoption Scenario (MT CO_2e)
Compost Application (CPS 808) and Nutrient Management (CPS 590)	2,264	6	21,056	3,509
Cover Cropping (CPS 340)	2,313	1	3,793	3,793
Filter Strip (CPS 393)	300	10	1,801	180
Hedgerow Planting (CPS 422)	86	34	23,862	702
Mulching (CPS 484)	2,267	5	3,853	771
Nutrient Management (CPS 590)	2,264	1	0	0
Residue and Tillage Management - No Till (CPS 329)	1,861	1	651	651
Residue and Tillage Management - Reduced Till (CPS 345)	1,861	1	223	223
Whole Orchard Recycling (CPS 808)	3,101	20	2,481	124
Windbreak/Shelterbelt Establishment (CPS 380)	83	80	54,721	684
Vineyard				
Biochar Application (CPS 336)	58,233	NA	NA	NA
Compost Application (CPS 808)	57,007	6	530,165	88,361
Compost Application (CPS 808) and Nutrient Management (CPS 590)	57,007	6	530,165	88,361
Cover Cropping (CPS 340)	58,233	1	95,502	95,502
Filter Strip (CPS 393)	300	10	1,800	180
Hedgerow Planting (CPS 422)	2,155	34	600,824	17,671
Mulching (CPS 484)	57,069	5	97,018	19,404
Nutrient Management (CPS 590)	57,007	1	0	0
Residue and Tillage Management - No Till (CPS 329)	54,657	1	19,130	19,130
Residue and Tillage Management - Reduced Till (CPS 345)	54,657	1	6,559	6,559
Windbreak/Shelterbelt Establishment (CPS 380)	2,100	80	1,377,849	17,223

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 Percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 Percent Adoption Scenario (MT CO_2e)
GRAZING LANDS				
Rangelands and Pasture				
Compost Application To Rangelands (CPS 808)	21,437	20	638,823	31,941
Rangelands				
Native Oak Restoration/Silvopasture (CPS 381)	51,655	50	3,460,885	69,218
Prescribed Grazing (CPS 528) (Rangelands)	142,371	10	128,134	12,813
Range Planting (CPS 550)	44,420	10	222,099	22,210
Riparian Forest Buffer (CPS 391)	1,400	45	570,780	12,684
Tree/Shrub Establishment (CPS 612)	2,847	20	1,075,755	53,788
Pasture				
Prescribed Grazing (CPS 528) (Pasture)	8,200	10	8,200	820

Note: NA = Not available. These are practices for which there is not a sequestration or emissions reduction coefficient available, yet are understood to increase carbon sequestration or reduce emissions, as well as provide other benefits, and for which we can estimate implementation acreages even though we cannot quantify the sequestration benefit estimate. Practices where the carbon sequestration benefits are not currently quantifiable are still recommended for inclusion in the suite of potential climate smart practices to be considered by the County.

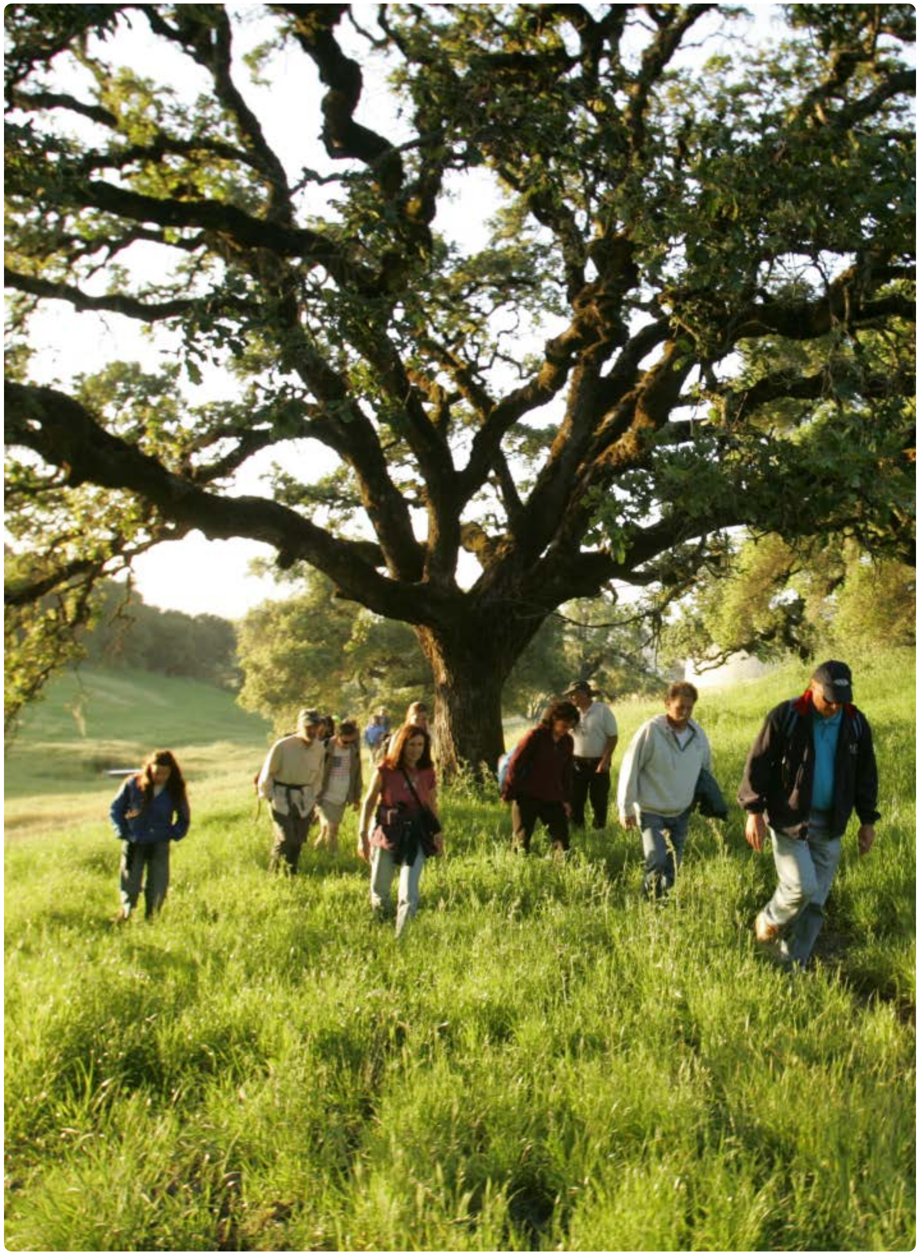
MOVING FORWARD

Sonoma County can use the results of this analysis, along with stakeholder input, to inform climate smart practice implementation, and targets for implementation. Whichever climate smart practices are ultimately selected, monitoring and reporting are going to play an essential role in all practice implementation to ensure practice compliance, transparency, and verification of progress towards achievement of selected goals and targets.

Practices undertaken as part of the California Department of Food and Agriculture (CDFA) Healthy Soils Program or other grant programs supporting and funding climate smart agriculture will have monitoring and reporting requirements as mandated through those programs. Reporting requirements for any activity may include, but are not limited to, the following:

- Assessor's Parcel Numbers of parcels where activity is being implemented
- Map of activity area, including total acreage upon which activity is being implemented
- Date of activity initiation
- Anticipated duration of activity (max. based on duration of analysis above)
- Ongoing reporting throughout activity implementation

The County can leverage partnerships and technology to reduce the reporting burden for land managers implementing climate smart practices, and to monitor implementation progress.



1. INTRODUCTION

Climate change has harmful, sometimes catastrophic effects on public health, natural resources, infrastructure, and emergency response. Sonoma County has already felt the effects of climate change at the local level, through lives and homes tragically lost to wildfire. Fires that have impacted Sonoma County includes Nuns, and Pocket Fires and Kincade fires, which burned 143,388 acres of Sonoma County between 2017 and 2019 (CAL FIRE, 2017, 2019). The LNU Lightning Complex, and Glass Fires of 2020 also burned significant acreage across Sonoma County. Natural and working lands have been recognized as a powerful tool to address climate change, allowing Sonoma County to make progress towards its greenhouse gas (GHG) reduction goals, while increasing resiliency to future climate impacts. Natural and working lands, which include the iconic redwood forests, oak woodlands, vineyards, and pasturelands found across Sonoma County, can be a powerful engine for mitigating climate change and increasing resilience to climate impacts through climate smart land management practices (climate smart practices).

The purpose of this Carbon Inventory and Sequestration Potential Study (Study) is to establish a detailed quantitative estimate of Sonoma County's historical and existing carbon stocks and changes over time. This is a critical first step in meeting local, state, and national climate goals as it identifies baseline conditions, and methods for identifying changes in carbon stocks over time. It should be noted that new programs are being undertaken to assess carbon sequestration on working lands, which will be described further in ***Section 2 Regional Efforts***. The Study also assesses the potential impact of climate smart practices, and ultimately identifies a set of measures and actions for the County and key stakeholders to implement across Sonoma County's rich and varied landscapes.

Natural and working lands include natural ecosystems of different types, lands used for agricultural production, and urban green spaces. Natural land types found in Sonoma include wetlands, forests, shrublands, and grasslands. Working land types found in Sonoma include pasture, vineyards, and croplands. Certain lands, for example, rangelands and silviculture, span both natural and working land types.

Climate smart land management practices, referred to across this Study as climate smart practices, refer to land management activities that leverage natural processes to sequester carbon from the atmosphere into, and avoid carbon stock losses from, natural and working lands through practices like vegetation management, compost application, urban greening, and ecosystem restoration (International Union of Concerned Scientists, 2023; London School of Economics, 2023).

Carbon pool describes a system, such as plants, soils, and rocks, which has the capacity to store or release carbon. Climate smart practices can increase the carbon stored in carbon pools, and can also support other priorities such as improving soil water holding capacity, decreasing erosion, increasing habitat, and securing food and water supplies (USDA NRCS, 2023).

SONOMA COUNTY

Sonoma County's landscape is comprised of a diverse array of natural lands, from redwood forest to oak woodland, agriculture and working lands stewarded by ranchers and growers, waters, and vibrant cities and towns. Spanning 1,044,510 acres, the county is home to approximately 482,650 people, who rely on the clean drinking water, nature and recreation, agritourism, and local food production provided by Sonoma's natural and working lands (U.S. Census, 2022). Sonoma County's natural and working lands are critical for the local economy, with agricultural lands including the county's vineyards and ranches producing $811,466,000 of value in 2021 (Sonoma County Department of Agriculture/Weights & Measures, 2023). A 2018 Sonoma County Agricultural Preservation and Open Space District (Ag + Open Space) analysis of the county's total valuation of natural capital[1] ranged from $2.2 - 6.6 billion dollars every year countywide (Ag + Open Space, 2018). Sonoma County's landscapes are essential in maintaining the thriving local economies, healthy ecosystems, and communities where residents live, work, and play.

Natural and working lands across the county play a critical role in reducing GHG emissions, through the capture and sequestration of carbon in the forests, grasslands, shrublands, agricultural lands, and soils. In fact, this Study finds that the county's natural and working lands stored over 105.3 million metric tons of carbon dioxide equivalent (MT CO_2e) in vegetation and soils as of 2022. This is the equivalent of the amount of carbon emitted to supply electricity to over 20.7 million homes for an entire year, which is more than double the population of the Bay Area (US EPA, 2023). This scale of carbon sequestration emphasizes the importance of protecting Sonoma County's existing carbon stocks. Optimizing the carbon sequestration potential of Sonoma County's natural and working lands will be critical in achieving the County's GHG reduction goals, as outlined in the County's 5-year Strategic Plan.

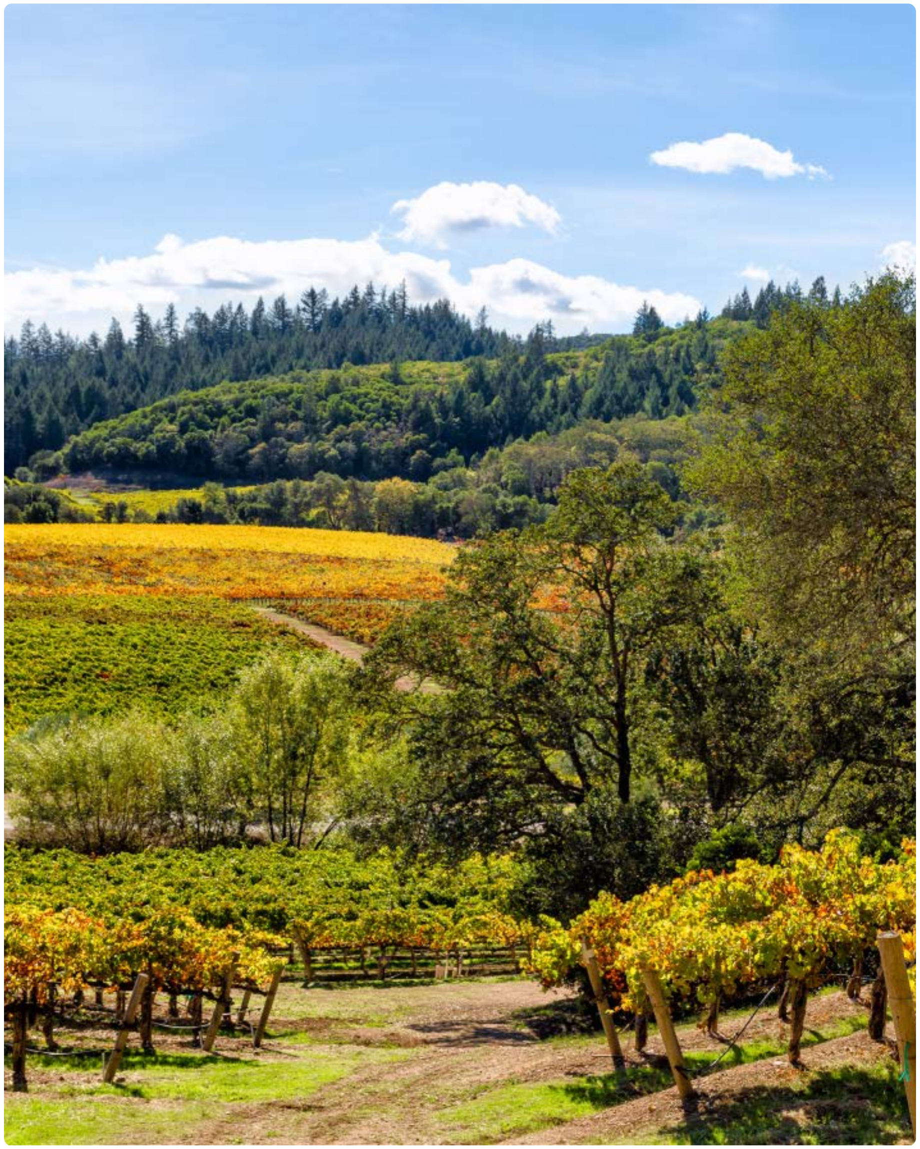
1. *Natural capital as defined by Ag + Open Space in 2018 includes value provided by natural and working lands for water supplies, pollination, habitat, tourism, and carbon sequestration, among other services.*

PURPOSE OF THIS STUDY

The County of Sonoma has developed specific goals to decrease net GHG emissions and achieve carbon neutrality by 2030 through decarbonization and sequestration and develop policies to optimize carbon sequestration while minimizing the loss of natural carbon sinks. This direction comes from the County of Sonoma 5-year Strategic Plan, which was approved by the Board of Supervisors on March 2, 2021.

The County and its related agencies have prepared numerous assessments focused on the importance of natural and working land management, conservation, and restoration. Key reports include the Climate Resilient Lands Strategy, the Climate Action through Conservation Project, and the Vital Lands Initiative. These reports assessed the potential for climate impacts on land, estimated carbon storage in natural lands, identified potential climate resilience projects, and identified biodiversity and conservation priorities. This Study builds upon previous work by providing a detailed quantitative assessment of carbon storage and sequestration potential across different land uses and land cover types including agricultural lands, natural lands, and urban spaces.

The goal of this Study is establishing a robust quantitative baseline of Sonoma County's existing carbon stocks and characterizing changes in carbon stocks over time, including the impact of drought and wildfire on the county's ability to store and sequester carbon. It is important to note that there are gaps in land cover data and understanding of the impact of wildfire and drought on the county's landscape, and subsequent impacts on carbon stocks, as well as how climate-driven trends in drought and wildfire may impact carbon stocks in the future. Nonetheless, the establishment of a quantitative baseline for Sonoma County's existing carbon stocks, and characterization of changes over time, will help address knowledge gaps regarding carbon stock values for agricultural, natural, and urban lands that were unknown prior to this Study. This analysis also builds on the previously completed assessments of Sonoma County's natural and working lands described in the paragraph above. A description of the methods and findings of the county carbon stock inventory and sequestration potential can be found in ***Section 3 Land Cover and Carbon Stock Analysis***. See ***Section 4 Climate Smart Practices and Analysis*** for more detail on sequestration potential methodology and results.

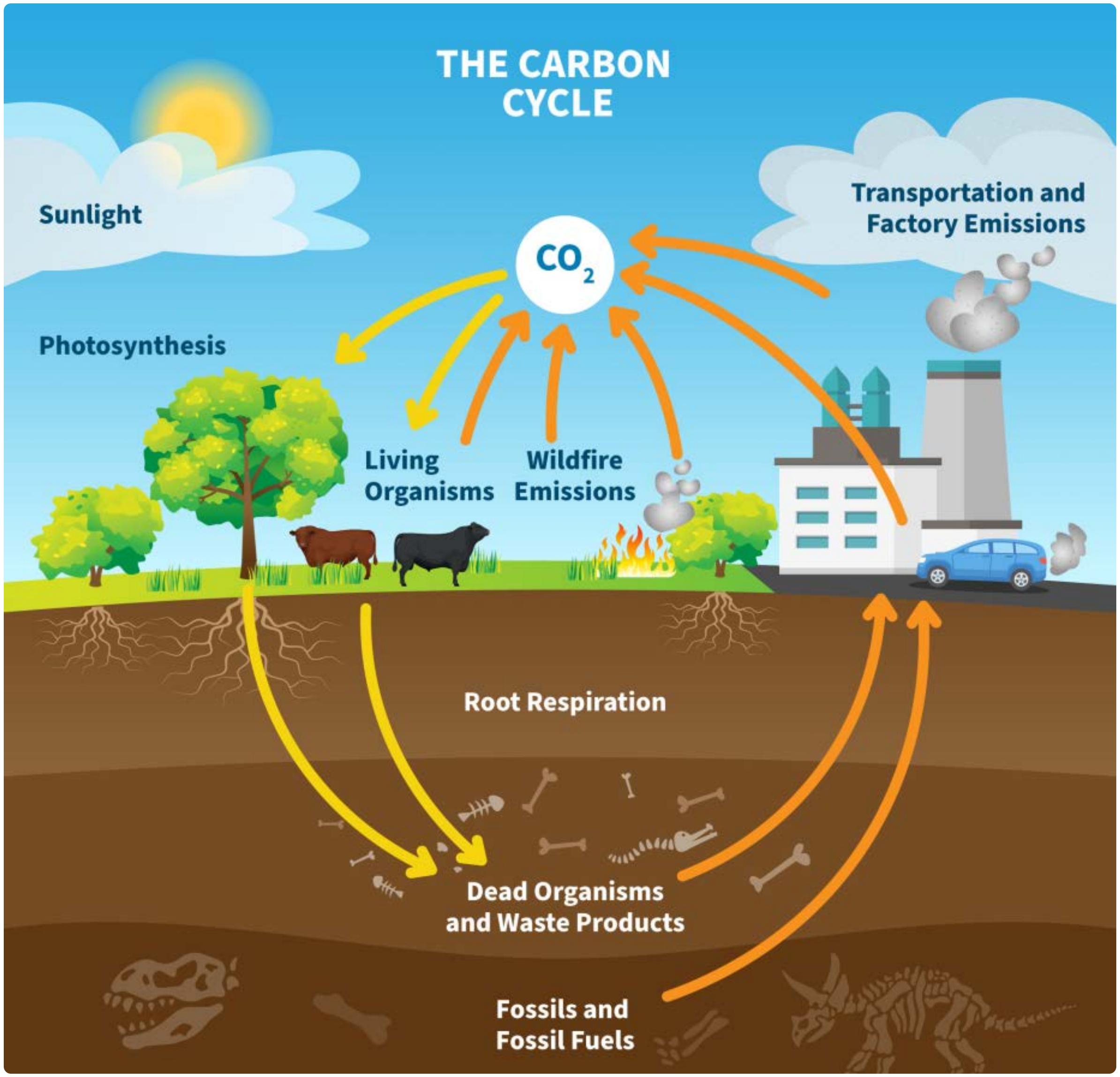


THE CARBON CYCLE, CLIMATE CHANGE, AND LAND MANAGEMENT

Carbon is the foundation of life on Earth, and understanding how it cycles through the atmosphere, land, and living organisms is crucial to understanding climate change. The carbon cycle describes the process in which carbon is exchanged or cycled between the atmosphere and the other parts of the earth system, or compartments, including the biosphere (plants, animals, and other life forms), hydrosphere (water bodies), pedosphere (soils), and lithosphere (Earth's crust and mantles, including rocks and fossil fuels) (CARB, 2018). Because our planet and its atmosphere are a closed environment, the total amount of carbon in the system does not change. However, where the carbon is located is constantly in flux, including how much is in the atmosphere versus other parts of the earth system. Some parts of the earth system store carbon for longer or shorter time periods. Carbon that is stored in the lithosphere or deep ocean tends to stay in those parts of the earth system for much longer time periods compared to carbon stored in the biosphere or pedosphere, but it also takes carbon a much longer time to be incorporated into those compartments. Carbon can be much more quickly incorporated into living biomass. Atmospheric carbon is absorbed by plants and water-based algae and sequestered in their biomass through photosynthesis, and when other living organisms eat plants or each other, carbon moves up the food chain. Carbon also moves from living organisms into the soil from the leaves and roots of dead plants and decaying matter from other organisms. Since soils are made in part of partially decomposed plant and other organic matter, they contain a lot of carbon that those plants and organisms took in while they were alive. Disturbances to soil can result in a greater rate of decay, releasing carbon into the atmosphere. Keeping soils minimally disturbed can keep carbon stored within them. Over very long periods, carbon within the soil can transform into carbon-rich oil and gas deposits sequestered deep underground. Once these carbon and energy-dense deposits of fossil fuels are extracted and combusted as an energy source, the carbon they stored deep underground for many thousands of years is reintroduced into the atmosphere.

Figure 1 shows a simplified depiction of the carbon cycle.

Figure 1. Carbon Cycle Graphic



Carbon can be released back into the atmosphere through a variety of mechanisms including plant respiration, decomposition, soil disturbance, volcanic eruption, fire, or fossil fuels combustion. Human activities and natural processes determine whether there will be more carbon lost or stored in natural and working lands in any given year. In the atmosphere, carbon in the form of carbon dioxide (CO_2) is a GHG that traps heat. CO_2 is naturally occurring, and having a balance of GHGs in the atmosphere is essential for creating warm enough temperatures on earth to support life. However, human activities are creating an imbalance in this natural process, vastly increasing the amount of carbon in the atmosphere relative to other earth compartments, driving climate change which includes a general trend of warming, changes in precipitation patterns, and increases in the frequency and intensity of hazards such as drought, heatwaves, wildfire, and flooding. Increasingly, the pattern of more GHGs in the atmosphere which trap more heat and cause more hazards is becoming a feedback loop where the impacts from climate change, especially increases in the frequency and size of wildfires, are themselves tipping the scale further to create additional releases of carbon stored in plants and soils back into the atmosphere.

WHAT IS CARBON SEQUESTRATION AND WHY IS IT IMPORTANT?

Carbon sequestration is the removal and storage of carbon from the atmosphere. This process occurs naturally through plant photosynthesis, where carbon is drawn from the atmosphere and into plants and soil. Both natural and working lands can be carbon sinks, where plants and soils take in more carbon than they release. Conserving these carbon sinks can help move the county closer to achieving the objectives of carbon neutrality, land conservation, and carbon sequestration (County of Sonoma, 2021). Carbon sequestration is not the only benefit of conserving, restoring, and strategically managing natural and working lands. Natural and working lands also provide numerous social, economic, and ecosystem benefits to wildlife and the wider community. In most cases, the co-benefits of climate smart practices (e.g., habitat creation and water quality) are prioritized over what will maximize carbon sequestration. The focus of this Study is to increase the pace and scale of implementing climate smart practices that increase the overall health of natural and working lands, while providing additional, social, economic, and ecosystem benefits.

Enhancing carbon sequestration while increasing the resilience and functioning of the natural and working lands within the county can help to achieve numerous objectives. Enhanced sequestration through climate smart practices can help to achieve climate goals while supporting the resilience and longevity of ranches, farms, orchards, vineyards, and dairies. These practices thereby support the local economy which is deeply tied to food production and agritourism. There are many opportunities to optimize existing carbon stocks in the region by protecting natural lands such as old growth forests like the Harold Richardson Redwoods Reserve, wetlands like Laguna de Santa Rosa, and rangelands like those at Tolay Lake Regional Park, from development and conversion. Reducing carbon loss through wildfire mitigation (e.g., forest management planning) can increase the safety and wellbeing of community members by reducing wildfire risk and preserve natural lands on which to recreate, and on which local wildlife depend. High intensity wildfires can emit large quantities of carbon and pollutants into the atmosphere during the fire and can continue to emit carbon for years afterward as fire damaged vegetation decays. The California Air Resources Board (CARB) Scoping Plan identifies wildfires as the primary reason that, when taken altogether, California's natural and working lands may act as a source rather than a sink for carbon. Therefore, taking action to mitigate the risk of wildfire is essential for protecting existing carbon stocks, and for maintaining the ability of ecosystems to sequester carbon. Aside from wildfire mitigation efforts, there are numerous opportunities for climate smart practices that include partnering with private and public landowners to increase carbon stocks on their land. Optimizing carbon sequestration will play an essential role in meeting the County of Sonoma's goal of carbon neutrality by 2030, in addition to providing best-available science and science-based options relevant to land types across Sonoma County to support the climate goals of relevant agencies, including the Regional Climate Protection Authority and Ag + Open Space. (County of Sonoma, 2021).

Different land management practices can affect how carbon is stored and emitted. Carbon stocks or sinks are regions that store or sequester substantial amounts of carbon, such as natural landscapes like forests or shrublands, oceans, or agricultural lands. Land management practices that enhance or avoid disrupting those carbon stocks can reduce atmospheric carbon by mitigating emissions and sequestering existing carbon. Some management practices, such as clearcutting forest or tilling agricultural soils, can disturb soils and vegetation causing the release of stored carbon into the atmosphere (CNRA, 2022). Beyond carbon sequestration, maintaining healthy soils can improve crop health and yields, increase water retention and infiltration, prevent erosion, improve water quality, and improve biodiversity and wildlife habitats (CDFA, 2020). These benefits impact the environment and farmers and form the basis for multiple dedicated federal, state, and local programs that fund healthy soils work. Maintaining healthy natural and working lands is key to human well-being because these lands are responsible for our agricultural abundance, water supply and quality, air quality, and biodiversity, which in turn influences socioeconomics and social equity.

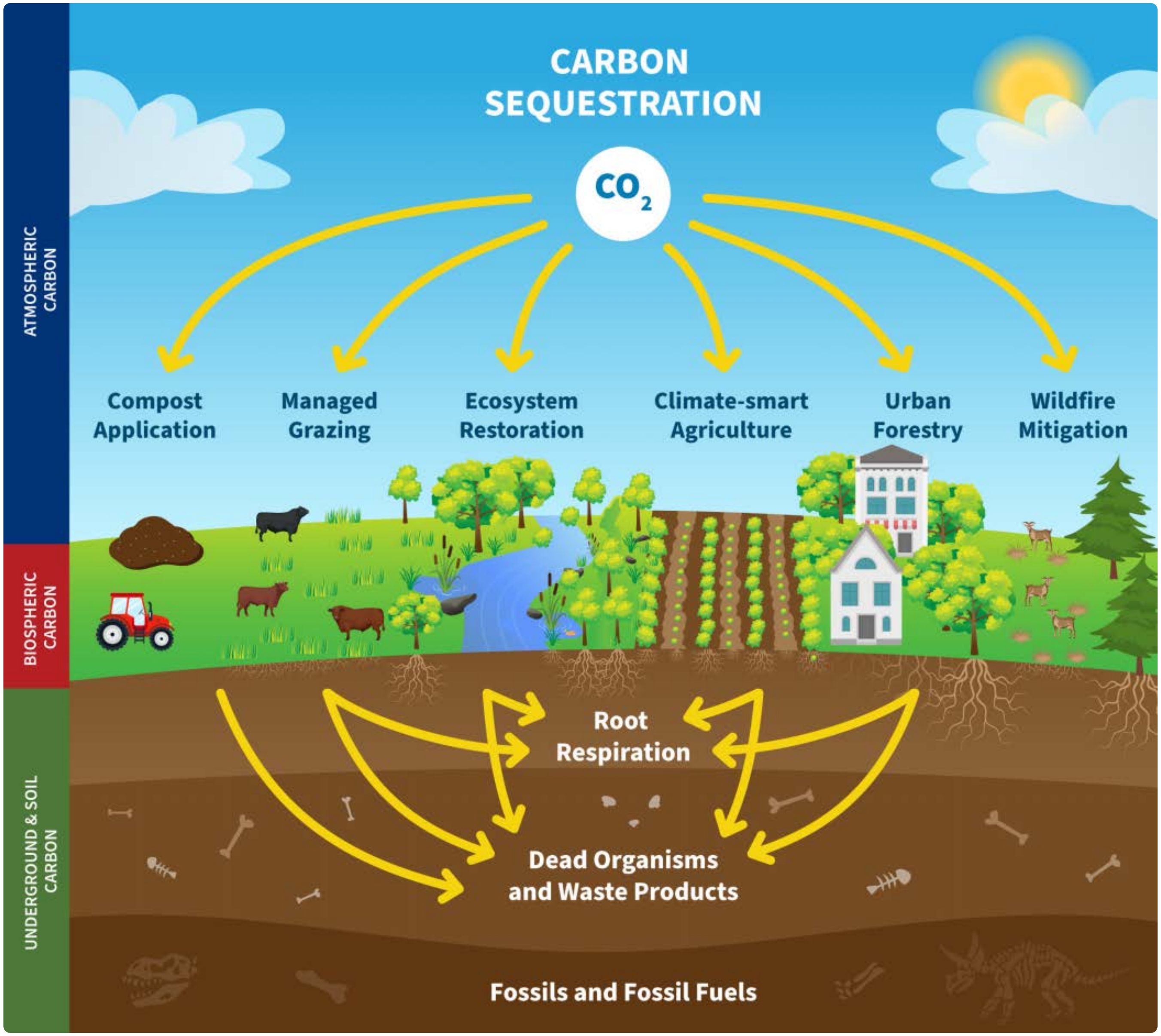
Figure 2 depicts some of the key ways carbon is sequestered in landscapes. A variety of climate smart land management activities implemented now can help to increase the health of soils and natural and working lands. Healthy lands sequester more carbon, hold more water in the soil, are more productive for farming and grazing, and are more resilient to climate impacts. Conservation is also an important part of climate smart land management as the conversion of forests, shrublands, grasslands, and wetlands into other uses can result in a loss of the carbon stored in those lands as well as the other ecosystem services, like healthy soils, water, and improved air quality, they provide.

Mechanical vs. Biological Carbon Sequestration

Biological sequestration enhances soil carbon or carbon storage in biomass (e.g., forests, grasslands, roots) though mechanisms like compost application, reforestation, and other climate smart management practices.

Mechanical Carbon sequestration describes carbon capture and storage (CCS), or direct air capture (DAC) which is achieved through technology like capture from power plant exhaust stacks followed by burial and injection in aquifers and oil and gas fields (Moriarty et al., 2017).

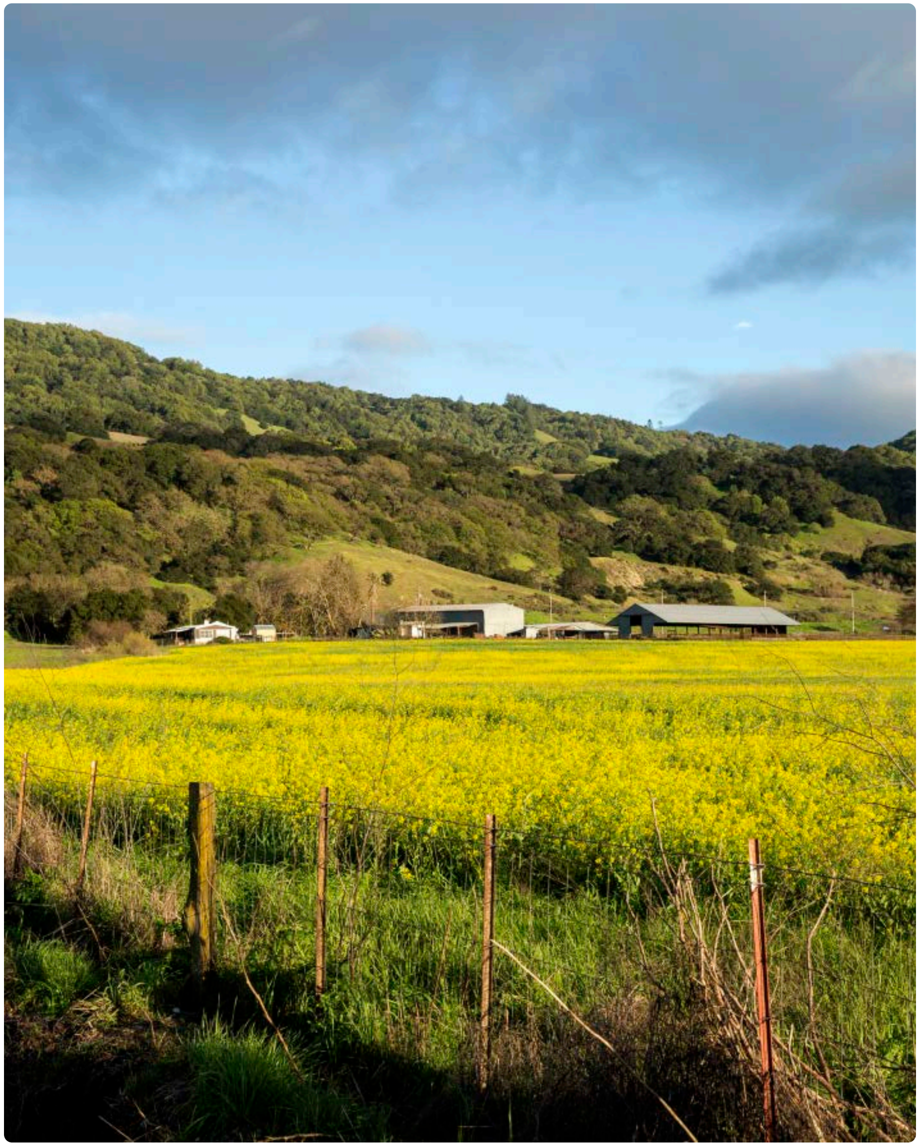
Figure 2. Carbon Sequestration Graphic



HEALTHY SOILS AND BIOLOGICAL CARBON SEQUESTRATION

Biological carbon sequestration is the process whereby living organisms remove carbon from the atmosphere and store or "sequester" it in the biomass of the microorganisms and vegetation in landscapes, such as forest, soils, and oceans. This is different than mechanical carbon sequestration, which is not discussed as part of this strategy, and is described in the callout box above. In addition to sequestering carbon in their biomass, plants also release carbon, in the form of carbohydrates and other molecules (collectively called exudates), into the soil through their roots, where they increase soil organic carbon (Poonam et. al., 2022) and support a diversity of soil microbes (Badri et. al., 2009) that facilitate soil carbon sequestration. Carbon filtered through soil microbes create stabilized forms of carbon that remain in the soil for a longer period when compared with soil lacking adequate microbial activity (Kerlin, 2019). Biological carbon sequestration and soil carbon stabilization processes can occur on different timelines, taking anywhere from a few hours to years (CNRA, 2022). Given that soil disturbance activates decomposition of organic matter by fungi and other microbes, and therefore, increases carbon release from soil, practices that protect soil and improve soil health are essential.

Maintaining healthy soils can achieve a host of co-benefits beyond carbon sequestration, like improved crop health, water retention, and improved water quality (CDFA, 2020). These benefits impact the environment and farmers and form the basis for multiple dedicated state, and local programs that fund healthy soils work described in the sections below. Maintaining healthy natural and working lands is key to human well-being because these lands are responsible for our agricultural abundance, water supply and quality, air quality, and biodiversity, which in turn influences socioeconomics and social equity.

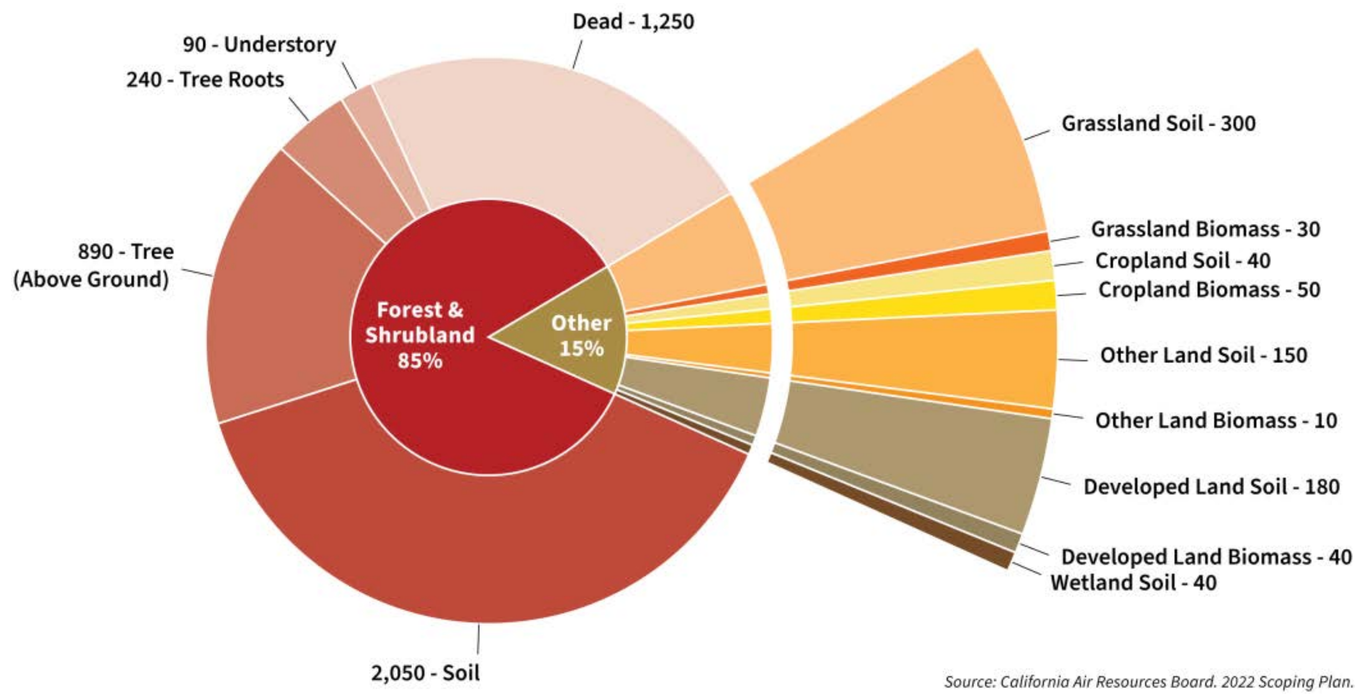


STATE EFFORTS: NATURAL AND WORKING LANDS

Carbon Stocks in California Natural and Working Lands

The California Air Resources Board's (CARB) 2018 statewide carbon inventory shows there are approximately 5,340 million metric tons (MMT) of carbon in California's natural and working lands (CARB, 2018). Forests and shrublands contain most of California's carbon stock (85 percent) because they cover the majority of California's landscape and have the highest carbon density of any land cover type. All other land categories combined comprise over 35 percent of California's total acreage, but only 15 percent of carbon stocks. Roughly half of the 5,340 MMT of carbon resides in soils and half in plant biomass. See ***Figure 3*** below for a breakdown of how carbon stocks in California's natural and working lands are distributed amongst land cover types. Units in the figure depict percentages of total MMT within carbon pools for the year of 2014. An inventory of Sonoma County carbon stocks is described in detail in ***Section 3 Land Cover and Carbon Stock Analysis***.

Figure 3. California Natural and Working Lands Carbon Inventory Summary (CARB)



Source: California Air Resources Board. 2022 Scoping Plan.

The Role of Natural and Working Lands in Carbon Neutrality

The 2022 CARB Scoping Plan is the first California Scoping Plan to include quantification of carbon stores and emissions of California's natural and working lands, and how future land management and climate scenarios can impact achievement of State carbon neutrality goals. Carbon neutrality occurs when there is a state of net-zero carbon emissions, achieved by reducing emissions from specific sectors and balancing the remaining carbon dioxide emissions with equal removal of atmospheric carbon. In the past, the focus of the Scoping Plan was restricted to reducing emissions of GHGs from sectors other than natural and working lands, including the energy, transportation, and industrial sectors. When regional sources of carbon emissions released into the atmosphere are balanced by a regional system that removes carbon from the atmosphere – known as carbon sinks - the region is carbon neutral.

Natural and working lands can function as both a carbon source and a carbon sink. Their ability to act as a carbon sink, by sequestering carbon from the atmosphere and storing it in vegetation and soils, means that they play a significant role in supporting State carbon neutrality goals. However, land cover modeling completed as part of the Scoping Plan found that California's lands will be a net source of GHG emissions, if no strategic land management activities are taken to maximize sequestration and minimize wildfire impacts. This expected trend is largely driven by increased drought, stress, and mortality in forests and shrublands, turning them from carbon sinks into sources of carbon emissions. However, implementing the 2022 Scoping Plan is projected to increase carbon stocks in some landscapes, including urban forests and grasslands. These modeling results further emphasize the need for strategic land management to help mitigate the impacts from climate change. CARB's general recommended approach is to restore carbon in places where it has been lost and reduce large carbon losses on natural and working lands through active, attentive, and adaptive management.

Natural and Working Lands Goals

CARB has established a statewide target of minimizing losses of carbon stock in natural and working lands to a decrease of only 4 percent between 2022 and 2045 (CARB, 2022). CARB has identified a set of actions to accelerate adoption of climate smart practices to support achieving this target, listed below:

- Increase climate smart forest, shrubland, and grassland management to at least 2.3 million acres per year—an approximate 10 times increase in management from current levels.
- Increase climate smart agricultural practices by at least 78,000 acres adopted per year, annually conserving at least 8,000 acres a year of croplands, and increasing organic agriculture to comprise at least 20 percent of cultivated acres in California by 2045—an approximate 7.5 times increase in healthy soils practices from previous levels and a 2 time increase in total acres of organic agriculture.
- Increase annual investment in urban trees in developed lands by at least 200 percent above historic levels and establish defensible space on all parcels by 2045.
- Restore at least 60,000 acres, or approximately 15 percent of all Sacramento–San Joaquin River Delta (Delta) wetlands, by 2045.
- Reduce land conversion of deserts and sparsely vegetated landscapes by at least 50 percent annually from current levels, starting in 2025.

RECENT AND PENDING LEGISLATION

As the California State Legislature continues to produce new legislation prioritizing climate action and GHG emissions reductions, the County can plan ahead, anticipating upcoming funding opportunities and chances to align with state goals, and potential future legislative requirements. Though the following California policies were drafted or adopted recently, and therefore, do not directly impact this Study, they may become relevant in the coming months and years. The implications of these policies for the County are significant, in that they collectively require increased carbon sequestration efforts, reduced GHG emissions, and expanded preservation of natural lands. Proposed legislation summarized in ***Table 1*** below includes bills that will provide additional technical support, guidance, funding, and/or opportunities for enhanced carbon sequestration and climate smart land management in the future, should the bills get signed into law.

Recent Legislation

Senate Bill 905 Carbon Sequestration: Carbon Capture, Removal, Utilization, and Storage Program

This bill requires CARB to establish a Carbon Capture, Removal, Utilization, and Storage Program to evaluate the efficacy, safety, and viability of carbon capture, utilization, or storage technologies and CO_2 removal technologies. In carrying out the program's objectives, the bill requires CARB to prioritize, among other things, reducing the emissions of GHGs and reducing fossil fuel production in the state. This bill was adopted in September 2022.

Assembly Bill 1757 California Global Warming Solutions Action of 2006: Climate Goal: Natural and Working Lands

This bill requires the Natural Resources Agency, in collaboration with other specified entities including CARB, to determine an ambitious range of targets for natural carbon sequestration, and for nature-based climate solutions, which reduce GHG emissions for 2030, 2038, and 2045 to support state goals to achieve carbon neutrality and foster climate adaptation and resilience. Targets must be set by January 1, 2024. The bill requires these targets to be integrated into the CARB scoping plan and other state policies. The bill will require an update of the Natural and Working Lands Climate Smart Strategy to achieve these targets. Additionally, the bill requires the establishment of an expert advisory committee to inform and review modeling and analyses for natural and working lands, to advise state agencies on implementation strategies and standardized accounting, and to provide recommendations on addressing barriers to efficient implementation of the provisions of the bill. The bill requires the Natural Resources Agency to publish data publicly on the Natural Resources Agency website on progress made in achieving these targets, as specified.

This bill also requires CARB to develop standard methods for state agencies to consistently track GHG emissions and reductions, carbon sequestration, and, where feasible and in consultation with the Natural Resources Agency and the Department of Food and Agriculture, additional benefits from natural and working lands over time no later than January 1, 2025. This bill was adopted in September 2022.

Assembly Bill 2278 Natural Resources: Biodiversity and Conservation Report

This bill requires the Natural Resources Agency to implement actions to achieve the goal of conserving at least 30 percent of state lands and coastal waters by 2030, established by Executive Order No. N-82-20. The bill also requires the Secretary of the Natural Resources Agency to prepare and submit, beginning on or before March 31, 2024, an annual report to the Legislature on the progress made during the prior calendar year toward achieving that goal, as provided. The bill also makes related findings and declarations. This bill was adopted in September 2022.

Assembly Bill 642 Wildfires

Amongst other directives, this bill requires the Director of Forestry and Fire Protection to appoint a Cultural Burning Liaison. The liaison will serve on the State Board of Fire Services to advise the Department of Forestry and Fire Protection on the development and expansion of cultural burning activity throughout the state. This bill also requires the department to actively engage Native American Tribes and cultural fire practitioners to enhance public education efforts on the restoration of cultural burning techniques and the importance of ecologically functional fire. Cultural burning practices have a long and storied history in California. One study suggests that prior to 1800, approximately 4.5 million acres of the state burned annually (Stephens et. al., 2007). Unfortunately, much of the knowledge and expertise these practitioners possessed was lost as over a century of cultural and fire suppression made these practices illegal. This new legislation and recognition of the effectiveness of cultural burning techniques can allow a renewed expansion of prescribed fire led by California's Native American groups. A continued push to provide funding for education and public outreach will properly cement these practices as pivotal tools in the effort to reduce over a century of hazardous fuel loading in the wildlands. Many of the native Californian ecosystems are fire adapted, meaning they need occasional low-intensity fire as part of their reproductive cycle. Controlled burning techniques promote low-intensity fires at appropriate times of year when conflagration is unlikely. Controlled burning can be an effective way to reduce hazard fuels and rejuvenate the land. This bill was adopted in September 2021.

Pending Legislation

The following table includes summaries of state bills that are still moving through the legislative process but are important to track to help anticipate future requirements and opportunities potentially relevant to the County. Accordingly, ***Table 1*** captures the status of legislation as of Summer 2023 and is subject to change in the future.

Table 1. Pending Legislation to Watch

Bill Number and Title	Summary	Status (Percent Through Legislative Process) – as of August 2023	Status Note
AB-45 Coastal Resources: Coastal Development Permits: Blue Carbon Demonstration Projects: New Development: Greenhouse Gas Emissions	This bill would authorize the [California Coastal Commission] to authorize blue carbon demonstration projects, as defined, in order to demonstrate and quantify the carbon sequestration potential of these projects to help inform the state's natural and working lands and climate resilience strategies. The bill would, among other things, authorize the commission to require an applicant with a project that impacts coastal wetland, subtidal, intertidal, or marine habitats or ecosystems to build or contribute to a blue carbon demonstration project.	60	In committee: Referred to APPR suspense file as of August 2023
AB-338 Expand Definition of "Public Works" to Include Fuel Reduction	This bill would, commencing January 1, 2025, expand the definition of "public works" to include fuel reduction work done under contract and paid for in whole or in part out of public funds performed as part of a fire mitigation project, as specified. The bill would limit those provisions to work that falls within an apprentice-able occupation in the building and construction trades for which an apprenticeship program has been approved and to contracts in excess of $100,000. The bill would delay the application of those provisions until January 1, 2026, for nonprofits.	60	In committee: Referred to APPR suspense file as of August 2023
AB-408 Climate-Resilient Farms, Sustainable Healthy Food Access, and Farmworker Protection Bond Act of 2024	This bill would enact the Climate-Resilient Farms, Sustainable Healthy Food Access, and Farmworker Protection Bond Act of 2024, which, if approved by the voters, would authorize the issuance of bonds in the amount of $3,365,000,000 pursuant to the State General Obligation Bond Law, to finance programs related to, among other things, agricultural lands, food and fiber infrastructure, climate resilience, agricultural professionals, including farmers, ranchers, and farmworkers, workforce development and training, air quality, tribes, disadvantaged communities, nutrition, food aid, meat processing facilities, and fishing facilities.	70	Read second time, amended, and re-referred to Committee on APPR as of August 2023

Bill Number and Title	Summary	Status (Percent Through Legislative Process) – as of August 2023	Status Note
AB-1407 Coastal Resources: Ocean Recovery and Restoration: Large-Scale Restoration	This bill would require the [Secretary of the Natural Resources Agency] on or before December 1, 2024, to establish acreage-based targets to restore kelp forests, eelgrass meadows, and native oyster beds, with the goal of achieving restoration by the year 2050, as provided. The bill would require the council to establish a Kelp Forest and Estuary Restoration and Recovery Framework to achieve the above-described acreage-based targets. The bill would require the framework to contain specified things, including criteria by which a designated area of kelp forests, eelgrass meadows, and native oyster beds can be considered restored. The bill would require the council to establish an interagency working group that coordinates and facilitates large-scale restoration along the coast, as provided. The bill would establish in the State Treasury the Ocean Restoration and Recovery Fund to be administered by the council and consisting of specified moneys. The bill would require the fund to be used, upon appropriation by the Legislature, to develop and carry out large-scale restoration and enhancement projects, as provided. The bill would require the council to publish various items on its internet website and to provide reports to the Legislature, regarding the above provisions, as provided.	70	In committee: Referred to APPR suspense file as of August 2023
AB-1567 Safe Drinking Water, Wildfire Prevention, Drought Preparation, Flood Protection, Extreme Heat Mitigation, Clean Energy, and Workforce Development Bond Act of 2024	This bill would enact the Safe Drinking Water, Wildfire Prevention, Drought Preparation, Flood Protection, Extreme Heat Mitigation, Clean Energy, and Workforce Development Bond Act of 2024, which, if approved by the voters, would authorize the issuance of bonds in the amount of $15,995,000,000 pursuant to the State General Obligation Bond Law to finance projects for safe drinking water, wildfire prevention, drought preparation, flood protection, extreme heat mitigation, clean energy, and workforce development programs.	60	Was in committee hearings as of August 2023

Bill Number and Title	Summary	Status (Percent Through Legislative Process) – as of August 2023	Status Note
SB-272 Sea Level Rise: Planning and Adaptation	This bill would require a local government, as defined, lying, in whole or in part, within the coastal zone, as defined, or within the jurisdiction of the San Francisco Bay Conservation and Development Commission, as defined, to implement sea level rise planning and adaptation through either submitting, and receiving approval for, a local coastal program, as defined, to the California Coastal Commission or submitting, and receiving approval for, a subregional San Francisco Bay shoreline resiliency plan to the San Francisco Bay Conservation and Development Commission, as applicable, on or before January 1, 2034, as provided. By imposing additional requirements on local governments, the bill would impose a state-mandated local program. The bill would require local governments that receive approval for sea level rise planning and adaptation on or before January 1, 2029, to be prioritized for sea level rise funding, upon appropriation by the Legislature, for the implementation of projects in the local government's approved sea level rise adaptation plan. The bill would require, on or before December 31, 2024, the California Coastal Commission, in close coordination with the Ocean Protection Council and the California Sea Level Rise State and Regional Support Collaborative, to establish guidelines for the preparation of that planning and adaptation. The bill would also require, on or before December 31, 2024, the San Francisco Bay Conservation and Development Commission, in close coordination with the California Coastal Commission, the Ocean Protection Council, and the California Sea Level Rise State and Regional Support Collaborative, to establish guidelines for the preparation of that planning and adaptation. The bill would make the operation of its provisions contingent upon an appropriation for its purposes by the Legislature in the annual Budget Act or another statute.	70	Date set for first hearing and bill placed on suspense file as of August 2023
SB-394 Master Plan for Healthy, Sustainable, and Climate-Resilient Schools	This bill would require the State Energy Resources Conservation and Development Commission to develop a Master Plan for Healthy, Sustainable, and Climate-Resilient Schools on or before March 31, 2025, if an appropriation is made for that purpose. The bill would require the commission to consult with specified state agencies and engage with a diverse group of stakeholders and experts regarding the development of the master plan, as provided. The bill would require the master plan to include specified elements, including, but not limited to, assessments of a representative sample of the state's public elementary and secondary school buildings and grounds, as provided, and a set of priorities, benchmarks, and milestones for health, resilience, and decarbonization of public school campuses and support facilities.	70	Read second time and amended. Re-referred to Committee on APPR as of August 2023
SB-638 Climate Resiliency and Flood Protection Bond Act of 2024	This bill would enact the Climate Resiliency and Flood Protection Bond Act of 2024 which, if approved by the voters, would authorize the issuance of bonds in the amount of $4,000,000,000 pursuant to the State General Obligation Bond Law, for flood protection and climate resiliency projects.	70	Bill is scheduled to receive a hearing, though hearing was postponed in July 2023

Bill Number and Title	Summary	Status (Percent Through Legislative Process) – as of August 2023	Status Note
SB-675 Prescribed Grazing: Local Assistance Grant Program: Regional Forest and Fire Capacity Program: Wildfire and Forest Resilience Task Force	This bill would expand the definition of fire prevention activities to include prescribed grazing, defined as the lawful application of grazing by a specific kind of livestock at a determined season, duration, and intensity to accomplish defined vegetation or conservation goals, including reducing the risk of wildfire by reducing fuel loads, controlling undesirable or invasive plants, and promoting biodiversity and habitat for special status species. The bill would expand allowable public education outreach activities to include training on community-supported prescribed grazing. The bill would also indefinitely extend the director's authority to issue advanced payments and authorize these payments to cover the cost of supplies or infrastructure, including, but not limited to, fencing and watering improvements for prescribed grazing, as provided. The bill would also require the department, in consultation with the advisory committee, to increase opportunities and outreach for projects on state and private land that include prescribed grazing in the local assistance grant program.	70	Date set for first hearing and bill placed on suspense file as of August 2023

AB = Assembly Bill; APPR = Appropriations; SB = Senate Bill
Draft bills may or may not be signed into law and may undergo revisions prior to adoption. All legislation should be reviewed, and current status of legislation will differ after publication of this document.

OPPORTUNITIES BEYOND THE CARB NATURAL AND WORKING LANDS GOALS

CARB acknowledges that even if the carbon stock target enumerated above (minimizing losses of carbon stock in natural and working lands to decrease only 4 percent between 2022 and 2045) is met, and the management actions outlined in the Scoping Plan are implemented, the modeling for natural and working lands indicates that California's lands will be a net source of GHG emissions. Additional climate smart management practices and additional landscapes, such as those included in the California Climate Smart Strategy, and ***Section 5 Looking Ahead of this Study***, have the potential to increase carbon stocks and reduce GHG emissions from natural and working lands.

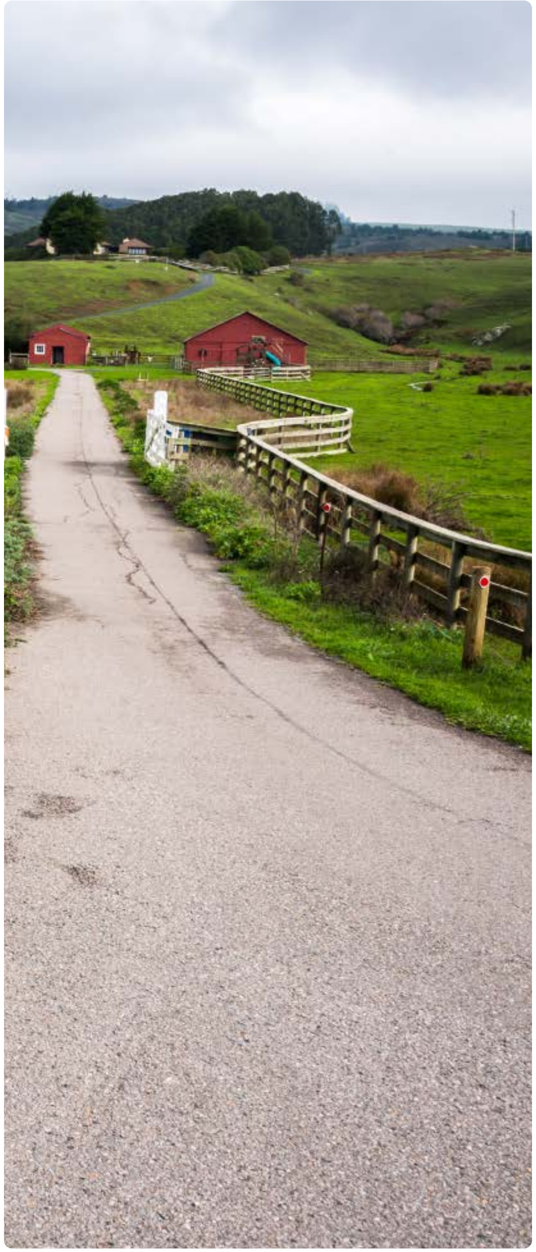
2.

REGIONAL EFFORTS

RELEVANT EXISTING COUNTY RESOURCES

There are numerous policies and plans developed by the County of Sonoma and other local agencies to address climate smart practices on natural and working lands. These efforts are led by the County of Sonoma Board of Supervisors, County Administrator's Office, Permit Sonoma, and Sonoma County Regional Parks for the County; as well as Sonoma Water, Ag + Open Space, and the Sonoma County Regional Climate Protection Authority (RCPA).

These policies and plans are complimented by the work of a larger network of local organizations, including, but not limited to, the Sonoma Resource Conservation District (Sonoma RCD), Gold Ridge Resource Conservation District (Gold Ridge RCD), Sonoma County Farm Bureau, North Coast Soil Hub, University of California Cooperative Extension, Point Blue Conservation Science, and Carbon Cycle Institute that facilitate land stewardship projects on both private and public lands within the county. Recent climate smart practice projects include carbon farm plans (CFP) developed by both RCDs, working with public and private landowners, to implement climate beneficial, soil health practices. This network, with additional community-based organizations (CBOs), also works directly on nature-based solution adjacent issues, such as habitat restoration, land conservation, and sustainable agriculture. Private landowners also play a critical role in land use and land management of the many private parcels of land that make up the majority of span Sonoma County's natural and working lands. All of these stakeholders play a vital role in climate smart practice implementation across Sonoma County's diverse landscapes.



County Planning and Policies

The following section describes key county-level planning documents related to climate smart practices on natural and working lands.

Sonoma County Board of Supervisors Climate Change Action Resolution (18-0166)

The Sonoma County Board of Supervisors adopted the Climate Change Action Resolution to support a countywide framework for reducing greenhouse gas emissions and to pursue local actions that support building climate action and resiliency. The resolution was adopted to help create countywide consistency and clear guidance about coordinated implementation of the GHG reduction measures.

Sonoma County 5-Year Strategic Plan 2021-2026

The Strategic Plan outlines the key strategic goals for the County between 2021-2026 and is intended to inform policies and projects that are prioritized during the five-year planning horizon. The plan was approved by the Sonoma County Board of Supervisors in March 2021. The plan includes five strategic pillars: Climate Action and Resiliency, Healthy and Safe Communities, Organizational Excellence, Racial Equity and Social Justice, and Resilient Infrastructure. The strategic plan describes specific climate resilience goals around wildfire preparedness, community resilience, and landscape and species resilience. The Climate Action and Resiliency pillar is of relevance to this carbon sequestration potential study which supports progress for Climate Action and Resiliency Goal 5, included below:

Climate Action and Resiliency: Goal 5

Maximize opportunities for mitigation of climate change and adaptation through land conservation work and land use policies.

Objective 1: By 2025, update the County General Plan and other county/special district planning documents to incorporate policy language and identify areas within the county that have the potential to maximize carbon sequestration and provide opportunities for climate change adaptation. The focus of these actions will be to increase overall landscape and species resiliency, reduce the risk of fire and floods, and address sea level rise and biodiversity loss.

Objective 2: Develop policies to maximize carbon sequestration and minimize loss of natural carbon sinks including old growth forests, the Laguna de Santa Rosa, and rangelands. Encourage agricultural and open space land management to maximize sequestration. Develop a framework and policies to incentivize collaboration with private and public landowners.

Sonoma County General Plan

The County of Sonoma's General Plan is blueprint for meeting the communities long term vision for the future. The General Plan includes several elements (or sections) that cover different topics including mandatory topics like Land Use, Circulation, Housing, Conservation, Open Space, Noise, and Safety and optional elements such as Agricultural Resources, Air Transportation, Water Resources, and Public Facilities and Services.

Policy LU-11 of the General Plan encourages "conservation of undeveloped land, open space, and agricultural lands, protection of water and soil quality, restoration of ecosystems, and minimization or elimination of the disruption of existing natural ecosystems and flood plain."

The General Plan is currently being updated by the County of Sonoma.

Sonoma County Climate Resilient Lands Strategy

The Sonoma County Climate Resilient Lands Strategy is a non-regulatory framework for how the County and its partners can conserve, manage, and restore natural and working lands to build climate resilience. The Strategy provides an overview of climate hazards, characterizes Sonoma County land types and eco-regions, and offers recommendations and guidance for the planning, design, and implementation of resilience-related projects. The Strategy was directed and funded by the County's Climate Action and Resiliency Division and Ag + Open Space.

Sonoma County Integrated Parks Plan

The Sonoma County Integrated Park Plan (SCIPP) is a strategic plan that establishes a vision to guide the ongoing and future work of the Regional Parks system. The four main goals of the plan are to: conserve and protect natural and cultural resources, ensure access for all to the County's recreational resources, promote physical, mental and community health, improve the vitality of the outdoor recreation economy in the County.

Regional Parks Sonoma County Strategic Plan 2023-2025

The Sonoma County Regional Parks Strategic Plan outlines goals that enable the Regional Parks to fulfill their mission of preserving irreplaceable natural and cultural resources and offering opportunities for recreation and education that enhance the quality of life and well-being of Sonoma County's residents and visitors. Regional Parks' main goals include investing in a climate-adapted parks system, assuring financial and organizational stability, making parks more equitable and accessible, enhancing visitor experience, and reducing the impacts of visitors on the parks.

Sonoma County Ag + Open Space 2021 Vital Lands Initiative

The Vital Lands Initiative is a long-range comprehensive plan to prioritize the land conservation activities of Ag + Open Space . The plan includes goals, priorities, and strategies for conservation, and identifies climate resilience as a co-benefit of conservation.

Sonoma County Ag + Open Space Healthy Lands and Healthy Economies

The Healthy Lands and Healthy Economies Initiative is a regional collaboration led by Ag + Open Space, the Resource Conservation District of Santa Cruz County, and the Santa Clara Valley Open Space Authority to quantify the benefits and economic values that are provided to the community by working lands and natural areas.

Community Grazing Collaboratives

Lead by University of California Cooperative Extension, grazing collaboratives will enable neighbors and their surrounding landscape to manage vegetation for a variety of resource goals, including fire severity reduction and ecological enhancements, such as carbon sequestration.

Sonoma Water Climate Adaptation Plan

Sonoma Water's Climate Adaptation Plan assesses the relationship between climate changes and regional water supply, flood management, and sanitation systems. It includes an assessment of vulnerable Sonoma Water infrastructure, systems, and services. The Plan outlines adaptation strategies and projects to increase resilience.

Sonoma Water Energy and Climate Resiliency Policy

Sonoma Water's Energy and Climate Resiliency Policy was adopted August 2023, and is an update to the 2011 Energy Policy (Carbon Free Water). The Policy directs Sonoma Water to maintain its energy program with the new directive to continue preparing its systems for climate change through continued investment in climate science and innovation; to develop and implement climate resiliency strategies; and to pursue energy and climate resiliency projects of regional benefit.

Sonoma Climate Mobilization Strategy, Regional Climate Protection Authority

RCPA's Climate Mobilization Strategy outlines a pathway for Sonoma County to reach carbon neutrality by 2030 and to increase climate resilience community wide. Climate adaptation strategies outlined focus on increased energy resilience and overall community resilience to climate hazards of concern. Relevant to climate smart practices, strategies 7 and 8 protect, and increase carbon stocks held in soils and plants across Sonoma County.

Looking Ahead: Future Plans and Policies

Sonoma County Regional Parks Climate Adaptation and Resiliency Plan

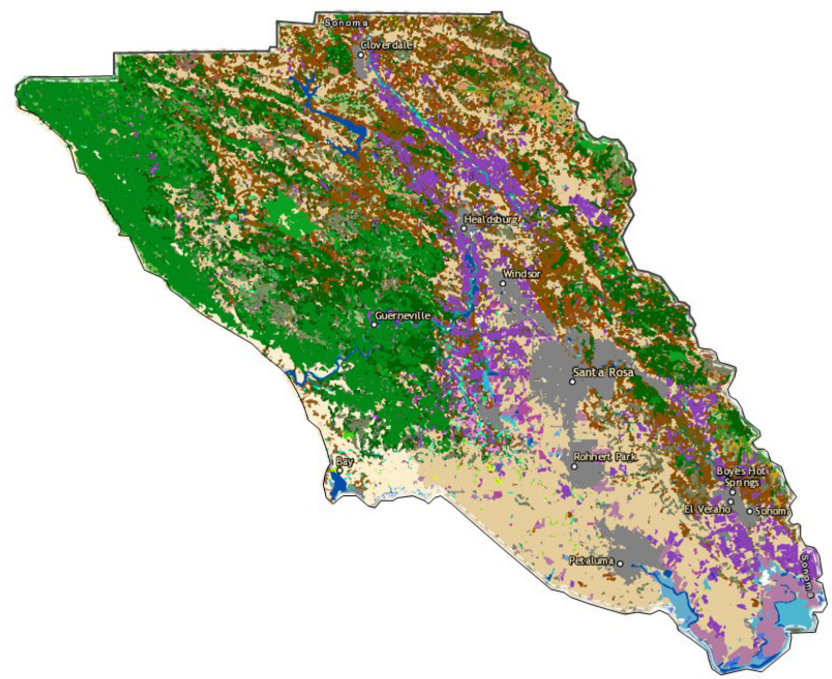
The Regional Parks' Climate Adaptation and Resiliency Plan will serve as a roadmap to build resilience within the Sonoma County Regional Parks system. The plan will protect park-adjacent communities, and the county as a whole from climate risks like wildfires and extreme heat while also reducing the greenhouse gas impact of park operations. By managing Regional Park system landscapes for resilience, the Plan will also stabilize the critical above and belowground carbon stocks held across these landscapes. The plan is currently being developed and is slated for adoption in winter of 2023.

Sonoma-Marin Ag and County Climate Coalition

The SMACCC project is a partnership across multiple organizations from the counties of Marin and Sonoma.. This regional approach to creating climate-resilient agricultural landscapes aims to do so by creating a regional supply chain, tracking system, and marketing for "climate-smart agricultural products", which are defined as agricultural commodities produced using farms, ranches, orchards, vineyards, dairies or forestry practices that sequester carbon or reduce greenhouse gasses. SMACCC, which will be implemented over the course of five years, started as of September 2023. One outcome of this partnership will be a carbon sequestration potential estimate for Sonoma County's agricultural lands.

Sonoma County Vegetation Mapping and Lidar Program (Sonoma Veg Map) Update

The Sonoma Veg Map Program is a joint program of Sonoma County Ag + Open Space and Sonoma Water established in 2012 to map Sonoma County's topography, physical and biotic features, and diverse plant communities and habitat. In 2017, the program successfully completed the Sonoma County Fine-Scale Vegetation & Habitat Map, in addition to numerous other land cover, topography, forest structure, and hydrology datasets based on 2013 high-resolution orthoimagery and LiDAR. The Sonoma Veg Map Program are used extensively by governmental, private, and non-governmental organizations for applications ranging from conservation prioritization, forest management, restoration planning and design, watershed management, and disaster response. The 2013 fine-scale vegetation map was used as a key piece of data in this Study to map and quantify changes in carbon stocks between 2013 and 2023. The fine-scale vegetation map will be updated in the near future using 2022 LiDAR data, which is currently being processed.



County Department and Partners Workshop: Charting the Path Forward for Climate Smart Practices in Sonoma County

The plans and policies described above demonstrate that the County is a leader in planning and implementing climate smart practices. However, enhancing the implementation of these practices across the diverse landcover, and land-owner contexts of the county is still a challenge. Increasing implementation of climate smart practices requires long-term collaboration, balancing competing organizational priorities, obtaining significant new funding, incorporation of emerging best available science, and continuous adaptive management. Accordingly, the climate smart practices selected for this study reflect not only the best available science, but also stakeholder perspectives and needs across the County (e.g., RCDS, individual landowners, CBOs).

The County convened two in-person stakeholder workshops to incorporate this critical stakeholder and cross-departmental feedback into the study early in the analysis process. The purpose of the workshops was to provide an overview of the study and increase understanding of Sonoma County natural and working lands planning efforts with key stakeholders. The purpose of the workshops was also to equip the County and Project Team with a nuanced understanding of the gaps and needs surrounding carbon sequestration related efforts in Sonoma County, and to workshop new climate-smart practices for inclusion in the study. Convening stakeholders during the workshop process was also critical in obtaining a status-update on the current successes and challenges faced by implementors of climate smart practices.

The workshop brought together different entities from within County government, and across the county including CBO leaders. The County recognizes that there are important groups that were not in attendance, such as local Native American tribes, and land stewards including private property owners and farmers/ranchers. The County will work with tribal partners and landowners to understand their needs and concerns about potential carbon sequestration actions. The County hopes to identify areas where tribal partners feel traditional ecological knowledge can inform and improve these activities. This workshop is a promising start for the creation of a shared vision for climate smart practices that complement gaps in existing approaches, strengthen existing initiatives, and reflect past challenges and successes in similar initiatives.

Workshop attendees included:

- Permit Sonoma
- Ag + Open Space
- Regional Parks
- Sonoma RCD
- Marin RCD
- Sonoma County Regional Climate Protection Authority
- Gold Ridge RCD
- Carbon Cyle Institute
- Occidental Arts and Ecology Center

Workshop attendees discussed their experiences with implementing climate smart solutions, articulated the importance of organizational and landowner values beyond GHG mitigation (especially equity and rural livelihoods); and workshopped innovative ideas and partnerships to increase land cover carbon sequestration in Sonoma County.

The outcomes of the workshops included:

- An updated list of goals to inform the selection of climate smart practices for the study, with three new goals added by workshop attendees. The existing goals also have updated wording, adding in new language as suggested by workshop attendees on partnership, equity, and structural change, as seen in the revised wording under the 'post-workshop goals' column in ***Table 2***.
- Innovative ways forward to leverage climate smart practices to stabilize carbon stocks and increase resiliency against two critical climate risks: drought, and wildfire. Attendees generated dozens of new project and partnership ideas for carbon smart practices, including:
  - Long-range grazing plan, increasing wildfire resilience through planned vegetation management with grazing as the tool, with a 10-20 year planning horizon, with an aim to get more herders, and increase access to- and number of training programs.
  - Evaluate the County's role in managed grazing for fuels management, including supporting the acquisition of grant funding to support prescribed grazing and financing programs for grazing and infrastructure needs (e.g. fencing).

- Continue to capitalize and scale compost application, as compost application was named as one of the most financially, culturally and technologically feasible drought-reduction climate smart practices.
- Collaboration between the County; Resource Conservation District(s); and landowners to obtain significant multi-million dollar funding opportunities (state and federal), via strategy sessions to identify specific stakeholder roles in the grant development and implementation
- Conduct new education on soil water holding capacity and water availability for rural landowners.

Though this workshop is an important first step in collaboratively identifying the climate smart practices proposed in this Study, the County will need to conduct, and support local entities in conducting, long-term outreach to local Native American tribes, landowners, stakeholders, and implementing bodies across the county to ensure that the goals of climate smart solutions are being achieved in a way that is both effective and equitable. The County has an opportunity to shape climate smart practices through grassroots outreach and participation from farmers and ranchers via the upcoming SMACCC project, funded by the USDA Climate Smart Commodities Grant Program, that has started as of September 2023. Continuing participant-based outreach early, and often in the project process will be critical in making sure that County-led initiatives reflect the implementation conditions, and values of the varied landowners across Sonoma.

Table 2. Impact of Stakeholder Workshops on County Climate Smart Practices Goals

Original Goals	Post- Stakeholder Workshop Goals (Revised Wording and New Goals)
Conserve and protect natural and working lands	Conserve, protect, and enhance natural working lands and the ecosystem services they provide
Climate risk reduction	Reduce climate risk
Promote sustainable agriculture	Support sustainable agriculture and adoption/implementation of healthy soil practices
Biodiversity enhancement	Maintain and enhance biodiversity
Identify funding and financing strategies to advance this work	Identify and obtain funding and financing to advance this work
Increase/maximize carbon sequestration	Optimize carbon sequestration
Coordinated action on climate resilience in Sonoma County	Coordinate action on climate resilience at the systems/ landscape-level
Prioritize equity and climate justice approaches that are measurable and clear	No change from original goal
Minimize loss of natural carbon sinks	Avoid, minimize, or mitigate loss of natural carbon sinks
Partnership with local Native American tribes in Sonoma County to elevate traditional ecological knowledge and preserve tribal cultural resources/ properties	Develop and engage with partnerships with local Native American tribes in Sonoma County to elevate traditional ecological knowledge and preserve tribal cultural resources/properties
	NEW GOAL: Conserve, protect, and improve watershed and hydrologic processes critical to carbon cycling
	NEW GOAL: Incentivize integration of climate-smart solutions into decisions, implementation, and land management
	NEW GOAL: Incorporate monitoring, assessment, and adaptive management into the implementation of climate smart practices

3.

LAND COVER AND CARBON STOCK ANALYSIS

WHAT IS A LAND-BASED CARBON INVENTORY?

Sonoma County spans 1,044,510 acres of diverse land types including rangeland, orchards, cropland, streams, forests, shrublands, grasslands, and urban areas. These landscapes hold approximately 106,402,838 MT CO_2e in carbon stocks, build resilience in ecosystems and communities, and support local sustainable agriculture, healthy watersheds, habitat for wildlife, and recreation areas for residents and visitors. In 2022 lands in Sonoma County were primarily comprised of forests (51 percent of total land area), grassland/herbaceous lands (24 percent), and developed land (9 percent) (***Appendix A Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***).

A land-based carbon inventory quantifies the amount of carbon stored across these different land cover classes, establishing a baseline to assess the existing carbon stock and sequestration potential of natural and working lands. This snapshot of existing carbon stock and sequestration by land cover class demonstrates what could be lost if carbon stocks across Sonoma County are not stabilized (e.g., if forests are lost to wildfire) or what could be built upon through optimizing climate smart land management practices.

This land-based carbon inventory is calculated by first assessing the vegetation type, height, and cover of contained within the broader land cover classes used to describe the natural, working and developed lands across Sonoma County. The amount of carbon stored in each 30 by 30-meter cell in the land cover dataset is estimated based on CARB volumetric data for different vegetation types, heights, and covers. Inventories provide a snapshot of the carbon stock in a region's land-based ecosystems at a given moment in time. In this study, land-based carbon inventories were conducted for the years of 2013 and 2022. Comparing land cover and carbon inventory values between years can help identify trends in land cover change and estimate increases or decreases in carbon stocks between 2013 and 2022. This analysis also includes a description of carbon stock by landownership, as implementing climate-smart solutions across public and private ownership will require different degrees of coordination, and different stakeholder-tailored strategies.

The different land cover classes are summarized below in ***Table 3***. Land cover describes what is physically present at a given location. The land cover classifications for 2013 used in this Study are based on the Sonoma Veg Map, which is derived from 2013 LiDAR data and high-resolution aerial imagery using human interpreters and computer algorithm and verified vegetation characteristics in the field, resulting in a fine-scale vegetation and habitat map. 2022 land cover analysis is based primarily on LANDFIRE and National Land Cover Database, as Sonoma Veg Map Data was only available for 2013. There was also an intensive quality assurance and quality control (QA/QC) process with input from the County, stakeholders, spatial analysis and desktop ground truthing to verify accuracy of and make refinements to the datasets for both years. Data availability, the QA/QC process, and methodology is further discussed below in this section under ***Uncertainties and Data Limitations***, as well as in ***Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***.

Land cover classes used in the Sonoma County inventories are defined below. Another important landscape type is blue carbon which is carbon captured and held in coastal vegetation, such as seagrasses. This landscape is important to consider in long-term climate goals, however, it is not currently covered by the Intergovernmental Panel on Climate Change (IPCC) inventory guidelines or included in California's Natural and Working Lands inventory and is therefore excluded from this analysis. However, some emergent blue carbon solutions (e.g., otter restoration) are explored in ***Section 5 Looking Ahead***.

Rangelands, which span multiple land cover classes, including grasslands, shrublands, and woodlands, are not identified as a separate land cover class in the land cover classification. However, measures and actions to manage grazing on different land cover classes are included in ***Section 4 Climate Smart Practices and Analysis***.

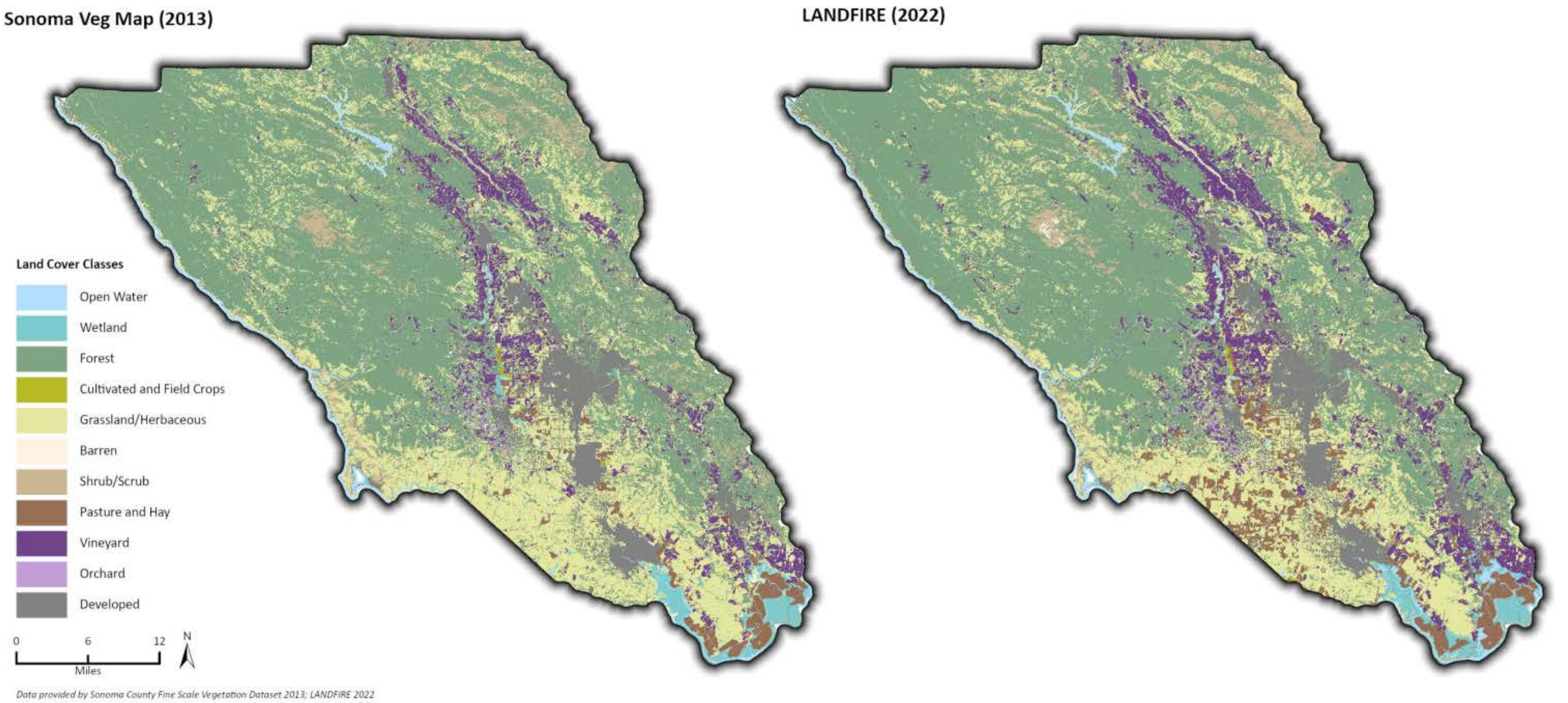
Pasture and hay land cover classes and grassland/herbaceous land covers are sometimes classified together in the sections below as increases/decreases between these land cover classes may be due to differences in map classification between 2013 and 2022.

Table 3. Land Cover Classes in Sonoma County

Land Cover Class	Description
Barren	Areas where vegetation accounts for less than 15 percent of total cover, for example areas of bedrock, sand dunes, or gravel pits.
Cultivated and Field Crops	Areas used for the production of vegetables and field crops generally grown for human consumption, such as squash, tomatoes, leafy greens, rye, and oat.
Development	Areas with constructed materials, including buildings and roads.
Forest	Areas dominated by trees with more than 10 percent tree cover (includes riparian areas that are dominated by trees with more than 10 percent tree cover).
Grassland/ Herbaceous	Areas dominated by herbaceous vegetation, with more than 10 percent herb cover, less than 10 percent tree cover and less than 10 percent shrub cover.
Open Water	Areas of open water such as lakes, reservoirs, rivers, and oceans, generally with less than 25 percent cover of vegetation or soil.
Orchard	Areas used to grow perennial woody tree crops such as apples, olives, and stone fruit.
Pasture and Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture or hay accounts for more than 20 percent of total vegetation.
Shrub/Scrub	Areas dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover (includes riparian areas that are dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover).
Vineyard	Areas planted with grapevines, generally used for producing grapes used in winemaking.
Wetland	Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the perennial herbaceous vegetation indicate soil or substrate periodically saturated with or covered with water.

Total land cover classes in 2013 and 2022 are depicted in the maps shown in ***Figure 4***, with further interpretation in the text and tables below.

Figure 4. 2013 and 2022 Land Cover Classes in Sonoma County



LAND COVER CLASSES ACROSS SONOMA COUNTY (2013 AND 2022)

The proportions of land cover class across Sonoma County have remained mostly consistent between 2013 and 2022, with forest; grassland/herbaceous and pasture and hay[3], and developed lands taking up over 80 percent of total land covers in the county in both inventory years.

Sonoma County's iconic agricultural sector, which includes pasture and hay, vineyards, cultivated and field crops, and orchards, holds significant economic and cultural importance in the region, and accounted for nearly 12 percent of total land cover area in 2022. Agricultural lands made up the following percentages of total land cover in 2022: Vineyards (7 percent), pasture and hay (3 percent), orchards (0.3 percent), and cultivated and field crops (0.1 percent).

The proportional makeup of land cover classes in Sonoma are depicted in ***Figure 5*** and ***Figure 6*** as well as ***Table 4***.

Figure 5. 2013 Acres by Land Cover Class

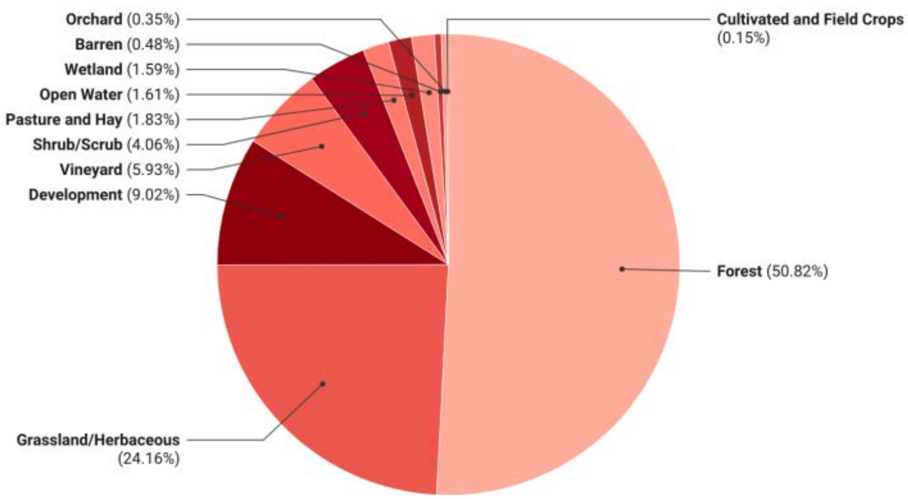
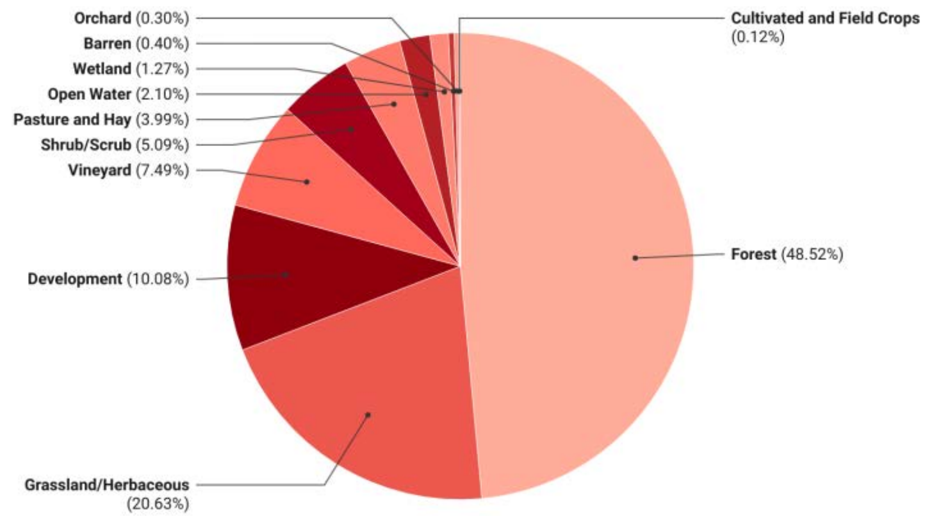


Figure 6. 2022 Acres by Land Cover Class



3. *Grassland/herbaceous and pasture and hay have been combined in this qualitative interpretation of land cover data because the increase/decrease between these land classes between years is likely due to a difference in classification of data between Sonoma Veg Map (2013) and LANDFIRE datasets in 2022.*

Land Cover Trends in Sonoma County

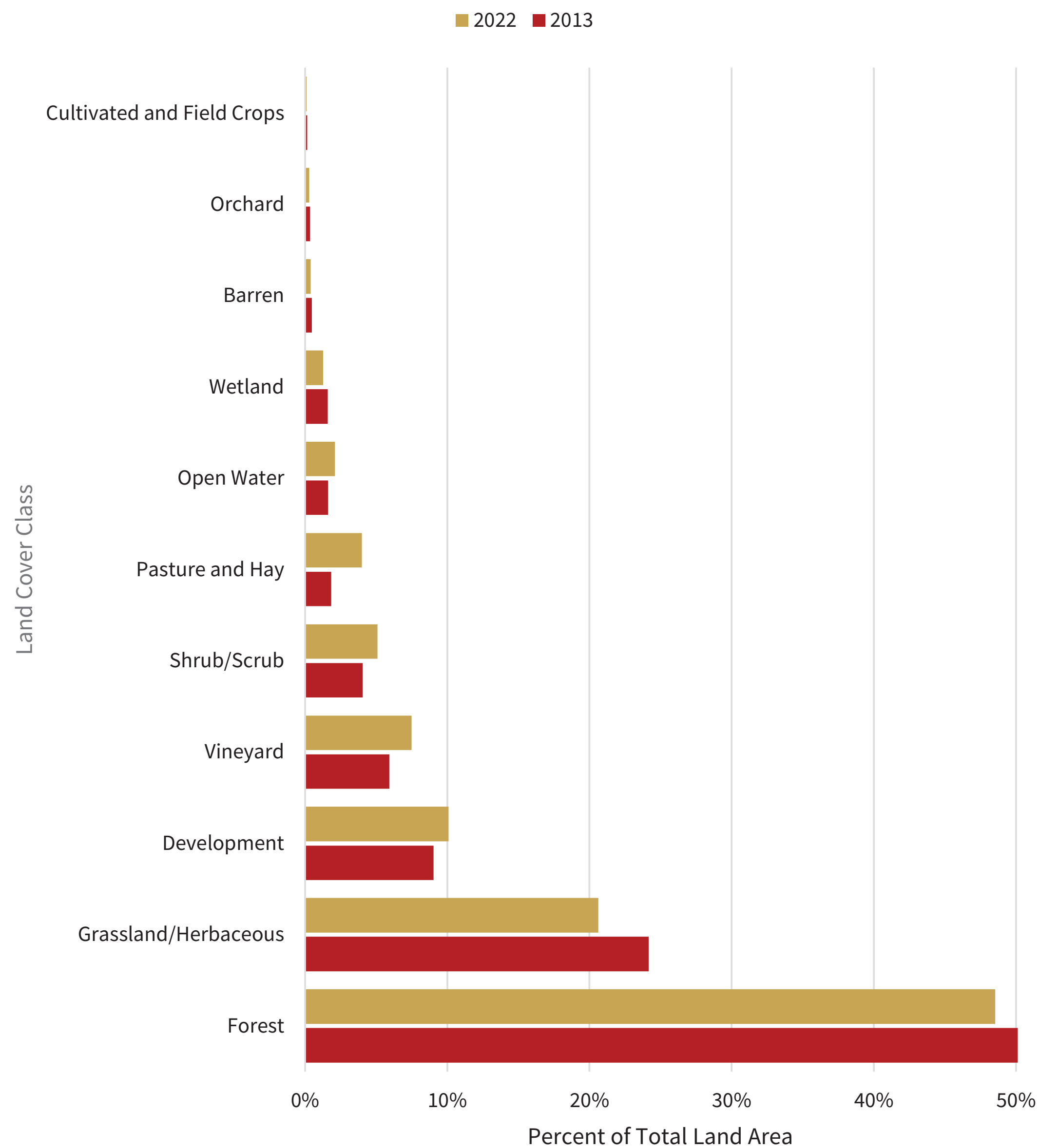
The largest land cover changes as shown in ***Table 4*** and ***Figure 7*** between 2013 and 2022 are a 23,929 acre loss of forest lands, a 16,307 acre gain in vineyards, and a 14,300 acre loss of pasture and hay and grassland/herbaceous land covers. Between 2013 and 2022 developed land cover increased from about 9 to 10 percent of total land cover, gaining an estimated 11,075 acres, for a total developed area of approximately 105,324 acres in 2022.

Table 4. 2013 and 2022 Land Cover Class Acreage across Sonoma County

Land Cover Class	2013	2022
Barren	4,977	4,144
Cultivated and Field Crops	1,526	1,234
Development	94,249	105,324
Forest	530,769	506,840
Grassland/Herbaceous	252,362	215,490
Open Water	16,808	21,950
Orchard	3,684	3,130
Pasture and Hay	19,121	41,693
Shrub/Scrub	42,417	53,201
Vineyard	61,921	78,228
Wetland	16,582	13,276
Total	**1,044,416**	**1,044,510**

Notes: Acres have been rounded to the nearest whole number therefore sums may not match.

Figure 7. 2013 and 2022 Land Cover Class as Percent of Total Land Area



Some of the changes in land cover depicted in the figures and tables below are due to changes in land use, while others may be due to climate-related impacts such as wildfire and drought. For example, decreases in forested land in the county may be due to climate-induced shifts from forests to shrub associated with the intensity and frequency of wildfires and extended drought between the two inventory years. Some of the observed changes in land cover classes may be related to methodological differences in the data sets rather than actual changes in land cover. ***Figure 8*** shows a spatial comparison between the Sonoma Veg Map dataset showing forest cover in 2013, and the 2022 LANDFIRE dataset for forest cover. The light grey areas depict where the datasets match, showing forest cover in both years and the purple shows areas designated as forest in the 2013 Sonoma Veg Map data that were not designated as forest in the 2022 LANDFIRE data. The green areas on the map show areas designated as forest in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. The orange areas are fire perimeters from 2013 to the present. Viewing the data this way indicates that the large areas of purple within the fire perimeters is likely representative of either actual loss of forest due to wildfire related conversion to shrub or other land cover types post-fire, or may be indicative of the early post-fire successional stages of forest recovery rather than permanent loss of forest. In some wildfire affected areas that were designated as forest in the earlier dataset and shrub in the later dataset, the shrubs may actually be, or include, young trees that are part of the natural regeneration of forest that can occur over several decades following a fire. The small, isolated pixels of purple and green scattered throughout the large forested areas may represent either actual differences in forest cover or differences in data sets resulting from the differences in how they were compiled (lidar versus satellite and algorithmic modeling).

Figure 8. Comparison of Forest Land Cover Between Years and Datasets

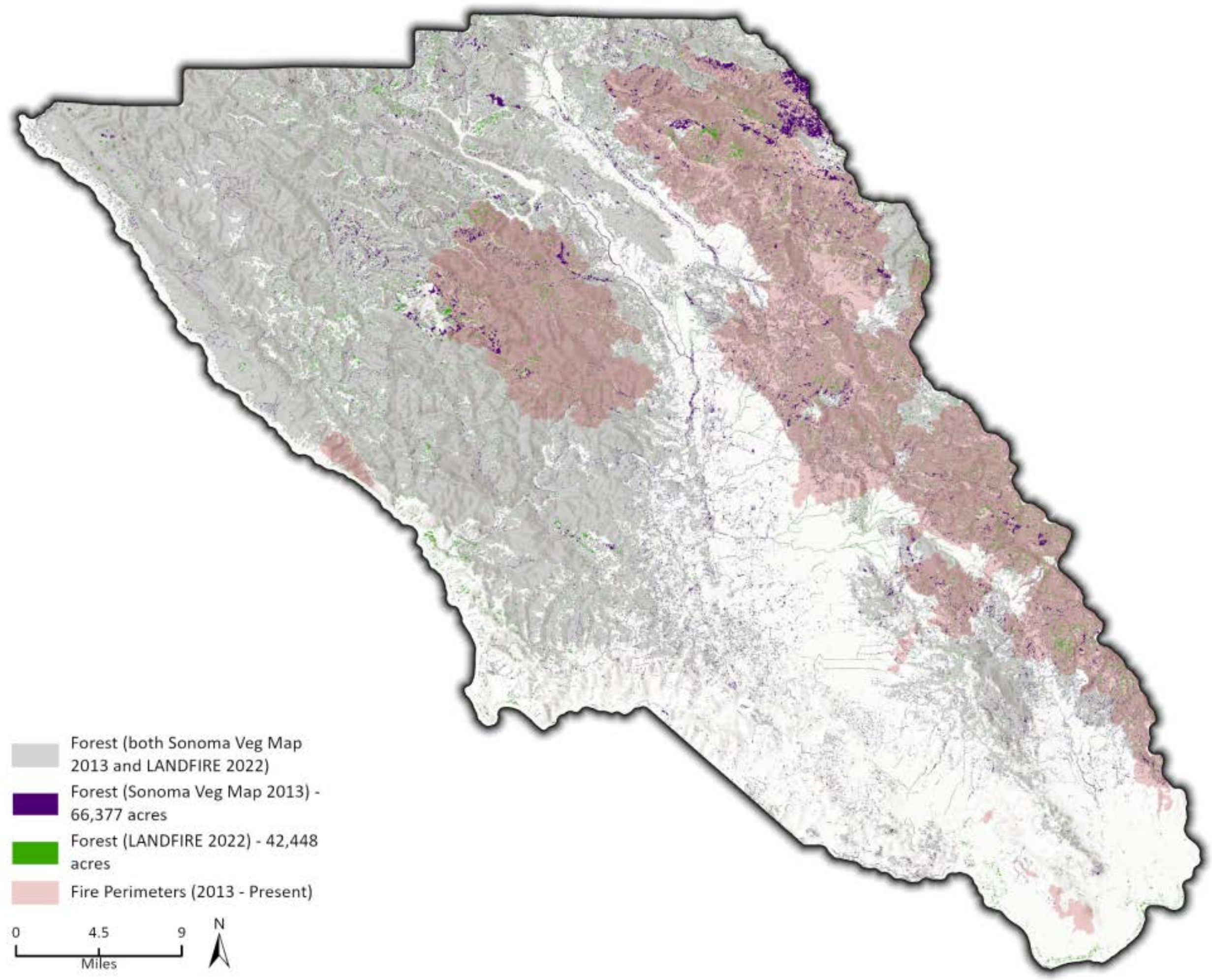


Figure 9 shows a spatial comparison between the Sonoma Veg Map dataset showing vineyards in 2013, and the 2022 LANDFIRE dataset for vineyards. The light grey areas depict where the datasets match, showing vineyards in both years. The pink areas show lands designated as vineyards in the 2013 Sonoma Veg Map data that were not designated as vineyard in the 2022 LANDFIRE data, this is representative of about 3,600 acres and is likely due to differences in the datasets rather than loss of vineyard. The purple areas on the map show lands designated as vineyards in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. The large blocks of purple likely indicate areas that are newly developed vineyard, and align with DWR spatial data for vineyards. However, a close up of the data shows that the 2022 LANDFIRE dataset also designates many small patches of land between vineyards as vineyard too. This is depicted in ***Figure 10***, where the grey areas show overlap between the data designating land as vineyard and the purple area shows 2022 LANDFIRE data designating land as vineyard. In the map it is easy to see how the areas between vineyards are classified as vineyard in many small patches by the LANDFIRE data. When summed over the entire county, this likely accounts for the additional acres over the expected gain of roughly 4,000 acres in vineyards based on DWR data.

Figure 9. Comparison of Vineyard Land Cover Between Years and Datasets

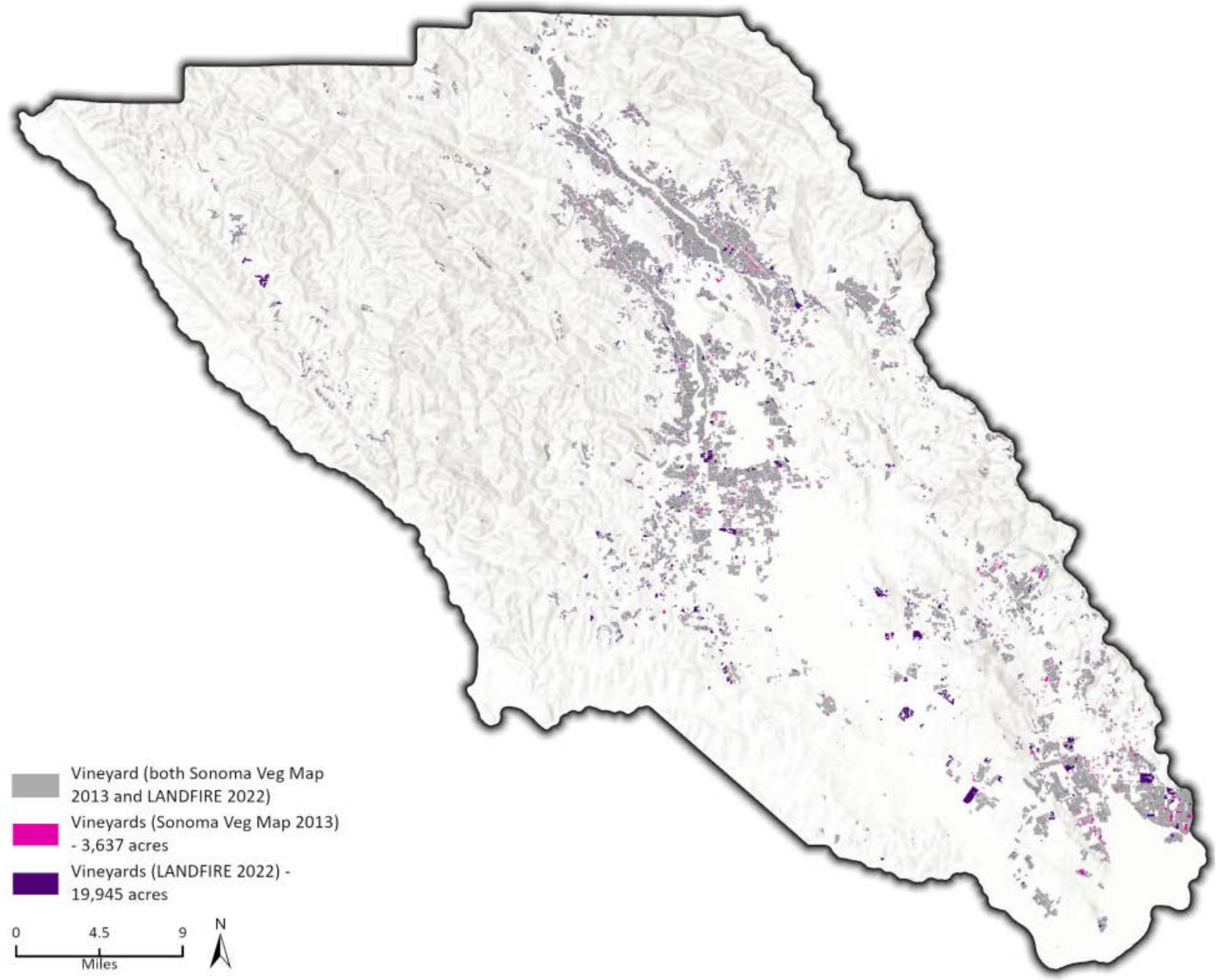
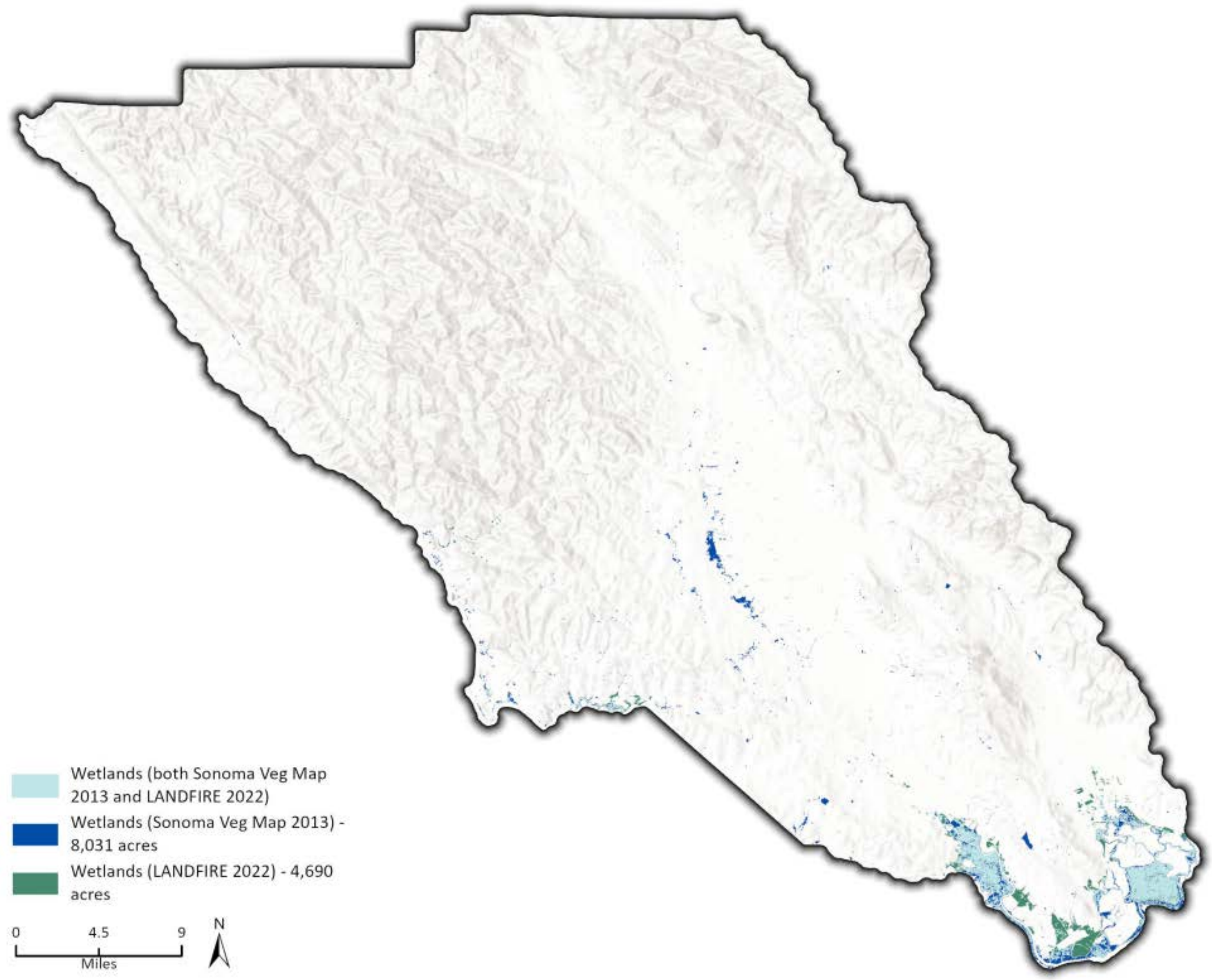


Figure 10. Close Up Comparison of Vineyard Land Cover Where Datasets Agree and Where LANDFIRE Designates Additional Vineyard Acreage

Figure 11 shows a spatial comparison between the Sonoma Veg Map dataset showing wetlands in 2013, and the 2022 LANDFIRE dataset for wetlands. The light blue areas depict where the datasets match, showing wetlands in both years. The dark blue shows areas designated as wetland in the 2013 Sonoma Veg Map data that were not designated as wetland in the 2022 LANDFIRE data. The green areas on the map show areas designated as wetland in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. There is the most overlap in the datasets around the bay wetlands. There are some concentrated areas of blue inland, as well as many smaller patches of dark blue sprinkled throughout the county and along the coastline. This may indicate some loss or drying of inland wetlands, but in many cases the difference is likely due to differences in recognition and designation of inland wetlands between the Sonoma Veg and LANDFIRE datasets.

A large component of the Study was to undergo a thorough quality assurance and quality control process of the land cover data with Sonoma County and partners. This process and the resulting data and methodological changes are further described in ***Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***.

Figure 11. Comparison of Wetland Land Cover Between Years and Datasets



The Importance of Conservation

Natural and undeveloped lands provide numerous benefits to the Sonoma County community including scenic value, recreation, economic activity related to tourism, refuge for wildlife, groundwater recharge, flood control, and air quality management. In addition to these benefits, natural lands store large volumes of carbon in their soils and vegetation. A study by the Bay Area Greenbelt Alliance, At Risk: The Bay Area Greenbelt, found that despite increasing levels of protection for natural and agricultural lands, there are 293,100 acres across the Bay Area at risk of conversion to developed land uses in the next 25 years, including lands in Sonoma County (Bay Area Greenbelt Alliance, 2017). Reducing and stopping land conversion of forests and grasslands can help prevent the loss of carbon stocks stored in those lands. Using the GIS dataset from the At Risk: Bay Area Greenbelt study, soil and slope data, and the 2022 LANDFIRE dataset, it was determined that within Sonoma County approximately 10,879 acres of forest were at risk of development within 5-25 years. An additional 5,282 acres of forest were potentially at risk for development into agricultural land and 16,085 acres of grassland were potentially at risk of development into agricultural land. The total emissions avoided as a result of protecting these at-risk lands through permanent conservation and protection are approximated to be 1,733,590 MT CO_2e for protecting forests from conversion to development, or the equivalent of taking 385,776 gasoline-powered cars off the road for one year (EPA, 2023). The emissions savings for protecting forests from conversion to agricultural uses is estimated to be 606,173 MT CO_2e, or the equivalent of taking 134,892 gasoline-powered cars off the road for one year (ibid.). Protecting grasslands from conversion to agricultural uses is estimated to prevent the loss of 290,202 MT CO_2e, or the equivalent of taking 64,579 gasoline-powered cars off the road for one year (ibid). Conservation can be a powerful tool for protecting carbon stocks and the many benefits that natural lands provide. Estimates for emissions avoided for several other categories of permanent conservation, or avoided conversion of land use, can be found in ***Appendix C Carbon Sequestration Analysis of Climate Smart Practices***.

CARBON STOCK METHODOLOGY

This section provides an overview of how carbon stocks are calculated. Carbon stocks and sequestration potential of California's natural and working lands have fluctuated over time. For example, the CARB inventory found that natural and working lands were a source of GHG emissions from 2001 to 2011, releasing more carbon than they stored. In 2012 to 2014, they returned to being a slight carbon sink, storing more carbon than they released.

This highlights the importance of outlining our methodological approach to calculating carbon stock estimates for carbon pools. Land-based inventories provide estimates of carbon stocks, stock changes, and resulting GHGs sequestered or emitted from different stock changes.

Carbon pools: A reservoir which has the capacity to accumulate or release carbon, such as forest biomass, wood products, soils, and the atmosphere (IPCC, 2023).

Carbon stock estimates are based on the sum of carbon stored in the following carbon pools:

- Above- and below-ground live biomass (e.g., trees, crops, shrubs, grasses, roots).
- Above- and below-ground dead standing trees.
- Lying dead wood (e.g., branches, logs, etc., lying on the ground surface).
- Litter (e.g., freshly fallen or slightly decomposed leaves, bark, twigs, flowers, fruits, and other vegetable matter).
- Soil

In alignment with the CARB natural and working lands carbon stock inventory and IPCC guidelines, GHG emissions associate with agricultural operations (such as nitrous oxide emissions from soils associated with fertilizer application) are considered anthropogenic and are not included in the carbon stock inventories. Inclusion would also risk double counting of GHG emissions since most land-based emissions are already accounted for in the Sonoma County RCPA Community GHG Inventory (RCPA, 2022). Changes in soil stocks, emissions from biomass burning, peat extraction and rice cultivation were not included in the inventory due to data limitations or irrelevance for the county. Changes in carbon stocks for agriculture, forestry, and land-use are also included in the carbon stock inventory through the quantification of changes in woody biomass carbon stocks (based on changes to vegetation, height, cover), as well as emissions from wetlands. While inclusion of emissions from wetlands is aligned with state practice and IPCC guidelines it is important to note that it has been shown that coastal wetlands and San Francisco Bay wetlands sequester more carbon each year than they release (Vaughn et al., 2022). These ecosystems provide an important natural, and established source of carbon sequestration in addition to essential habitat for wildlife and other benefits.

The carbon stock calculations do not capture land management activities (e.g., application of soil amendments like compost), which are influential for carbon sequestration, but often do not result in land cover changes. Land management implementation is not currently being tracked in a comprehensive data set nor compiled for projects countywide, though management practices are being tracked by the Gold Ridge and Sonoma Resource Conservation Districts in a public database project tracker. This RCD management practices tracker will be a significant part of the upcoming SMACCC project funded by the USDA Climate Smart Commodities grant (USDA, 2022) and represents a promising start to future tracking of management activities at the County-scale. The County is also working to stabilize carbon stocks through wildfire prevention· These efforts are summarized in this section under ***Carbon Stock Stability in the Face of Climate Change*** . Analysis covering fuel reduction practices is included in ***Appendix C Carbon Sequestration Analysis of Climate Smart Practices***, the results of which are summarized in ***Section 4 Climate Smart Practices and Analysis***.

A high-level overview of carbon stock calculation methodologies is provided in ***Table 5***. A full discussion on included emissions categories for land-based emissions is included in ***Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***.

Table 5. Calculation Methodologies for Carbon Stocks

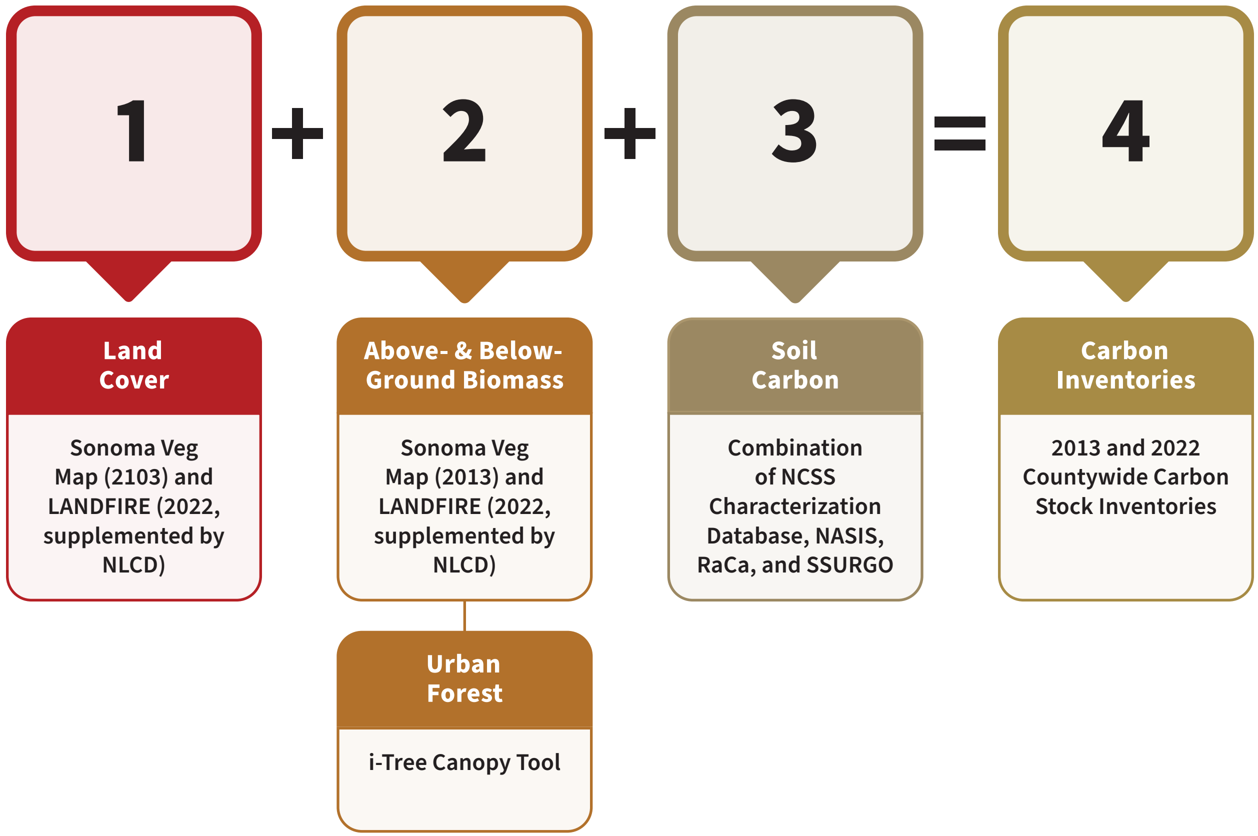
Carbon Type	Calculation Methodology and Data Sources
Above and Below-ground biomass (e.g., living trees, crops, bushes, standing dead trees, leaf-litter)	**Data Source:** California Air Resources Board (CARB) provides volumetric estimates of carbon mass (metric tons per hectare), which are provided for every combination of existing vegetation type, height, and cover (CARB, 2020). **Quantification Methodology:** Values are then assigned to the 30-by-30-meter cells in the GIS map in the county. Carbon values are then summed by land cover class.
Soil Carbon	**Data Source:** Values for soil carbon are obtained using the National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets. **Quantification Methodology:** Soil organic carbon from depths of 0-30 centimeters are calculated according to the Quantification Guidance for use with the Forest Carbon Projects Report (Climate Action Reserve, 2017)
Wetland Emissions	**Data Source:** California Coastal Commission (GIS data); IPCC; San Francisco Estuary Institute (SFEI) (Vaughn et al., 2022). **Quantification Methodology:** Emission factors from the San Francisco Estuary Institute and IPCC were applied to San Francisco Bay and Coastal wetlands acreages to estimate annual emissions. Emission factors for coastal and Bay Area wetlands were negative, indicating that these wetlands sequestered more carbon than they emitted each year.
Land-based Emissions	Encompassed under wetland emissions, and changes in woody biomass carbon stocks between 2013 and 2022 (Above-and below-ground biomass).

UNCERTAINTIES AND DATA LIMITATIONS

Many factors will influence potential future trends in carbon stocks, including both anticipated and unforeseen impacts from climate change (e.g., future wildfires and drought on landscapes) and policy implementation at the state and local level. Continued improvements in the science and protocols for tracking and estimating carbon stocks in land will mean that future estimations may be further refined and include additional sets of assumptions or data than were available and considered best practice at the time this analysis was conducted.

A summary of land cover classification and carbon inventories data is shown below in ***Figure 12***.

Figure 12. Land Cover Classifications and Carbon Inventories Data



Data Limitations on Analysis

Determining land cover, and extrapolating trends between 2013 and 2022 required a 2-part QA/QC process with the County, and other stakeholders to verify land cover acreage results between Sonoma Veg Map data, which was the basis for the 2013 land cover analysis, and LANDFIRE and the National Land Cover Database (NLCD) for 2022.[4] Key data limitations, and considerations that were addressed during the multi-stakeholder QA/QC process included:

- Two different datasets were used to calculate land areas for 2013 and 2022. The Sonoma Veg Map provides detailed information on vegetation classification for the land cover classification analysis and is the foundation of the 2013 Sonoma County land cover analysis. However, Sonoma Veg Map data was only available for the year of 2013. Due to this data limitation, LANDFIRE spatial land cover data, supplemented by the National Land Cover Database (NLCD), Department of Water Resources (DWR) Crop Mapping, satellite imagery, and desktop ground-truthing was used to develop the land cover map for 2022.
- There was some misclassification of land cover by datasets, including missing forest and grassland/herbaceous lands within city boundaries, and misattributed pasture/hay, grassland/herbaceous categories, which were identified by stakeholders, the County, and the project team. These land clovers were reclassified to new land cover classes following the QA/QC process.
- Calculation of carbon stocks based on land cover classification values for acreage also included uncertainties and data limitations that were considered and acknowledged by the project team. Key uncertainties and limitations in the calculation of carbon stocks included:
  - Soil carbon estimations are based on one year of available data (2017), making it impossible to describe changes in soil carbon stocks between years.
  - Inability to capture previous changes in carbon stock related to land management practices due to lack of data availability for:
    - Lack of availability for temporal data for land management activities, such as the acres of farmland to which cover cropping has been practiced each year, meaning that changes in 2013-2022 GHG emissions is driven entirely by land use change as analyzable by land cover class.
    - Separate estimation of wetland emissions (emissions were negative indicating that wetlands sequestered more carbon than they released), and exclusion of inland wetlands in this calculation due to data availability.

These data limitations and considerations are further discussed in ***Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum***.

4. *Vegetation mapping efforts like Sonoma Veg Map program in 2013 are resource intensive. LANDFIRE data is publicly available and is updated on an annual basis (starting from 2022). Therefore, to evaluate potential trends in land cover over time, two different data sets were required. Continuing to explore methods that local agencies can continuously update their carbon inventories and carbon sequestration is critical to meeting climate goals and adaptative management.*

CARBON STOCK AND TRENDS

Sonoma County's diverse landscapes hold approximately 105,365,950 MT CO_2e in carbon stocks (2022), and provide critical co-benefits like healthy ecosystems and watersheds, recreation areas, and local food production. Carbon stocks and emission potential varies by land cover. For example, in vineyard and orchard carbon stocks are relatively stable to fire risks because they are generally irrigated and heavily managed landscapes, while shrubland and forests may be more susceptible to losses from wildfire. Land conversion (e.g., development conversions of wildland or agricultural to other uses), can result in carbon stock losses. This analysis captures carbon stock changes based on vegetation type, cover, and height. Carbon stock changes resulting from management practices are not captured due to data limitations; however, annual carbon sequestration is estimated for a number of land management practices in ***Section 4 Climate Smart Practices and Analysis***.

As shown in ***Figure 13*** and ***Figure 14***, most of the carbon stock in the county is predominantly held in forested areas in the west and east, and wetlands in the south. These carbon inventories are further described in the text and tables below.

Figure 13. 2013 Total Carbon Stock Map

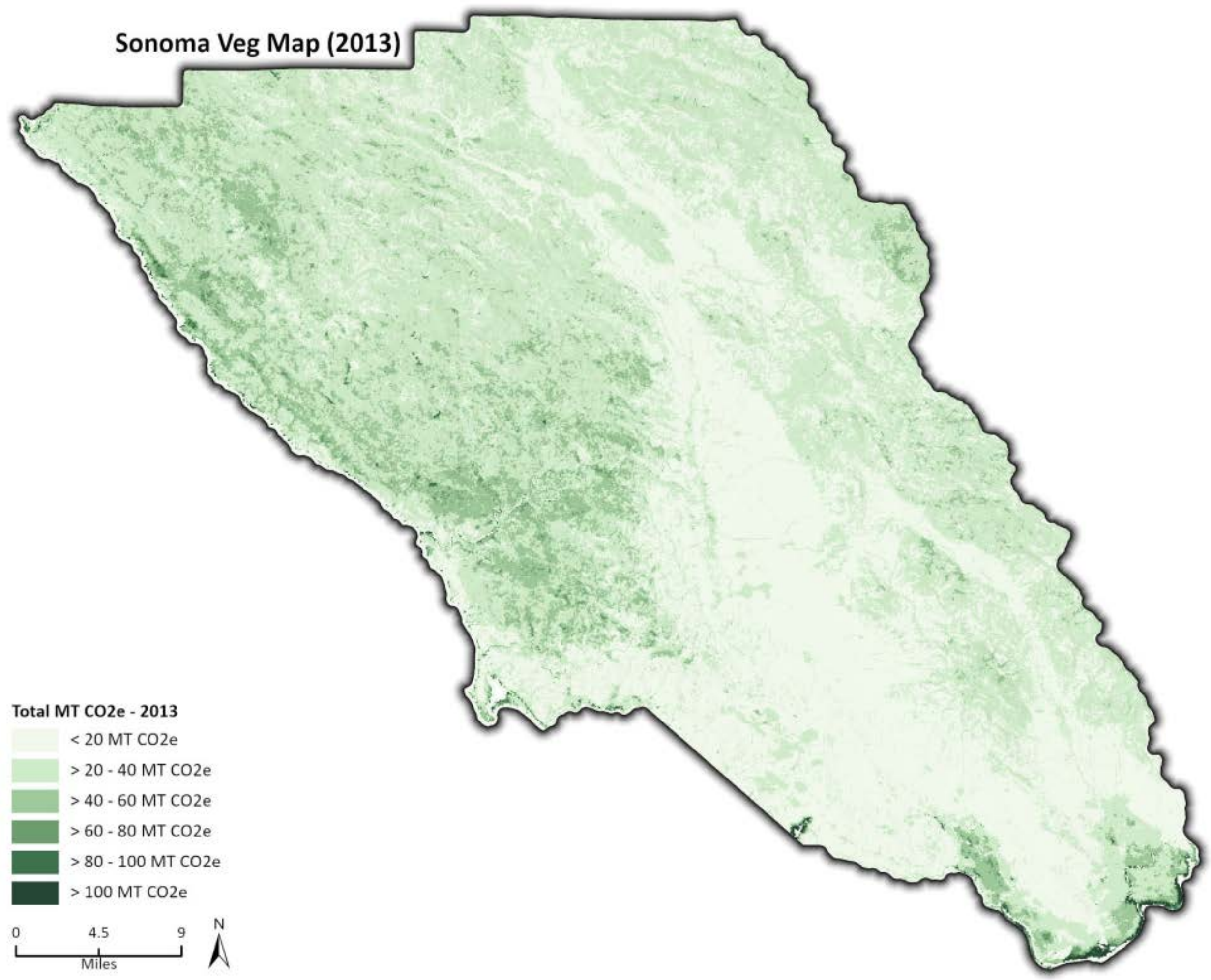
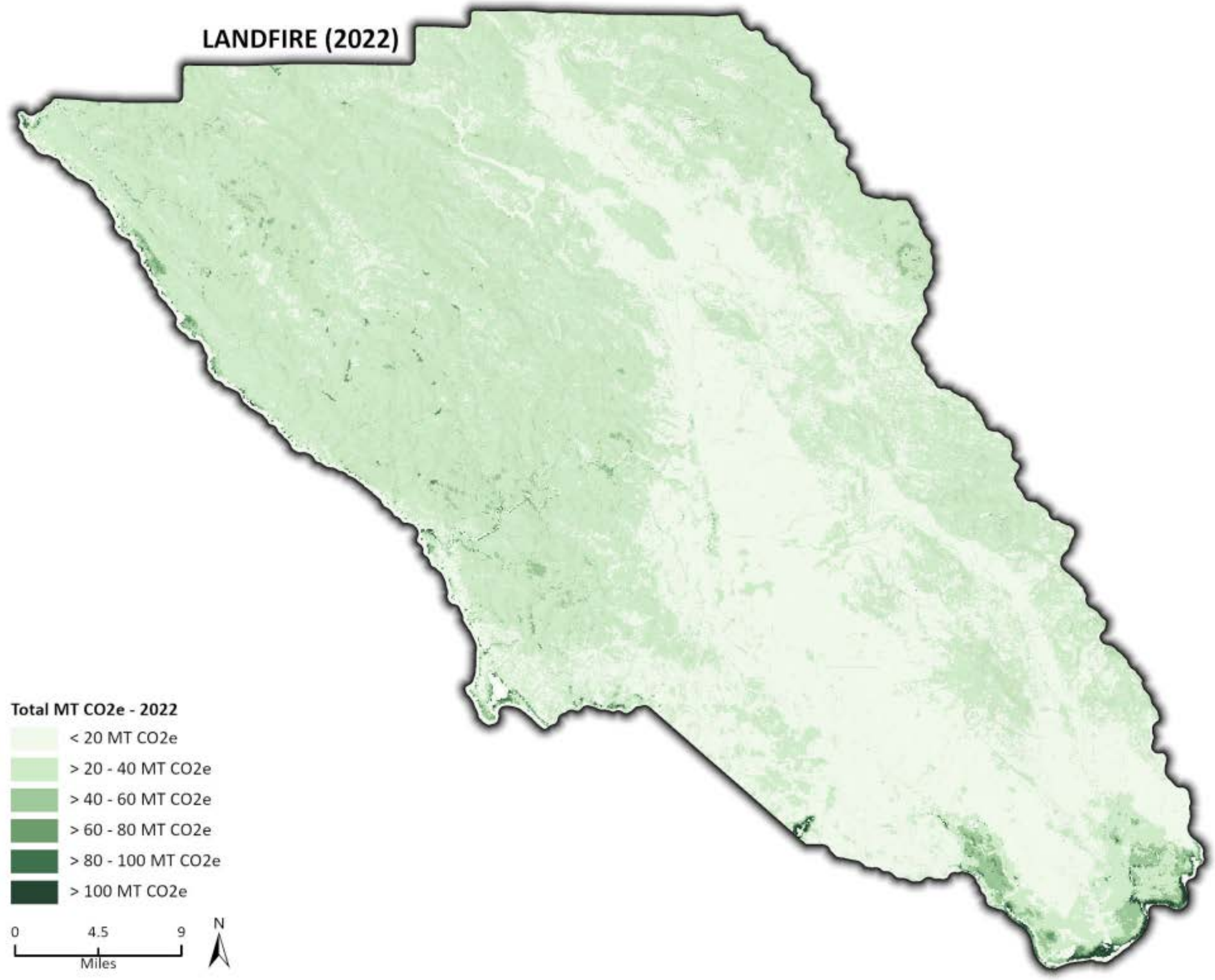


Figure 14. 2022 Total Carbon Stock



Sonoma County's carbon stocks (values all displayed in MT CO_2e) are described by land cover class under the following categories:

- Above-and below-ground carbon per acre, which quantifies carbon stocks from vegetation (e.g., shrubs, roots, dead trees, leaf litter); as shown in ***Table 6***
- Total carbon stock (above-and below-ground carbon + soil carbon) per acre, and total over land cover class, shown in ***Table 7*** and ***Table 8***
- Total carbon stock by land-owner are summarized in ***Figure 15*** and ***Table 9***

Above-and Below-ground Carbon

This above-and-below ground carbon inventory shows the carbon held in above and below ground carbon pools (ex. shrubs, roots, leaf litter) in Sonoma County by land cover. The largest stocks of above-and-below ground carbon per acre between both years is in development (which includes the carbon stored in the urban forest), forests, and shrub/scrub. In Sonoma County, there was an estimated decrease 18 percent in total carbon per acre for forests, and an increase of 17 percent in total carbon per acre for grassland/herbaceous landcover between the two years. Despite this change, forests still contain the largest carbon stocks out of all landcover in the county. This is difficult to determine what proportion of the increase in grassland/herbaceous land above-and below-ground carbon per acre is due to data artifacts that resulted from the reclassification[5] of grasslands during the data refinement process. The wetland land cover class shows a decrease of 32 percent in above- and below- ground storage per acre between the two years.

These changes in per acre carbon storage are due to changes in vegetation type, height, and/or percent cover between the two years. All other land cover classes maintained the same amount of above- and below-ground carbon storage per acre between the two datasets. 2013 and 2022 values for above-and below-ground carbon are shown below in ***Table 6***.

Table 6. 2013 and 2022 Sonoma County Above- and Below-Ground Carbon per Acre

Land cover Class	2013 Average Above- and Below-Ground Carbon/Acre (MT CO_2e)	2022 Average Above- and Below-Ground Carbon/Acre (MT CO_2e)
Barren	0.8	0.8
Cultivated and Field Crops	2.0	1.7
Development	15.5	14.1
Forest	68.5	41.8
Grassland/Herbaceous	2.7	15.7
Open Water	0.0	0.0
Orchard	7.5	7.5
Pasture and Hay	2.3	2.1
Shrub/Scrub	13.1	13.5
Vineyard	1.6	1.6
Wetland	3.1	2.5

MT CO_2e = Metric Tonnes of Carbon Dioxide equivalent

5 *The Sonoma Veg Map data layer does not include vegetation height and cover classifications for the grassland and shrub/scrub categories. To resolve this, the missing attribute data was substituted from the closest LANDFIRE 2014 data point which does include a vegetation height and cover classification associated with it. Vegetation height, vegetation cover, and vegetation type are necessary to join to the CARB volumetric dataset that contains the carbon values necessary for estimating carbon stocks. By pulling the required data from LANDFIRE (which is a lower resolution data source than the Sonoma Veg Map) there may be discrepancies in the vegetation height and cover data utilized that affect the estimated carbon stock values.*

Total Carbon Stock (Soil + Above-and Below-Ground Carbon)

In 2022, forest land stored the most total carbon per acre followed by grassland/herbaceous lands, developed lands, and shrub/scrub lands. *Table 8* shows the total carbon stock countywide for each land cover class in 2013 and 2022 and the percent change between the two years. In both years, forests and grassland/herbaceous lands held the most, and second most total carbon in the county (respectively). In 2022, the most carbon stored in the county after forests were grassland/herbaceous lands, development, and shrub/scrub lands. These carbon stocks, and percent changes between 2013 and 2022 are displayed per acre, and in total in *Table 7* and *Table 8*.

Table 7. 2013 and 2022 Sonoma County Carbon Stock per Acre

Land Cover Class	2013 Average Carbon Stock/Acre (MT CO_2e)	2022 Average Carbon Stock/Acre (MT CO_2e)
Barren	88.4	88.7
Cultivated and Field Crops	65.9	81.9
Development	73.9	73.6
Forest	147.0	121.5
Grassland/Herbaceous	71.8	83.5
Open Water	40.2	59.4
Orchard	65.0	64.7
Pasture and Hay	125.3	94.6
Shrub/Scrub	96.5	97.7
Vineyard	58.0	58.6
Wetland	177.7	177.3

MT CO_2e = Metric Tonnes of Carbon Dioxide equivalent

Table 8. 2013 and 2022 Sonoma County Total Carbon Stock

Land Cover Class	2013 Total Carbon Stock (MT CO_2e)	2022 Total Carbon Stock (MT CO_2e)	Percent Change between 2013 and 2022 (MT CO_2e)
Barren	440,119	367,468	-17
Cultivated and Field Crops	100,577	101,027	0
Development	6,962,559	7,749,627	11
Forest	78,034,944	61,577,998	-21
Grassland/Herbaceous	18,109,720	17,986,840	-1
Open Water	675,920	1,303,248	93
Orchard	239,362	202,396	-15
Pasture and Hay	2,396,328	3,944,917	65
Shrub/Scrub	4,094,253	5,196,075	27
Vineyard	3,593,475	4,582,317	28
Wetland	2,945,905	2,354,039	-20
Total	**117,593,161**	**105,365,950**	**-10**

MT CO_2e = Metric Tonnes of Carbon Dioxide equivalent
Note: The increase in total carbon associated with open water is likely the result of differences between the datasets for both years. There was more open water land cover associated with the 2022 LANDFIRE data than the 2013 Sonoma Veg Map data. Because LANDFIRE is a raster dataset (rather than a vector dataset) and is in a resolution of 30x30 meter pixels which is lower resolution than the 2013 fine-scale Sonoma Veg Map data, there was likely more area picked up than is strictly true for 2022. This would result in open water "gaining" the carbon stock associated with the additional area classified as open water.

Carbon Stock Categorized by Landownership (Public vs. Private)

Public and private landowners both play critical roles in the implementation of climate smart practices. As described below in ***Figure 15*** and ***Table 9***, private lands make up the vast majority (88 percent) of Sonoma County. Accordingly, shifts in land management implemented across disparate private landowners have a large role to play in carbon sequestration and emissions reductions. 12 percent of Sonoma County is owned by public entities, which include over 300 different owners of public land, including County entities like Sonoma County Ag + Open Space and the County of Sonoma Water Agency. Among publicly owned land covers, County land ownership through County of Sonoma, Ag + Open Space, and the Sonoma County Water Agency account for 24 percent of total publicly owned land acreage, with Sonoma County owning the largest total share of acres.

Implementing widespread climate smart practices on privately held land requires coordination with many individual landowners with costs shared across participating landowners and supporting agencies. The County has an important role to play in both arenas (public, and private land), as implementing climate smart practices across these land covers requires overcoming shared challenges of planning, permitting, funding, and implementation hurdles.

Figure 15. 2022 Public and Private Ownership Categorization

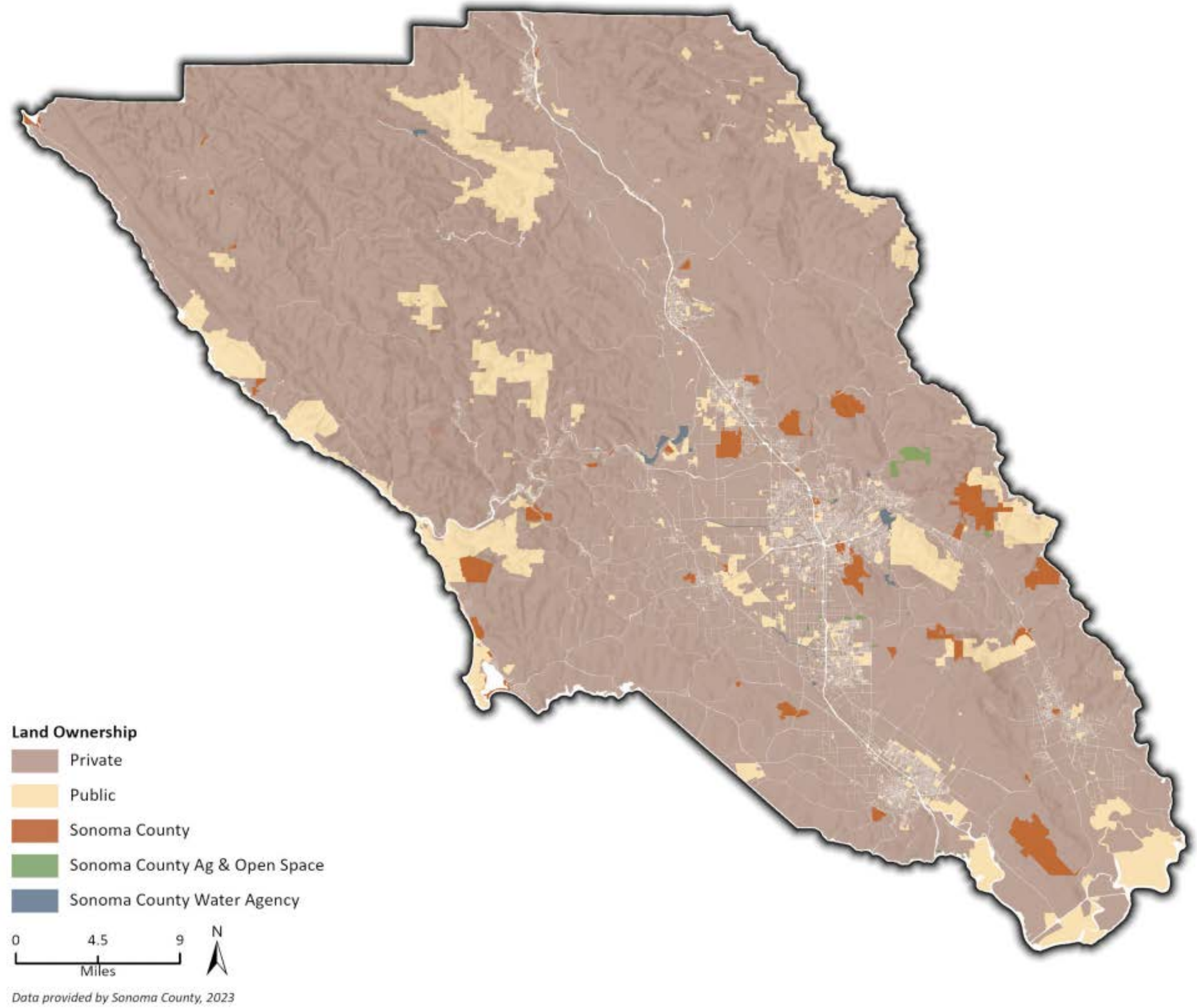


Table 9. Total Metric Tons of Carbon and Acreage by Landownership Category

Landowner	2022 Total Acres	2022 Total MT CO_2e
Privately Owned	881,225	88,841,962
Publicly Owned	111,974	12,513,728
Total	993,199	101,355,691
County Land Ownership Summary *		
County of Sonoma	18,831	1,837,223
Ag + Open Space	6,9721	126,405
Sonoma County Water Agency	2,400	202,888
Total	**28,202**	**2,166,515**

*Notes: Acres have been rounded to the nearest whole number therefore sums may not match. Refer to **Appendix B Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum** for additional explanation of these results.*
**Subsection of Publicly Owned land, County lands*
1 In addition, Ag + Open Space holds 251 conservation easements on over 122,400 acres, which preserve agricultural lands, open space, and natural resources. Potential for nature-based solutions implementation on these lands will also be considered in the Carbon Inventory and Sequestration Potential Study.
Source: Sonoma County Ag + Open Space, 2023.

CARBON STOCK STABILITY IN THE FACE OF CLIMATE CHANGE

Natural and working lands provide many benefits to California and the Sonoma County community, including capturing and storing carbon in soil and vegetation, acting as a carbon "sink." Depending on how natural and working lands are managed, conserved, or developed, they can also act as a source of carbon. For example, when shrubland converts to forest, there is an increase in carbon sequestration, but when forests are burned in large wildfires the carbon that was stored in the trees is emitted back into the atmosphere. The CARB 2022 Scoping Plan provides an overview of trends and changes in statewide carbon stock through periodic natural and working lands inventories. In California, natural and working lands carbon stocks decreased from 2001 to 2011, releasing more carbon than they stored, and increased slightly from 2012 to 2014, storing more carbon than they released. These recent historical trends highlight how natural and working lands can function as both a source and sink for carbon emissions. Climate change can alter the natural cycles of carbon release and storage in natural and working lands, and land management practices can either help mitigate or exacerbate these impacts.

Natural and working lands play a key role in mitigating climate change through carbon storage and sequestration. However, carbon stocks and their stability can be diminished by climate change impacts including extended drought and more severe and frequent wildfires. The following sections describe climate change impacts to Sonoma County natural and working lands and the outsized impacts of wildfire and drought on carbon stock stability.

Estimated Carbon Stock Loss from Wildfire and Drought

In order to estimate the impact of climate change conditions, including severe drought and wildfire, between the two reference years, a GIS data analysis was conducted. The estimate is based on the change in carbon stock between 2013 and 2022 within the perimeters of fires that occurred between the two years. The resulting difference in carbon stock is assumed to be due to the collective climate context including drought and wildfire climate on the Sonoma County landscape during the study period. This approach both reflects the difficulty in isolating carbon stock changes from specific climate impacts and is aligned with actual conditions in Sonoma County natural and working lands which experience climate change and other factors in combination.

The analysis found that the areas within fire perimeters contained a total of 27,680,579 MT CO_2e in 2013; and, in 2022 those same areas contained a total of 24,616,829 MT CO_2e. This represents a decrease of 3,063,750 MT CO_2e between the two years, which is an 11.7 percent decrease in carbon stock for the wildfire and drought impacted lands. The results of this analysis illustrate the impact that climate change has on carbon stocks in Sonoma County and the need to focus on climate smart practices that protect existing carbon stocks.

Climate Change in Sonoma County Natural and Working Lands

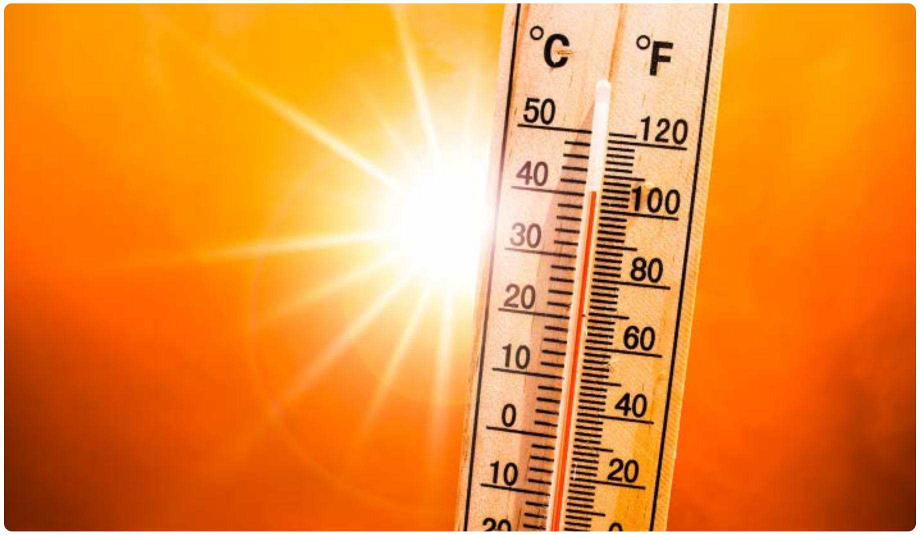
Climate change impacts to natural and working lands throughout the state are already significant, with a marked increase in the more frequent occurrence of unusually large, high-severity wildfires. As climate change accelerates, these large, high-severity wildfires are likely to become more common and impact greater amounts of natural and working lands, diminishing their stored carbon. Climate change is also expected to have other significant effects on natural and working lands, including more frequent and prolonged droughts, floods, extreme heat, and the spread of invasive aquatic and terrestrial species, pests, diseases, and parasites (CARB, 2022). The primary climate change driven hazards that will impact Sonoma County's natural and working lands are wildfire, drought, sea level rise, extreme storms and flooding, and extreme heat.

The following discussion provides an overview of potential climate change impacts to natural and working lands. For more detailed discussions of potential climate impacts on natural and working lands, as well as maps and figures depicting land cover and hazard risk, see the Sonoma County Climate Change Vulnerability Assessment (County of Sonoma, 2023). The Sonoma County Climate Resilient Lands Strategy provides further characterization of the impacts of climate hazards on natural and working lands (County of Sonoma, 2022). The Climate Resilient Lands Strategy divides the county into nine ecoregions that have distinctive physical and biological features, and provides detailed information on each ecoregion's unique qualities, land use, demographics, critical assets, impacts from climate change, and resilience indicators.

Extreme Heat and Warm Nights

Both mid- and end- of century projections depict dramatic increases in extreme heat days (CEC, 2021). Extreme heat and warm nights impact the plants and animals in natural and working lands which are highly exposed to temperature changes. Wildlife under these conditions face impacts of heat stress and heat related illness as well as disrupted reproductive cycles, and compounding risks associated with early and extended seasonal temperature increases (Backlund 2008). Timing of seasonal warmth may not overlap with food sources and extreme heat may stress dependent vegetation communities and wildlife (Dale, 1997; Hamerlynck, 1995; Maclean, 2011). Plants are more likely to experience heat stress and drying, and species' habitat ranges may shift. Some pests can proliferate more easily with warmer temperatures (Hamerlynck, 1995), and some plants and animals ill-suited to the new warmer conditions may suffer increased mortality rates (Ackerly et al., 2018).

A greater number of extreme heat events and warmer nights could cause declines in crop yields due to increased heat stress. Lower crop yields associated with extreme heat could increase costs and ultimately decrease agriculture profitability. Livestock operations are potentially less viable during extreme heat events as livestock may suffer from heat related illness. Livestock and poultry are vulnerable to extreme heat conditions, leading to mortality, which, in turn, may impact rendering plant capacity.



Riverine and Stormwater Flooding

There are several major rivers that run through Sonoma County as well as many creeks. FEMA flood zones are identified alongside most of these rivers and creeks. A majority of the flood-prone areas throughout the County are part of the Russian River (Sonoma County MJHMP, 2021a). Flooding impacts include erosion, and the detrimental effects flooding can have on water quality, especially to aquatic and fish species dependent on water quality for survival (Talbot, 2018). Riverine and stormwater flooding will mostly affect sensitive species of plants and wildlife that are not upland. Other impacts include damage from inundation within storm flooded areas, such as habitats and lands around streams and waterbodies in the county.

Agricultural Land overlapping flood plains occurs in areas throughout central Sonoma County next to the Russian River and the North Bay Area. Operations in these areas along the rivers that run through the county have the potential to be disrupted during flood events and could result in reduction in crop yields.

Sea Level Rise

The direct effects of sea level rise on natural resources are the losses of prime recreational and natural areas. Bodega Bay may be almost completely flooded by 2100. The negative impacts of sea level rise include the risks of squeezing and permanently submerging coastal habitats, which could lead to losses in the biodiversity of habitats and shrinking the area between habitats and human developments. As sea level rises, it can inundate the county's natural land and open spaces, which in certain areas serve as natural protections against flooding, further decreasing coastal habitat values. In addition, saltwater intrusion into freshwater due to sea level rise may alter coastal habitat and ecosystems (Sonoma County MJHMP, 2021a). Sea level rise can also outpace the ability of wetlands to migrate inland and upland or accrete enough sediment to adapt vertically to rising water levels. This can result in "wetland drowning", where key animal and plants species are eliminated and eventually wetlands are simply lost to higher seas. Although substantial wetland drowning is not expected by 2045, losses could be large by the end of the century without management intervention (SFEI, 2014). Loss of coastal wetlands means loss of crucial habitat and ecosystem services they provide, as well as their carbon sequestration potential.

Sea level rise will result in increasing shoreline and bluff erosion, which will narrow the beach. Coastal erosion due to sea level rise could make some beaches inaccessible and it may become much more costly to maintain. It will also negatively impact dune habitats and coastal wetlands areas such as the ones south of the Russian River mouth, where sea level rise will intensify flooding, changing the depositional environment and altering the stability of the natural berm (Sonoma County MJHMP, 2021a). The shifts in coastal processes will affect the management of the freshwater lagoons in the Russian River estuary (Sonoma Water, 2021).

Sea level rise can impact working lands located in low-lying areas due to saltwater contamination since rising seas will increase saltwater pollution of the State's delta and levee systems (Sonoma County MJHMP, 2021a). The impacts of saltwater intrusion due to sea level rise is one of the primary climate change concerns for agricultural practices in Sonoma County bordering the San Pablo Bay to the south. Agricultural lands in reclaimed tidal areas in southern Sonoma County will be at risk of inundation due to the risk of levee breaches and failure (Cornwall et al., 2014).

Drought

Drought will disrupt habitats and the ability for wildlife to survive due to dehydration and unreliable food sources. Extended or variable drought conditions affect the amount and duration water is available in ephemeral and permanent water sources, impacting plants and wildlife dependent on those aquatic resources. Higher temperatures will decrease the statewide snowpack and raise the snowline, decreasing important surface water reserves for agriculture (Ackerly et al., 2018). Like extreme heat and warm nights, drought is linked to declines in crop yields, increasing costs, and decreasing crop profitability. Drought can result in regional losses of crops and can stress the statewide water supply. A majority of the county's agricultural water is drawn from the Russian River watershed, which supplies Lake Sonoma and Lake Mendocino. These lakes have experienced drought related reduction in capacity. In 2009, Lake Sonoma was at 74 percent capacity and Lake Mendocino was at 38 percent capacity (Sonoma County MJHMP, 2021a).

Crops reliant on high depths of water and subsequently higher water intensity needs are most impacted by drought (Cooley et al., 2012). In 2022, all of Sonoma County was in a Severe or Extreme Drought (NOAA, 2023). According to NOAA, extreme drought conditions result in the following impacts:

- Forage on grazing lands decreases in quantity and quality causing livestock to need expensive supplemental feed and additional water sources; cattle and horses are sold; little pasture remains; fruit trees bud early; and producers begin irrigating in the winter.
- Fire season lasts year-round; fires occur in typically wet parts of state; and burn bans are implemented.
- Water is inadequate for agriculture, wildlife, and urban needs; reservoirs are extremely low; and hydropower is restricted.

Wildfire

The largest direct impacts to natural and working lands are caused by wildfires. There is direct mortality and loss of resources and wildlife from wildfire as well as indirect mortality due to loss of habitat area and available food sources and seed bank (Backlund, 2008). The severity and frequency of wildfires can exacerbate these impacts further through habitat conversions resulting in vegetation communities that no longer support the species using that habitat (Coop et al., 2020). Projected annual burned acreage is expected to increase as are the decadal probabilities of wildfire. Increased wildfire probabilities and expansion of wildfire zones may lead to increased park and natural resource exposure to wildfires (Sonoma County, 2022).

Wildfires can destroy crops and disrupt rangeland operations while wildfire smoke may stress the health of crops and livestock. Agricultural land cover overlaps very high fire hazard severity zones at the eastern edge of the county. Moderate fire hazard severity zones overlap agriculture throughout the entire county particularly in the southwestern portion of the County and southeast of Healdsburg The probability of wildfires across Sonoma County is expected to increase by the end of the century in areas throughout the county with significant new exposures of agriculture lands in the east, north, and west jurisdictional ends of the county.

Outsized Impact of Wildfire and Drought

This section assesses the impacts of wildfire and drought on carbon stock in Sonoma County because they are both directly impacted by changes in the major climate drivers, precipitation and temperature, and they are two of the main climate hazards that the CARB has identified in the 2022 Scoping Plan.

Extended drought and wildfire are the two main climate hazards impacting carbon stocks in natural and working lands identified in the 2022 Scoping plan. Given the number of wildfires that have occurred in Sonoma in recent years (2015 Valley Fire, 2017 Tubbs Fire, 2017 Nuns Fire, 2017 Pocket Fire, 2019 Kincade Fire, 2020 Meyers fire, 2020 Walbridge fire, 2020 Hennessey fire, and 2020 Glass fire) and the large carbon stock contained in Sonoma's extensive forests, shrublands, and grasslands, wildfire and drought are the two primary threats to carbon stock stability in the county (Mandeno, 2021).

Wildfire and Carbon Stock Loss

The carbon cycle exchange between the biosphere and atmosphere includes emissions caused by wildfire. When forests and plants are growing, carbon dioxide from the atmosphere is sequestered by vegetation in the biosphere. When biomass is burned, carbon is released back into the atmosphere as GHG emissions and causes a corresponding loss of carbon stock. The health of the majority of California's ecosystems is dependent on wildfire, which can reduce buildup of organic debris that can fuel high-severity wildfires, release nutrients into the soil, and trigger changes in vegetation community composition (CARB, 2020). Historically, indigenous people of California understood the interactions of wildfire and the natural lands, even using controlled burns to promote the health of natural lands. However, in the 20th century fire suppression became the guiding force for U.S. fire policy that was intended to protect communities and resources (Bruno, 2020). This has created a disruption in the natural carbon cycle of forests that arises from a lack of naturally occurring fires that serve to regularly clear undergrowth, enhance available nutrients, and promote the long-term health of mature trees. Many fire-excluded forests have too much carbon stored in the form of excessive biomass, crowded trees and underbrush, which can fuel severe wildfires (North and Hurteau, 2011).

Wildfires contribute significantly to carbon stock losses. Due to the volume of biomass in forested areas shrublands, and grasslands, these are the landscapes with larger potentials for carbon storage losses due to wildfire.

It is difficult to accurately estimate GHG emissions and carbon stock losses from wildfire, as each wildfire event has different characteristics that influence the degree to which carbon stocks are lost. The intensity of fires can vary greatly, even within areas of the same wildfire event. Some events can result in a nearly complete loss of all living biomass, whereas some may only burn undergrowth and leave longstanding trees relatively unharmed. These variables may greatly impact the degree to which carbon stocks are lost and GHG emissions are generated. Additionally, the decomposing deadfall that remains after live vegetation has been burned by wildfire also serves as an emissions source for decades after the initial emissions impact of fuel burning, which further complicates the full understanding of GHG emissions and carbon stock loss impact (North and Hurteau, 2011). A study on high-severity wildfire and carbon stock in California pine forests found that approximately 28.9 to 30.7 percent of the biomass carbon is converted to emissions in areas of the wildfire that were untreated, which decreased to a range of 12.7 to 12.9 percent for treated forests in the area studied (North and Hurteau, 2011). Untreated forest was forest that had not been thinned, preserving the tree density resulting from fire suppression management practices over time, while treated forests had undergone mechanical thinning to reduce forest tree density. The study found that the incidence of high-severity wildfires can be reduced through thinning and other treatments, but that these treatments reduce the amount of carbon stored in forests corresponding to the reduction in biomass from thinning or prescribed burning. However, these measures can help create wildfire resistance in forests and can still provide a net carbon benefit if treatments prevent greater carbon stock losses from high-severity and large-scale wildfires than is removed during treatment. Forest thinning can improve carbon sink strength during dry months compared to unthinned forests, prevent deforestation and degradation from high-severity fires, and increase the stability of carbon stocks in forested areas (North and Hurteau, 2011).

Drought and Carbon Stocks

Climate change driven intense drought stress has caused shifts in plant communities, species ranges, and widespread vegetation mortality. Seasonal patterns of temperature and precipitation strongly influence the distribution of carbon stored in living biomass. Higher temperatures drive decreases in carbon stored in forests and decreases in precipitation greatly increase those losses. It is estimated that 41 percent to 49 percent of trees in the central and southern Sierra Nevada died during California's 2012–2015 drought, resulting in an enormous loss of stored carbon, and a shift in forest composition and redistribution of major species. Projections for the 20 highest biomass containing tree types show widespread replacement of conifers by oak species at lower elevations in central and northern California. This change in species dominance and range corresponds to projected decreases in carbon stocks (Coffield et al., 2021). Dead vegetation slowly decomposes releasing a large portion of stored carbon back into the atmosphere, as well as providing potential fuel for wildfires. Even when trees are not killed during drought periods, they sequester less carbon.

Water stress affects the ability of trees to photosynthesize by disrupting the balance between water uptake and water loss through transpiration. When soil moisture is limited during drought, trees experience difficulties in absorbing water through their roots. As a result, the stomata, small openings on the leaves responsible for gas exchange, begin to close to prevent excessive water loss. However, this closure also restricts the entry of carbon dioxide (CO_2) into the leaves, which is essential for photosynthesis. With limited CO_2 availability, the photosynthetic rate decreases, leading to reduced carbon assimilation and subsequent carbon sequestration in trees. Additionally, prolonged water stress can cause damage to the photosynthetic machinery and accelerate leaf senescence, further impairing photosynthesis and carbon sequestration (McDowell et al., 2008).

Drought can also increase tree vulnerability to pests or change attack preferences of pests such as the bark beetle. One study found that in non-drought periods smaller Pinus species had significantly higher mortality due to bark beetle attacks, but during a severe drought period the smallest Pinus class had significantly lower bark beetle mortality that large Pinus sizes; however, the impacts of drought and bark beetle attack varied by tree species (Stephenson, 2019). Due to the increased stress on trees, changes in pest behavior, and increased mortality that can be caused by droughts, above-ground living carbon stocks are likely to become less stable as climate driven droughts become more frequent, hotter, and more severe.

Studies have found that drought reduced the amount of organic carbon in the soil by decreasing the input of plant litter (dead plant material) by 8.7 percent and slowing down litter decomposition by 13.0 percent. This led to a decrease of 3.3 percent in soil organic carbon content across all three ecosystem types. Drought also increased the accumulation of dissolved organic carbon and nitrogen in the soil by 59 percent and 33 percent, respectively, compared to normal precipitation conditions (Deng et al., 2021). Studies indicate that drought-stressed forests can actually enhance belowground carbon sequestration, despite reduced carbon uptake by the ecosystem as a whole (Brunn et al., 2023). This variation in soil carbon storage and stability based on landscape, species, soil depth, and climatic factors means that it is difficult to estimate the impact of drought on soil carbon stocks overall, and how they compare to the simultaneous changes in aboveground carbon stocks during droughts. While the impacts of drought on soil carbon are complex and variable, increased soil carbon content can provide resilience against drought as it can increase water infiltration and soil water holding capacity.

Climate Change Compounding Risks of Carbon Loss

Climate change impacts will compound to cause imbalances in the carbon cycle. For example, when forests have become increasingly affected by drought and invasive species. This can turn forests into a carbon source, with decaying biomass emitting carbon to the atmosphere and becoming fuel for more frequent wildfires. The current state of many California forests is that of a carbon cycle imbalance, where more severe wildfires occur that burn hotter and more intensely resulting in a higher loss of carbon storage in biomass and, in turn, generate a greater release of GHG emissions into the atmosphere from both the initial burning and later decay of burned trees. This loss of biomass also reduces the ability for forests to continue to absorb carbon generated by human activities, furthering the carbon imbalance seen in the atmosphere.

Carbon cycle imbalances between the atmosphere and biosphere create a feedback loop that exacerbates the impacts of wildfire. The increased carbon dioxide levels in the atmosphere contribute to climate change, which impacts forests by increasing tree mortality due to extreme heat events, droughts, and increased levels of invasive species (CARB, 2021). The combination of climate change and the unhealthy forests that result from human policy and land use development are both contributing to high-severity wildfires (high present long-term perturbations to ecosystems, biodiversity, and carbon storage potential) and increased GHG emissions from the direct loss of carbon stock during wildfire events.

4.

CLIMATE SMART PRACTICES AND ANALYSIS

This assessment of climate smart practices in this study is intended to provide a starting point for further analysis informed by local climate smart practice planning and implementation activities. The County, along with many regional partners, has embarked on the SMACCC project, funded by the USDA Climate Smart Commodities grant program. SMACCC project implementation and monitoring efforts within Sonoma County will be led by the Gold Ridge RCD and the Sonoma RCD. The RCDs will leverage their local expertise and ongoing relationships with the agricultural community to increase the pace and scale of carbon farm planning and climate smart practice implementation. Data gathered from these efforts will be used to refine the sequestration and co-benefits analysis, further localized climate smart agricultural planning, and evaluate realistic adoption targets for practices given the sequestration potential, logistics, costs, and numerous co-benefits associated with each practice. Future planning for climate smart practice implementation should incorporate RCD data based on local implementation activities as much as possible and be guided by the work of the SMACCC project. Additionally, future analysis could elaborate on how the land use categories utilized for the purposes of this study equate to local zoning designations, to aid decision makers in incorporating these findings into general plan policies and goals. The following sections provide an overview and the results of this initial climate smart practice analysis to be built upon by SMACCC.

CLIMATE SMART PRACTICES DEVELOPMENT

Climate smart practices were sourced primarily from COMET-Planner for the California Department of Food and Agriculture Healthy Soils Program and California Department of Conservation's TerraCount, both of which are based largely on United States Department of Agriculture Natural Resource Conservation Science conservation management practices and provide the information necessary to quantify estimated carbon sequestration. These tools were developed to allow for consistent replication and estimation of the GHG benefits of various land management practices across the country and state, respectively. The list of potential practices was also informed by input gathered during the stakeholder workshop, and the semi-final list of practices were reviewed by County stakeholders to determine which practices were most locally relevant to Sonoma County farmers and natural and working lands.

There are a number of practices that are not quantifiable at this time but may provide carbon sequestration benefits, enhance the carbon sequestration benefits of currently quantifiable practices, or provide necessary support for these practices. Some practices are emerging, such as beaver assisted restoration, application of biochar, application of crushed basalt and other mineral soil amendments, and do not as of yet have a reliable protocol or tool for quantifying the sequestration benefit. Emerging practices are discussed further in ***Section 5 Looking Ahead***. Examples of practices that compliment or enhance the sequestration benefits of other practices include fencing projects to support prescribed grazing and oak woodland restoration in grazing lands, forest fuel reduction using goats or other livestock, forest slash treatments, and conservation of lands for future wetland upland migration to preserve wetland carbon sequestration and biodiversity benefits despite rising sea levels. The carbon sequestration and environmental benefits of these practices may be described qualitatively but are not currently quantifiable given the available tools, protocols, and data. Where it is possible to estimate potential implementation acreage for these practices, those results are included in the implementation acreage part of the analysis. Practices where the carbon sequestration benefits are not currently quantifiable are not included in this analysis, though they are nonetheless valuable and are recommended for inclusion in the suite of potential climate smart practices to be considered by the County. The climate smart practices analyzed in this study are listed below in ***Table 10*** along with the activity source, expected lifespan of the practice, and the sequestration/emissions reduction coefficient. Practices are organized by the land use category and land cover to which they are applicable.

Table 10. Climate Smart Practices

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
NATURAL LANDS				
Forest				
Forest Slash Treatment (CPS 384)	Woody plant residues managed (chipped, scattered, etc.) on-site will increase soil carbon and soil organic matter. Forest slash that is removed can serve as a renewable fuel and feedstock.	NRCS GHG and Carbon Sequestration Ranking Tool	NA***	NA***
Fuel Reduction	Activity reductions are the result of the removal of excess biomass contributing to unhealthy forest fuel conditions. Reductions are based on changes in on-site biomass over time and probabilistic emissions from future wildfires after fuel reduction treatments have been performed on the site, per the California Climate Investments methodology for forest health projects, assuming treatments under the activity are effective for a period of 20 years.	TerraCount Activity Sheets	1	20
Improved Forest Management Thinning from Below	Activity reductions are the result of committing to 'thin from below' silviculture activities that retain co-dominant and dominant trees at harvest and reduce ladder fuels. Growth rates are managed at a high level while reducing risks of catastrophic carbon loss through wildfires that burn through tree crowns. Practitioners must indicate intent to perform one of the following: 1) Harvest commercially within 5 years of Activity implementation with at least one successive commercial harvest; 2) Harvest commercially within 5 years of Activity implementation with no subsequent plans to for commercial harvest; 3) Only remove ladder fuels within 5 years of Activity implementation.	TerraCount Activity Sheets	1.8	50
Riparian Restoration	Activity reductions are the result of woody plantings on degraded streambanks, which are characterized by lack of vegetation, allowing the movement of heavy runoff through the riparian zone directly into stream channels. Management is based on NRCS COMET-Planner description for riparian restoration.	TerraCount Activity Sheets (practice, leakage rate); Matzek et al. 2020 (sequestration coefficient, practice lifespan)	6.80	45

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Grassland				
Native Grassland Restoration	Activity reductions are the result of restoration of native grasses to a site currently dominated by non-native grasses.	TerraCount Activity Sheets	0.6	50
Oak Woodland Restoration	Activity reductions are the results of the restoration of grasslands to native oak woodland cover in ecologically appropriate areas.	TerraCount Activity Sheets	1.45	50
Riparian Restoration	Restoration of woody riparian vegetation in areas near streams and rivers.	TerraCount Activity Sheets (practice, leakage rate); Matzek et al. 2020 (sequestration coefficient, practice lifespan)	6.80	45
URBAN FOREST				
Development				
Urban Forestry	Activity reductions are the result of committing to the maintenance and increase of CO_2e in trees within the urban land cover. Reductions can occur from sequestration on existing trees and/or newly planted trees. Benefit is attributed to increase in urban canopy cover.	TerraCount Activity Sheets	133.14	50
URBAN FARMS				
Cultivated and Field Crops, Orchards, and Vineyards				
Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA
Cultivated and Field Crops				
Compost Application and Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments (compost) derived from plant materials or treated animal byproducts.	NRCS/ COMET-Planner	2.05	6
Conservation Crop Rotation (CPS 328)	Conservation crop rotation is growing a planned sequence (i.e., the rotation cycle) of various crops on the same piece of land for a variety of conservation purposes.	NRCS/ COMET-Planner	0.22	1

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/ COMET-Planner	0.40	1
Field Border (CPS 386)	A strip of permanent vegetation established at the edge or around the perimeter of a field. This practice is applied around the inside perimeter of fields.	NRCS/ COMET-Planner	1.23	20
Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.	NRCS/ COMET-Planner	8.41	34
Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface.	NRCS/ COMET-Planner	0.32	5
Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/ COMET-Planner	0.22	1
Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/ COMET-Planner	0.12	1
Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/ COMET-Planner	8.41	80
Orchards and Vineyards				
Compost Application and Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments derived from plant materials or treated animal byproducts.	NRCS/ COMET-Planner	1.55	6

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/ COMET-Planner	1.64	1
Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.	NRCS/ COMET-Planner	8.20	34
Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface.	NRCS/ COMET-Planner	0.34	5
Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/ COMET-Planner	0.35	1
Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/ COMET-Planner	0.12	1
Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/ COMET-Planner	8.20	80
WORKING LANDS				
All Agricultural Land Covers				
Riparian Forest Buffer (CPS 391)	Apply riparian forest buffers on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands where channels and streambanks are sufficiently stable. This practice creates an area predominantly covered by trees and/or shrubs located adjacent to and up-gradient from a watercourse or water body.	NRCS/COMET-Planner (practice); Matzek et al. 2020 (sequestration coefficient and practice lifespan)	9.06	45

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Riparian Herbaceous Cover (CPS 390)	This practice creates an area with grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats.	NRCS/ COMET-Planner	0.21	10
Cultivated and Field Crops				
Alley Cropping (CPS 311)	Alley cropping is an agroforestry practice where agricultural or horticultural crops are grown in the alleyways between widely spaced rows of woody plants. By combining annual and perennial crops that yield varied products and profits at different times, a landowner can more effectively use available space, time, and resources. Replace 20% of annual cropland with woody plants-tree-planting/single row.	NRCS/ COMET-Planner	1.74	15
Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA
Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost C/N </= 11, 3 tons per acre.	NRCS/ COMET-Planner	2.07	6
Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost C/N > 11, 6 tons per acre.	NRCS/ COMET-Planner	4.34	6
Compost Application (CPS 808) and Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments derived from plant materials or treated animal byproducts. Reduce fertilizer rate by 15% and apply compost - 3 tons per acre C/N </= 11.	NRCS/ COMET-Planner	1.03	6
Conservation Cover (CPS 327)	Convert Irrigated Cropland to Permanent Unfertilized Grass/Legume Cover-can use native, introduced, pollinator, or monarch supporting species.	NRCS/ COMET-Planner	0.63	Permanent
Conservation Crop Rotation (CPS 328)	Conservation crop rotation is growing a planned sequence (i.e., the rotation cycle) of various crops on the same piece of land for a variety of conservation purposes. Decrease fallow frequency or add perennial crops to rotations.	NRCS/ COMET-Planner	0.22	1
Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/ COMET-Planner	0.4	1
Field Border (CPS 386)	A strip of permanent vegetation established at the edge or around the perimeter of a field. This practice is applied around the inside perimeter of fields.	NRCS/ COMET-Planner	1.23	20

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Filter Strip (CPS 393)	Establishment of an area of herbaceous vegetation situated between cropland, grazing land, or disturbed land (including forestland) and environmentally sensitive areas that removes contaminants from overland flow of water or runoff.	NRCS/ COMET-Planner	1.23	10
Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose. Replace a strip of cropland with one1 row of woody plants.	NRCS/ COMET-Planner	8.41	34
Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface. May use natural materials or wood chips.	NRCS/ COMET-Planner	0.32	5
Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce fertilizer rate by 15%.	NRCS/ COMET-Planner	-0.02	1
Pasture and Hay Planting (CPS 512)	Conversion of annual cropland to irrigated grass/legume forage/biomass crops-non-native species, standard seeding rate, with or without fertilizer.	NRCS/ COMET-Planner	1.22	5
Residue And Tillage Management - No Till (CPS 329)	Switch from Intensive Till to No Till or Strip Till on Irrigated Cropland. The residue and tillage management no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/ COMET-Planner	0.22	1
Residue and Tillage Management - Reduced Till (CPS 345)	Switch from Intensive Till to Reduced Till on Irrigated Cropland. Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/ COMET-Planner	0.12	1
Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations. Replace a Strip of Cropland with 1 Row of Woody Plants-1-row/Tree or Shrub/Wind Protection Fence.	NRCS/ COMET-Planner	8.41	80
Orchard and Vineyard				
Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. May be purchased from a certified compost facility or produced on-farm. (C/N </=11), 3 tons/acre.	NRCS/ COMET-Planner	1.55	6
Compost Application (CPS 808) and Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce Fertilizer Application Rate by 15% . Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost may be purchased from a certified compost facility or produced on-farm. (C/N </=11), 3 tons/acre.	NRCS/ COMET-Planner	1.55	6
Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Add Legume/Legume Mix Cover Crop to Orchard/Vineyard Alleys - Basic or multi-species, Organic or Non-organic Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/ COMET-Planner	1.64	1
Filter Strip (CPS 393)	A strip or area of herbaceous vegetation that removes contaminants from overland flow. Filter strips are established where environmentally sensitive areas need to be protected from sediment, other suspended solids, and dissolved contaminants in runoff. Convert Idle Land near Orchards/Vineyards to Permanent Unfertilized Grass Cover. May include native or introduced species.	NRCS/ COMET-Planner	0.6	10
Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose. plant 1 row of woody plants on border of orchard or vineyard-single row.	NRCS/ COMET-Planner	8.2	34
Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface. May use wood chips or natural materials.	NRCS/ COMET-Planner	0.34	5
Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce fertilizer application rate by 15%.	NRCS/ COMET-Planner	0	1
Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/ COMET-Planner	8.2	80

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned. Conventional till to no till in orchard/vineyard alleys-no-till or strip-till.	NRCS/ COMET-Planner	0.35	1
Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crops and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting. Conventional till to reduced till in orchard/vineyard alleys.	NRCS/ COMET-Planner	0.12	1
Orchard				
Whole Orchard Recycling (CPS 808)	Using carbon-based amendments (orchard materials) to increase soil carbon and improve the physical, chemical, and biological properties of the soil. Whole orchard recycling followed by orchard replant within 3 years.	NRCS/ COMET-Planner	0.04	20
GRAZING LANDS				
Rangelands and Pasture				
Compost Application to Rangelands (CPS 808)	Using carbon-based amendments to increase soil carbon and improve the physical, chemical, and biological properties of the soil. Compost C/N > 11, 6 tons/acre.	NRCS/COMET-Planner (practice); Ryals et al. 2015 (sequestration coefficient)	1.49	20
Rangelands				
Native Oak Restoration/ Silvopasture (CPS 381)	Establishment and/or management of desired trees (native oaks) and forages on the same land unit.	NRCS/ COMET-Planner	1.34	50
Prescribed Grazing (CPS 528) (Rangelands)	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.	NRCS/ COMET-Planner	0.09	10
Range Planting (CPS 550)	The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals. May include native or non-native species, broadcast or drilled planting, high or low forb mixes, and shrub plugs.	NRCS/ COMET-Planner	0.5	10

Climate Smart Practice	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (years)
Riparian Forest Buffer (CPS 391)	Apply riparian forest buffers on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands where channels and streambanks are sufficiently stable. This practice creates an area predominantly covered by trees and/or shrubs located adjacent to and up-gradient from a watercourse or water body.	NRCS/COMET-Planner (practice); Matzek et al. 2020 (sequestration coefficient and practice lifespan)	9.06	45
Tree/Shrub Establishment (CPS 612)	Conversion of grasslands to a Farm Woodlot. Establishing woody plants by planting, by direct seeding, or through natural regeneration.	NRCS/ COMET-Planner	18.89	20
Pasture				
Prescribed Grazing (CPS 528) (Pasture)	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.	NRCS/ COMET-Planner	0.1	10

** Reduction/Sequestration coefficient factors in leakage rates were provided by TerraCount*
*** Expected or maximum practice lifespan in years per the NRCS standard and specifications, TerraCount Activity Sheets, or typical practice*
**** Not currently quantifiable due to lack of site-specific parameters, quantification protocol, etc. - but practice does provide carbon sequestration and other benefits*
Note: Practices where the carbon sequestration benefits are not currently quantifiable are not included in this analysis, though they are nonetheless valuable and are recommended for inclusion in the suite of potential climate smart practices to be considered by the County.

CARBON SEQUESTRATION POTENTIAL ESTIMATE

Implementation Acreages

In order to estimate potential sequestration, implementation acreage of climate smart practices must first be estimated. Determining implementation acreage for climate smart practices is typically done at the project or site level. Generating site-specific implementation acreages and plans for implementing climate smart practices takes many site-specific factors into consideration when planning on a per-farm or per-project basis that are not possible to include in estimations at the county level. For example, when developing carbon farm plans, planners visit the farm and interview the farmer to determine implementation needs, consider available resources and property characteristics. Restoration projects for natural landscapes would be similarly complex planning endeavors, potentially spanning multiple landscapes and land managers. This time and resource-intensive effort cannot be replicated at the county level for the purposes of this analysis. However, estimating the potential implementation acreage of each climate smart practice is key to this analysis and estimates can be further refined with follow up analysis in the future. Several methods and numerous data sets were utilized to assist in development of county-wide estimates as a basis for general target setting and later site-specific analysis and project planning. The methods used for estimating implementation acreage include GIS analysis, sequestration modeling parameters, and implementation coefficients (a proportion of farmland to which a climate smart practice would be applied). For a full description of the methodology for estimating implementation acreages please refer to ***Appendix C Carbon Sequestration Analysis of Climate Smart Practices***.

Table 11 below lists the maximum potential implementation acreages for each climate smart practice, organized by land use category and land cover. These estimations represent a maximum for the potential implementable area in the county for each practice. Likely implementation rates will be much lower than the maximum in most cases. However, it is instructive to consider the maximum possible implementation areas to quantify the maximum potential sequestration and to see which practices have the greatest potential for implementation at large scales versus which practices are likely to be implemented at a smaller scale. The implementation acreages represent a total area that may be suitable for implementation of a given practice within the county and does not include a timeframe for implementation. Any implementation target set as part of later planning or analysis should consider the baseline implementation of practices that is already occurring, what increases in implementation are likely, and the timeframe over which that increase is going to occur.

Carbon Sequestration Potentials

The estimated carbon sequestration and emissions reduction for 100% adoption over the lifespan of each practice is also provided in ***Table 11*** below. Additional adoption level scenarios are available in the full calculation table provided in ***Appendix C Carbon Sequestration Analysis of Climate Smart Practices***. These adoption level scenarios should be useful during stakeholder engagement and later planning processes for setting adoption targets.

Comparison of the relative benefits of practices should take into account that practices with short expected lifespans, the practice may be repeated to accrue continued sequestration benefit. For example, cover cropping may be repeated on an annual basis to accrue the estimated sequestration benefit annually.

Table 11. Estimated Implementation Acreages for All Climate Smart Practices

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 percent Adoption Scenario (MT CO_2e)
NATURAL LANDS				
Forest				
Forest Slash Treatment (CPS 384)	414,591	NA	NA	NA
Fuel Reduction	399,044	20	7,980,870	399,044
Improved Forest Management Thinning from Below	15,548	50	1,399,284	27,986
Riparian Restoration	970	45	296,602	6,591
Grasslands				
Native Grassland Restoration	132,077	50	3,957,357	79,147
Oak Woodland Restoration	11,889	50	861,953	17,239
Riparian Restoration	339	45	103,658	2,304
URBAN FOREST				
Development				
Urban Forestry	5,266	50	35,056,040	701,121
URBAN FARMS				
Cultivated and Field Crops Orchards and Vineyards				
Biochar Application (CPS 336)	59	NA	NA	NA
Cultivated and Field Crops				
Compost Application and Nutrient Management (CPS 590)	7.1	6	87	14
Conservation Crop Rotation (CPS 328)	24.0	1	5	5
Cover Cropping (CPS 340)	5.3	1	2	2
Field Border (CPS 386)	6.7	20	165	8
Hedgerow Planting (CPS 422)	0.4	34	121	4
Mulching (CPS 484)	7.7	5	12	2

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 percent Adoption Scenario (MT CO_2e)
Residue and Tillage Management - No Till (CPS 329)	24.0	1	5	5
Residue and Tillage Management - Reduced Till (CPS 345)	24.0	1	3	3
Windbreak/Shelterbelt Establishment (CPS 380)	1.6	80	1,048	13
Orchard and Vineyard				
Compost Application and Nutrient Management (CPS 590)	51.8	6	482	80
Cover Cropping (CPS 340)	38.8	1	64	64
Hedgerow Planting (CPS 422)	3.1	34	864	25
Mulching (CPS 484)	56.1	5	95	19
Residue and Tillage Management - No Till (CPS 329)	114.4	1	40	40
Residue and Tillage Management - Reduced Till (CPS 345)	114.4	1	14	14
Windbreak/Shelterbelt Establishment (CPS 380)	11.4	80	7,493	94
WORKING LANDS				
All Agricultural Land Covers				
Riparian Forest Buffer (CPS 391)	4,503	45	1,835,873	40,797
Riparian Herbaceous Cover (CPS 390)	4,503	10	9,456	946
Cultivated and Field Crops				
Alley Cropping (CPS 311)	1,210	15	31,581	2,105
Biochar Application (CPS 336)	849	NA	NA	NA
Compost Application (CPS 808) - Compost C/N </= 11, 3 tons per acre	849	6	10,545	1,758
Compost Application (CPS 808) - Compost C/N > 11, 6 tons per acre	849	6	22,109	3,685
Compost Application (CPS 808) and Nutrient Management (CPS 590)	849	6	10,443	1,741
Conservation Cover (CPS 327)	61	1	38	38
Conservation Crop Rotation (CPS 328)	1,210	1	266	266
Cover Cropping (CPS 340)	849	1	340	340

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 percent Adoption Scenario (MT CO_2e)
Field Border (CPS 386)	109	20	2,679	134
Filter Strip (CPS 393)	17	10	215	21
Hedgerow Planting (CPS 422)	23	34	6,539	192
Mulching (CPS 484)	551	5	882	176
Nutrient Management (CPS 590)	849	1	-17	-17
Pasture and Hay Planting (CPS 512)	121	5	738	148
Residue and Tillage Management - No Till (CPS 329)	1,210	1	266	266
Residue And Tillage Management - Reduced Till (CPS 345)	1,210	1	145	145
Windbreak/Shelterbelt Establishment (CPS 380)	33	80	21,899	274
Orchard				
Biochar Application (CPS 336)	2,313	NA	NA	NA
Compost Application (CPS 808)	2,264	6	21,056	3,509
Compost Application (CPS 808) and Nutrient Management (CPS 590)	2,264	6	21,056	3,509
Cover Cropping (CPS 340)	2,313	1	3,793	3,793
Filter Strip (CPS 393)	300	10	1,801	180
Hedgerow Planting (CPS 422)	86	34	23,862	702
Mulching (CPS 484)	2,267	5	3,853	771
Nutrient Management (CPS 590)	2,264	1	0	0
Residue and Tillage Management - No Till (CPS 329)	1,861	1	651	651
Residue and Tillage Management - Reduced Till (CPS 345)	1,861	1	223	223
Whole Orchard Recycling (CPS 808)	3,101	20	2,481	124
Windbreak/Shelterbelt Establishment (CPS 380)	83	80	54,721	684
Vineyard				

Climate Smart Practice	Estimated Implementation Acreage (AC)	Expected Practice Lifespan	Estimated Carbon Sequestration for 100 percent Adoption Over Practice Lifespan (MT CO_2e)	Annual Carbon Sequestration – 100 percent Adoption Scenario (MT CO_2e)
Biochar Application (CPS 336)	58,233	NA	NA	NA
Compost Application (CPS 808)	57,007	6	530,165	88,361
Compost Application (CPS 808) and Nutrient Management (CPS 590)	57,007	6	530,165	88,361
Cover Cropping (CPS 340)	58,233	1	95,502	95,502
Filter Strip (CPS 393)	300	10	1,800	180
Hedgerow Planting (CPS 422)	2,155	34	600,824	17,671
Mulching (CPS 484)	57,069	5	97,018	19,404
Nutrient Management (CPS 590)	57,007	1	0	0
Residue and Tillage Management - No Till (CPS 329)	54,657	1	19,130	19,130
Residue and Tillage Management - Reduced Till (CPS 345)	54,657	1	6,559	6,559
Windbreak/Shelterbelt Establishment (CPS 380)	2,100	80	1,377,849	17,223
GRAZING LANDS				
Rangelands and Pasture				
Compost Application To Rangelands (CPS 808)	21,437	20	638,823	31,941
Rangelands				
Native Oak Restoration/Silvopasture (CPS 381)	51,655	50	3,460,885	69,218
Prescribed Grazing (CPS 528) (Rangelands)	142,371	10	128,134	12,813
Range Planting (CPS 550)	44,420	10	222,099	22,210
Riparian Forest Buffer (CPS 391)	1,400	45	570,780	12,684
Tree/Shrub Establishment (CPS 612)	2,847	20	1,075,755	53,788
Pasture				
Prescribed Grazing (CPS 528) (Pasture)	8,200	10	8,200	820

Note: NA = Not available. These are practices for which there is not a sequestration or emissions reduction coefficient available, yet are understood to increase carbon sequestration or reduce emissions, as well as provide other benefits, and for which we can estimate implementation acreages even though we cannot quantify the sequestration benefit estimate. Practices where the carbon sequestration benefits are not currently quantifiable are still recommended for inclusion in the suite of potential climate smart practices to be considered by the County.

CO-BENEFITS OF CLIMATE SMART PRACTICES

Carbon sequestration and emissions mitigation is a central benefit of climate smart practices; however, the benefits of these practices extend beyond climate change mitigation. Climate smart practices also offer a range of complementary benefits, or "co-benefits," that contribute to broader environmental and socio-economic objectives. The evaluation of these co-benefits helps in prioritizing the target setting and implementation of practices to optimize carbon sequestration with broader goals and values in order to deliver the maximum cumulative advantage.

Co-Benefit Analysis Methodology

A key challenge in climate smart practice evaluation is a lack of a standardized and quantifiable approach to identify and account for the co-benefits associated with implementation of climate smart practices. The following tools utilized in this analysis provide a standardized way to evaluate and compare the potential co-benefits of implementing climate smart practices:

- TerraCount, developed by the Department of Conservation and The Nature Conservancy, provides a qualitative assessment for the impact of each practice as positive (+), negative (-) or potentially positive or negative depending on site-specific factors (+/-), for a range of effects on human wellbeing and natural resources.
- The Conservation Practice Physical Effects (CPPE) tool, developed by the Natural Resources Conservation Service (NRCS), provides a comprehensive evaluation of the physical effects of different conservation practices on natural resources and human-economic environments. Practices are scored from -5 to 5 depending on the level of positive or negative impact on the physical effect being assessed (NRCS, 2022).
- Quantification of complementary benefits at the county or regional level is not possible with a high degree of accuracy given the currently available tools and data constraints. Therefore, the quantification of co-benefits is a summation of the qualitative improvement or worsening expected from application of practices to a range of effects. The improvement or worsening is assigned a positive or negative value and the sum of those values produces a total co-benefit score. The scores are comparable within the same comparison table (the NRCS CPPE-based tables or the TerraCount table) but not across tables because the scoring and effect categories are slightly different. For a full description of the methodology for evaluating co-benefits please refer to ***Appendix D Analysis of Co-Benefits of Climate Smart Practices***.

Co-Benefit Analysis Results

These results are a summary of the co-benefit analysis conducted using TerraCount and NRCS CPPE Tool. For the full scoring of co-benefits please refer to ***Appendix D Analysis of Co-Benefits of Climate Smart Practices***. Utilizing the TerraCount, the practices with the highest co-benefit scores are all conservation-based practices. These following practices show the same number of co-benefits: avoided conversion of grassland to row crops/vineyard, avoided conversion of shrubland to urban, and avoided conversion of wetland to row crops/vineyard. Avoided conversion of forest and shrublands to row crops/vineyard and avoided conversion of forest to urban, were tied for the second highest number of co-benefits.

Table 12 summarizes the effect category and total co-benefit scores for each practice.

Table 12. TerraCount Co-benefits Assessment: Summary of Scores

Climate Smart Practice by Land Use Category	Total Co-Benefit Score	Human Wellbeing Score	Water Quality Score	Biodiversity and Ecosystem Resilience Score
NATURAL LANDS				
Avoided Conversion of Forest to Row Crop/Vineyard	11	2	3	6
Avoided Conversion of Forest to Urban	11	3	2	6
Avoided Conversion of Grassland to Row Crops/Vineyard	12	2	3	7
Avoided Conversion of Shrubland to Row Crop/Vineyard	11	2	3	6
Avoided Conversion of Shrubland to Urban	12	3	2	7
Avoided Conversion of Wetland to Row Crops/Vineyard	12	2	3	7
Oak Woodland Restoration/Silvopasture Establishment	7	2	2	3
Restoration of Native Grasses	7	1	2	4
Riparian Restoration	8	3	1	4
URBAN FOREST				
Increase Urban Forest Canopy Cover	6	2	1	3

Note: Practices where the carbon sequestration benefits are not currently quantifiable are not included in this analysis, though they are nonetheless valuable and are recommended for inclusion in the suite of potential climate smart practices to be considered by the County.

Table 13 provides a summary of the effect category scores and total co-benefits scores by practice and land use category.

Table 13. CPPE Co-benefits Assessment: Summary of Scores

Climate Smart Practice by Land Use Category	Practice Code	Total Benefit Score	Soil Benefit Score	Water Benefit Score	Air Quality Benefit Score	Plant & Crop Benefit Score	Rangeland & Habitat Benefit Score	Energy Efficiency Benefit Score
WORKING LANDS								
Alley Cropping	311	10.8	3.2	1.5	0.8	2.8	1.6	1.0
Conservation Cover	327	9.2	2.5	1.4	1.5	3.0	0.8	0.0
Conservation Crop Rotation	328	6.8	1.7	1.2	0.3	2.0	0.6	1.0
Cover Crop	340	7.7	1.7	0.8	1.0	1.8	0.4	2.0
Field Border	386	4.9	1.5	0.5	0.5	1.8	0.6	0.0
Filter Strip	393	3.1	0.7	1.3	0.3	0.3	0.6	0.0
Hedgerow Planting	422	5.4	0.4	0.2	1.5	2.8	0.6	0.0
Mulching	484	4.7	1.4	0.7	1.0	1.5	0.2	0.0
Nutrient Management	590	6.2	0.4	1.1	2.3	1.8	0.8	0.0
Pasture and Hay Planting	512	7.5	2.4	0.6	0.8	2.0	1.8	0.0
Prescribed Grazing	528	11.1	2.5	1.0	0.8	3.5	2.4	1.0
Range Planting	550	9.7	2.8	1.1	0.8	3.5	1.6	0.0
Residue and Tillage Management, No Till	329	10.1	2.1	0.8	2.5	0.5	0.2	4.0
Residue and Tillage Management, Reduced Till	345	7.5	1.6	0.7	1.5	0.5	0.2	3.0
Riparian Forest Buffer	391	11.6	2.6	2.1	0.5	3.3	2.2	1.0
Riparian Herbaceous Cover	390	9.1	1.7	1.7	0.3	3.3	1.2	1.0
Silvopasture	381	9.1	2.0	1.4	0.5	1.8	2.4	1.0
Soil Carbon Amendment	336	1.8	1.2	0.4	0.0	0.3	0	0.0
Tree/Shrub Establishment	612	12.2	3.2	1.3	0.8	3.8	2.2	1.0
Tree/Shrub Pruning	660	6.1	0.7	0.4	0.5	3.5	1	0.0
Tree/Shrub Site Preparation	490	3.6	NA	0.0	0.0	4.5	0	0.0
Windbreak/Shelterbelt Establishment and Renovation	380	11.0	2.2	1.0	2.5	1.8	2.6	1.0

Climate Smart Practice by Land Use Category	Practice Code	Total Benefit Score	Soil Benefit Score	Water Benefit Score	Air Quality Benefit Score	Plant & Crop Benefit Score	Rangeland & Habitat Benefit Score	Energy Efficiency Benefit Score
NATURAL LANDS								
Forest Slash/Woody Residue Treatment	384	5.7	0.3	0.2	1.5	3.0	0.8	0.0
Restoration and Management of Rare or Declining Habitats	643	6.1	0.5	0.2	0.0	3.0	2.4	0.0
Wetland Creation	658	4.5	0.2	0.7	NA	3.0	0.8	0.0
Wetland Restoration	657	4.4	0.1	0.7	NA	3.0	0.8	0.0
Brush Management	314	7.2	0.8	0.3	0.0	4.8	1.4	0.0
Fuel Break (Unshaded)	383	1.9	NA	NA	0.8	1.3	-0.2	1.0
Prescribed Burning	338	7.7	0.5	0.3	NA	4.5	1.6	1.0

NA = Not available
Note: Practices where the carbon sequestration benefits are not currently quantifiable are not included in this analysis, though they are nonetheless valuable and are recommended for inclusion in the suite of potential climate smart practices to be considered by the County.

ENHANCED BENEFITS FROM STACKING CLIMATE-SMART PRACTICES

It is important to utilize a diversity of practices in order to better mimic natural, healthy systems. When climate smart practices, such as composting, cover cropping, mulching, etc., are utilized in tandem, or stacked, both carbon sequestration capacity and co-benefits are increased. For example, rotating plantings of cover crops between cash crops can add carbon to the soil. When compost is applied to land regularly, the overall capacity to store carbon in soil is increased. Thus, if composting and cover cropping practices are stacked together, the soil carbon storage capacity is increased further from compost application alone, meaning that more carbon from cover crops can be sequestered.

Co-benefits may also have cumulative effects when assessed at a larger scale and when implemented across many individual sites. For example, implementing riparian buffers at a particular site can help reduce runoff and filter pollutants, improving the water quality of a nearby stream. And when riparian buffers are implemented across multiple sites within a watershed, the cumulative effect can significantly improve the overall water quality in the entire watershed, benefiting downstream ecosystems and communities. This underscores the importance of considering cumulative impacts from individual practices applied across many places, forming part of the county-wide approach to landscape-level planning, collaboration, and resource allocation. However, while implementation at the landscape level may increase the cumulative effects of some co-benefits, the impacts of individual projects are not necessarily additive.

MONITORING AS AN ESSENTIAL PART OF ALL PRACTICES

The County of Sonoma will use the results of the analysis conducted for this study in additional stakeholder engagement, consideration of the proposed suite of climate smart practices, and selection of targets for implementation. Whichever climate smart practices are ultimately selected, monitoring and reporting are going to play an essential role in all practice implementation to ensure practice compliance, transparency, and verification of progress towards achievement of selected goals and targets.

Practices undertaken as part of the California Department of Food And Agriculture (CDFA) Healthy Soils Program or other programs supporting and funding climate smart agriculture will have monitoring and reporting requirements as mandated through those programs. Reporting requirements for any activity may include, but are not limited to, the following:

- Assessor's Parcel Numbers of parcels where activity is being implemented
- Map of activity area, including total acreage upon which activity is being implemented
- Date of activity initiation
- Anticipated duration of activity (max. based on duration of analysis above)
- Ongoing reporting throughout activity implementation

The County can leverage partnerships and technology to reduce the reporting burden for land managers implementing climate smart practices, and to monitor implementation progress.

5. LOOKING AHEAD

INNOVATIVE AND EMERGING CLIMATE MITIGATION AREAS TO CONSIDER

Carbon sequestration is an imperative component to climate change mitigation efforts in California. Due to continually emerging science and limited availability of data related to carbon sequestration, broad understanding and best practice in this area continues to evolve and funding mechanisms become more readily available. This section highlights some of the recent developments in these areas, including beaver-assisted restoration, and the application of biochar on agricultural soils. Some of the emergent climate smart practices described here, including biochar application and beaver assisted-restoration, are included for consideration in ***Appendix E Compendium of Measure and Actions for Consideration***. They were included for consideration by the County in the near and mid-term due to stakeholder feedback at in-person workshops or exiting availability of funding and or promising pilots in Sonoma County.

However, most of these emerging climate mitigation practices for natural and working lands are included for County and local agency consideration for future, long-term consideration. This section can be seen as a compliment to ***Appendix E Compendium of Measure and Actions for Consideration***, which proposes actions to implement shovel-ready climate smart practices that the County can pursue in the near and mid-term. While most of the measures and actions proposed reflect practices that are immediately feasible due to scaled available technology, existing expertise and well-established long-term implementation, and existing pools of funding, emergent practices outlined here are more nascent but suggest significant climate impact and are in the pilot or research stage.

To apply these emerging climate mitigation solutions for natural and working lands, the County should continue to monitor pilots and funding for these solutions in order to assess their readiness for application at the local level.

Explanation of emerging science and practices

Application of Biochar on Agricultural Soils

Biochar application as a soil amendment has been suggested numerous times to the CDFA for inclusion under the Healthy Soils Program, and likewise to the NRCS for inclusion under Environmental Quality Incentives Program (EQIP). Biochar is the remaining residue after organic matter (trees, vegetation, food waste, etc.) undergoes heating or baking with limited oxygen in a process known as pyrolysis. Biochar use as a soil amendment in agricultural settings has gained interest for its potential to increase water holding capacity, soil fertility, and carbon sequestration. A lack of readily available research and information on biochar usage prompted the development of the UC Davis Biochar Database, which exists as a resource for collating and characterizing data from various approved peer and non-peer reviewed sources (UC Davis, 2023). Biochar use is limited by its availability, as it is produced in very few locations, and many of the estimated GHG benefits are lost once the product is shipped over a certain distance. Still, with the exploration into new energy production technologies derived from biomass and the potential for biochar to be widely available, it is a management practice to further consider.

Locally, the Sonoma Biochar Initiative is a project of the Sonoma Ecology Center dedicated to promoting biochar education and sustainable production in Sonoma County and throughout California. The Sonoma Ecology Center was awarded a CAL FIRE Urban Forestry grant in February 2021 to produce biochar in the Bay Area using pyrolysis technology from the Advanced Renewable Technology International company in Iowa. This project will work closely with a sustainably managed tree care company, A Plus Tree based in Vallejo, California, to divert 480 tons of wood chips annually from landfills and produce biochar instead. A Plus Tree will use the biochar in their tree care activities and distribute it to local community and school gardens in economically challenged areas of the East Bay Area. Similar projects may help increase the availability of biochar for use locally.

As described in the biochar measures and actions included in ***Appendix E Compendium of Measure and Actions for Consideration***, siting of future biochar facilities should ensure that facility placement considers local environmental health impacts, equity, and environmental justice. Local biochar production must not burden surrounding communities with compounded environmental health stressors, especially communities that may have been previously impacted by the location of waste management and industrial facilities.

Beaver-assisted Restoration

The North American Beaver (Castor canadensis) is native to California and considered a "keystone species." A keystone species is one on which other species in an ecosystem depend, such that if the keystone species were removed, the ecosystem would change drastically. There is evidence that the historic range of beaver included coastal California and the San Francisco Bay Area, including Sonoma County (Lanman et al., 2013). However, trapping, habitat loss, and consideration of beaver as a potential nuisance have all contributed to drastic reductions in beaver populations and habitat range. The California Department of Fish and Wildlife (CDFW) supports an approach to beaver management in California that is responsive to conservation needs and reported human-beaver conflict, such as property damage (depredation), and strives to provide funding to partners in conservation who conduct restoration projects that can benefit the beaver.

Beavers can help to engineer the ecosystems they inhabit, which can help to expand wetland, riparian, and wet meadow habitats and increase wildfire resiliency. Wetland habitats hold and sequester substantial amounts of carbon, and severe wildfires cause large carbon losses, so there is potential for utilization of beavers in protecting and enhancing carbon stocks, while providing other ecosystem benefits. Specific benefits of beavers include improved water quality and control downstream, repair of eroded channels, reconnecting streams to their floodplains, providing perennial flow to streams that would otherwise run dry, and creating beneficial habitats as refugia to drought, wildfire, and climate change. Areas with known beaver activity can also experience an increase in biodiversity (Lundquist et al., 2020; CDFW, 2023).

The CDFW recently created a Beaver Restoration Program (BRP). The program's goals are to improve human-beaver coexistence, gather a comprehensive understanding of when and how beavers can be utilized to restore ecosystem processes and habitats in California, and communicate those findings to facilitate future nature-base solutions that utilize beavers to restore and conserve habitats and watersheds in California (CDFW, 2023). While on-demand beaver translocation project support is not currently in place, the program is undertaking beaver translocation pilot projects, development of a beaver co-existence toolkit, and policy updates to support such projects in the future. All future beaver translocations will require an approved translocation plan that includes an evaluation of potential impacts from the reintroduction of beavers, and strategies for mitigating those risks. There are currently plans to create a beaver translocation request mechanism on the department website later in 2023 for those interested in utilizing beavers for increasing ecosystem resilience, which the County should continue to monitor.

Local Sonoma County researchers Kate Lundquist and Broc Dolman have contributed to the ongoing efforts and advocacy for beaver reintroduction and depredation policy advancement through their work at the Occidental Arts and Ecology Center (OAEC), Water Institute. OAEC is an 80-acre research, demonstration, education, advocacy, and community-organizing center in West Sonoma County that works to develop strategies for regional-scale community resilience and the restoration of biological and cultural diversity. OAEC's Water Institute works to develop innovative science-based solutions to address the legacy of hydrologically destructive land-use practices and policies on California's watersheds. The institute also works to find solutions to address the impacts of climate change on the water cycle. Lundquist and Dolman produced a report that details the potential benefits of beaver to ecosystems, information on beaver stewardship in California, and a suite of potential actions that community members and stakeholders can take to help create a culture of beaver stewardship in the county and state (Lundquist et al., 2020). This local research is also supported by recent primary literature exploring the impacts of trophic rewilding (reintroduction and conservation of large animals into landscapes), which specifically names beaver conservation as a driver of increases in carbon sinks due to their ecosystem engineering impacts. Sea otters are also specifically named in this Study as having the potential to uptake significant CO_2 in the coastal kelp forest ecosystem, if conserved and rewilded (Schmitz et al., 2023).

Blue Carbon & Sea Otter Re-introduction

Though not included in the scope of this Study, which focuses on climate smart practices on terrestrial lands, blue carbon solutions are a promising and emergent climate smart solution for the County to consider. Blue carbon refers to the carbon captured by ocean and coastal ecosystems in Sonoma County, these ecosystems would include kelp forests and eelgrass beds (NOAA, 2023). Current established techniques to increase the carbon holding capacity of these coastal landscapes include ecosystem restoration and conservation on coastlines, including grasses and salt marshes, which can be seen to a costal-parallel to reforestation or other terrestrial ecosystem restoration as a climate smart practice.

RECENT SPOTLIGHT:
Sea otter (Enhydra lutris) reintroduction: In Fall of 2022, the County of Sonoma Board of Supervisors wrote a letter of support for the U.S. Fish and Wildlife Service's 2022 report "Feasibility Assessment: Sea Otter Reintroduction to the Pacific Coast". The assessment found that the re-establishment of sea otters in California coastal landscapes is feasible in their historic range, which includes the Sonoma County coastline. It also established that there could be significant carbon gains through reintroduction of sea otters, as this reduces the impact of sea-urchin barrens on kelp forests through the re-introduction of a native predator. The County plans to support this emergent work moving forward: it is recommended that emergent methodology calculating carbon impacts of sea otter reintroduction, if available, and quantifying stocks of blue carbon, is included in future work conducted by the County.

FUNDING OPPORTUNITIES

There are many funding opportunities available in California for projects that reduce GHG emissions and sequester carbon. These opportunities take the form of grants, loans, or market mechanisms, such as Cap and Trade programs. It should be noted that this is not an exhaustive list of opportunities and additional State and federal funding opportunities are developing; there may be opportunities in addition to the ones listed below, since the publication of this report.

Grants, Loans, and Other Funding Mechanisms

Carbon Sequestration and Climate Resiliency Project Registry: CNRA is required by Senate Bill 27 (Skinner 2021) to create a registry intended to facilitate funding of nature-based and direct-air capture projects that deliver on California's climate goals by connecting listed projects with public and private sources of funds. The registry was scheduled for launch in July of 2023, though appears not to have been launched as of late August 2023, and so will have to be monitored for future updates. There are two pathways for a project to be listed on the registry. Pathway A is for projects that meet CARB's minimum program requirements and that applied for but did not receive State funding. Pathway B is for projects that are approved through the registry's application process. Project requirements include:

- Achieves GHG reduction or carbon removal.
- Includes monitoring and reporting.
- Improves the state's climate resilience.
- Documents 1) the amount of GHG reduction or carbon sequestered, 2) project location 3) resilience benefits, and 4) whether the project provides real, verifiable, quantifiable, additional, and permanent carbon removal benefits.
- Projects shall not create carbon credits or be used by a State or private entity to offset a statutory or regulatory obligation.

For more information on the CNRA, visit the Project website ***here.***

California Strategic Growth Council's Sustainable Agricultural Lands Conservation (SALC) Program: Funds for this program are supported through the State's Cap and Trade auction. The SALC Program supports agricultural land conservation, economic growth, and sustainable development by providing grants for three types of projects: Land Use Planning grants, Agricultural Conservation Acquisition grants, and Capacity and Project Development grants. This report was funded through a SALC planning grant. For more information, visit the Program website ***here***.

CARB Funding Agricultural Replacement Measures for Emission Reductions (FARMER Program): Local air districts receive funds based on a formula and award them to farmers and agricultural businesses for individual projects that reduce GHG emissions. For more information, visit the Program website ***here.***

CDFA Programs: supports many programs implementing agriculture research, innovation, climate smart agriculture, and programs to enhance soil, water, and general biodiversity. Key programs and grants supporting climate-smart practices include:

- **Healthy Soils Program:** Financial incentives for on-farm management practices that sequester carbon, including soil management, establishment of herbaceous and woody cover, and demonstration projects highlighting these practices. On-farm management practices that include, but are not limited to, cover cropping, no-till, reduced-till, mulching, compost application, and conservation plantings.
- **Conservation Agriculture Planning Grant Program:** Funds carbon farm plan development
- **State Water Efficiency and Enhancement Program:** Funds energy efficiency upgrades for farm equipment, irrigation efficiency, etc.
- **Urban Agriculture Grant Program:** Funds urban farm support
- **Water Efficiency Technical Assistance Program:** Funds technical assistance to increase on-farm water and energy use efficiency, as well as nutrient management

For more information on the CDFA programs, visit the Program website ***here.***

Climate Smart Agriculture Technical Assistance: Funds technical assistance in the form of hands-on application assistance to farmers and ranchers participating in the Healthy Soils Program, the State Water Efficiency and Enhancement Program, and the Alternative Manure Management Program. For more information, visit the Program website ***here***.

The California Infrastructure and Economic Development Bank's (IBank) Climate Catalyst Fund: Provides low-interest loans for projects that deliver on priority actions to meet the State's climate goals, and where technologies and infrastructure exist that should be deployed at much greater speed and scale, yet face barriers in the private market. For more information, visit the Program website ***here.***

CAL FIRE's California Forest Improvement Program: Encourages private and public investment in California forest lands and resources, including management planning, tree purchase and planting, timber stand improvement, habitat improvement, and land conservation practices. For more information, visit the Grant website ***here.***

CAL FIRE's Wildfire Prevention Grants: Provides funds for projects in and near fire threatened communities to reduce greenhouse gas emissions and improve public health and safety. Project types include hazardous fuels reduction, wildfire prevention planning, and wildfire prevention education. For more information, visit the Grant website ***here***.

CAL FIRE's Urban and Community Forestry Grants: Provides funds for urban forest management and tree care, as well as outreach and education on public understanding and appreciation of urban trees. For more information, visit the Grant website ***here.***

U.S. Department of Agriculture Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP): Supports farmers, ranchers, and forest landowners integrate conservation into working lands through technical and financial assistance via one-on-one collaboration with producers. Although EQIP is mainly a program providing technical assistance, financial assistance may be available, and in some cases, producers may also qualify for advance payment. For more information, visit the EQIP website ***here***.

Governor's Office of Planning and Research Adaptation Planning Grant Program: Supports local, regional, and tribal planning needs to provide communities with resources to identify climate resilience priorities and develop infrastructure project, with a focus on equity. For more information, visit the Grant website ***here***.

Carbon Offsets

CDFW's Regional Conservation Investment Strategies Program: Uses a science-based approach to identify habitat conservation and enhancement opportunities that can contribute to species adaptation to climate change and resiliency. These strategies can be used as a basis to provide advanced mitigation through the development of credits or to inform other conservation investments. California aims to make climate smart land management cost-effective through the implementation of market mechanisms. For more information, visit the Program website ***here.***

California Cap and Trade Program (managed by CARB): The Cap-and-Trade program is one of the largest market mechanisms in the state. It establishes a declining limit on GHG emissions and creates a powerful economic incentive for investment in efforts that support GHG reductions and carbon neutrality. To meet its compliance obligations under the program, a regulated entity may use offsets from one of the six approved compliance offset protocols. These protocols include forestry, urban forestry, and rice-cultivation nature-based solutions. In addition to compliance offset projects, the Cap-and-Trade program also generates auction proceeds for the State, which has provided significant funding for nature-based solution projects.

Voluntary Carbon Market (CNRA): Allows regulated and non-regulated sources of GHG emissions to offset emissions through the purchase of credits derived from projects that support carbon neutrality. A team lead by the Sacramento San Joaquin Delta Conservancy has received approval by the American Carbon Registry on a voluntary market protocol that allows landowners to convert their land to managed wetlands or rice fields to stop subsidence and related carbon emissions.

Climate Action Reserve, Protocols for Carbon Offsets: The Climate Action Reserve is a carbon offset registry that sets the standards for offset protocols and has a voluntary program for creating carbon offsets. There are 19 protocols available for emissions-reductions activities in the United States, including urban forest, grassland, livestock manure, fertilizer management, rice cultivation, soil enrichment, and composting. For more information, visit the Climate Action Reserve website ***here.***

The Climate Action Reserve Climate Forward Program: The Carbon Project Registry issues credits ex ante, or before emissions-reductions projects are completed. This expands the scope and scale of carbon project types that can achieve carbon offsets by shifting the economics to help cover a portion or all of the project implementation costs. Forecasted mitigation units are issued to carbon mitigation projects that follow Reserve-approved methodologies. Climate Forward credits are issued about 1 year after project commencement for the forecasted climate benefit over the project's lifetime. These credits are well-suited for local projects and community-based measures and may be used to help create economic viability and offset costs associated with activities where costs are a primary barrier to implementation. There are currently methodologies for developing credits for six project types, including reforestation, mature forest management, and dairy digester installation. A methodology for Avoided Wildfire Emissions is currently under development and may provide much needed source of funding for wildfire mitigation projects. For more information, visit the Program website ***here.***

6. CONCLUSION

The Study represents just one of the many steps the County and local agencies are taking to strategically manage lands and reduce GHG emissions. The Study adds new evidence and climate science to the many reasons why Sonoma County's iconic agricultural and natural lands are not only critical for human health and economic wellbeing, but also, as a key asset in combatting climate change.

Specifically, the Study adds a new tool to the County's climate planning toolbox: a carbon stock baseline for Sonoma County's natural and working lands, as well as ranges for increases in carbon sequestration based on specific climate smart practices. Quantifying the carbon stock and carbon sequestration potential associated with Sonoma's natural and working lands allows the County to better understand how to prioritize projects and optimize carbon sequestration throughout the County. It establishes the foundation needed to develop measurable metrics and track the implementation of climate smart practices.

Widespread behavior change by land stewards will be necessary to leverage Sonoma County's natural and working lands in the fight against climate change. This effort will require more coordination, new sources of funding, innovation, incorporation of emergent science, new policy mechanisms, and increased capacity of all parties to scale existing implementation work. Luckily, Sonoma County is home to a plethora of local experts that are highly driven to take this on, both within local government, and within Sonoma County's robust network of land stewards and community activists.

Next steps from the Study include engagement with tribal partners on land-based practices, equity-centered outreach with landowners and communities, and coordination across agencies, as well as County selection of climate smart practices, such as those identified in this Study. Moving forward, the County and local agencies will continue to lead the way in innovating climate smart practices on Sonoma's rich and varied natural and agricultural landscapes. Through leading by example, the County can inspire regional action to implement climate smart practices, all while building healthy lands and communities, optimizing sequestration, and continuing to move forward towards carbon neutrality.

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A.

APPENDICES

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Appendix E
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Sonoma County Carbon Inventory and Sequestration Potential Study

Data Evaluation and Literature Review Summary

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Appendices

1 Introduction

This Data Evaluation and Literature Review Summary is an initial step in developing the **Sonoma County Carbon Inventory and Sequestration Potential Study** (Study). This Study will include a quantitative estimate of the existing above- and belowground carbon stored in the county's land and an analysis of how this has changed in the last decade. It will also include an evaluation of the stability of the carbon stock in the face of climate change, and how carbon sequestration practices and nature-based solutions can optimize carbon stock and provide additional complementary benefits (co-benefits). This Data Evaluation and Literature Review Summary provides an overview of the methodology for the carbon inventories and how the literature and data reviewed will inform the Carbon Inventory and Sequestration Potential Study.

Purpose

The purpose of this Data Evaluation and Literature Review Summary is to give an overview of the methodology for the carbon inventories and explain how the literature and data will be used to inform the countywide **Carbon Inventory and Sequestration Potential Study**. It provides a scientific foundation for the following tasks that underpin the Study:

- **Carbon stock inventories** to quantify aboveground, belowground, soil carbon estimates, and sequestration rates per year. This literature will also be used to QA/QC results of the inventory (Task 4.2)
- **Carbon stock stability risk** evaluations for wildfire and drought, defining scenarios for loss of carbon stock for these two climate hazards using findings from this literature review (Task 4.4.1).
- **Evaluation of best practices for carbon sequestration and nature-based solutions (NBS)** for Sonoma County, including design parameters and evaluation criteria, carbon sequestration benefits, co-benefits, data gaps, and recommendations (Task 4.4.2).

Data and Literature Consolidation

The following sources were selected based on their relevance and scope. Locally specific sources were prioritized in this data evaluation and literature review and where gaps exist, regional, state, and national sources were also reviewed. The list of sources was refined using a questionnaire sent to County staff and stakeholders on April 21, 2023, to confirm that the most relevant information would be included in the Data Evaluation and Literature Review summary and Carbon Inventory and Sequestration Potential Study. This summary provides an overview of 46 sources that describe the most recent, quantitative, peer-reviewed, or third-party vetted (e.g., published by an agency or local government), Sonoma County-relevant science on the three major components of the Carbon Inventory and Sequestration Potential Study: quantitative data for carbon inventories, carbon stock stability, and carbon sequestration practices and nature-based solutions. These sources are summarized by analysis type (categorized by the three bullets above) in Figure 1.

Figure 1: Literature Review Sources at a Glance[1]

Government and Agency Sources: 21

Including:
- **Climate Change Scoping Plan**, CARB
- **[Draft] California 2030 Natural and Working Lands Climate Change Implementation Plan**, CARB
- **Fuels Reduction Guide**, CAL FIRE
- **Greenhouse Gas Emissions of Contemporary Wildfire, Prescribed Fire, and Forest Management Activities**, CARB
- **i-Tree Canopy**, USDA Forest Service
- **LANDFIRE**, USDA, US Forest Service, USDoI
- **Multi-Resolution Land Characteristics Consortium (MRLC): National Land-cover Database (NLCD)**, multiple agencies
- **NCSS Characterization**, the National Soil Information System (NASIS)
- **Sonoma Climate Mobilization Strategy**, RCPA
- **Sonoma County Climate Resilient Lands Strategy**, County of Sonoma
- **Sonoma County Multi-Jurisdictional Hazard Mitigation Plan**, Permit Sonoma
- **Sonoma County Vital Lands Initiative, Ag + Open Space**; County of Sonoma
- **Sonoma Open Space Climate Action through Conservation Project Report**, Sonoma County
- **Sonoma Veg Map**, Sonoma County Agricultural Preservation and Open Space District & Sonoma County Water Agency
- **TerraCount,** California Department of Conservation
- **Wildfire Resilience Planner**, Sonoma County Wildfire Resilience Planner

Peer Reviewed Scientific Sources: 18

Including:
- **2013 Supplement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands,** IPCC
- Auten et al.; Berril et al.; Birdsey et al.; Brunn et al.; Coffield et al.; Deng et al.; Jones et al.; McDowell.; Nader et al.; Namm et al.; North and Hurteau.; Sillett et al..; Stephenson et al.; Tien Shiao, et al.

Nonprofits/ Other Sources: 9

Including:
- **BayArea Greenprint** (Dashboard), BayArea Greenprint
- **Carbon Sequestration**, UC Davis
- **Nature Based Solutions**, The World Bank
- **Roadmap for Wildfire Resilience,** The Nature Conservancy & Aspen Institute
- **The Climate Action through Conservation Project**, The Nature Conservancy and Sonoma County
- **The Rangeland Monitoring Network: Handbook of Field Methods.** Point Blue Conservation Science

Methodology

Sources were first analyzed using the Literature and Data Review Spreadsheet (Appendix A) to crosswalk each source by climate hazard, impact on carbon stock stability, gaps in understanding/ uncertainty, nature-based solution/carbon sequestration potential, and extract any associated quantification methodology. The Data Evaluation and Literature Review Summary includes the following:

- Quantitative Data for Carbon Inventories – a review of data sources and methodology to be used to estimate the 2013 and 2022 Sonoma County carbon stock inventories.
- Carbon Stock Stability Risks – a summary of natural and working lands carbon stock dynamics, and carbon stock loss from wildfire and drought.
- Carbon Sequestration Practices & Nature-Based Solutions – an overview of carbon sequestration practices and nature-based solutions, including co-benefits, available quantification methodologies, and implementation considerations, organized by land cover types.

The sources and information in this summary will be used to inform and evaluate the countywide Carbon Inventory and Sequestration Potential Study.

[1] Note that sources between all three categories may not add up to 36 as there is overlap between sources used across categories.

2 Quantitative Data for Carbon Inventories

Data Sources

The County of Sonoma will prepare countywide carbon stock inventories as part of the Carbon Inventory and Sequestration Potential Study to quantify aboveground, belowground, and soil carbon estimates. This section describes the data reviewed and how it will be used to create Sonoma County land cover maps and the carbon inventories for 2013 and 2022.

The State's Natural and Working Lands Inventory indicates that data used to develop carbon inventories should be accurate, consistent, and available for past and present years and into the future. Jurisdictional carbon inventories require the use of large-scale spatial data sets and carbon or biomass data. Geographic information system (GIS) is used to capture, store, manipulate, analyze, manage, and present spatial, or geographic, data across the county. Baseline reference trends use historic and current datasets, and future data can be used to monitor progress or impacts from implemented management activities.

The Sonoma County Carbon Inventories will use publicly available data sources that are expected to be updated in the future. Table 1 includes the summary of data sources used to complete the Sonoma County carbon inventories and baseline projection. These data sources work together to provide different information needed to estimate carbon stock. Each data source is described below and illustrated in Figure 2.

Table 1: Data Sources used for carbon inventories

Land Type	Data Name and Developing Agencies	Publication Frequency	Latest Publication Year
County-wide Land Cover Classification	Sonoma Veg Map[1] developed by the Sonoma County Agricultural Preservation and Open Space District and the Sonoma County Water Agency. Contributing partners include the California Department of Fish and Wildlife, the United States Geological Survey, the Sonoma County Information Systems Department, the Sonoma County Transportation and Public Works Department, The Nature Conservancy, the City of Petaluma, NASA, and the University of Maryland.	N/A[2]	2013
	LANDFIRE[3] developed, in part, by the United States Department of Agriculture (USDA) Forest Service and the United States Department of the Interior.	2 years	2022
	Multi-Resolution Land Characteristics Consortium (MRLC) – National Land Cover Database (NLCD)[4] developed by a group of federal agencies. Partners include the United States Bureau of Land Management, National Agricultural Statistics Service (NASS), National Oceanic and Atmospheric Administration (NOAA), USDA Forest Service and the United States Geological Survey.	5 years	2019
Urban Tree Density	i-Tree Canopy (v7.1)[5] developed, in part, by the USDA Forest Service.	Annual	2021
Soil	The National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets[6] developed, in part, by the	N/A[7]	2017

	National Soil Survey Center (NSSSC), Kellogg Soil Survey Laboratory (KSSL), USDA, and National Resource Conservation Service (NRCS).

[1] Sonoma Veg Map data - https://sonomavegmap.org/

[2] Currently a snapshot in time for 2013

[3] LANDFIRE data - https://www.landfire.gov/

[4] NLCD data - https://www.mrlc.gov/data?f%5B0%5D=category%3ALand%20Cover

[5] i-Tree Canopy Tool - https://canopy.itreetools.org/

[6] Soil data - https://scholarsphere.psu.edu/resources/ea4b6c45-9eba-4b89-aba6-ff7246880fb1

[7] Currently a snapshot in time for 2017 – future updates not planned.

County-wide Land Cover Classification

Sonoma Veg Map, LANDFIRE, and National Land Cover Database (NLCD)

The Sonoma Veg Map data is derived from 2013 LiDAR data and high-resolution aerial imagery using human interpreters and computer algorithm and verified vegetation characteristics in the field. The result is a fine scale (<1:5,000 map scale) vegetation and habitat map for the county. This dataset provides the foundation of the 2013 Sonoma County land cover analysis that will support the County's 2013 inventory.

Since Sonoma Veg Map is only available for 2013, LANDFIRE spatial land cover data will provide the basis for the Sonoma County land cover analysis for 2022. LANDFIRE data are created for the entire United States at a 30-meter resolution and are updated on a two-year cycle. Due to the scale at which LANDFIRE data are created, the accuracy of the data can be limited at the county scale, which is why the LANDFIRE data for Sonoma County will be supplemented by other data, satellite imagery, and ground-truthing. LANDFIRE was used and customized for the State's Natural and Working Lands Carbon Inventory developed for the California Air Resources Board (CARB) (DOC et al 2018).

The LANDFIRE layers used for the analysis include Existing Vegetation Type, Cover, and Height. Inaccuracies have been identified in other areas, requiring reclassification using the National Land Cover Database (NLCD) and satellite imagery. Given the evidence of these LANDFIRE inaccuracies, Rincon will supplement the 2022 land cover data with NLCD data and conduct desktop ground truthing using satellite imagery to develop a draft land cover map for 2022. This draft 2022 land cover map will be finalized based on County staff and project stakeholders review and site visits to confirm reclassification and provide recommendations to correct classification of average vegetation type, height, and cover.

Urban Tree Density

i-Tree Canopy

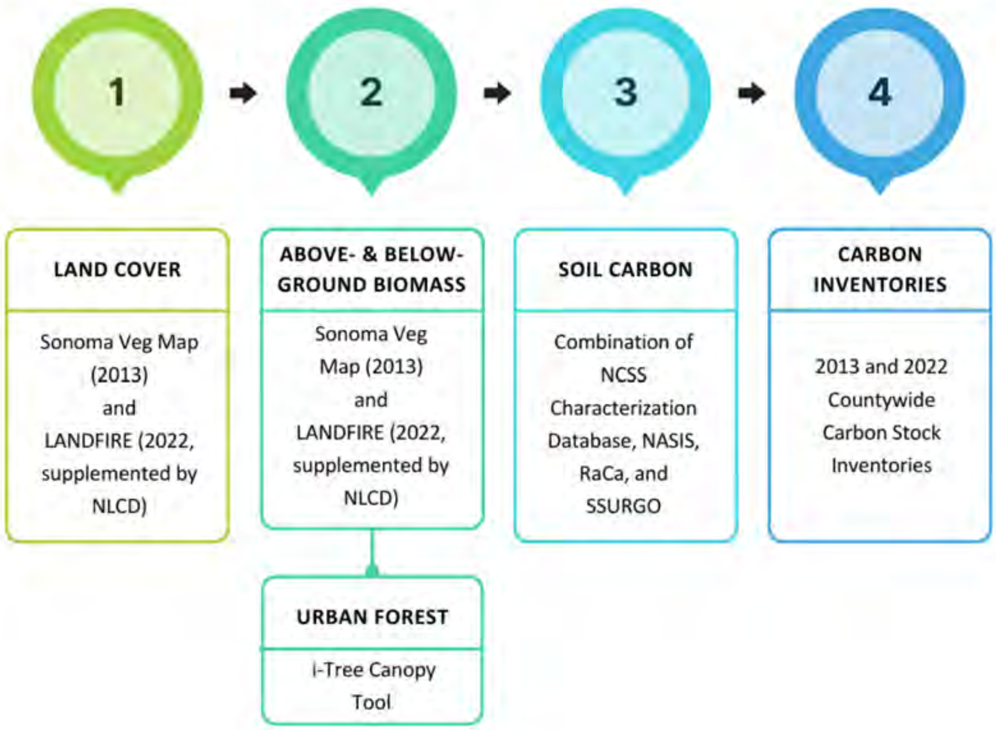
Urban forests are the major contributors to carbon sequestration on urban lands. The urban forest density estimate for Sonoma County was calculated using the i-Tree Canopy tool. This tool is the most robust publicly available tool available to calculate tree canopy in urban areas. I-Tree estimates the percentage of tree cover with a random sampling process and aerial imagery at the individual tree level across urban areas. The percentage of tree cover in urban areas of the county is estimated to be about 19 percent. This percentage will be used to estimate carbon stored in urban areas of the county.

Soil

NCSS, NASIS, RaCA and SSURGO

Soil data used in the analysis includes three national United States soil point datasets: The National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets. These datasets include remote sensing images, predictions of soil properties (e.g., percent organic carbon, total nitrogen, bulk density, PH) and classes, conventional soil polygon maps from the Soil Survey Geographic database (SSURGO), and machine learning. The data were generated at 100-meter spatial resolution.

Figure 2: Land Cover Classification and Carbon Inventories Data



Land Cover Classification Methodology

The land cover classification follows the methodology outlined in Resilient Merced and the State's Natural and Working Lands Inventory (DOC et al 2018, CARB 2017, CARB 2018). The methodology of the land cover classification is presented below.

The land cover classification analysis will be conducted using 30-meter cell resolution across the county for 2013 and 2022.[2] The carbon inventories will be derived from the assignment of all land in the county comprised of discrete land cover classes. The Existing Vegetation Type Sonoma Veg Map, LANDFIRE, and NLCD datasets were used to determine the land cover classes. Since each data source has slightly different vegetation types, the vegetation types are grouped into more general

[2] 2013 land cover is based on Sonoma Veg Map, which is at a finer scale (<1:5,000 map scale) than LANDFIRE data (30-meter cells). For the purposes of this analysis the 2013 data will be resampled to a lower resolution to be consistent with LANDFIRE.

land cover classes. The generalized land cover classes assigned in the 2013 and 2022 inventories will be:

- Barren – areas where vegetation accounts for less than 15 percent of total cover, for example areas of bedrock, sand dunes, or gravel pits.
- Cultivated and Field Crops – areas used for the production of vegetables and field crops generally grown for human consumption, such as squash, tomatoes, leafy greens, rye, and oat.
- Development – areas with constructed materials, including buildings and roads.
- Forest – areas dominated by trees with more than 10 percent tree cover (includes riparian areas that are dominated by trees with more than 10 percent tree cover).
- Grassland/Herbaceous – areas dominated by herbaceous vegetation, with more than 10 percent herb cover, less than 10 percent tree cover and less than 10 percent shrub cover.
- Open Water – areas of water with less than 25 percent cover of vegetation or soil.
- Orchard – areas used for the production of fruits and nuts.
- Pasture and Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture or hay accounts for more than 20 percent of total vegetation.
- Shrub/Scrub – areas dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover (includes riparian areas that are dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover).
- Vineyard – areas planted with grapevines, generally used for producing grapes used in winemaking.
- Wetland – areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the perennial herbaceous vegetation indicate soil or substrate periodically saturated with or covered with water.

Carbon Inventories Methodology

Carbon stock estimates are based on the sum of carbon stored in different carbon pools. Carbon stock analysis includes carbon stored in the following carbon pools:

- Above- and below-ground live biomass
- Above- and below-ground dead standing trees
- Lying dead wood (e.g., branches, logs, etc. lying on the ground surface)
- Litter (e.g., freshly fallen or slightly decomposed leaves, bark, twigs, flowers, fruits, and other vegetable matter).
- Soil

Carbon stored in all above- and below-ground biomass (including live, dead, and litter), is calculated using volumetric estimates of carbon mass (metric tons per hectare) provided by the California Air Resources Board (CARB).[3] These estimates will be provided for every combination of Existing Vegetation Type, Height, and Cover and assigned to each 30 by 30-meter cell in the county. The carbon values are then summed within each land cover class. For example, the above- and below-

[3] Volumetric estimates of carbon mass were provided by Klaus I. Scott, Emission Inventory Analysis Section of the Greenhouse Gas & Toxics Emission Inventory Branch, AQPS Division at CARB on November 17, 2020.

ground carbon stored in annual crops is 0, because they are harvested annually, however, bush fruit and berries, vineyards, and orchards do maintain a carbon stock and therefore have higher carbon value than annual crops. The carbon value for all cultivated crops is then summed to provide the total carbon stored in that land cover class.

Soil Carbon

Soil carbon values are obtained using the combined The National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets.

The soil carbon inventory estimates are determined by using the values provided for soil organic carbon and soil bulk density at a depth of 0-30 centimeters.[4] The soil organic carbon estimates are calculated as described in Quantification Guidance for Use with Forest Carbon Projects report from the CAR FPP Quantification Guidance Version 4.0, as shown in the following equation (the Conversion of Organic Matter to Carbon step was skipped as the input data was provided as Soil Organic Carbon, Climate Action Reserve, 2017):

$$\begin{aligned} \text{Soil } CO_2e \quad = \quad & \text{Organic Matter Value (Steps 2 or 4)} \times \\ & 0.58 \text{ (Conversion of Organic Matter to Carbon)} \times \\ & \text{Bulk Density Value (Steps 3 or 5)} \times \text{Soil Depth Sampled (30 cm)} \times \\ & 40{,}468{,}564.224 \text{ (Conversion of 1 } cm^2 \text{ to 1 acre)} \times \\ & 10^{-6} \text{ (Conversion of 1 gram to 1 metric ton)} \times 3.67 \text{ (Conversion of Carbon to } CO_2\text{)} \end{aligned}$$

Land-based Emissions

GHG inventories for agriculture, forestry, and land use generally include the following emissions categories (TerraCount, 2018):

- Changes in soil carbon stocks
- Nitrous oxide emissions from soils (including fertilizers), biomass burning, and drained organic soils
- Changes in woody biomass carbon stocks
- Methane emissions from wetland, rice cultivation, and biomass burning
- Carbon dioxide emissions from burning, liming, urea fertilization, and drained organic soils
- Carbon monoxide emissions from biomass burning

For the purposes of the Sonoma County Land-based carbon inventories, only some emissions categories will be estimated based land use systems present in the county and availability of data. Changes in soil carbon stocks will not be captured because the soil data available is only available for 2017. Nitrous oxide emissions from soils associated with fertilizer application for agricultural uses are included in the 2020 Sonoma County GHG Inventory, therefore, including them in this analysis would result in double-counting emissions. Changes in woody biomass carbon stocks will be captured between 2013 and 2022 based on changes to vegetation type, height, and cover.

Only methane emissions associated with wetlands will be estimated because rice cultivation is not prominent in the county and data on emissions from biomass burning or drained organic soils in the

[4] A portion of soil organic carbon is located below 30 centimeters, and management practices that lead to enhanced carbon storage in both shallow and deep soils will be included in the carbon sequestration feasibility assessment for this project.

county are not available. An assessment of the impacts of wildfire on carbon stock in the county will be provided in the Carbon Inventory and Sequestration Potential Study. Changes in GHG emissions over time are driven by both changes in land use and in land management practices. Temporal data on land management activities is largely unavailable, therefore changes in GHG emission from 2013 to 2022 will be driven by land use change.

Emissions from wetlands will be estimated for 2013 and 2022. The level of methane emissions varies depending on whether wetlands are inundated continuously or intermittently. Continuously inundated wetlands have estimated methane emissions of 16.02 tonnes per hectare per year (carbon dioxide equivalent), while intermittently inundated wetlands have estimated methane emissions of 3.53 tonnes per hectare per year (carbon dioxide equivalent) (IPCC, 2013). Nitrous oxide (N_2O) emissions from wetlands are very low, absent the input of organic or inorganic nitrogen from runoff (IPCC, 2013). A large proportion of nitrogen is lost from agricultural soils through leaching and runoff. This nitrogen enters the groundwater, riparian areas and wetlands, rivers, and eventually the ocean, where it enhances biogenic production of N_2O. To estimate the amount of applied nitrogen that leaches or runs off the IPCC guidelines are to multiply the total amount of synthetic fertilizer nitrogen and animal excretion applied to soils by the fraction of nitrogen that is lost through runoff, and then multiply this by the emission factor for leaching and runoff to obtain emissions of N_2O (IPCC, 2018).

EQUATION 4.34

DEPOSITED N FROM LEACHING/RUNOFF [23]

$$N_2O_{(L)}\text{-}N = [N_{FERT} + \sum_T(N_{(T)} \bullet Nex_{(T)})] \bullet Frac_{LEACH} \bullet EF_5$$

Where:

$N_2O_{(L)}$-N = emissions of N_2O from runoff and leaching of applied nitrogen

N_{FERT} = total amount of synthetic nitrogen fertilizer applied

$(\Sigma_T(N_{(T)} \bullet Nex_{(T)}))$ = total animal excretion

$Frac_{(LEACH)}$ = fraction of N input that is lost through leaching and runoff, IPCC default value: 30%

EF_5 = the emission factor for leaching and runoff into water bodies, IPCC default value: 0.025 kg N_2O-N/kg N leached & runoff

Information about IPCC emission factors (EF_4, EF_5, and EF_6), leaching and volatilization fractions are sparse and highly variable. Expert judgement indicates that emission factor uncertainties are at least in order of magnitude and volatilization fractions of about +/−50% (IPCC, 2018). Some research has suggested that nitrogen runoff can increase N_2O fluxes from wetlands and other water bodies, but that the size and duration of emissions peaks can vary for the same site based on soil mineral application, climate factors, and other unidentified mechanisms. Therefore, it is good practice to have locally tailored activity data, leaching fractions, and emission factors when possible. Local data on nitrogen application, animal excrement application, and localized runoff fractions for Sonoma County were not found in this data and literature review. Without this data, the emissions resulting from runoff cannot be estimated accurately, and will therefore be excluded from the analysis. The table below shows the variation in methane emissions based on annual period of inundation for wetlands (IPCC, 2013). The calculations below show how to estimate methane emissions from wetlands (IPCC, 2013).

TABLE 5A.2.3
CH_4 EMISSIONS FROM TEMPERATE, REWETTED, CREATED AND NATURAL WETLANDS WITH IWMS, STRATIFIED BY PERIOD OF INUNDATION

Climate region	Annual period of inundation	Mean CH_4 emission ($kg\ CH_4\ ha^{-1}\ yr^{-1}$)	Standard deviation	95% confidence interval[A]	Number of studies
Temperate	Continuous	572	191	±125	5[B]
	Intermittent	126	108	±75	14[C]

Note: All values are derived from studies of temperate wetlands listed in Table 5A.2.1.

A The 95% confidence interval is calculated from the mean, standard deviation, and the critical values of the t distribution, according to the degrees of freedom.

B The studies used to determine this value are listed in Table 5A2.1; Kim et al., 1999; Song et al., 2003 (*Carex* marshes); Ding and Cai, 2007; Altor and Mitsch, 2008; Nahlik and Mitsch, 2010.

C The studies used to determine this value are listed in Table 5A2.1; Pulliam, 1993; Bartlett and Harriss, 1993 (n=3 wetland types); Song et al., 2003 (*Deyeuxia* marshes); Song et al., 2009 (n=2 wetland types); Huang *et al.*, 2010; Badiou *et al.*, 2011; Pennock *et al.*, 2010; Gleason *et al.*, 2009; Morse *et al.*, 2012; Herbst *et al.*, 2011; Yang *et al.*, 2012.

EQUATION 3a.3.1
CO_2 EMISSIONS IN WETLAND REMAINING WETLAND

$$CO_2\ emissions_{WW} = CO_2\ emissions_{WW\ peat} + CO_2\ emissions_{WW\ flood}$$

Where:

$CO_2\ emissions_{WW}$ = CO_2 emissions in wetland remaining wetland, Gg $CO_2\ yr^{-1}$

$CO_2\ emissions_{WW\ peat}$ = CO_2 emissions from organic soils managed for peat extraction (Section 3a.3.1), Gg $CO_2\ yr^{-1}$

$CO_2\ emissions_{WW\ flood}$ = CO_2 emissions from flooded land (Section 3a.3.2), Gg $CO_2\ yr^{-1}$

At present, a default methodology for CH_4 can be provided only for flooded land (Equation 3a.3.3):

EQUATION 3a.3.3
METHANE EMISSIONS FROM WETLANDS REMAINING WETLANDS

$$CH_4\ emissions_{WW} = CH_4\ emissions_{WW\ flood}$$

Where:

$CH_4\ emissions_{WW}$ = CH_4 emissions from wetlands remaining wetlands, Gg $CH_4\ yr^{-1}$

$CH_4\ emissions_{WW\ flood}$ = CH_4 emissions from flooded land (Section 3a.3.3), Gg $CH_4\ yr^{-1}$

3 Carbon Stock Stability Risks

This section summarizes the literature on major climate risks to carbon stock in the county: wildfire and drought. Rincon will use the following qualitative analysis as well as changes in carbon stock between 2013 and 2022 and LANDFIRE disturbance data to assess the impact of wildfire and drought on carbon stock in the county.

The carbon cycle is an essential aspect for Earth to maintain the carbon balance required to sustain life. The carbon cycle primarily consists of flows of carbon between the atmosphere, biosphere, oceans, and Earth's crust, through various natural processes. The largest contributor to climate change is the human-influenced release of carbon that has long been sequestered in Earth's crust as fossil fuels (long-term carbon cycle). Climate smart land management practices and nature-based solutions can help in maintaining the carbon exchanges between the biosphere (i.e., plants, animals, insects) and atmosphere (short-term carbon cycle) that is essential for reducing the impacts of climate change and preserving valuable ecosystem services (CARB 2022). However, even with the implementation of these practices and solutions, climate change is still occurring and can cause large risks to the stability of Sonoma County's carbon stock. Therefore, it is important to understand what these risks are and to prioritize land management practices accordingly. This section provides a summary of the existing literature on carbon stock stability as it relates to Sonoma County's Carbon Sequestration Feasibility Study. A full list of documents reviewed is listed below in Table 2.

Table 2: Sources Used to Analyze Carbon Stock Stability Risks

Source Title	Author	Year
Climate-Driven Limits to Future Carbon Storage in California's Wildland Ecosystems	Coffield, S. R., Hemes, K. S., Koven, C. D., Goulden, M. L., & Randerson, J. T.	2021
2021 Sonoma County Multi-Jurisdictional Hazard Mitigation Plan	Permit Sonoma	2021
USDA NRCS Cropland In-Field Soil Health Assessment Guide	USDA	2021
Sonoma County Hazard Mapping Tool	Sonoma County	2021
Wildfire Resilience Planner	Sonoma County Wildfire Resilience Planner	-
Wildfire Fuel Mapper	Numerous, including University of California Cooperative Extension, Pepperwood, and Tukman Geospatial, CAL FIRE	-
California's 2017 Climate Change Scoping Plan	California Air Resources Board (CARB)	2022
Public Comment Draft: Greenhouse Gas Emissions of Contemporary Wildfire, Prescribed Fire, and Forest Management Activities	CARB	2020
High-Severity Wildfire Effects on Climate Stocks and Emissions in Fuels Treated and Untreated in Forests	North and Hurteau	2011
Sonoma County Climate Resilient Lands Strategy	Sonoma County	2022
LANDFIRE	USDA, USDOI	Updated every two years

Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought?	McDowell et al.	2008
Which trees die during drought? The key role of insect host-tree selection.	Stephenson et al.	2019
Drought effects on soil carbon and nitrogen dynamics in global natural ecosystems	Deng et al.	2021
Experimental drought increased the belowground sink strength towards higher topsoil organic carbon stocks in a temperature mature forest	Brunn et al.	2023

NWL Carbon Stock Dynamics

Natural and working lands (NWL) provide many benefits to California and the Sonoma County community, including capturing and storing carbon in soil and vegetation, acting as a carbon "sink." Depending on how NWLs are managed, conserved, or developed, they can also act as a source of carbon. For example, when shrubland converts to forest, there is an increase in carbon sequestration, but when forests are burned in large wildfires the carbon that was stored in the trees is emitted back into the atmosphere. The California Air Resources Board (CARB) 2022 Scoping Plan provides an overview of trends and changes in statewide carbon stock through periodic NWL inventories. In California, NWL carbon stocks decreased from 2001 to 2011, releasing more carbon than they stored, and increased slightly from 2012 to 2014, storing more carbon than they released. These recent historical trends highlight how NWL can function as both a source and sink for carbon emissions. Climate change can alter the natural cycles of carbon release and storage in NWL, and land management practices can either help mitigate or exacerbate these impacts.

Climate change impacts to NWL throughout the state are already significant, with a marked increase in the more frequent occurrence of unusually large, high-severity wildfires. As climate change accelerates, these large, high-severity wildfires are likely to become more common and impact greater amounts of NWL, diminishing their stored carbon. Climate change is also expected to have other significant effects on NWL, including more frequent and prolonged droughts, floods, extreme heat, and the spread of invasive aquatic and terrestrial species, pests, diseases, and parasites (CARB 2022). The primary climate change driven hazards that will impact Sonoma County's NWL are wildfire, drought, sea level rise, extreme storms and flooding, and extreme heat. Extended drought and wildfire are the two main climate hazards impacting carbon stocks in NWL identified in the 2022 Scoping plan. Given the number of wildfires that have occurred in Sonoma in recent years (2015 Valley Fire, 2017 Tubbs Fire, 2017 Nuns Fire, 2017 Pocket Fire, 2019 Kincade Fire, 2020 Meyers fire, 2020 Walbridge fire, 2020 Hennessey fire, and 2020 Glass fire) and the large carbon stock contained in Sonoma's extensive forests, shrublands, and grasslands, wildfire and drought are the two primary threats to carbon stock stability in the county (Mandeno, 2021).

Wildfire and Carbon Stock Loss

The carbon cycle exchange between the biosphere and atmosphere includes emissions caused by wildfire. When forests and plants are growing, carbon dioxide from the atmosphere is sequestered by vegetation in the biosphere. When biomass is burned, carbon is released back into the atmosphere as GHG emissions and causes a corresponding loss of carbon stock. The health of the majority of California's ecosystems is dependent on wildfire, which can reduce buildup of organic debris that can fuel high-severity wildfires, release nutrients into the soil, and trigger changes in vegetation community composition (CARB. 2020). Historically, indigenous people of California understood the interactions of wildfire and the natural lands, even using controlled burns to promote the health of natural lands. However, in the 20th century fire suppression became the guiding force for U.S. fire policy that was intended to protect communities and resources (Bruno 2020). This has created a disruption in the natural carbon cycle of forests that arises from a lack of naturally occurring fires that serve to regularly clear undergrowth, enhance available nutrients, and promote the long-term health of mature trees. Many fire-excluded forests have too much carbon stored in the form of excessive biomass, crowded trees and underbrush, which can fuel sever-wildfires (North and Hurteau, 2011).

Wildfires contribute significantly to carbon stock losses. Due to the volume of biomass in forested areas shrublands, and grasslands, these are the landscapes with larger potentials for carbon storage losses due to wildfire. Figure 3 below shows the relative wildfire hazard index layer from the Sonoma County Hazard Mapping Tool indicating the distribution of increased fire hazard which largely aligns with forested and shrubland areas as shown in Figure 4 from the Sonoma County Climate Smart Lands Strategy.

Figure 3: Relative Wildfire Hazard Index Map Layer for Sonoma County

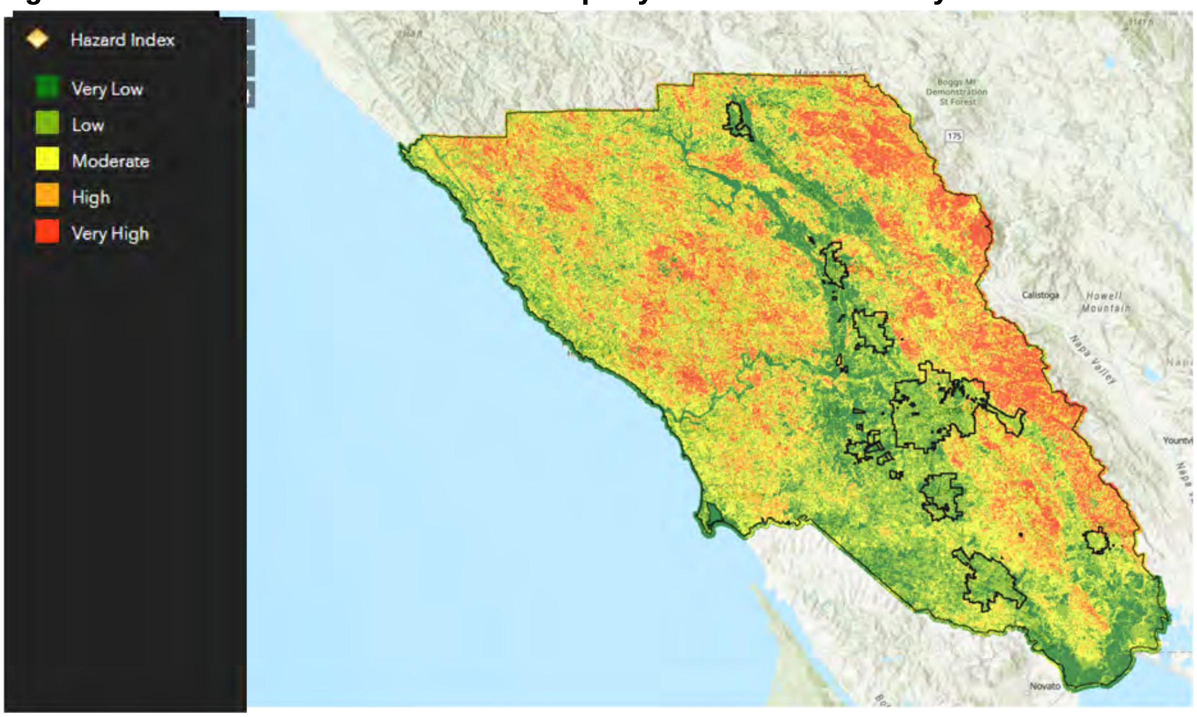
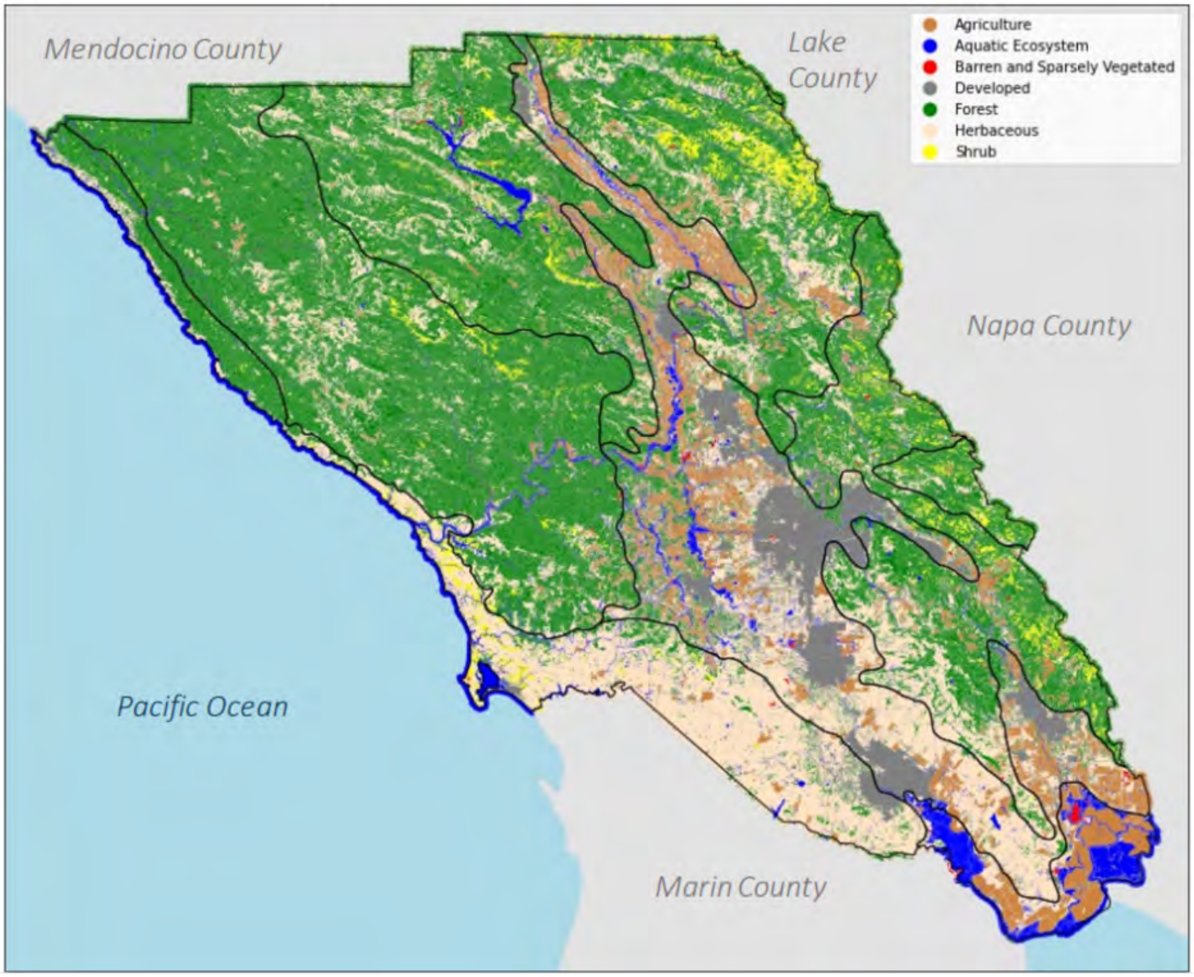


Figure 4: Sonoma County Land Cover from the Climate Smart Land Strategy



It is difficult to accurately estimate GHG emission and carbon stock losses from wildfire, as each wildfire event has different characteristics that influence the degree to which carbon stocks are lost. The intensity of fires can vary greatly, even within areas of the same wildfire event. Some events can result in a nearly complete loss of all living biomass, whereas some may only burn undergrowth and leave longstanding trees relatively unharmed. These variables may greatly impact the degree to which carbon stocks are lost and GHG emissions are generated. Additionally, the decomposing deadfall that remains after live vegetation has been burned by wildfire also serves as an emissions source for decades after the initial emissions impact of fuel burning, which further complicates the full understanding of GHG emissions and carbon stock loss impact (North and Hurteau, 2011). A study on high-severity wildfire and carbon stock in California pine forests found that approximately 28.9 to 30.7 percent of the biomass carbon is converted to emissions in areas of the wildfire that were untreated, which decreased to a range of 12.7 to 12.9 percent for treated forests in the area studied (North and Hurteau, 2011). Untreated forest was forest that had not been thinned, preserving the tree density resulting from fire suppression management practices over time, while treated forests had undergone mechanical thinning to reduce forest tree density.

While the live tree and surface fuel types may be different between this study and Sonoma County forests, the study findings may still be useful for other types of conifer forest regarding increasing forest carbon stock stability. The study found that the incidence of high-severity wildfires can be reduced through thinning and other treatments, but that these treatments reduce the amount of carbon stored in forests corresponding to the reduction in biomass from thinning or prescribed burning. However, these measures can help create wildfire resistance in forests and can still provide a net carbon benefit if treatments prevent greater carbon stock losses from high-severity and large-scale wildfires than is removed during treatment. Forest thinning can improve carbon sink strength during dry months compared to unthinned forests, prevent deforestation and degradation from high-severity fires, and increase the stability of carbon stocks in forested areas (North and Hurteau, 2011).

LANDFIRE disturbance datasets reflect changes on the landscape caused by management activities and natural disturbance. These datasets will be used to estimate Sonoma County's historical carbon stock loss due to wildfire and develop a magnitude of potential carbon stock loss based on wildfire projections due to climate change. Soil Burn Severity data prepared as part of the Watershed Emergency Response Team reports for the Nuns, Tubbs, Kincade, Glass, and Walbridge fires will be used to estimate historical wildfire impact in Sonoma County.

Drought and Carbon Stocks

Climate change driven intense drought stress has caused shifts in plant communities, species ranges, and widespread vegetation mortality. Seasonal patterns of temperature and precipitation strongly influence the distribution of carbon stored in living biomass. Higher temperatures drive decreases in carbon stored in forests and decreases in precipitation greatly increase those losses. It is estimated that 41% to 49% of trees in the central and southern Sierra Nevada died during California's 2012–2015 drought, resulting in an enormous loss of stored carbon, and a shift in forest composition and redistribution of major species. Projections for the 20 highest biomass containing tree types show widespread replacement of conifers by oak species at lower elevations in central and northern California. This change in species dominance and range corresponds to projected decreases in carbon stocks (Coffield et al 2021). Dead vegetation slowly decomposes releasing a large portion of stored carbon back into the atmosphere, as well as providing potential fuel for wildfires. Even when trees are not killed during drought periods, they sequester less carbon.

Water stress affects the ability of trees to photosynthesize by disrupting the balance between water uptake and water loss through transpiration. When soil moisture is limited during drought, trees experience difficulties in absorbing water through their roots. As a result, the stomata, small openings on the leaves responsible for gas exchange, begin to close to prevent excessive water loss. However, this closure also restricts the entry of carbon dioxide (CO2) into the leaves, which is essential for photosynthesis. With limited CO2 availability, the photosynthetic rate decreases, leading to reduced carbon assimilation and subsequent carbon sequestration in trees. Additionally, prolonged water stress can cause damage to the photosynthetic machinery and accelerate leaf senescence, further impairing photosynthesis and carbon sequestration (McDowell et al. 2008).

Drought can also increase tree vulnerability to pests or change attack preferences of pests such as the bark beetle. One study found that in non-drought periods smaller *Pinus* species had significantly higher mortality due to bark beetle attacks, but during a severe drought period the smallest *Pinus* class had significantly lower bark beetle mortality that large *Pinus* sizes; however, the impacts of drought and bark beetle attack varied by tree species (Stephenson 2019). Due to the increased stress on trees, changes in pest behavior, and increased mortality that can be caused by droughts, above ground living carbon stocks are likely to become less stable as climate driven droughts become more frequent, hotter, and more severe.

The literature reviewed is somewhat more mixed with regard to the impact of drought on soil carbon, depending on land cover type, soil depth, and species. Researchers conducted a meta-analysis of 148 recent publications from around the world to investigate how drought affects soil carbon and nitrogen in forests, shrubs, and grasslands (Deng et al., 2021). They found that drought reduced the amount of organic carbon in the soil by decreasing the input of plant litter (dead plant material) by 8.7% and slowing down litter decomposition by 13.0%. This led to a decrease of 3.3% in soil organic carbon content across all three ecosystem types. The study also observed that drought increased the accumulation of dissolved organic carbon and nitrogen in the soil by 59% and 33%, respectively, compared to normal precipitation conditions (Deng et al., 2021). Another study investigated the distribution and stability of SOC stocks in a forest subjected to artificial drought for five consecutive growing seasons, focusing on deciduous beech and coniferous spruce trees. The research found that SOC stocks increased by 1.5 times in the 30 cm depth under spruce during drought, while there was no change under beech (Brunn et al., 2023). In the topsoil (0-5 cm depth), SOC stocks increased by more than 80% with drought under both species, significantly contributing to the total SOC. However, at 5-15 cm depth, SOC stocks decreased under beech but remained unchanged under spruce. The study also revealed changes in the stability of soil organic matter, with decreased stability under beech and increased stability under spruce. These findings indicate that drought-stressed forests can actually enhance belowground carbon sequestration, despite reduced carbon uptake by the ecosystem as a whole (Brunn et al. 2023). This variation in soil carbon storage and stability based on landscape, species, soil depth, and climatic factors means that it is difficult to estimate the impact of drought on soil carbon stocks overall, and how they compare to the simultaneous changes in aboveground carbon stocks during droughts.

Climate Change, Drought, and Wildfire Compound Risk of Carbon Loss

Climate change impacts will compound to cause imbalances in the carbon cycle. For example, when forests have become increasingly affected by drought and invasive species. This can turn forests into a carbon source, with decaying biomass emitting carbon to the atmosphere and becoming fuel for more frequent wildfires. The current state of many California forests is that of a carbon cycle imbalance, where more severe wildfires occur that burn hotter and more intensely resulting in a higher loss of carbon storage in biomass and, in turn, generate a greater release of GHG emissions into the atmosphere from both the initial burning and later decay of burned trees. This loss of biomass also reduces the ability for forests to continue to absorb carbon generated by human activities, furthering the carbon imbalance seen in the atmosphere.

Carbon cycle imbalances between the atmosphere and biosphere create a feedback loop that exacerbates the impacts of wildfire. The increased carbon dioxide levels in the atmosphere contribute to climate change, which impacts forests by increasing tree mortality due to extreme heat events, droughts, and increased levels of invasive species (CARB, 2021). The combination of climate change and the unhealthy forests that result from human policy and land use development are both contributing to high-severity wildfires (high present long-term perturbations to ecosystems, biodiversity, and carbon storage potential) and increased GHG emissions from the direct loss of carbon stock during wildfire events.

4 Carbon Sequestration Practices & Nature-Based Solutions

Recommendations for carbon sequestration practices and nature-based solutions (to be developed as a part of the forthcoming Study) should be based on best available science and grounded by input gathered from local stakeholders.[5] Carbon sequestration practices capture, secure, and store carbon dioxide from the atmosphere, stabilizing carbon in solid and dissolved forms. These above and belowground sources of carbon are also categorized as 'pools' of carbon, see section *Carbon Inventories* for more information (U.C. Davis, 2023). Nature-based solutions (NBS) are specific carbon sequestration practices that are further developed to a policy and management level. NBS are implemented in NWL to maximize carbon storage in above and belowground carbon, and soils as well as offer a host of co-benefits such as the creation of species habitat, improved public health outcomes, climate adaptation, opportunities for recreation, and food and fiber production (World Bank, 2023; CARB, 2019).

For example, the California 2030 Natural and Working Lands Climate Change Implementation Plan (CARB, 2019) identifies key strategies for Sonoma (encompassed by the North coast and Klamath Interior Coast analyzed region) including riparian restoration, agroforestry, land protection, improved forest health and reduced wildfire severity, increased biomass utilization, wetland restoration, grazing land and grassland management, and cropland management.

This literature review summary gives an overview of the best available data regarding carbon sequestration practices and NBS (including the California 2030 Natural and Working Lands Climate Change Implementation Plan, Sonoma Open Space Climate Action Through Conservation Project Report, Sonoma County Vital Lands Initiative, and the Sonoma County Climate Resilient Lands Strategy). This literature review will be used as the basis to develop carbon sequestration practices and NBS in conjunction with an analysis of carbon stock stability. The aim will be to develop NBS solutions tailored to pools of carbon that will be less vulnerable to climate threats of drought and wildfire. The overall process of how the NBS development process is shown in Figure 5, while an overview of all sources assessed as part of this section is shown in Table 3.

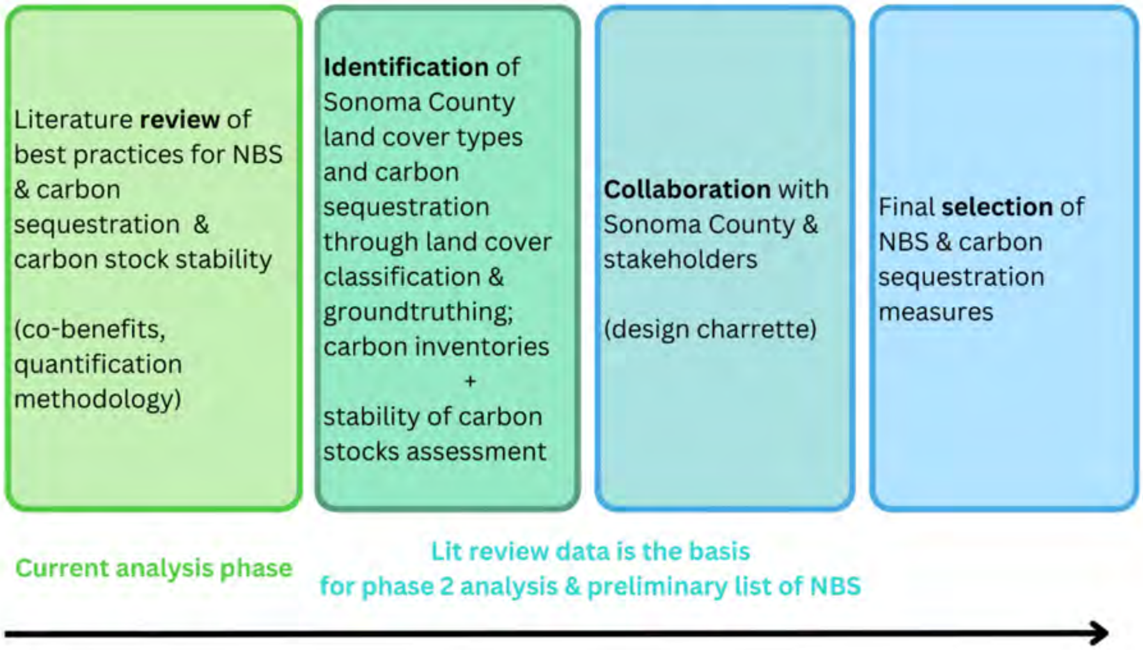
Table 3: Sources Used to Analyze Carbon Sequestration Practices and Nature-Based Solutions

Source Title	Author	Year
Carbon Sequestration	UC Davis	2023
Nature-Based Solutions	The World Bank	2022
[Draft] California 2030 Natural and Working Lands Climate Change Implementation Plan	California Air Resources Board (CARB)	2019
Sonoma Open Space Climate Action through Conservation Project Report	Sonoma County	2021
Sonoma County Vital Lands Initiative	Ag + Open Space; Sonoma County	2023
Sonoma County Climate Resilient Lands Strategy	Sonoma County	2022

[5] Best available science is classified as sources with recent, robust multi-year data, peer reviewed or state/ local government vetted, with quantifiable metrics for success applicable to Sonoma County land cover types.

California's 2017 Climate Change Scoping Plan	California Air Resources Board (CARB)	2022
Conifer retention and hardwood management affect interplay between harvest volume and caron storage over 200 years in douglas-fir/ tanoak: a case study	Berril et al	2020
TerraCount	California Department of Conservation	2022
Aboveground biomass dynamics and growth efficiency of Sequoia sempervirens forests	Sillet et al.	2020
Carbon storage in young growth coast redwood stands	Jones et al.	2012
Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands.	Birdsey et al.	2023
Bay Area Greenprint (Dashboard)	BayArea Greenprint	2023
Sonoma Climate Mobilization Strategy	RCPA	2021
2013 supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands	International Panel on Climate Change (IPCC)	2013
How do tree-and stand-level factors influence belowground biomass and carbon storage in tanoak (Notholithocarpus densiflorus)?	Namm et al.	2020
Damage and mortality assessment of redwood and mixed conifer forest types in Santa Cruz Count following wildfire	Auten et al.	2011
Fuels Reduction Guide	CAL FIRE	2021
The Grazing Handbook	Sotoyome Resource Conservation District	2017
Planned Herbivory in the Management of Wildfire Fuels	Nader et al.	2007
Soil Health: Cropland In-Field Soil Health Assessment Guide	USDA	2021
The Rangeland Monitoring Network: Handbook of Field Methods	Point Blue	2018
Carbon Inventory Estimates for the North Coast Resource Partnership	Nickerson	2023

Figure 5: Role of literature review in NBS development process



The following NBS analysis uses resilient land cover types identified by the Sonoma Climate Resilient Lands Strategy (Sonoma County, 2022). The Climate Resilient Lands Strategy identifies the ecoregions of Sonoma County and provides numerous NBS project concepts that are applicable to various ecoregions and land cover types. Ecoregions are made up of numerous land cover types (such as forest, agriculture, etc.) using distinctive physical and biological features such as geology, landform, soil, vegetation, climate, wildlife, water, and human factors that influence biological community use and composition. The Climate Resilient Land Cover Types Map is shown in Figure 4 in the previous section, and the ecoregions map from the report is included below as Figure 6.

Land cover types used to categorize NBS:

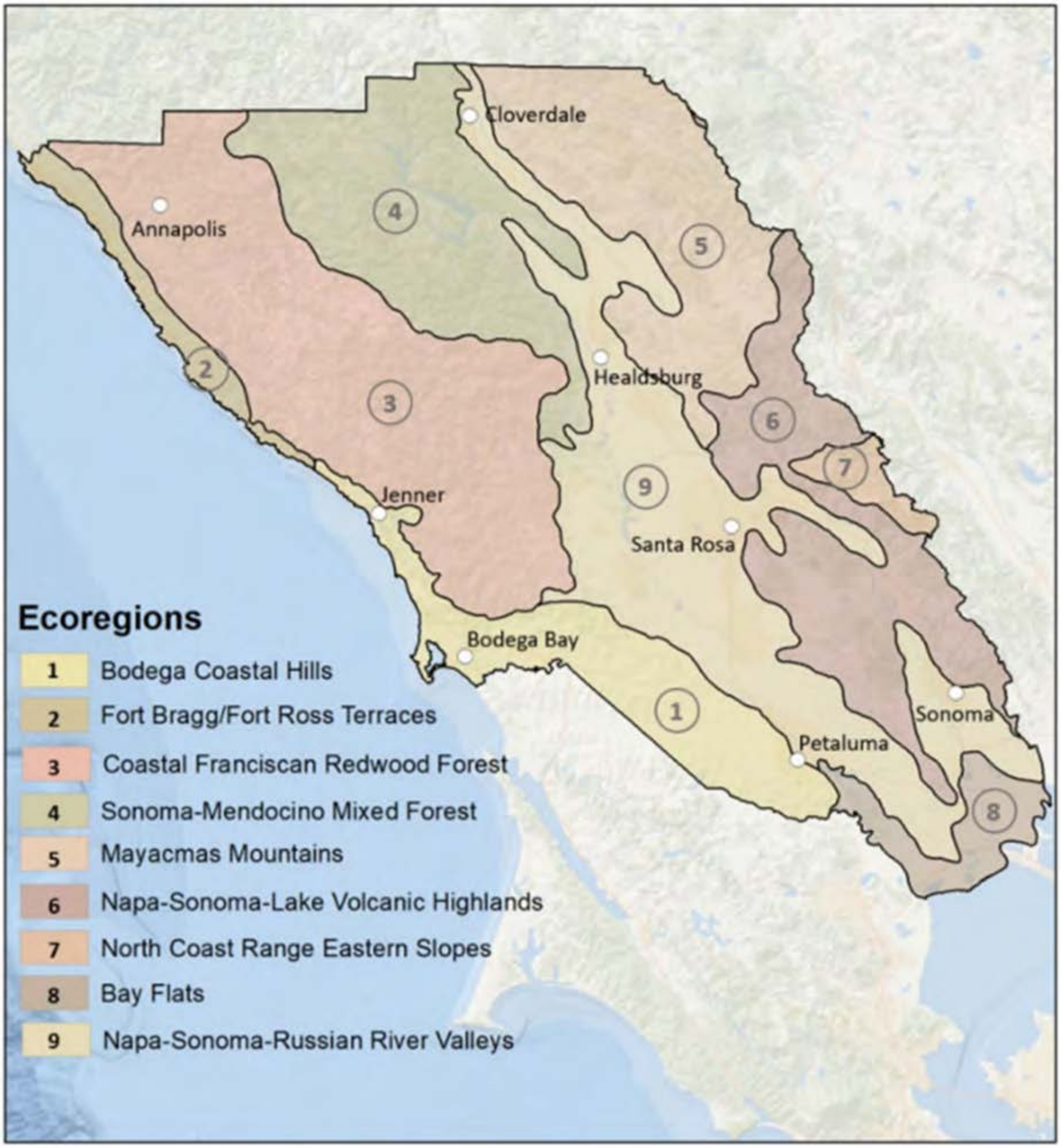
- Forests, Grasslands, Shrubland and Chapparal: land cover types are combined as NBS primarily focuses on avoided land conversion, restoration and forest health and wildfire prevention, such as manual and mechanical thinning, prescribed burn, herbivory, and enhanced biomass utilization.
- Agricultural Lands: Croplands, Vineyards, Grazing Lands
- Urban Green Space

Each NBS is described in the following sections and organized according to the most applicable to various land cover types. Each description gives a high-level summary of the following:

- **Associated co benefits** characterize benefits of NBS beyond carbon sequestration, contributing to equitable distribution of additional benefits, such as improved ecosystem health, biodiversity, community health, climate resilience, increased value for agricultural land, and improved air and water quality, among others.
- **Methods of quantification** identify sources to quantify the carbon impact of NBS, when implemented. Co-benefits with quantifiable methods are also indicated throughout the following section.

- **Screening criteria and implementation considerations** outline implementation specifics for NBS implementation (ex. depth of compost application, selection of landscape restoration tree species), and specific policy considerations for Sonoma County.
- **Data sources** indicate quantitative and qualitative data used to inform NBS carbon quantification, co-benefits, and screening criteria.

Figure 6: Climate Resilient Lands Strategy Ecoregions Map



Carbon Sequestration & Nature-Based Solutions Spanning Multiple Land Cover Types

Land Protection & Avoided Conversion

Land protection and avoided conversion is a key NBS for the State, and for Sonoma County. Land protection and avoided conversion uses policy mechanisms like conservation easements, urban growth boundaries, zoning, and greenbelts to protect high quality natural and working lands from conversion into developed/ urban areas. Land protection has been identified as a crucial NBS for State-level climate planning (CARB, 2019), and by the County of Sonoma in the Sonoma Climate Resilient Lands Strategy and The Vital Lands Initiative. Implementing land protection and avoided conversion is unique as it utilizes policy mechanisms and collaboration, much of which could be under jurisdictional or county control, to protect existing pools of carbon, as opposed to NBS that require significant investments in infrastructure, materials (ex. Mulch, compost), and collaboration across a patchwork landscape of landowner types with competing interests. Accordingly, land protection and avoided conversion can be viewed as one of the most powerful and implementable NBS tools within the County's reach and jurisdiction.

Land protection and avoided conversion reduces the potential future loss of above, belowground, and SOC pools of carbon through the reduced conversion of natural and working lands to urbanized land. Land protection and avoided conversion is a NBS that applies to *all land types* (forests, agricultural lands, aquatic ecosystems, grasslands, shrubland and chapparal, and other land use types) because protecting and maintaining NWL preserves existing carbon pools.

One type of land protection includes avoidance of loss through timber harvest, which is applicable to the 'Forest' land cover type. Feasibility considerations for land protection and avoided conversion primarily involve coordination across public and private landowners, as well as conflicting profit motives (ex. Timber harvest versus carbon project profits; conflicting interests with developers versus conservation), and ability for the County to collaborate with, regulate, or incentivize diverse landowner types. NBS related to land conservation can also be seen as having significant overlap with stabilizing existing carbon stocks (discussed in the previous section), as the main carbon benefit of this NBS type is in avoiding the *loss* of existing carbon sequestration potential. Overlap with other categories analyzed in this literature review primarily involves the analysis of the stability of carbon stocks.

Carbon sequestration of land conservation and restoration NBS are highly variable and involve the long-term and ongoing quantification of existing carbon stocks. Key screening criteria and implementation considerations include the prioritization of land cover types based on carbon sequestration potential, evolving knowledge about landscape carbon sequestration potential, and coordination with stakeholders involved in landscape management across different types of NWL. Understanding evolving research around quantification of carbon stocks will continue to be a challenge in quantifying the carbon impact of land conservation and restoration.

For example, even for land cover types whose carbon sequestration is well studied, with vetted methods used to generate carbon credits (e.g., Forests), there remain significant opportunities to refine research on actual carbon sequestration potential of trees found in the Sonoma County region. For example, Berril et al. found that existing methods to quantify carbon sequestration potential of forests for carbon credits significantly underestimated the actual carbon sequestration potential of young redwoods. As carbon accounting methodology evolves, and carbon stock stability is analyzed, the carbon sequestration potential of land protection and avoided conversion as a nature-based solution will evolve as well. See Table 4 for a summary of land protection and avoided conversion metrics resulting from the literature review.

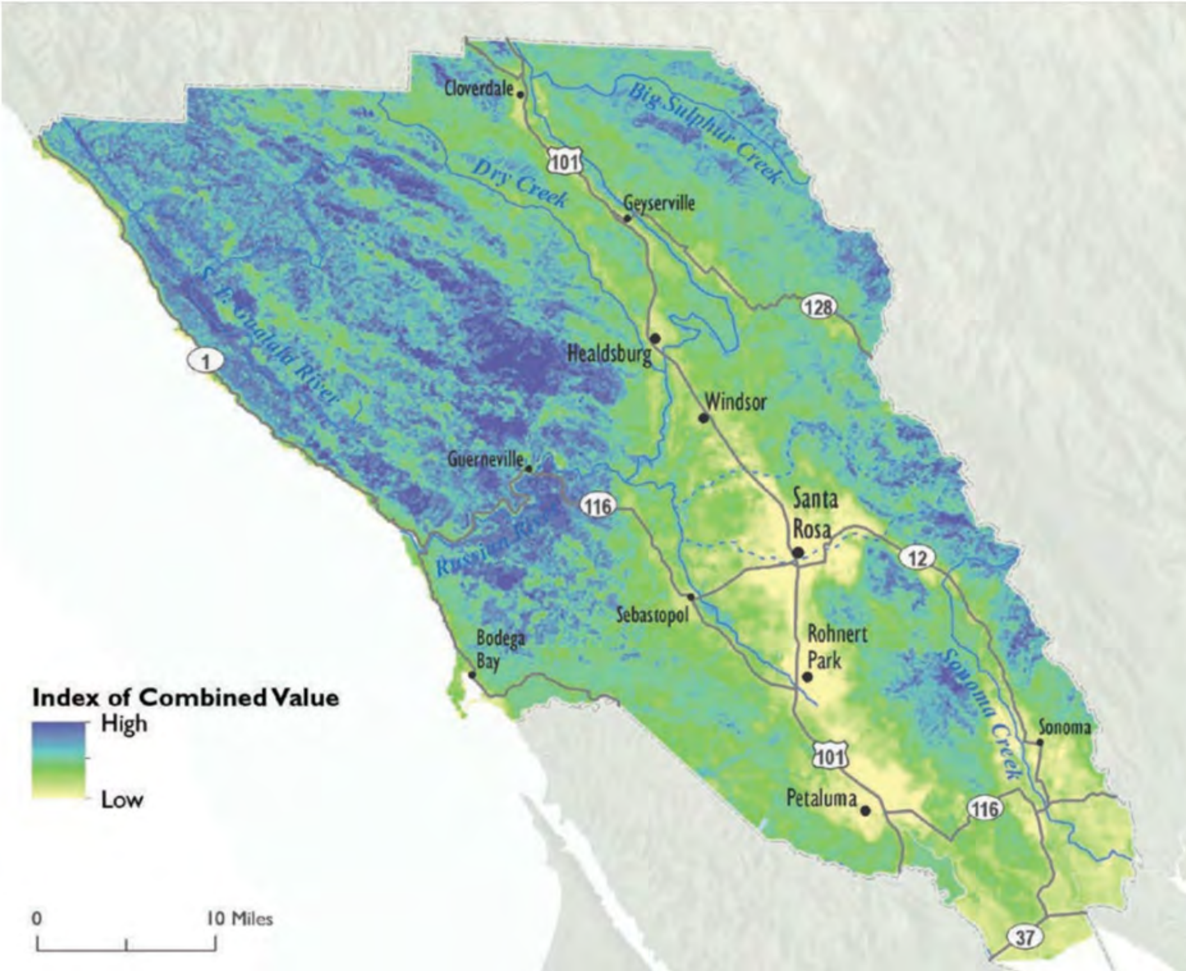
Table 4: Land Protection & Avoided Conversion Literature Review Summary

Co-Benefits[1]	Available Carbon Sequestration Quantification Methodologies	Screening Criteria/ Implementation Considerations	Data Source(s)
Land Protection and Avoided Conservation			
Biodiversity Terrestrial Habitat areas & Connectivity** Recreation** Increased soil water holding capacity** Groundwater recharge** Increased resilience** Food and fiber production** Air and Water Quality** Public health	Multiple methods to calculate carbon stocks; see 'Data Sources(s)' column for different quantification methodologies across multiple land cover types.	▪ Prioritization of land cover type based on carbon sequestration potential ▪ Landowner type (private; Public) ▪ Ability of County to collaborate with multiple stakeholders ▪ Profitability of carbon credit projects vs. logging; profit motive by land type cross walked with landowner type (REF#234)	▪ California Department of Conservation (TerraCount) ▪ CARB, 2019 ▪ Sillet et al, 2020 ▪ Jones et al, 2012 ▪ Berrill et al, 2019 ▪ Sonoma County, 2022 ▪ Ag + Open Space, Sonoma County. Climate Action through Conservation Project. 2023. ▪ Birdsey et. Al, 2023 ▪ BayArea Greenprint, 2023 ▪ RCPA. Sonoma Climate Mobilization. Strategy. 2021

[1] Coding: **= quantifiable co-benefit

The Climate Action Through Conservation Project report included a conservation values assessment that evaluated all land in Sonoma County according to four broad conservation themes including agriculture, terrestrial biodiversity, water, and climate, which were based on a set of 11 conservation metrics. The result of this analysis was a series of maps that can be used to understand the benefits of different conservation and land-use scenarios, plans, and to help inform decision making as new land use and conservation questions emerge. Figure 7 is from the Climate Action Through Conservation Project Report and visually represents the aggregated value of the combine conservation metrics and values assessed across Sonoma County lands. This map complements the findings from the literature review regarding the benefits and screening criteria of conservation and helps to identify potential priority conservation areas.

Figure 7: Combined Conservation Value of Sonoma County Lands



Restoration of Natural Lands

Restoration of natural lands, where ecosystems spanning all land types (urban creeks, marshes, wetlands, riparian habitats, forest, etc.) are replanted or restored to their intact, or near-intact ecosystem state is a key complimentary NBS for landscape conservation. Where landscape conservation stops the loss of existing pools of carbon, restoration creates, and grows, new carbon pools in degraded, under managed, or vacant lands. Some restoration also takes one type of land cover and converts it into a more intact ecosystem with greater biodiversity and carbon sequestration potential (ex. The reforestation of oak savannas) (CARB, 2019; Sonoma Climate Resilient Lands Strategy; Vital Lands Initiative). Co-benefits from restoration of natural lands are numerous, as they essentially restore lost ecosystem services, with all their associated biodiversity, recreation, watershed, and public health benefits.

Restoration of natural lands involves identification of land to restore (entailing collaboration with landowners), implementation of conservation policy or zoning to protect restored lands from future development, selection of plants and materials (ex. Mulch, compost) needed for ecosystem restoration, and significant funding and coordination to provide labor needed for initial restoration, and ongoing monitoring and maintenance. After restored landscapes are established, they will need to be stabilized against climate threats that may disrupt or destroy existing carbon pools, like drought and wildfire. In this implementation sequence, prioritizing species for restoration based on criteria like biodiversity and carbon sequestration potential (as well as potential for carbon stock disruption) is a key factor for maximizing the future carbon sequestration potential of restoration.

Restoration as a NBS also requires an evolving understanding of the carbon sequestration potential of the intact ecosystems that restoration activities seek to replicate. This requires a deep, and evolving understanding of carbon sequestration potential and dynamics across different land cover types, which are still evolving in the scientific literature. Certain land cover types, in particular, wetlands, have highly variable estimates for carbon sequestration potential, potentially emitting climate pollutants instead of sequestering carbon. For example, continuously inundated wetlands have estimated methane emissions of 16.02 metric tons per hectare per year (carbon dioxide equivalent), while intermittently inundated wetlands have estimated methane emissions of 3.35 metric tons per hectare per year (IPCC, 2013). However, a study conducted in Sonoma County's estuarine wetlands found that this landscape type sequesters between 0.6 and 3.5 tons of carbon dioxide equivalent per acre each year (Callaway et al., 2012). Wetland restoration projects have the potential to increase soil carbon (Callaway et al., 2012). See Table 5 for a summary of restoration of natural lands metrics resulting from the literature review.

Table 5: Restoration of Natural Lands Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies (Carbon)	Screening Criteria/ Implementation Considerations	Data Source(s)
Restoration of Natural Lands: Forests, riparian restoration of oaks, wetlands, streams and riparian corridors, tidal marshes			
Biodiversity Terrestrial Habitat areas & Connectivity** Recreation** Increased soil water holding capacity** Groundwater recharge** Increased resilience** Food and fiber production** Air and Water Quality** Public health	Multiple methods to calculate carbon stocks; see 'Data Sources(s)' column for different quantification methodologies across multiple land cover types	▪ Prioritization of land cover type based on carbon sequestration potential ▪ Restoration plant type ▪ Baseline carbon in landscape ▪ Collaboration across multiple landowner types	▪ BayArea Greenprint, 2023 ▪ California Department of Conservation (TerraCount) ▪ CARB, 2019 ▪ Birdsey et al. 2023 ▪ Sillet et al. 2020 ▪ Jones et al, 2012 ▪ Berrill et al. 2019 ▪ Count of Sonoma, 2022 ▪ Ag + Open Space, Sonoma County. Climate Action through Conservation Project. 2023.

[1] Coding: **= quantifiable co-benefit

Forests, Grasslands, Shrubland and Chapparal

CARB's 2022 Scoping Plan calls for an increase in climate smart forest, shrubland, chapparal, and grassland management to at least 2.3 million acres annually (Statewide) to achieve carbon sequestration goals and maintain carbon stock stability (CARB, 2022). The Natural and Working

Lands Climate Smart Strategies developed by the California Natural Resources Agency outline the NBS to support the goals of the scoping plan and calls for the need to double the pace and scale of forests managed or restored to meet 2030 state climate goals (CARB, 2019).

The Sonoma County Resilient Lands Strategy provides a project concept for climate resilient forest conservation and management. Forests cover about half of Sonoma County's land area, and the strategy identifies all ecoregions in Sonoma County as appropriate locations for implementing NBS and climate smart management practices.

These NBS work towards preventing the loss of above and belowground carbon stored in forests, shrubland, chapparal, and grassland through management practices to decrease the risk of wildfire, and maximize carbon storage and sequestration potential of vegetation through increased canopy, stems, root mass, and soil organic carbon (reforestation), and diversion of slash[6] from burn piles to storage in durable wood products and compost. This literature review also delved into the quantification and preservation of carbon stocks related to the unique species mix in Sonoma County forests, comprised of conifers, redwoods, and tanoak trees. Though much of this forest management research is emergent, with a high degree of uncertainty, the County should continue to monitor research on NBS in forest land cover types as forest management and restoration offers the largest opportunity to sequester carbon (Berrill et al; Namm et al; Jones et al; Auten et al; Sillet et al; Birsey et al). Accrual of carbon in these different land cover types is highly variable, based on stability of carbon stock, implementation scale of NBS, and carbon sequestration potential of vegetation types. NBS included in this literature review summary for forests, grasslands, shrubland and chapparal land cover types are:

- Manual and mechanical thinning
- Prescribed Fire
- Prescribed Herbivory
- Increased Biomass Utilization

Avoiding land conversion and restoration/reforestation are also a critical NBS for forests, grasslands, shrubland and chapparal land cover types and are discussed in Section *Carbon Sequestration & Nature Based Solutions Spanning Multiple Land Cover Types* above.

Manual and mechanical thinning

Manual and mechanical thinning works towards optimizing carbon sequestration by increasing forest health and lowering fuel load to reduce the risk of wildfire. The goal of these practices is to change the arrangement of the fuel to disrupt the horizontal and vertical fuel continuity, decreasing the volume of the fuel, reducing the flammability of the fuel load by altering the structure, and decreasing the available surface area across which fire can spread. There are several different ways to conduct manual and mechanical thinning of vegetation to reduce fuel load. Generally, thinning of vegetation involves an overall reduction of woody biomass to break up horizontally and vertically continuous fuels. Site specific conditions and fire threat potential dictate the level of thinning needed and the amount or distance that that thinning occurs in relation to structures, emergency access routes, and other assets. Factors such as topography, sensitive species, and surrounding land uses also play a large role in determining the thinning strategy. For the purposes of this literature summary, these are the types of fuel treatment methods that are considered manual and

[6] Logging debris left after forest after a harvest.

mechanical thinning that either directly or indirectly to prevent wildfire, improve forest health, and optimize the carbon stock:

- Dead/Dying Tree and Plant Removal
- Tree and Shrub Pruning
- Vertical Separation
- Horizontal Separation
- Vegetation Grouping
- Exotic/Invasive Plant Removal
- Chipping and Mastication
- Crushing
- Lopping and Scattering

Manual and mechanical thinning should focus on changing the structure of the material. Manual labor treatments are generally effective for removing litter below trees, cutting, removing lower branches and dead limbs, removing exotic species, and conducting other treatment actions prior to prescribed burning to remove debris. Hand labor treatments are also effective for selectively thinning stands of hazardous trees (i.e., dead trees or flammable species) on sites too steep for mechanical equipment use or at sites with other special considerations. Manual fuel treatments can be exact and are effective on non-uniform surfaces and around built infrastructure. Manual labor treatments minimize soil disturbance and target only specified plants, making them effective for selective pruning and development of desired spacing, but may not be cost-effective over large treatment areas.

Due to annual growth patterns, manual fuel treatments will need to be completed each year after material has dried. Multiple annual treatments may be necessary if targeting a specific species or if late rainfall allows a second flush of growth.

Mechanical treatments such as mowing, mastication, chipping, crushing can be effective for fuel reduction but implementation of each is heavily dependent on the vegetation type. Mowing is generally a good method for fuel reduction treatment of grasslands near roadsides, trail sides, and open fields. However, mechanical treatments are not commonly used for vegetation types like oak woodlands or riparian woodlands, because the numerous tree trunks in oak woodlands make placement and maneuverability of equipment difficult and mechanical treatments carry a high risk of erosion, runoff pollution, and other adverse impacts to riparian area. Even so, mechanical treatments may be suitable to reduce shrub encroachment depending on individual stand structure. Other limitations to the use of mechanical treatment methods include slope, access, seasonality (due to breeding animals and obligate seeding plant species), spread a pathogen fungus (e.g., sudden oak death) and distance to riparian habitat and streams. See Table 6 for a summary of manual and mechanical thinning metrics resulting from the literature review.

Table 6: Manual and Mechanical Thinning Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies	Screening Criteria/ Implementation Considerations	Data Source(s)
Manual and mechanical thinning			
▪ Water quantity and quality	▪ See CARB Source	▪ Water quantity and quality	▪ CARB, 2019

▪ Air quality ▪ Biodiversity and habitat and ecosystem health ▪ Public health and resilience to climate change		▪ Air quality ▪ Biodiversity and habitat and ecosystem health ▪ Food fiber production, ▪ Terrestrial Connectivity ▪ Natural Habitat ▪ County control of land types ▪ Ability to collaborate across land-owners ▪ Informed on emergent research classifying certain tree types	

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Prescribed Fire

Prescribed fire (also known as prescribed burn) is the planned and controlled application of fire to the land, under specified, low-risk weather conditions. As a land management tool, prescribed fire is an efficient and cost-effective way to reduce fuel where physical and social conditions are conducive to its use. Before implementing a prescribed fire, a site must be prepared by reducing and removing the amount of vegetation to a safe burning density. Methods include using bulldozers, hand tools, herbicide treatment pile and burn or a combination of these methods. A key element in site preparation is the construction of a well-established fire line to limit spread (CAL FIRE, 2021). Broadcast burns in the summer or early fall are known to favor native plants. Pile burns may be an alternative treatment to broadcast burns as an initial management technique in conjunction with other treatments. If pile burns are used, actions should consider letting fire creep between piles within treatment areas so that low-intensity fire may promote native plant regeneration.

Prescribed burns can also be conducted in foggy periods using fine grassy fuel to carry the fire (however, results are tied to fuel moisture and composition). Burning often can be made more acceptable if alternated in a cycle with other methods. Sowing native plant seed into the ash or during the following fall season can further advance restoration of native species. Factors such as timing, intensity, and frequency of burns must be carefully considered for each site and will vary depending on objectives and site characteristics. Prescribed burning is not recommended for riparian habitats due to their high moisture content and relative inability to burn efficiently. Appropriate burn prescriptions and good relationships with fire agencies can sometimes alleviate these issues (Sonoma Resource Conservation District, 2017). See Table 7 for a summary of prescribed fire metrics resulting from the literature review.

Table 7: Prescribed Fire Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies	Screening Criteria/ Implementation Considerations	Data Source(s)
Prescribed Fire*			
▪ Public health and resilience to climate change	▪ See CARB source	▪ Extent of burning, extent of understory vegetation, downed dead material, mortality of living trees	▪ CARB, 2019 ▪ CAL FIRE, 2021 ▪ Sotoyome Resource

		▪ County control of land types ▪ Ability to collaborate across landowners	Conservation District, 2017

[1] Coding: **= quantifiable co-benefit, no marking = not quantifiable

*Leads to short term loss of stored carbon during year of implementation, but year of duration depends on practice

Prescribed Herbivory

Prescribed herbivory includes the use of grazing by cows, goats, and sheep. Prescribed grazing is similar to the managed grazing NBS which is discussed in the section *Agricultural Lands: Croplands, Vineyards, and Grazing Lands below.* Prescribed herbivory is best used for green herbaceous plants that produce fine fuels and smaller diameter woody species that produce highly flammable fire fuels (Nader et al. 2007). After the initial treatment, the use of prescribed herbivory in subsequent years can limit regrowth and assist with breaking down ground fuel. Prescribed herbivory can be useful for breakdown of ground fuel through intensive hoof action as well as herbivory of leaves.

When using prescribed herbivory, animal selection should be monitored with respect to seasonal grassland production, stocking rate, and quantity and quality of the vegetation left. For example, Prescribed herbivory using goats is recommended for maintenance treatments after the initial thinning treatments have been conducted. Vegetation and wildlife responses vary greatly based on which prescribed herbivory practices are utilized. There is minimal scientific study on the potential impacts of prescribed herbivory but anecdotally concerns include increased surface erosion, expansion of weed populations, depletion of sensitive herbaceous species, and breakdown of stream banks. Prescribed herbivory at moderate levels has been shown to change wildfire behavior, by slowing its spread, shortening flame length, and reducing fire intensity. Near urbanized areas, prescribed herbivory can prevent or minimize expansion of shrublands which have much greater fuel loading and pose greater fire hazard than grasslands (Sonoma Resource Conservation District, 2017). Prescribed herbivory operations will typically require installation of temporary fencing. Exclusion fencing for sensitive resource protection may also be necessary within a treatment area. See for Table 8 a summary of prescribed herbivory metrics resulting from the literature review.

Table 8: Prescribed Herbivory Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies	Screening Criteria/ Implementation Considerations	Data Source(s)
Herbivory			
▪ Biodiversity ▪ Terrestrial Habitat areas & Connectivity** ▪ Food and fiber production**	▪ CARB, 2019	▪ Commonly best strategy for steep slopes ▪ Continued maintenance ▪ Little information on potential impacts	▪ CARB, 2019 ▪ Nader et al. 2007 ▪ Sotoyome Resource Conservation District, 2017

[1] Coding: **= quantifiable co-benefit, no marking = not quantifiable

*Leads to short term loss of stored carbon during year of implementation, but year of duration depends on practice

Increased Biomass Utilization

Carbon from wood and biomass generated by forest health, restoration, and hazardous fuels treatments can be stored in durable wood products, compost and other soil amendments, and animal feed and bedding, or be used to produce renewable energy. Expanding utilization of biomass from forest management activities can provide an alternative to mastication and pile burning. Diverting thinned material and wood waste from open pile burning to bioenergy, biofuels and long-lived wood products can reduce emissions from pile burning, offset emissions from fossil fuels, and retain carbon sequestered in downed trees. Using California-sourced wood in buildings also sequesters carbon and can reduce the embodied GHG emissions of materials used in buildings.

However, the lack of infrastructure to process biomass is a significant impediment to this NBS. Therefore, the improvement of biomass markets is needed to facilitate treatment efforts, which would also provide energy and other resources and create jobs. See Table 9 for a summary of increased biomass utilization metrics resulting from the literature review.

Table 9: Increased Biomass Utilization Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies	Screening Criteria/ Implementation Considerations	Data Source(s)
Increased Biomass Utilization			
▪ Food and Fiber	▪ Multiple (see Data Sources)	▪ End destination of slash ▪ Collaboration with timber companies, landowners, end market of products	▪ CARB, 2019

Note: This increased biomass utilization leads to short term loss of stored carbon during year of implementation, but year of duration depends on practice

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Agricultural Lands: Croplands, Vineyards, and Grazing Lands

Nature-based solutions applying to Sonoma County's agricultural land includes reduced nitrogen fertilizer inputs (Table 10), soil amendments and compost application (Table 11), cropland management (Table 12) , agroforestry (Table 13), and managed grazing (Table 14) . Throughout the literature, these practices are also referred to as 'carbon farming' or 'regenerative farming.' Mechanisms for carbon gain through NBS preserve and maximize SOC through increased organic matter and increase above and belowground pools of carbon through the establishment of trees, shrubs, and other herbaceous cover on working lands. Carbon emissions are also avoided through reduced inputs of nitrogen-based fertilizer and disturbance of soil carbon through crop management techniques like tilling and managed grazing (RCPA; Sonoma County; CARB; Point Blue, USDA, TerraCount).

Nature-based solutions for Sonoma County's critical agricultural sector were called out specifically in CARB's California 2030 Natural and Working Lands Climate Change Implementation Plan: specifically, regional restoration agroforestry, grazing land and grassland management, and cropland management. Accrual of carbon in working lands is highly variable, based on stability of carbon stock, implementation scale of NBS, and carbon sequestration potential of working land type (RCPA; Sonoma County; CARB; Point Blue, USDA, TerraCount). Significant uncertainties exist in the research for degree of carbon sequestration by land cover type, as agriculture practices feature so many multifaceted impacts on the environment. As there are so many proposed NBS under the

'Agricultural Lands' category, analysis of co-benefits, quantification methodology, design parameter, and data sources have been split out by NBS type and sub-type through the following tables for this section.

The Sonoma County Climate Resilient Lands Strategy has project concepts centered on increasing the resilience of agricultural lands through management, conservation, carbon sequestration, and policy and program improvement. The ecoregions with the greatest percentage of agricultural lands are the Bodega Coastal Hills, Napa-Sonoma-Lake Volcanic Highlands, Bay Flats, and Napa-Sonoma-Russian River Valleys.

Nitrogen Fertilizer Management

Nitrogen fertilizer management refers to the careful and strategic application of nitrogen-based fertilizers in agricultural practices. Proper nitrogen fertilizer management involves assessing the specific nutrient requirements of crops and applying fertilizers in the right amounts, at the right time, and in the right places. This approach helps to maximize nitrogen uptake by plants, minimizing losses to the environment such as nitrate leaching, volatilization of ammonia, and nitrous oxide emissions. By reducing nitrogen losses, farmers can minimize water pollution, protect biodiversity, and mitigate greenhouse gas emissions, contributing to climate change mitigation efforts. Additionally, nitrogen fertilizer management can enhance soil health and fertility. It can improve soil structure, water-holding capacity, and nutrient availability (NRCS CPS-590). See Table 10 for a summary of nitrogen fertilizer management metrics resulting from the literature review.

Table 10: Nitrogen Fertilizer Management Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Nitrogen Fertilizer Management			
▪ Increased soil water holding capacity. ▪ Reduced fertilizer and pesticides use. ▪ Increased agricultural productivity. ▪ Agriculture quality** ▪ Human wellbeing** ▪ Biodiversity ** ▪ Soil health and agricultural productivity ▪ Reduced nitrogen runoff ▪ Increased water quality	▪ TerraCount; CARB	▪ Multi-stakeholder collaboration ▪ Resources and availability for behavior change ▪ Education and outreach; inclusion of small farmers. ▪ Baseline use of nitrogen fertilizer and associated emissions	▪ CARB, 2019 ▪ California Department of Conservation (TerraCount) ▪ RCPA, 2021

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Soil Amendments: Mulching, Cover Cropping, Compost Application

Soil amendments, such as mulching, cover cropping, and compost application, contribute to increasing agricultural resilience by improving soil health, enhancing nutrient availability, and promoting ecosystem resilience.

Mulching involves covering the soil surface with materials like straw or wood chips. It helps to conserve soil moisture by reducing evaporation, suppresses weed growth, and moderates soil temperature. Mulching also adds organic matter to the soil as it decomposes, improving soil structure, water infiltration, and nutrient retention. This promotes healthier root development, increases soil biodiversity, and reduces erosion, ultimately contributing to improved plant growth and productivity.

Cover cropping involves growing specific plant species during periods when the main crop is not present. These cover crops provide numerous benefits, including reducing soil erosion, enhancing nutrient cycling, and suppressing weeds. Cover crops capture and store carbon from the atmosphere, helping to mitigate climate change. They also improve soil fertility by fixing nitrogen from the air or scavenging nutrients from deeper soil layers, making them available for subsequent crops. Furthermore, cover crops promote soil microbial activity and enhance soil organic matter content, which enhances soil structure, moisture retention, and overall soil health.

Compost application involves the addition of decomposed organic matter to the soil. Compost provides a range of essential nutrients and improves soil structure, water holding capacity, and nutrient availability. It enhances microbial activity and diversity, supporting beneficial soil organisms that aid in nutrient cycling. Compost application also helps sequester carbon in the soil, reducing greenhouse gas emissions. By enriching the soil with organic matter, compost application contributes to long-term soil fertility, resilience against drought and nutrient imbalances, and sustainable agricultural practices. See Table 11 for a summary of soil amendment metrics resulting from the literature review.

Table 11: Soil Amendment Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Soil Amendment			
▪ Increased soil water holding capacity ▪ Reduced fertilizer and pesticides use ▪ Increased agricultural productivity ▪ Agriculture quality** ▪ Human wellbeing** ▪ Biodiversity ** ▪ Soil health and agricultural productivity	▪ TerraCount, CARB	▪ Baseline analysis of soil (existing resource concerns) ▪ C:N ratio of compost ▪ Thickness of compost application ▪ Land type of application ▪ Frequency and seasonality of application (compost) and planting ▪ Type of soil amendment	▪ CARB, 2019 ▪ California Department of Conservation (TerraCount) ▪ USDA, 2021 ▪ RCPA, 2021 ▪

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Cropland management: no till, reduced till, crop diversity

No-till and reduced tillage refer to practices where the soil is left undisturbed or minimally disturbed during the planting and cultivation of crops. By avoiding or reducing the use of intensive plowing or tilling, these practices help to protect the soil structure, preserve soil moisture, and reduce soil erosion. The undisturbed soil promotes the accumulation of organic matter, enhances soil fertility, and improves water infiltration and retention. No-till and reduced tillage also contribute to carbon sequestration in the soil, helping to mitigate climate change. These practices promote soil health, increase water-use efficiency, and reduce energy inputs, leading to sustainable and resilient cropland ecosystems.

Crop diversity, or the practice of growing a variety of crops on a particular piece of land, is another important aspect of cropland management. Monoculture, or the continuous planting of the same crop, can lead to nutrient imbalances, increased pest and disease pressure, and soil degradation. In contrast, crop diversity promotes natural pest and disease suppression, improves soil fertility through the complementary nutrient requirements of different crops, and enhances overall ecosystem resilience. A wider variety of crops can also provide forage for a larger number of pollinators. Additionally, crop diversity contributes to improved farm profitability by reducing market risks associated with a single crop and providing a more stable and diverse income source. See Table 12 for a summary of cropland management metrics resulting from the literature review.

Table 12: Cropland management Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Cropland Management			
▪ Reduction of water usage ▪ Increased biodiversity ▪ Improved water quality ▪ Enhanced conditions for pollinators ▪ Safer environment for farmworkers ▪ Increased wildlife movement	▪ CARB; TerraCount	▪ Type of crops planted. ▪ Funding, knowledge access for behavior change ▪ Underlying carbon storage potential of land pre-management practice ▪ Stability of carbon pools (agriculture) due to climate change pressures like drought and wildfire	▪ Sonoma County, 2022 ▪ California Department of Conservation, TerraCount, 2023 ▪ CARB, 2019 ▪ Point Blue, 2018. ▪ Nickerson, 2017

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Agroforestry: woody cover, silvopasture, riparian forest buffer, herbaceous cover, hedgerows

Note that this NBS solution combines subcategories under ‘Agroforestry,’ as the primary driver of gains in carbon stock is the establishment of woody biomass in working lands, increasing above and belowground carbon stock, while preventing the loss of SOC.

Woody cover refers to the strategic planting of trees or shrubs within agricultural areas. These woody plants provide numerous benefits, including windbreaks, shade, erosion control, and habitat for wildlife. They also contribute to carbon sequestration and help mitigate climate change by capturing and storing atmospheric carbon dioxide. **Silvopasture** integrates trees, forage crops, and livestock in a mutually beneficial system. Trees provide shade for livestock, improving their welfare and reducing heat stress. The forage crops grown beneath the trees provide feed for livestock, and their root systems contribute to soil health and prevent erosion. Silvopasture systems enhance biodiversity, sequester carbon, and can increase overall productivity and profitability. **Riparian forest buffers** are strips of trees and shrubs planted along the banks of rivers, streams, or other water bodies. These buffers help filter and trap sediment, nutrients, and pollutants from agricultural runoff, improving water quality. They also stabilize stream banks, reduce erosion, provide habitat for aquatic organisms and wildlife, and enhance biodiversity. **Herbaceous cover** refers to the use of diverse herbaceous plants, such as cover crops or native grasses, in agricultural fields. These plants help prevent soil erosion, suppress weed growth, improve soil fertility, and enhance water infiltration. Herbaceous cover also promotes beneficial insect populations, reduces the need for chemical inputs, and provides additional forage or fodder resources. **Hedgerows** are linear strips of trees, shrubs, and grasses planted along field edges or as field dividers. Hedgerows serve as windbreaks, reducing wind erosion and protecting crops from wind damage. They provide habitats for beneficial insects and pollinators, enhance biodiversity, and improve landscape aesthetics.

Overall, agroforestry practices contribute to sustainable land management by providing multiple ecological benefits. They improve soil health, conserve water, enhance biodiversity, sequester carbon, reduce erosion, and promote resilience in agricultural systems. See Table 13 for a summary of agroforestry metrics resulting from the literature review.

Table 13: Agroforestry Literature Review Summary

Co-Benefits*	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Agroforestry			
▪ Water quantity and quality ▪ Biodiversity and habitat and ecosystem health ▪ Food and fiber production ▪ Public health and resilience to climate change ▪ Nitrate runoff** ▪ Nitrate leaching**	▪ Nickerson; CARB	▪ Selection of plant type for tree/ shrub ▪ Proximity to riparian area ▪ Baseline carbon sequestration potential pre-management practice ▪ Incentives for behavior change and funding ▪ Incorporation of small farmers	▪ Nickerson, 2017 ▪ CARB, 2019

*Potentially quantifiable via TerraCount

Managed Grazing

Managed grazing is similar to the prescribed herbivory NBS discussed in section *Forests, Grasslands, Shrubland and Chapparal.* Prescribed herbivory utilizes cattle, goats, and sheep to graze on a variety of habitat types, where this managed grazing NBS focuses on the management of livestock grazing (i.e., cattle) in large pastures. Managed grazing, also known as rotational or deferred grazing, involves moving cattle through a series of pastures, with the goal of maintaining/improving vegetation health, reducing fuel load, and improving forage yield and improving animal productivity. Vegetation management through managed grazing can improve forage root structure and depth, which directly increases vegetation health and also causes enhanced soil structure, enhanced soil cover, greater water infiltration, less susceptibility to drought, reduces runoff, limits soil erosion, and promotes improved water quality. These all lead to greater carbon sequestration directly with improved ecosystem health and indirectly through decreased wildfire risk. Constraints or considerations when implementing managed grazing are that livestock densities need to be properly managed to prevent soil compaction, degradation to vegetation health, and water quality issues. Rotational stocking requires more labor, capital, and management than a continuous grazing system. Managed grazing can also require additional infrastructure such as fencing, watering systems, and laneways. When managed grazing is not done properly it can impair animal health and productivity, which can reduce profitability. There are many strategies and resources to mitigate against these challenges such as consulting with the University of California Cooperative Extension, Resources Conservation Districts, and other farmers currently practicing managed grazing. See Table 14 for a summary of managed grazing metrics resulting from the literature review.

Table 14: Managed Grazing Literature Review Summary

Co-Benefits[1]	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Managed Grazing			
▪ Riparian health ▪ Water quantity and quality (CARB) ▪ Biodiversity and habitat and ecosystem health ▪ Food and fiber production ▪ Public health and resilience to climate change	▪ Sonoma County, CARB	▪ Timing, duration intensity of planned grazing ▪ Acres of land using practices ▪ Soil, slope, water conditions ▪ Funding availability to support behavior shifts ▪ Inclusion of small farmers	▪ CARB, 2019 ▪ Sonoma County, 2022 ▪ Point Blue, 2018 ▪ California Department of Conservation, TerraCount, 2023 ▪ Sotoyome Resource Conservation District, 2017

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it

Urban Green Space

Urban green space (managed spaces like parks, parklets, neighborhoods, etc.) NBS increases the above and belowground pools of carbon in the County's developed lands, as detailed in Table 15. Though this NBS has limited acreage in comparison to carbon sequestration actions on the County's natural and working lands, urban green space NBS offers a host of important co-benefits, including increased community resilience to extreme heat, increased air filtration and water system resilience, and community stewardship of highly visible landscapes in populated areas. Carbon is sequestered through the expansion and restoration of sources of above and belowground carbon, like street trees and urban riparian and wetland landscapes. Feasibility considerations include the labor and coordination needed to facilitate stewardship of these urban lands, ongoing monitoring and restoration, and the need for multi-party collaboration (Sonoma County, Nickerson, California Department of Conservation, CARB).

Expansion of Urban Canopy

Table 15: Expansion of Urban Canopy Literature Review Summary

Co-Benefits1	Available Quantification Methodologies (Carbon)	Screening criteria/ Implementation Considerations	Data Source(s)
Expansion of Urban Canopy			
▪ Water quality and quantity ▪ Air quality ▪ Biodiversity and habitat and ecosystem health ▪ Food and fiber production ▪ Public health and resilience to climate change ▪ Scenic Value * ▪ Natural Resilience ▪ Recreation potential	▪ TerraCount; CARB (LANDFIRE Urban Forest Suite)	▪ Tree/ species selection ▪ Acreage implementation ▪ Maximization of stream x recreation area overlap	▪ Sonoma County, 2022 ▪ Nickerson, 2017 ▪ CARB, 2019 ▪ California Department of Conservation, TerraCount, 2023

[1] Coding: **= quantifiable co-benefit; if no marking, then co-benefit does not have a quantifiable methodology associated with it. In this section, quantifiable co-benefits come from TerraCount

5 Conclusion

This summary acts as a scientific foundation for the Sonoma County Carbon Inventory and Sequestration Potential Study and includes the following:

- An overview of the data and methodology to be used for the Sonoma County carbon inventories.
- A literature review of carbon stock stability risks related to wildfire and drought.
- A synopsis of the suite of carbon sequestration practices and nature-based solutions that could be implemented in the county.

The information provided in this summary, as well as additional information gathered through stakeholder engagement, will be used to draft the Carbon Inventory and Sequestration Potential Study.

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Via email: Simone.Albuquerque@sonoma-county.org

Subject: Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum

Dear Ms. Albuquerque,

Rincon Consultants, Inc. (Rincon) has completed the Carbon Inventory Study for Sonoma County (Sonoma). This memorandum summarizes the results of the carbon stock and natural GHG emissions inventories for 2013 and 2022. The land-based carbon inventories were developed based on methodology presented in the Resilient Counties Guide, [1] California's 2022 Climate Change Scoping Plan, [2] and California's 2018 Natural and Working Lands Inventory.[3] These methods were reviewed with County staff and confirmed to be the best available at the time of analysis (July-August 2023). These sources identify principles to guide the quantification of carbon stored in, and emitted from, natural and working lands in a complete, accurate, consistent, and transparent manner. This memorandum includes the following sections:

- Introduction and Background
  - Overview of evaluating carbon stored in natural and working lands and a summary of Sonoma County's land use and plans.
- Data Sources
  - Summary of data sources used for land cover classification and carbon inventories.
- Countywide Land Cover Classification
  - Description of quality assurance and quality control (QA/QC) process and land cover classification results using Sonoma County Vegetation Mapping & Lidar Program (2013) and LANDFIRE (2022).
- Countywide Carbon Inventories
  - Description of carbon inventory methodology and results for 2013 and 2022, and overview of carbon stock by land ownership.
- Conclusion
  - A summary of next steps including land management activities to be analyzed.

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Introduction and Background

Why Evaluate Carbon Stored in Natural and Working Lands

Natural and working lands evaluated in this memorandum encompass the eight resilient land types that are the focus of the Sonoma Climate Resilient Lands strategy: forests, agricultural lands, aquatic ecosystems, grasslands, shrubland and chapparal, and developed lands. The classification of these land types are further described in Countywide Land Cover Classification.

Natural and working lands are increasingly considered a critical part of local climate action planning across the State. Sonoma County has been a leader in early research, planning, and implementation in this space, even during the period when it was not incorporated into State targets for greenhouse gas (GHG) reduction. These efforts are summarized in Alignment in Regional, County, and Local Plans, and described in full in Appendix A (Data Evaluation and Literature Review Spreadsheet) . However this policy landscape has started to change, with the State recognizing the critical importance of nature based solutions in achieving carbon neutrality, as established by the 2022 Assembly Bill 1279 (The California Crisis Act), which codifies California's carbon neutrality by 2045 target into law.[4] In addition, Assembly Bill 1757 calls for the Natural Resources Agency, in collaboration with specified entities including the California Air Resources Board and an expert advisory committee, to determine an ambitious range of targets for natural carbon sequestration, and for nature-based climate solutions, that reduce greenhouse gas emissions for 2030, 2038, and 2045 to support State Goals to achieve carbon neutrality and foster climate adaptation and resilience.[5] Sonoma regional efforts, described in sections below also mirror, or exceed these ambitious State targets. Therefore, to meet these existing and anticipated goals, jurisdictions across California need to increase efforts to conserve, restore, and manage forests, rangelands, farms, urban green spaces, wetlands, and soils. Efforts to conserve, restore, and manage natural and working lands effectively require understanding the current land-based carbon stock and carbon sequestration potential of land management activities on these lands. The land-based carbon stock is the total amount of carbon sequestered in woody and herbaceous material and in the soil. The purpose of this memorandum is to provide the County of Sonoma with an overview of the data and methodology to be used for the 2013 and 2022 land-based carbon inventories.

How to Inventory Carbon Stored in Natural and Working Lands

A land-based carbon inventory is a quantitative estimate of the existing state of carbon stored in the land. Land-based inventories provide estimates of carbon stocks and stock-changes between years as GHGs are sequestered or emitted. The Resilient Counties Guide was developed as a collaboration between Merced County, The Nature Conservancy, and the California Department of Conservation, and outlines the methodology used in Merced County to inventory and project carbon stored in natural and working lands in line with State guidance. The Resilient Counties Guide was funded in part by the California Department of Conservation and The Nature Conservancy. The goal of the guide is to help local governments, landowners, planners, and land managers understand the links between land

[4] State of California Legislative Information. 2022. Assembly Bill No. 1279. Available https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279. Accessed August 8,2023.
[5] State of California Air Resources Board (CARB). 2022. Frequently Asked Questions on AB 1757. Available: <https://ww2.arb.ca.gov/resources/documents/frequently-asked-questions-ab-1757 >.

management and conservation and greenhouse gas reductions so that they may incorporate that knowledge into planning and management decisions.

The Sonoma County carbon inventories follow the methodology outlined in the Resilient Counties Guide (which provides the most recent County-level methodology for natural and working lands analysis), California's 2022 Climate Change Scoping Plan, and the State's Natural and Working Lands Inventory.[6,7,8] Land-based emissions exist in the form of methane and nitrous oxide, which are associated with wetlands and agricultural practices such as fertilizer application. Emissions from agricultural practices will not be included in the Sonoma County carbon inventories because they are anthropogenic emissions and are included in the Sonoma County Community GHG Emissions Inventory.[9] The agricultural emissions included in the Sonoma County GHG Emissions Inventory are related to fertilizer application and manure management practices. The scope of the Sonoma County carbon inventories includes carbon stored in natural and working lands, including urban areas, and natural land-based emissions (such as wetland methane emissions). The exclusion of agricultural emissions from the carbon inventories is consistent with the State's Natural and Working Lands Inventory methodology. The carbon inventories will estimate carbon stocks by land-cover class (e.g., forest, grassland, shrub, etc.) and estimate wetland emissions for 2013 and 2022.

Sonoma County Land Use and Plans

Sonoma County stretches over 1,016,469 acres of land and water, which includes all natural, agricultural, and urban areas, both incorporated and unincorporated. Regional and local planning help to shape how this land is developed or maintained for different uses over time, including the loss or preservation of agricultural and working lands, and open spaces. Given that the County's open spaces can serve to sequester or emit greenhouse gases, changes in land-use have the potential to impact the County's ability to support California and the County's carbon neutrality goals and community emissions.

Natural and Working Lands

Plan Bay Area 2050 maintains the urban growth boundaries established by local jurisdictions and counties as of 2020 to direct new growth within the existing urban footprint to limit sprawl and preserve open spaces. Open spaces provide a range of important benefits, including limits to urban sprawl, health benefits, support for climate goals, improvements to the local watershed, food production, and increased biodiversity. These benefits are recognized in the Plan Bay Area 2050 Environment Chapter, which encompasses the analysis areas of Sonoma County, including both urban areas and natural working lands. Regional funds that augment local investments to conserve and manage critical lands would support a regional goal of protecting and maintaining over 2 million acres of open space by 2050. Natural and working lands have the potential to be both a source of carbon emissions and a sink for carbon. Directing new growth within existing urban footprints and preserving open space prevents the

[6] California Department of Conservation, The Nature Conservancy, Tukman Geospatial, Climate Action Reserve, and Merced County. 2018. Resilient Counties Guide. Available: https://maps.conservation.ca.gov/TerraCount/downloads/. Accessed August 8, 2023.
[7] California Air Resources Board (CARB). 2022. California's 2022 Climate Change Scoping Plan. Available: < https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan>. Accessed August 9, 2023.
[8] CARB. 2018. An Inventory of Ecosystem Carbon in California's Natural and Working Lands. Available: <https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf>. Accessed August 8, 2023.
[9] Regional Climate Protection Authority. 2012. Sonoma County Greenhouse Gas Inventory, 2020 Update. Available: < https://rcpa.ca.gov/wp-content/uploads/2022/09/RCPA-Community-GHG-Inventory-2020-Update-FINAL-2022-09-06.pdf> Accessed August 29, 2023.

emission of carbon stored in natural or working lands when they are converted to other uses. Preserving natural and working lands also preserves the opportunity to enhance carbon sequestration through the adoption of strategic management practices that increase the amount of carbon stored in soil and vegetation. Land use policy and land management are important avenues to achieve GHG emissions reductions along with the recreational, health, and environmental benefits they bring the community.

Alignment in Regional, County, and Local Plans

Sonoma County has numerous plans and policies in place to govern land use and support achievement of climate goals through natural and working land carbon sequestration. These plans include Climate Action 2020 and Beyond, the Sonoma Climate Mobilization Strategy, Sonoma County's 5-Year Strategic Plan, Sonoma County Vital Lands Initiative, and the Sonoma County Integrated Parks Plan. These plans were created, and are being implemented by key stakeholders, agencies, and organizations including the County of Sonoma, Permit Sonoma, Sonoma County Agricultural Preservation and Open Space District (Ag + Open Space), The Nature Conservancy[10], Sonoma County Regional Parks, the Regional Climate Protection Authority, and Sonoma County Water Agency (Sonoma Water). Carbon Farm Plans are being developed at a parcel-scale to facilitate the design and implementation of land management practices that sequester carbon and reduce greenhouse gas emissions. These results will be informed by parcel-scale work that has the potential to ground-truth outcomes. Key local partners in this work are University of California Cooperative Extension, Gold Ridge and Sonoma Resource Conservation Districts, and the Carbon Cycle Institute.

Because of this robust network of existing plans that span multiple landowner types, stakeholders balance multiple approaches to store and sequester carbon across Sonoma's diverse landcover types, through strategies like land conservation, climate-smart agriculture, and prescribed herbivory, among others.

For a comprehensive list of Sonoma-relevant plans and policies, please reference Appendix A (Data Evaluation and Literature Review Spreadsheet) of the Literature and Data Evaluation review provided to the County in July 2023.

Data Sources

Jurisdictional carbon inventories require the use of large-scale spatial data sets and carbon or biomass data that is accurate, consistent, and available for past and present years and into the future. The Sonoma County carbon inventories use publicly available data sources that are expected to be updated in the future. Table 1 and Figure 1 include the data sources used to complete the Sonoma County land cover analysis that is the basis for the Countywide carbon inventories. The best available data were used in this analysis to allow for progress on estimating carbon stock stability and developing strategies for optimizing carbon sequestration in Sonoma in a timely manner.

Although the best available data are used for this analysis, uncertainties and limitations are present in the data used and analysis conducted for the Sonoma County carbon inventories. Uncertainties and limitations in the data include the use of datasets with different resolutions for the different inventory years and the use of soil data that provides only a snapshot in time (2017) from 0 centimeters – 30

[10] The Climate Action through Conservation Project (2016), is a collaboration between Sonoma County and The Nature Conservancy

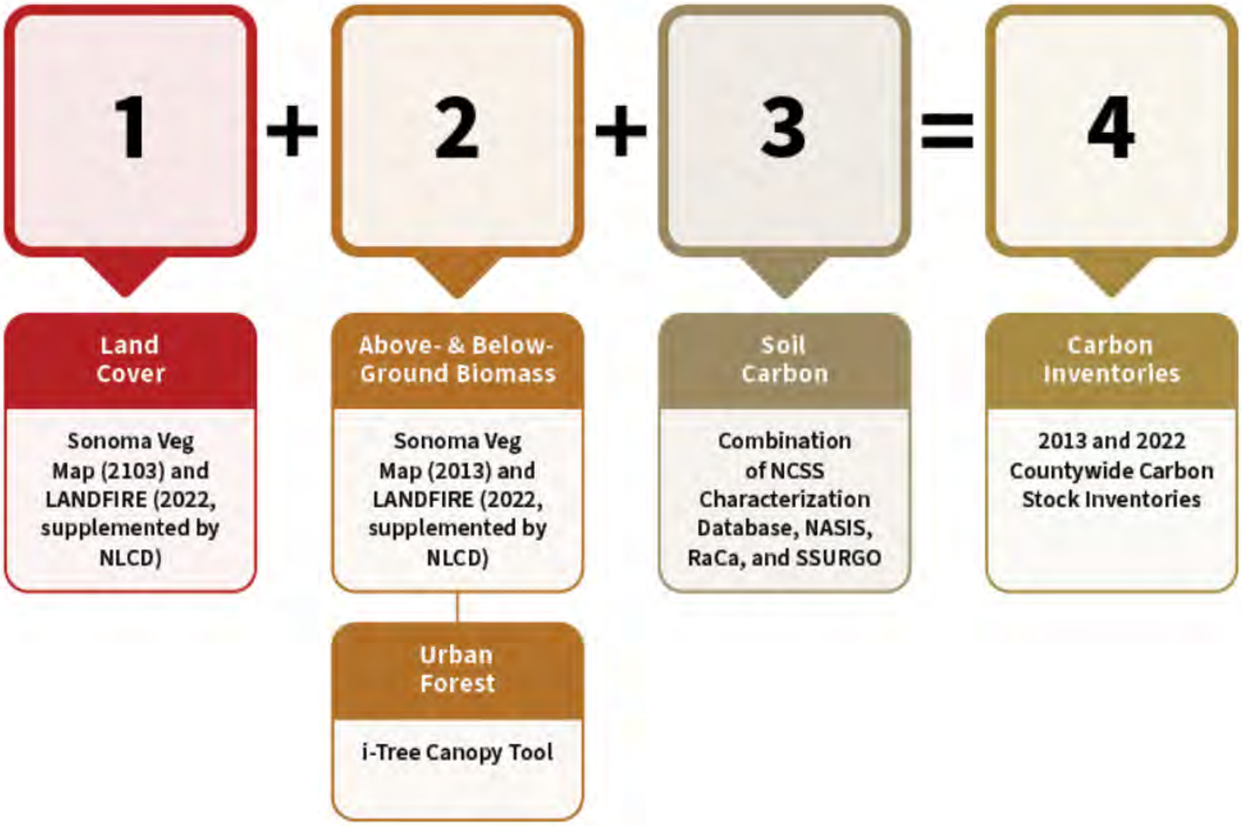
centimeters. Additionally, continued improvements in the science and protocols for tracking and estimating carbon stocks in land will mean that future estimations may be further refined and include additional sets of assumptions or data than were available and considered best practice at the time this analysis was conducted.

Table 1 Data Sources Used

Land Type	Data Name and Developing Agencies	Publication Frequency	Latest Publication Year
Countywide Land Cover Classification	Sonoma County Vegetation Mapping & Lidar Program (Sonoma Veg Map) [1] developed by Ag + Open Space and Sonoma Water. Contributing partners include the California Department of Fish and Wildlife, the United States Geological Survey, the Sonoma County Information Systems Department, the Sonoma County Transportation and Public Works Department, The Nature Conservancy, the City of Petaluma, NASA, and the University of Maryland.	N/A[2]	2013
	LANDFIRE[3] developed, in part, by the United States Department of Agriculture (USDA) Forest Service and the United States Department of the Interior.	2 years	2022
	California Department of Water Resources (DWR) Statewide Crop Mapping	1-2 years	2020
	Multi-Resolution Land Characteristics Consortium (MRLC) – National Land Cover Database (NLCD)[4] developed by a group of federal agencies. Partners include the United States Bureau of Land Management, National Agricultural Statistics Service (NASS), National Oceanic and Atmospheric Administration (NOAA), USDA Forest Service and the United States Geological Survey.	5 years	2019
Urban Tree Density	i-Tree Canopy (v7.1)[5] developed, in part, by the USDA Forest Service.	Annual	2021
Soil	The National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets[6] developed, in part, by the National Soil Survey Center (NSSSC), Kellogg Soil Survey Laboratory (KSSL), USDA, and National Resource Conservation Service (NRCS).	N/A[7]	2017

[1] Sonoma Veg Map data - https://sonomavegmap.org/
[2] Currently a snapshot in time for 2013
[3] LANDFIRE data - https://www.landfire.gov/
4 DWR Statewide Crop Mapping https://data.ca.gov/dataset/statewide-crop-mapping
[5] NLCD data - https://www.mrlc.gov/data?f%5B0%5D=category%3ALand%20Cover
[6] i-Tree Canopy Tool - https://canopy.itreetools.org/
[7] Soil data - https://scholarsphere.psu.edu/resources/ea4b6c45-9eba-4b89-aba6-ff7246880fb1
[8] Currently a snapshot in time for 2017 – future updates not planned.

Figure 1 Land Cover Classification and Carbon Inventories Data



Land Cover Data Source Descriptions

The following datasets were used for land cover classification:

- Sonoma County Vegetation Mapping & Lidar Program (Sonoma Veg Map)
- LANDFIRE and National Land Cover Database (NLCD)
- Department of Water Resources (DWR) Statewide Crop Mapping

Sonoma County Vegetation Mapping & Lidar Program (Sonoma Veg Map)

Sonoma Veg Map is a joint program of Ag + Open Space and Sonoma Water that included support from a variety of contributing partnership including the California Department of Fish and Wildlife, the United States Geological Survey, the Sonoma County information Systems Department, the Sonoma County Transportation and Public Works Department, The Nature Conservancy, the City of Petaluma, NASA, and the University of Maryland. In 2013, Ag + Open Space and Sonoma Water received $1.2 million dollars in remote sensing data through a NASA research grant, which funding 58 percent of the Sonoma Veg Map program. Sonoma County partners funded the remaining 42 percent. This unique program provides an accurate inventory of Sonoma County’s landscape features, ecological communities, and habitats.

Sonoma Veg Map data is derived from 2013 LiDAR data and high-resolution aerial imagery using human interpreters and computer algorithm and verified vegetation characteristics in the field. The result is a fine scale (<1:5,000 map scale) vegetation and habitat map for the county. Sonoma Veg Map provides detailed information on vegetation classification for the land cover classification analysis; however, it does not include carbon stock information for all carbon pools countywide. This dataset provides the foundation of the 2013 Sonoma County land cover analysis. This dataset lacked vegetation height and cover data attributes for most land cover types. Therefore, in order to estimate carbon stocks for 2013 vegetation height and cover was needed, with the exception of tree height and cover contained within Sonoma Veg layer for forested land classifications. For the rest of the land cover classification, LANDFIRE 2014 data was utilized by spatially joining it to the Sonoma Veg Map and taking the nearest height and cover data based on the land classification type.

LANDFIRE and National Land Cover Database (NLCD)

Since Sonoma Veg Map is only available for 2013, LANDFIRE spatial land cover data provides the basis for the Sonoma County land cover analysis for 2022. LANDFIRE data are created for the entire United States at a 30-meter resolution and are updated on a two-year cycle. Due to the scale at which LANDFIRE data are created, the accuracy of the data can be limited at the county scale, which is why the LANDFIRE data for Sonoma County will be supplemented by NLCD, DWR Crop Mapping, satellite imagery, and desktop ground-truthing. LANDFIRE was used and customized for the State's Natural and Working Lands Carbon Inventory developed for the California Air Resources Board (CARB).[11]

LANDFIRE existing vegetation layers describe the following elements: Existing Vegetation Type (EVT), Existing Vegetation Canopy Cover (EVC), and Existing Vegetation Height (EVH). These layers are created using predictive landscape models based on extensive field-referenced data, satellite imagery and biophysical gradient layers using classification and regression trees. LANDFIRE potential vegetation layers describe the following elements: Bio-Physical Settings and Environmental Site Potential. Rincon identified inaccuracies in areas of the county by comparing Sonoma Veg Map, NLCD, DWR Crop Mapping, and satellite imagery. Rincon supplemented the 2022 land cover data with NLCD data, conducted desktop ground truthing using satellite imagery, and solicited review from stakeholders (described in the Countywide Land Cover Classification section) to reclassify inaccuracies in the data and develop a land cover map for 2022.

Department of Water Resources (DWR) Statewide Crop Mapping

DWR updated the 2020 Crop Mapping dataset in March 2023. For many years, DWR has collected land use data throughout the state and uses this information to develop water use estimates for statewide and regional planning efforts, including water use projections, water use efficiency evaluation, groundwater model development, and water transfers. These data are essential for regional analysis of croplands and decision making, which has become increasingly important as DWR and other state agencies seek to address resource management issues, regulatory compliance issues, environmental impacts, ecosystem services, urban and economic development, and other issues. Increased availability of digital satellite imagery, aerial photography and new analytical tools make remote sensing land use surveys possible at a field scale comparable to that of the DWR historical field surveys. Current technologies allow accurate, large-scale crop and land use identification to be performed at time increments as desired, and make possible more frequent, comprehensive statewide land use information. Responding to this need, DWR sought expertise and support for identifying crop types and other land uses and quantifying crop acreages statewide using remotely sensed imagery and associated

[11] California Air Resources Board (CARB). 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands, 2018 Edition. Available: <https://ww2.arb.ca.gov/nwl-inventory>.

analytical techniques. Currently, Statewide Crop Maps are available for the years 2014, 2016, 2018, 2019, 2020, and provisionally for 2021.

Countywide Land Cover Classification

The land cover classification follows the methodology outlined in the Resilient Counties Guide and the State's Natural and Working Lands Inventory.[12,13,14] The methodology of the land cover classification is presented below. The following subsections describe the Sonoma County land cover classification methodology and results.

Quality Assurance and Quality Control (QA/QC) Process

Given the importance of the underlying data in driving the results of the carbon inventories, Rincon undertook quality assurance and quality control (QA/QC) measures. Data availability and quality were assessed throughout the collection and land classification analysis process through input from the County, stakeholders, spatial analysis, and desktop ground truthing. As part of the QA/QC process, Rincon created a data review platform and form for stakeholders to identify issues with vegetation types and misclassified areas in the land cover classification. Staff from Permit Sonoma, Ag + Open Space, Sonoma Land Trust, and the Regional Climate Protection Authority identified areas on the 2013 Sonoma Veg Map and 2020 LANDFIRE land cover maps that were misclassified and provided the correct classification. Data discrepancies were addressed as outlined below.

The Sonoma Veg Map dataset was used as the foundation for land cover classification for 2013, but it was upscaled to a 30-meter resolution to align with LANDFIRE. The LANDFIRE data covers Sonoma County at a 30-meter resolution. The LANDFIRE layers used for the analysis include Existing Vegetation Type, Cover, and Height. Identified inaccuracies were found in the LANDFIRE dataset. Where there were significant discrepancies, the NLCD, Sonoma Veg Map, and DWR datasets were used to refine the 2022 data. Examples of inaccuracies found and data refinements made are described in detail in the Initial Desktop Data Refinement section below.

Based on data evaluation and review, the data and tools used in this analysis are the best available at the time of this study. An updated fine scale vegetation and habitat map may be developed using the same methodology as the 2013 Sonoma Veg Map dataset used for this analysis. Future work to develop an updated Sonoma Veg Map would allow for an analysis of changes in land cover changes and carbon stock changes over time.

Initial Desktop Data Refinement

Following the project team's review of currently publicly available data, LANDFIRE was determined to be the most appropriate base dataset for use in this landscape-level regional analysis for 2022 because it provides information on vegetation type, cover, and height, which are required to calculate carbon stock. Over 4 million 30-meter pixels made up the area analyzed for Sonoma County for 2022. During

[12] California Department of Conservation, The Nature Conservancy, Tukman Geospatial, Climate Action Reserve, and Merced County. 2018. Resilient Counties Guide. Available: https://maps.conservation.ca.gov/TerraCount/downloads/. Accessed August 08, 2023.
[13] California Air Resources Board (CARB). 2022. California's 2022 Climate Change Scoping Plan. Available: < https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan>. Accessed August 9, 2023.
[14] California Air Resources Board (CARB). 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands, 2018 Edition. Available: <https://ww2.arb.ca.gov/nwl-inventory>.

the QA/QC process inaccuracies were identified in the LANDFIRE dataset, for example, shrub/scrub areas were categorized as grassland/herbaceous or forest. Given these discrepancies, NLCD and the Sonoma Veg Map datasets were determined to accurately categorize land cover in the county, and desktop ground truthing was used to supplement the LANDFIRE data. Forest and grassland/herbaceous cells with mismatched LANDFIRE, NLCD, and Sonoma Veg Map categories were reclassified to the values of the nearest LANDFIRE cell of that type within 2,000 feet. For example, if a cell has a LANDFIRE classification of forest in 2022 but an NLCD classification and Sonoma Veg Map of shrub/scrub, that cell would be reclassified to shrub/scrub if there was another LANDFIRE shrub/scrub cell within 2,000 feet. The nearest LANDFIRE cell is used to update the data because LANDFIRE provides information needed for carbon stock calculations, including vegetation type, height, and cover, whereas NLCD and the Sonoma Veg Map only provides vegetation type. After reviewing the pixels during QA/QC, 93,000 pixels (approximately 2 percent) were reclassified to correct the land cover classification.

Stakeholder Review

Rincon facilitated stakeholder review of the countywide land cover maps by creating an interactive online data review platform and holding two data review meetings to gather additional feedback and share data refinements made. Experiential knowledge based on personal experiences and observations of local experts was critical to the QA/QC process of this analysis. Experiential knowledge helped to identify and remediate errors in the land cover classification, as well as confirm trends shown in the data.

Land Cover Classification First Review Summary

During the first review meeting of the land cover classification, staff from the Climate Action and Resiliency Division, Permit Sonoma, Ag + Open Space, and the Regional Climate Protection Authority identified additional areas that were incorrectly classified in the LANDFIRE (2022) dataset. The County and stakeholders submitted their feedback in the interactive online data review platform with the year and notes of the misclassification.

Some common themes included:

- Missing forest and Grassland/Herbaceous areas within City boundaries, urban sprawl areas in general were more densely classified as Developed in the LANDFIRE (2022) data than in the Sonoma Veg Map (2013) data.
- The southern area of Sonoma County showed Cultivated and Fields Crops in the LANDFIRE (2022) data which should have been classified as Pasture and Hay.
  - Resolution of issues: The areas identified by stakeholders were cross-checked with satellite imagery, the Sonoma Veg Map dataset, and DWR Crop Mapping, and updated to reflect the appropriate land cover type using the same process as previously mentioned in the Initial Desktop Data Refinement section. After reviewing the pixels during the QA/QC process, 244,000 pixels (about 5 percent) were reclassified to correct the land cover classification.
- Review of Sonoma Veg Map (2013) data included noting a large swath of grassland in the southwest part of the county was classified as Grassland/Herbaceous. After County comments and desktop ground truthing this area was determined to possibly be misclassified Pasture and Hay in the Sonoma Veg Map (2013) dataset.

  - Resolution of issues: Reclassification via ground truthing or desktop ground truthing was determined not feasible for an area of this size for 2013 and may contribute to discrepancies in the landcover and carbon analysis for this general class.
- Additionally, the crosswalk between Sonoma Veg Map 2013 map classifications and CARB EVT classifications, needed for carbon stock calculations (see the Carbon Stock Estimate Methodology section), were reviewed by the County and stakeholders and several modifications were suggested and implemented by Rincon.

Land Cover Classification Second Review Summary

During the second review meeting of the land cover classification, the County and stakeholders determined the acreage discrepancy for Developed land classes between the Sonoma Veg Map (2013) and LANDFIRE (2022) datasets was too large and likely due to a difference in classification rules for Developed areas between the two datasets. It was suggested that the Sonoma Veg Map dataset could be missing some developed land acreage since minor roads are not mapped. The following solutions were considered or implemented:

- The areas identified were cross-checked with LANDFIRE 2014, specifically developed-road pixels, and the 2013 impervious surfaces dataset from the Sonoma Veg Map Program. The 2013 Sonoma Veg Map was updated to more closely align with the classification of Developed areas in the 2022 LANDFIRE dataset. After reviewing the pixels during QA/QC, 106,000 pixels (approximately 2 percent) in the 2013 Sonoma Veg Map dataset were reclassified to developed land cover, which more accurately represents the change in developed land between the two years.

While there was an extensive QA/QC process and the best available data were used, there may be some areas that remain misclassified due to the nature and scale of the original datasets. These areas may have an influence on trends represented.

Land Cover Classification Results

The general land cover classes used in the Sonoma County inventories are defined below.

- Barren – areas where vegetation accounts for less than 15 percent of total cover. For example, areas of bedrock, sand dunes, or gravel pits.
- Cultivated and Field Crops – areas used for the production of vegetables and field crops generally grown for human consumption, such as squash, tomatoes, leafy greens, rye, and oats.
- Development – areas with constructed materials, including buildings and roads.
- Forest – areas dominated by trees with more than 10 percent tree cover (includes riparian areas that are dominated by trees with more than 10 percent tree cover).
- Grassland/Herbaceous – areas dominated by herbaceous vegetation, with more than 10 percent herb cover, less than 10 percent tree cover and less than 10 percent shrub cover.
- Open Water – areas of water with less than 25 percent cover of vegetation or soil.
- Orchard – areas used for the production of fruits and nuts.
- Pasture and Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle.

- Shrub/Scrub – areas dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover (includes riparian areas that are dominated by shrubs greater than 10 percent of total shrub cover and less than 10 percent tree cover).
- Vineyard – areas planted with grapevines, generally used for producing grapes used in winemaking.
- Wetland – areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the perennial herbaceous vegetation indicate soil or substrate periodically saturated with or covered with water.

Rangelands, which span multiple land cover types, including grasslands, shrublands, and woodlands, are not identified as a separate land cover type in the landcover classification. However, measures and actions to manage grazing on different land cover types will be included in the Carbon Inventory and Sequestration Potential Study. Another important landscape type is blue carbon which is carbon captured and held in coastal vegetation, such as seagrasses. This landscape is important to consider in long-term climate goals, however, it is not currently covered by the IPCC inventory guidelines or included in California's Natural and Working Lands inventory and is therefore excluded from this analysis.[15]

Land Cover Classification Results are summarized in Figure 2, Figure 3, Figure 4, Figure 5, and Table 2.

[15] California Air Resources Board (CARB). 2022. Scoping Plan. Appendix I – Natural and Working Lands Technical Support Documentation. Available: < https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-i-nwl-modeling.pdf>.

Figure 2 2013 and 2022 Land Cover Maps

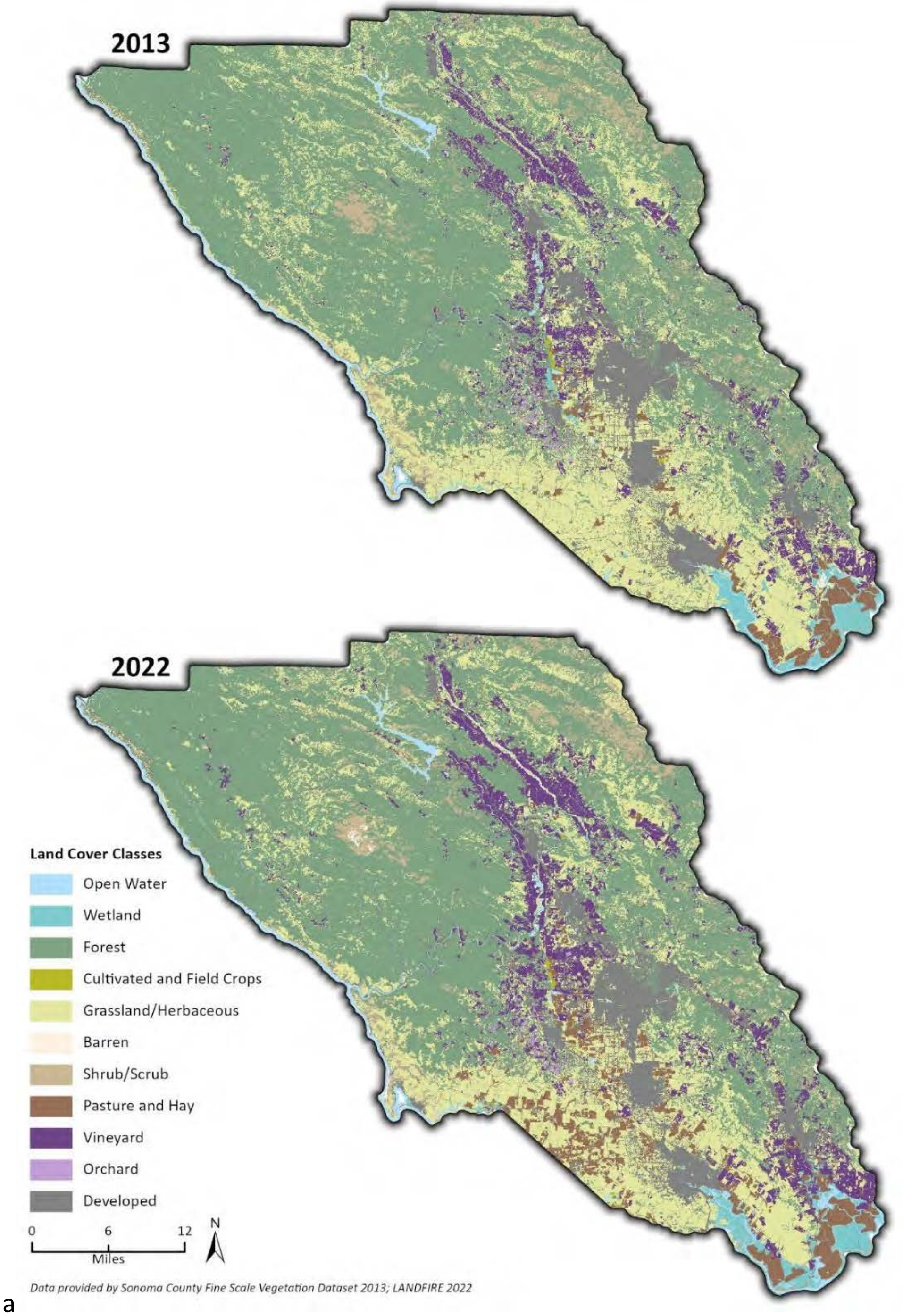


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Figure 3 2013 Land Cover

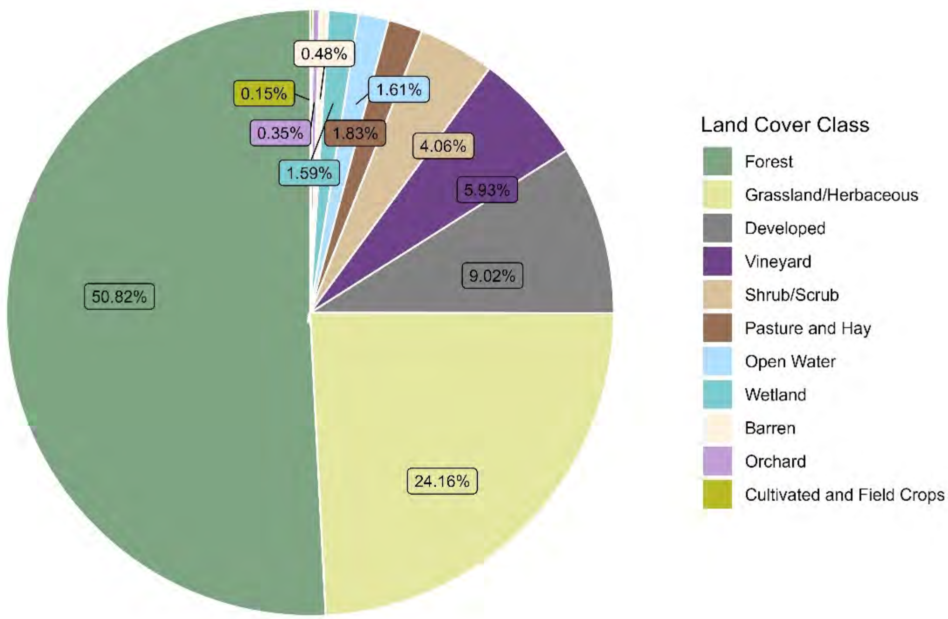


Figure 4 2022 Landcover

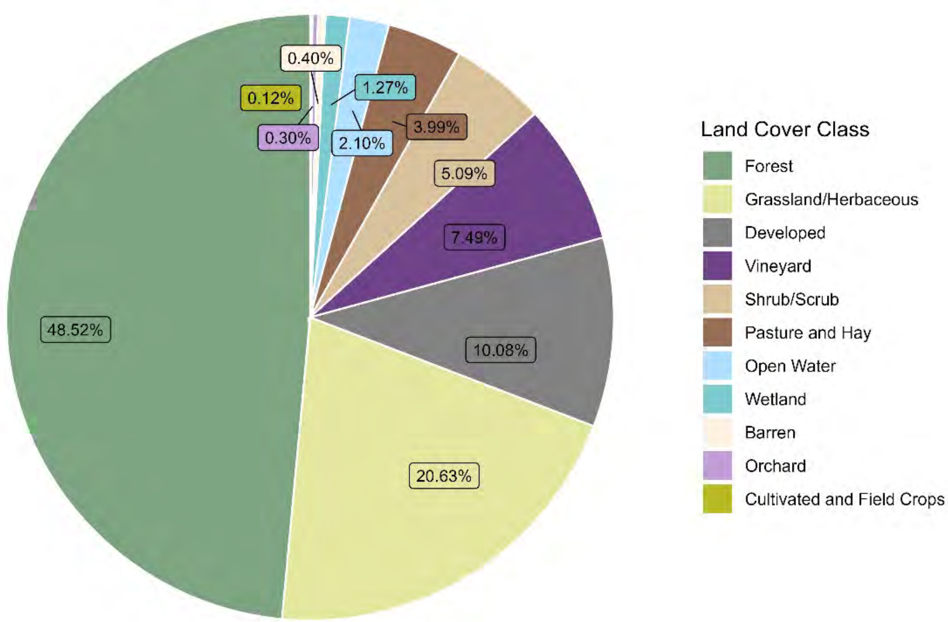
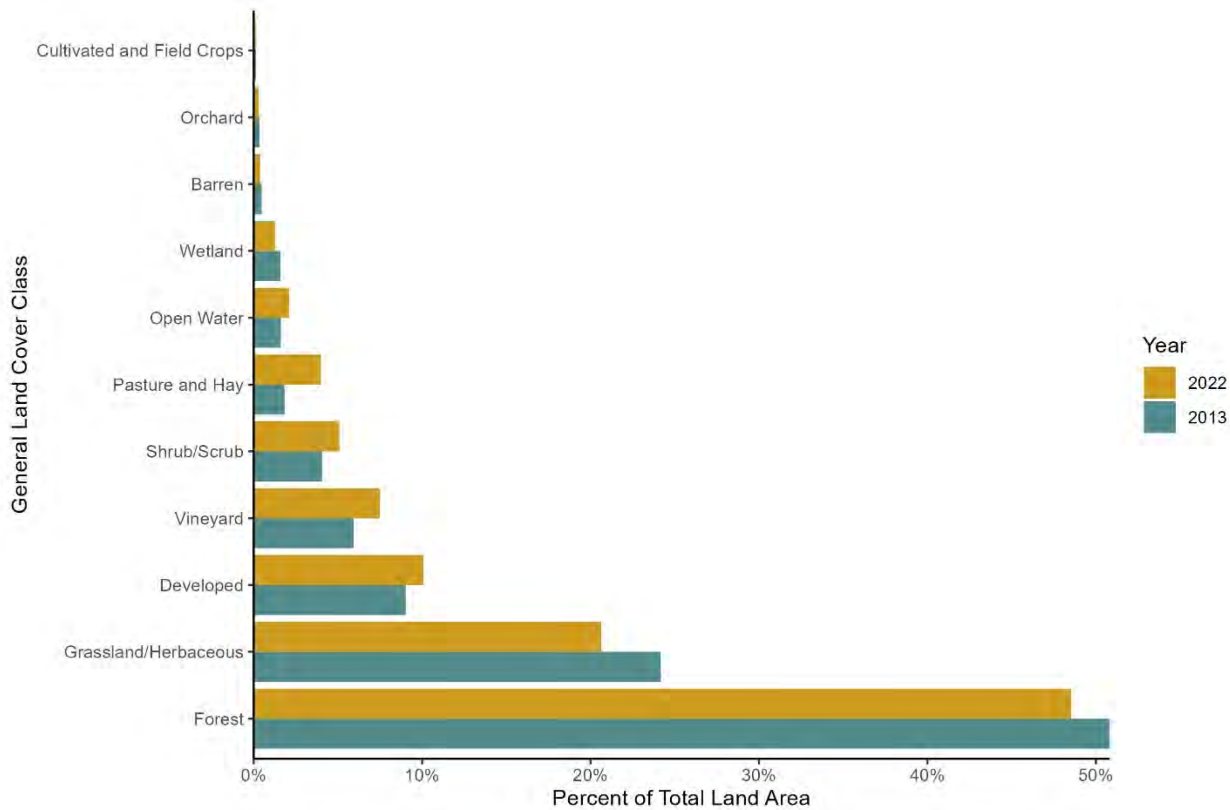


Figure 5 2013 and 2022 Land Cover Class as Percent of Total Land Area



The data show that between 2013 and 2022, developed land cover increased from about 9 to 10 percent of total land cover and totaled an estimated 105,324 acres in 2022. The area classified as grassland/herbaceous decreased by 15 percent, a difference of an estimated 36,872 acres. During this same period, pasture and hay acreage increased by 118 percent, gaining 22,572 acres between the two years. When combined, these two landcovers collectively decreased by 14,300 acres. The decline in grassland/herbaceous landcover and increase in pasture and hay is likely due to differences in map classification between the two years. Areas classified as barren land decreased by 17 percent, a difference of an estimated 933 acres. Differences in areas classified as forest were the second largest decrease of acreage between the two years, with a loss of 5 percent, representing 23,929 acres. Areas classified as open water, pasture and hay, shrub/scrub, and vineyard all show increases between the two years. Among the most notable, is a 26 percent increase in vineyards, totaling a gain of 16,307 acres between years. Some of the changes in land cover are due to changes in land use, for example, increases in vineyards and developed areas over the past decade, while others may be due to climate-related impacts such as wildfire and drought. For example, decreases in forested land in the county may be due to climate-induced shifts from forests to shrub due to the intensity and frequency of wildfires and extended drought between the two inventory years. Some of the observed changes in land cover types may be due to methodological differences in the data sets rather than actual changes in land cover. This was explored further with additional analysis for forest, vineyard, and wetland land cover classifications.

Figure 6 shows a spatial comparison between the Sonoma Veg Map dataset showing forest cover in 2013, and the 2022 LANDFIRE dataset for forest cover. The light grey areas depict where the datasets match, showing forest cover in both years. The purple areas show areas designated as forest in the 2013 Sonoma Veg Map data that were not designated as forest in the 2022 LANDFIRE data. The green areas on the map show areas designated as forest in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. The orange areas are fire perimeters from 2013 to the present. Viewing the data this way indicates that the large areas of purple within the fire perimeters is likely representative of either actual loss of forest due to wildfire related conversion to shrub or other land cover types post-fire, or may be indicative of the early post-fire successional stages of forest recovery rather than permanent loss of forest. In some wildfire affected areas that were designated as forest in the earlier dataset and shrub in the later dataset, the shrubs may actually be, or include, young trees that are part of the natural regeneration of forest that can occur over several decades following a fire. The small, isolated pixels of purple and green scattered throughout the large, forested areas may represent either actual differences in forest cover or differences in data sets resulting from the differences in how they were compiled (lidar versus satellite and algorithmic modeling).

Figure 6 Comparison of Forest Land Cover Between Years and Datasets

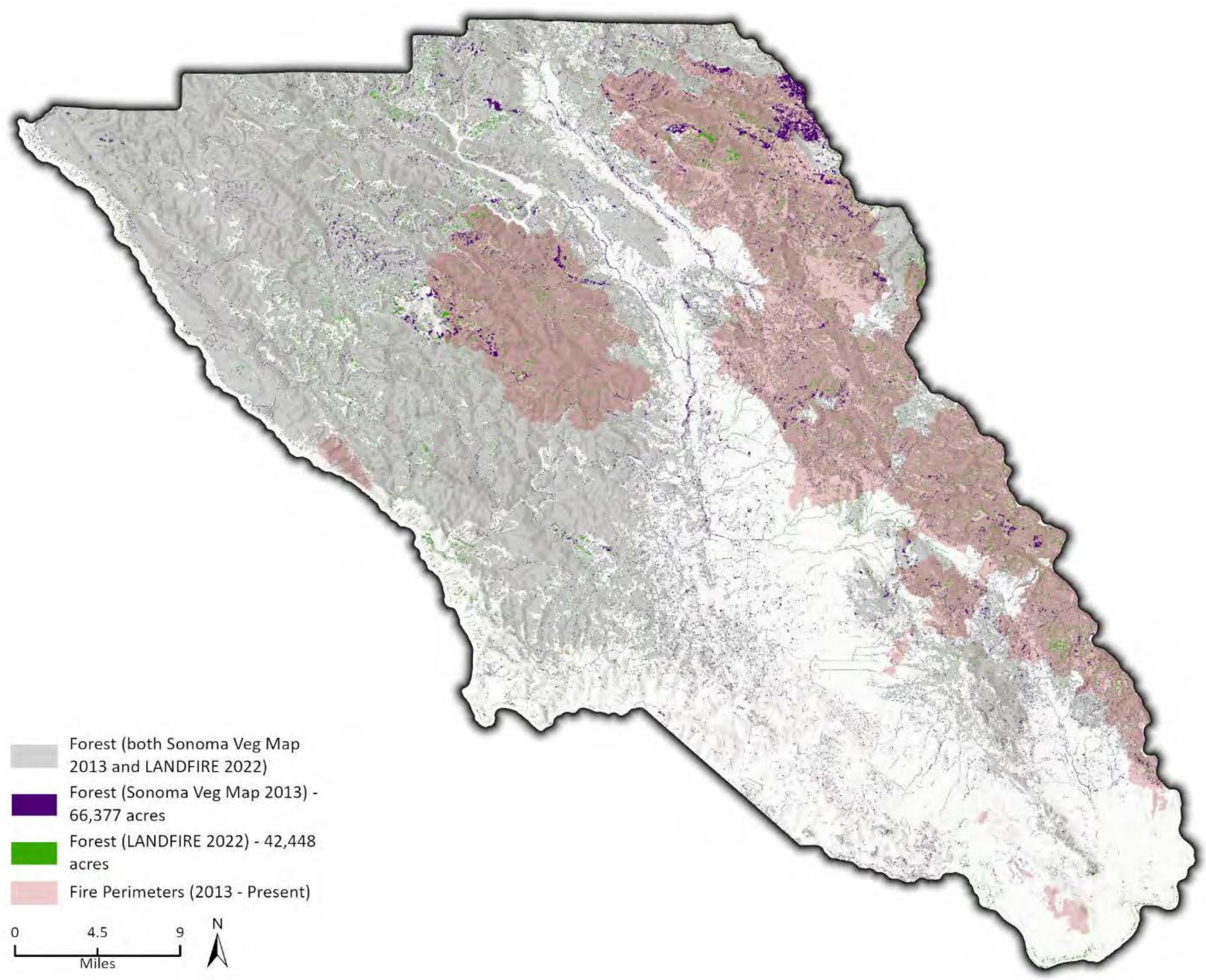


Figure 7 shows a spatial comparison between the Sonoma Veg Map dataset showing vineyards in 2013, and the 2022 LANDFIRE dataset for vineyards. The light grey areas depict where the datasets match, showing vineyards in both years. The pink areas show lands designated as vineyards in the 2013 Sonoma Veg Map data that were not designated as vineyard in the 2022 LANDFIRE data, this is representative of about 3,600 acres and based on conversations with local experts, this is likely due to differences in the datasets rather than loss of vineyard. The purple areas on the map show lands designated as vineyards in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. The large blocks of purple likely indicate areas that are newly developed vineyard, and align with DWR spatial data for vineyards. However, a close up of the data shows that the 2022 LANDFIRE dataset also designates many small patches of land between vineyards as vineyard too. This is depicted in Figure 8, where the grey areas show overlap between the data designating land as vineyard and the purple area shows 2022 LANDFIRE data designating land as vineyard. In the map it is easy to see how the areas between vineyards are classified as vineyard in many small patches by the LANDFIRE data. When summed over the entire county, this likely accounts for the additional acres over the expected gain of roughly 4,000 acres in vineyards based on DWR data.

Figure 7 Comparison of Vineyard Land Cover Between Years and Datasets

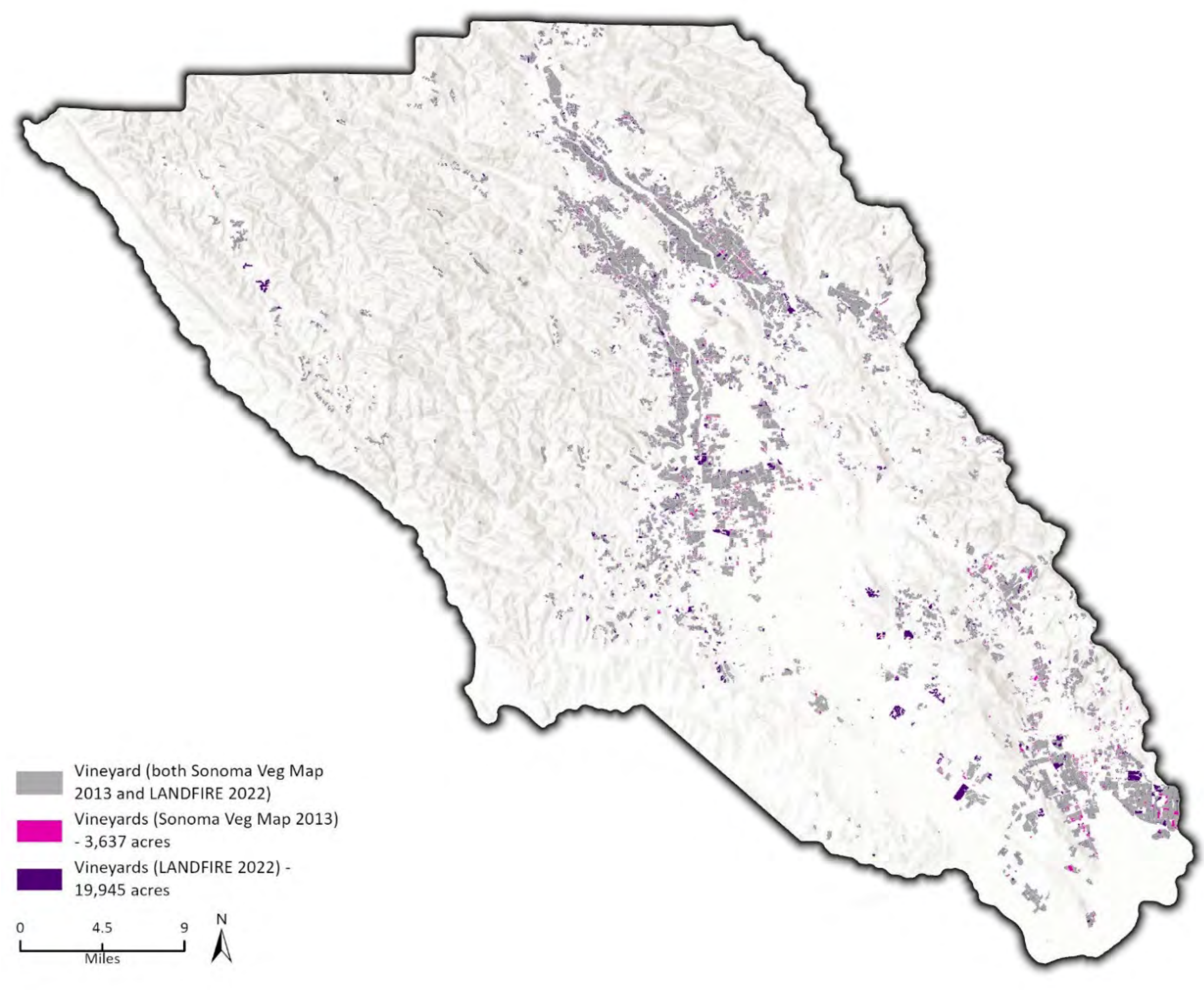


Figure 8 Close Up Comparison of Vineyard Land Cover Where Datasets Agree and Where LANDFIRE Designates Additional Vineyard Acreage

Figure 9 shows a spatial comparison between the Sonoma Veg Map dataset showing wetlands in 2013, and the 2022 LANDFIRE dataset for wetlands. The light blue areas depict where the datasets match, showing wetlands in both years. The dark blue areas show lands designated as wetland in the 2013 Sonoma Veg Map data that were not designated as wetland in the 2022 LANDFIRE data. The green areas on the map show areas designated as wetland in the 2022 LANDFIRE dataset and not in the 2013 Sonoma Veg Map dataset. There is the most overlap in the datasets around the bay wetlands. There are some concentrated areas of blue inland, as well as many smaller patches of dark blue sprinkled throughout the county and along the coastline. This may indicate some loss or drying of inland wetlands, but in many cases the difference is likely due to differences in recognition and designation of inland wetlands between the Sonoma Veg and LANDFIRE datasets.

Figure 9 Comparison of Wetland Land Cover Between Years and Datasets

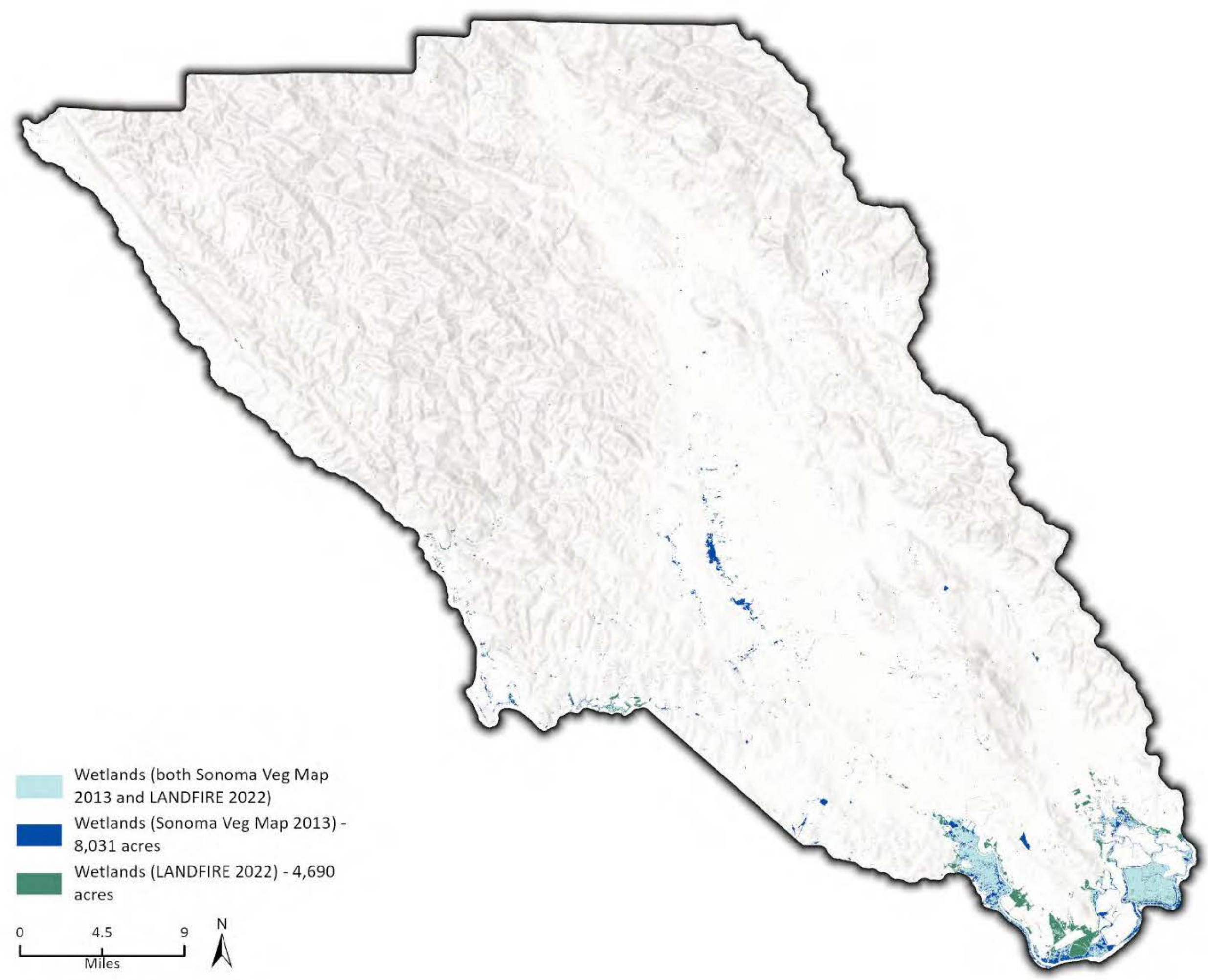


Table 2 below shows the number of acres in each land cover class for 2013 and 2022 between the two years.

Table 2 Land Cover Class Acreage (2013 & 2022)

Land Cover Class	2013	2022
Barren	4,977	4,144
Cultivated and Field Crops	1,526	1,234
Development	94,249	105,324
Forest	530,769	506,840
Grassland/Herbaceous	252,362	215,490
Open Water	16,808	21,950
Orchard	3,684	3,130

Land Cover Class	2013	2022
Pasture and Hay	19,121	41,693
Shrub/Scrub	42,417	53,201
Vineyard	61,921	78,228
Wetland	16,582	13,276
Total	**1,044,416**	**1,044,510**

Notes: Acres have been rounded to the nearest whole number therefore sums may not match.

Countywide Carbon Inventories

Where possible, the inventories are based on regional datasets that are updated over time and provide a consistent approach. However, the scale of management activities that influence carbon sequestration often does not result in land cover change, and therefore is not captured in the inventories. Capturing carbon stock and natural GHG emissions resulting from management activities, rather than land cover changes, requires a monitoring approach that modifies carbon stock estimates in places where these activities have been applied. This information is not currently being tracked in a comprehensive data set nor compiled for projects countywide, though management practices are being tracked by the RCDS on a public database project tracker. This RCD management practices tracker will be a significant part of the upcoming USDA Climate Smart Commodities grant and represents a promising start to future tracking of management activities at the County-scale. The County is also working to stabilize carbon stocks through wildfire prevention: these efforts will be summarized in future memorandums on carbon stock stability, and in the final report.

The Sonoma County carbon inventories methodology is based on the Resilient Counties Guide, which provides the most up-to-date county-level natural and working lands analysis in line with State's 2018 natural and working lands inventory.[16] The first step includes estimating carbon stocks by land cover class (i.e., forest, grassland, and shrub) using the 2013 and 2022 datasets described in the Data Sources section and Literature and Data Evaluation review provided to the County in July of 2023. The second step involves calculating carbon stored in different carbon pools (i.e., above- and below-ground live biomass, litter, and soil) based on existing vegetation type, cover, and height. The sections below describe the methodology and findings of the two carbon inventories. The inventory of carbon stocks for natural and working lands in Sonoma County will cover 1,016,469 acres, which includes all natural, agricultural, and urban areas countywide.

The best available data were used in this analysis to allow for progress on estimating carbon stock stability and developing strategies for optimizing carbon sequestration in Sonoma in a timely manner. Some changes in land cover and carbon stock between the two years may be data artifacts. Future updates to the Sonoma Veg Map data will allow for more accurate carbon stock and trends analysis.

Carbon Stock Estimate Methodology

Carbon stock estimates are based on the sum of carbon stored in different carbon pools. Carbon stock analysis includes carbon stored in the following carbon pools:

[16] California Air Resources Board (CARB). 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands, 2018 Edition. Available: <https://ww2.arb.ca.gov/nwl-inventory>.

- Above- and below-ground live biomass
- Above- and below-ground biomass associated with dead standing trees
- Lying dead wood (e.g., branches, logs, etc., lying on the ground surface)
- Litter (e.g., freshly fallen or slightly decomposed leaves, bark, twigs, flowers, fruits, and other vegetable matter).
- Soil

Above- and Below-ground Carbon

Carbon stored in all above- and below-ground biomass (including live, dead, and litter), is calculated using volumetric estimates of carbon mass (metric tons per hectare) provided by the California Air Resources Board (CARB).[3] These estimates will be provided for every combination of Existing Vegetation Type, Height, and Cover and assigned to each 30 by 30-meter cell in the county. The carbon values are then summed within each land cover class. For example, the above- and below-ground carbon stored in annual crops is 0, because they are harvested annually, however, bush fruit and berries, vineyards, and orchards do maintain a carbon stock and therefore have higher carbon value than annual crops. The carbon value for all cultivated crops is then summed to provide the total carbon stored in that land cover class.

Soil Carbon

Soil carbon values are obtained using the combined The National Cooperative Soil Survey (NCSS) Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets.

The soil carbon inventory estimates are determined by using the values provided for soil organic carbon and soil bulk density at a depth of 0-30 centimeters.[4] The soil organic carbon estimates are calculated as described in Quantification Guidance for Use with Forest Carbon Projects report from the CAR FPP Quantification Guidance Version 4.0, as shown in the following equation (the Conversion of Organic Matter to Carbon step was skipped as the input data was provided as Soil Organic Carbon, Climate Action Reserve, 2017):

Soil CO_2e	=	Organic Matter Value (Steps 2 or 4) **x** 0.58 (Conversion of Organic Matter to Carbon) **x** Bulk Density Value (Steps 3 or 5) **x** Soil Depth Sampled (30 cm) **x** 40,468,564.224 (Conversion of 1 cm^2 to 1 acre) **x** 10^{-6} (Conversion of 1 gram to 1 metric ton) **x** 3.67 (Conversion of Carbon to CO_2)

Natural Land-based Emissions

GHG inventories for agriculture, forestry, and land use generally include the following emissions categories: [17]

- Changes in soil carbon stocks
- Nitrous oxide emissions from soils (including fertilizers), biomass burning, and drained organic soils.

[17] California Department of Conservation, The Nature Conservancy, Tukman Geospatial, Climate Action Reserve, and Merced County. 2018. Resilient Counties Guide. Available: https://maps.conservation.ca.gov/TerraCount/downloads/. Accessed August 08, 2023.

- Changes in woody biomass carbon stocks.
- Methane emissions from wetland, rice cultivation, and biomass burning.
- Carbon dioxide emissions from burning, liming, urea fertilization, and drained organic soils.
- Carbon monoxide emissions from biomass burning.

For the purposes of the Sonoma County Land-based carbon inventories, only some emissions categories will be estimated based land use systems present in the county and availability of data. Changes in soil carbon stocks will not be captured because the soil data available is only available for 2017. Nitrous oxide emissions from soils associated with fertilizer application for agricultural uses come from anthropogenic sources and are included in the 2020 Sonoma County Communty GHG Emissions Inventory, therefore, they are excluded from this analysis. Woody biomass is the biomass derived from trees. Changes in woody biomass carbon stocks will be captured between 2013 and 2022 based on changes to vegetation type, height, and cover of forested areas.

An assessment of the impacts of wildfire on carbon stock in the county will be provided in the Carbon Inventory and Sequestration Potential Study. Changes in GHG emissions over time are driven by both changes in land use and in land management practices. Temporal data on land management activities is largely unavailable, therefore changes in GHG emission from 2013 to 2022 will be driven by land use change. These carbon stock calculations do not reflect the carbon sequestration associated with the current implementation of land management activities (e.g., application of soil amendments like compost), which are influential for carbon sequestration but often do not result in land cover changes. Land management implementation is not currently being tracked in a comprehensive data set nor compiled for projects countywide, though management practices are being tracked by the Gold Ridge and Sonoma Resource Conservation Districts in a public database project tracker. This RCD management practices tracker will be a significant part of the upcoming Sonoma-Marin Ag and County Climate Coalition (SMACCC) project funded by the USDA Climate Smart Commodities grant[18] and represents a promising start to future tracking of management activities at the County-scale.

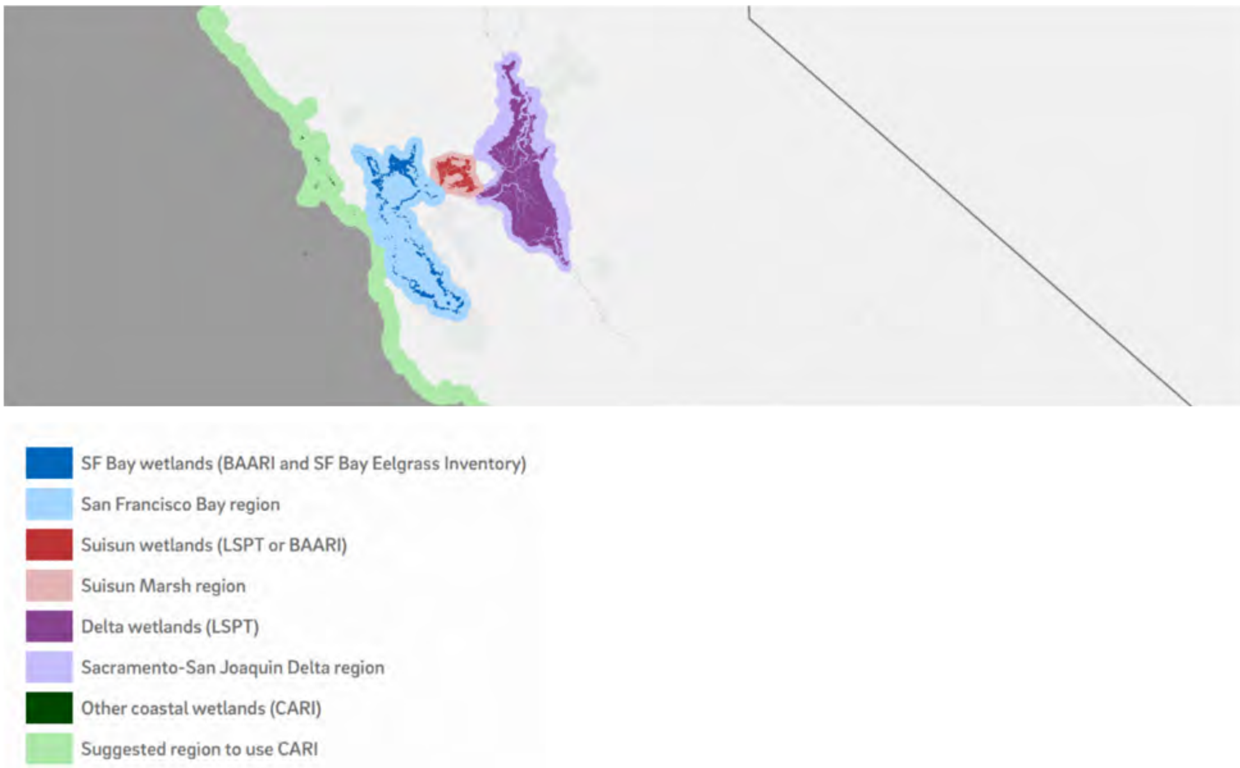
Only methane emissions associated with wetlands will be estimated because rice cultivation is not prominent in the county and data on emissions from biomass burning or drained organic soils in the county are not available. While inclusion of emissions from wetlands is aligned with state practice and IPCC guidelines, it is important to note that it has been shown that coastal wetlands and San Francisco Bay wetlands sequester more carbon each year than they release.[19] These ecosystems provide an important natural, and established source of carbon sequestration in addition to essential habitat for wildlife and other benefits. Emissions from wetlands will be estimated for 2013 and 2022. Carbon GHG emission factors can be applied to wetland acreages to evaluate carbon sequestration and GHG emissions as part of developing reference scenarios against which to measure future change. The San Fancisco Estuary Institute (SFEI) produced a report entitled, “Leverageing Wetlands for a Better Climate Future”, assessing how wetlands can be incorporated into future CARB Scoping Plan NWL assessments and alternative emissions scenarios. As part of this report SFEI identified mapping datasets appropriate to different coastal, bay, and delta regions that could be used to track wetland extents, and for which different emission factors are supplied. Using this map, we concluded that Sonoma wetlands occur in both the “SF Bay wetland” area and the “other coastal wetland” area. For the SF Bay wetland area,

[18] USDA. 2022. Partnerships for Climate-Smart Commodities. https://www.usda.gov/climate-solutions/climate-smart-commodities

[19] Vaughn, L. Smith; Plane, E.; Harris, K.; Robinson, A.; Grenier, L. 2022. Leveraging Wetlands for a Better Climate Future: Incorporating Blue Carbon into California's Climate Planning. SFEI Contribution No. 1084. San Francisco Estuary Institute: Richmond, CA. p 31.

wetland acreages can be derived using the land cover map for each reference year and clipping the wetlands that fall within the BAARI dataset. The SF Bay wetlands specfic emission factor is to be applied to this acreage. The same approach is used to derive coastal wetland acreage using the CARI data set to capture the acreage of land cover classified as wetlands that falls within the coastal region for both reference years. The IPCC teir 1 emission factor will be applied to this acreage to estimate emmissions, as suggested in the SFEI report. Subtracting the coastal and SF Bay wetland acreages from the total wetland acreage in the county provides the inland wetland acreage, for which there are not specific emission factors nor enough specific wetland characteristic data to estimate emissions. A portion of the SFEI wetland region map that includes Sonoma County is shown in Figure 10 below for reference.

Figure 10 SFEI Wetland Region Map



Applying emission factors to wetland acreages is consistent with IPCC guidance for national inventories and has been used by CARB in the current Scoping Plan to evaluate the effect of wetland restoration on the Sacramento-San Joaquin Delta on GHG emissions and soil carbon accumulation or loss. The emission factors supplied for coastal wetland carbon accumulation/loss and GHG emissions are based on a variety or primary data types including peat core samples, radiometric dating of layers in sediment profiles, flux measurements from eddy covariance towers or soil chambers, and biogeochemical models. Table 3 below is a reproduction of the carbon accumulation and GHG emission factors for California coastal wetlands corresponding to the wetland regions delineated in the SFEI report.

Table 3 Carbon Accumulation and GHG Emissions Factors for California Coastal Wetlands

Region	NWL coastal wetland type	Total emissions MT CO_2-e/acre/yr	Soil carbon accumulation MT C/acre/yr	CH_4 emissions MT CO_2e/acre/yr
Delta	Drained wetlands used for agriculture	9.56 (7.77 to 11.3)	-2.51 (-3.00 to -2.03)(1)	0.6 (0.2 to 1.0)(1)
Delta	Rice	7.02 (3.63 to 10.4)	-1.46 (-2.38 to -0.54)(1)	1.8 (1.2 to 2.4)(1)
Delta	Freshwater tidal wetlands	0.10 (-1.03 to 2.01)	0.51 (0.41 to 0.61)(2)	2.2 (1.1 to 4.1)(3)
Delta	Rewetted or restored wetlands (impounded marshes)	1.35 (-0.48 to 3.17)	1.37 (0.94 to 1.81)(1)	7.1 (5.9 to 8.3)(1)
Delta	Seasonal wetlands (organic and highly organic mineral soils)	3.6 (1.7 to 5.5)	-0.98 (-1.5 to -0.46)(4)	0(5)
Delta	Seasonal wetlands (mineral soils)	Data unavailable		
Suisun Marsh	Brackish tidal wetlands	-1.83 (-2.18 to -1.48)	0.50 (0.41 to 0.60)(6)	0.015(7)
Suisun Marsh	Brackish managed seasonal wetlands (organic or highly organic mineral soils)	4.0 (2.2 to 5.4)	-1.1 (-1.5 to -0.6)(4)	0.2(8)
Suisun Marsh	Brackish managed seasonal wetlands (mineral soils)	Data unavailable		
SF Bay	Saline tidal wetlands	-1.39 (-1.68 to -1.08)	0.40 (0.32 to 0.48)(6)	0.1 (0.04 to 0.2)(9)
SF Bay	Eelgrass	-0.55 (-0.95 to -0.19)	0.17 (0.1 to 0.3)(10)	0.1 (0.04 to 0.2)(10)
Statewide	Saline tidal wetlands	-1.26 (-1.55 to -0.93)	0.37 (0.3 to 0.4)(9)	0.1 (0.04 to 0.2)(9
Statewide	Eelgrass	-0.55 (-0.95 to -0.19)	0.17 (0.1 to 0.3)(10)	0.1 (0.04 to 0.2)(10)

Sonoma County wetlands that fall within two of the mapped regions for which there are emissions factors, San Francisco Estuary and other statewide coastal wetlands. Sonoma County also has inland wetlands, specifically lands under the wetland land cover classification that fall outside of the SF Bay and other coastal regions for which there are methodologies and emission factors available. The *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (Wetlands Supplement), and *2019 Refinement to the 2006 IPCC Guidelines*, (Chapter 07: Wetlands) are primarily focused on the GHG emissions and removals for human-altered wetlands and the methodologies required for estimating the anthropogenic emissions and removals associated with that management. Only emission factors and methodologies relevant to coastal wetlands are provided. The *Inventory of U.S. Greenhouse Gas Emission and Sinks 1990-2021* only included GHG emissions and removals from coastal wetlands and other constructed water bodies. The "Leveraging Wetlands for a Better Climate Future" report only provides methodologies and emissions factors for coastal wetlands and delta wetlands. There are insufficient data, emissions factors, or standard methodologies for estimating emissions and removals for inland wetlands, such as wet meadows. Thus, inland wetlands are excluded from the estimated GHG emissions and removals for Sonoma County.

Carbon Inventory Results

Table 4, Table 5, Table 6, and Table 7 below summarize the carbon stock estimates for Sonoma County. Table 4 includes estimates of carbon stored in the various above- and below-ground pools by land cover class. Table 5 includes the estimated carbon stored in soils by each land cover class. Table 6 shows the average carbon stock based on 2013 and 2022, which is the sum of above- and below-ground carbon and soil carbon, per acre for each land cover class in Sonoma County. All carbon stock values are presented in metric tons of carbon dioxide equivalent (MT CO_2e).

Above- and Below-ground Carbon

In Sonoma County, forests hold the most above- and below-ground carbon per acre, followed by grassland/herbacous land, and then developed land which includes carbon stored in the urban forest. According to this analysis, the forest land cover class showed a decrease of 39 percent in above- and below- ground carbon storage per acre. The grassland/herbaceous land class increased from 2.7 to 15.7 MT CO_2e in above- and below-ground carbon stored per acre between the two years, which is a 480 percent increase. This outsized increase is likely due to data artifacts that resulted from the reclassification of grasslands during the data refinement process.[20] The wetland land cover class shows a decrease of 33 percent in above- and below- ground storage per acre between the two years. These changes in per acre carbon storage are due to changes, or dataset differences, in vegetation type, height, and/or percent cover between the two years. All other land cover classes maintained the same amount of above- and below- ground carbon storage per acre between the two datasets.

Table 4 2013 and 2022 Sonoma County Above- and Below- Ground Carbon per Acre

Land cover Class	2013 Average Above- and Below-Ground Carbon/Acre (MT CO_2e)	2022 Average Above- and Below-Ground Carbon/Acre (MT CO_2e)
Barren	0.8	0.8
Cultivated and Field Crops	2.0	1.7
Development	15.5	14.1
Forest	68.5	41.8
Grassland/Herbaceous	2.7	15.7
Open Water	0.0	0.0
Orchard	7.5	7.5
Pasture and Hay	2.3	2.1
Shrub/Scrub	13.1	13.5
Vineyard	1.6	1.6
Wetland	3.1	2.5

[20] The Sonoma Veg Map data layer does not include vegetation height and cover classifications for the grassland and shrub/scrub categories. To resolve this, the missing attribute data was substituted from the closest LANDFIRE 2014 data point which does include a vegetation height and cover classification associated with it. Vegetation height, vegetation cover, and vegetation type are necessary to join to the CARB volumetric dataset that contains the carbon values necessary for estimating carbon stocks. By pulling the required data from LANDFIRE (which is a lower resolution data source than the Sonoma Veg Map) there may be discrepancies in the vegetation height and cover data utilized that affect the estimated carbon stock values.

Soil Carbon

Soil carbon values are obtained using the combined NCSS Characterization Database, the National Soil Information System (NASIS), and the Rapid Carbon Assessment (RaCA) datasets. The soil carbon inventory estimates are determined by using the values provided for soil organic carbon and soil bulk density at a depth of 0-30 centimeters.[21] Because the soil data used is from a snapshot in time (2017) it does not capture changes in soil carbon over time due to management or land cover change. Future inventories should use updated data, as available, to reflect changes in soil carbon over time.

While the soil data is a snapshot and soil carbon values did not change between years, the average soil carbon per acre associated with each land cover did change. This change is due to the carbon content of the soil in the land areas classified under the different land cover types. If the vegetation or land use changes on a piece of land changes between datasets, causing a shift in land cover classification, the land cover may include areas with more or less carbon rich soils than it did in the previous dataset, resulting in changes in the soil carbon attributed to that landcover. For example, the 2022 LANDFIRE dataset included more area designated as open water, compared to the 2013 dataset. Because LANDFIRE data is in raster format with a resolution of 30x30 meter pixels rather than the fine-resolution data from Sonoma Veg Map's 2013 data, there was likely more soil, including more carbon rich soils, attributed to that land cover than in 2013, increasing the average per acre soil carbon. It is also important to note that soil carbon is only one component of total carbon stock, so changes in soil carbon associated with a land cover may be offset by changes to the above and belowground carbon for that landcover resulting in increases or decreases in total carbon based on the sum of those carbon pools.

Table 5 2013 and 2022 Sonoma County Soil Carbon per Acre

Land cover Class	2013 Average Soil Carbon/Acre (MT CO_2e)	2022 Average Soil Carbon/Acre (MT CO_2e)
Barren	88	88
Cultivated and Field Crops	64	80
Development	58	59
Forest	79	80
Grassland/Herbaceous	69	68
Open Water	40	59
Orchard	58	57
Pasture and Hay	123	93
Shrub/Scrub	83	84
Vineyard	56	57
Wetland	175	175

The carbon inventories associated with each land cover type, including all above- and below-ground biomass and soil carbon for 2013 and 2022, are provided in Table 6 (carbon stock per acre) and Table 7 (total carbon stock). In 2022, forests stored the most total carbon per acre followed by grassland/herbaceous lands, developed lands, and shrub/scrub lands. Table 7 shows the total carbon

21 A portion of soil organic carbon is located below 30 centimeters, and management practices that lead to enhanced carbon storage in both shallow and deep soils will be included in the carbon sequestration potential assessment for this project.

stock countywide for each landcover type in 2013 and 2022 and the percent change between the two years. In both years, forests and grassland/herbaceous lands held the most, and second most total carbon in the county (respectively). As shown in Figure 11 and Figure 12, most of the carbon stock in Sonoma County is held in forested areas in the west and east, and wetlands in the south.

Table 6 2013 and 2022 Sonoma County Carbon Stock per Acre

Land Cover Class	2013 Total Carbon Stock per Acre ($MT\ CO_2e$)	2022 Total Carbon Stock per Acre ($MT\ CO_2e$)
Barren	88.4	88.7
Cultivated and Field Crops	65.9	81.9
Development	73.9	73.6
Forest	147.0	121.5
Grassland/Herbaceous	71.8	83.5
Open Water	40.2	59.4
Orchard	65.0	64.7
Pasture and Hay	125.3	94.6
Shrub/Scrub	96.5	97.7
Vineyard	58.0	58.6
Wetland	88.4	88.7

Table 7 2013 and 2022 Sonoma County Total Carbon Stock

Land Cover Class	2013 Total Carbon Stock ($MT\ CO_2e$)	2022 Total Carbon Stock ($MT\ CO_2e$)	Percent Change between 2013 and 2022 ($MT\ CO_2e$)
Barren	440,119	367,468	-17
Cultivated and Field Crops	100,577	101,027	0
Development	6,962,559	7,749,627	11
Forest	78,034,944	61,577,998	-21
Grassland/Herbaceous	18,109,720	17,986,840	-1
Open Water	675,920	1,303,248	93
Orchard	239,362	202,396	-15
Pasture and Hay	2,396,328	3,944,917	65
Shrub/Scrub	4,094,253	5,196,075	27
Vineyard	3,593,475	4,582,317	28
Wetland	2,945,905	2,354,039	-20
Total	**117,593,161**	**105,365,950**	**-10**

Figure 11 2013 Total Carbon Stock

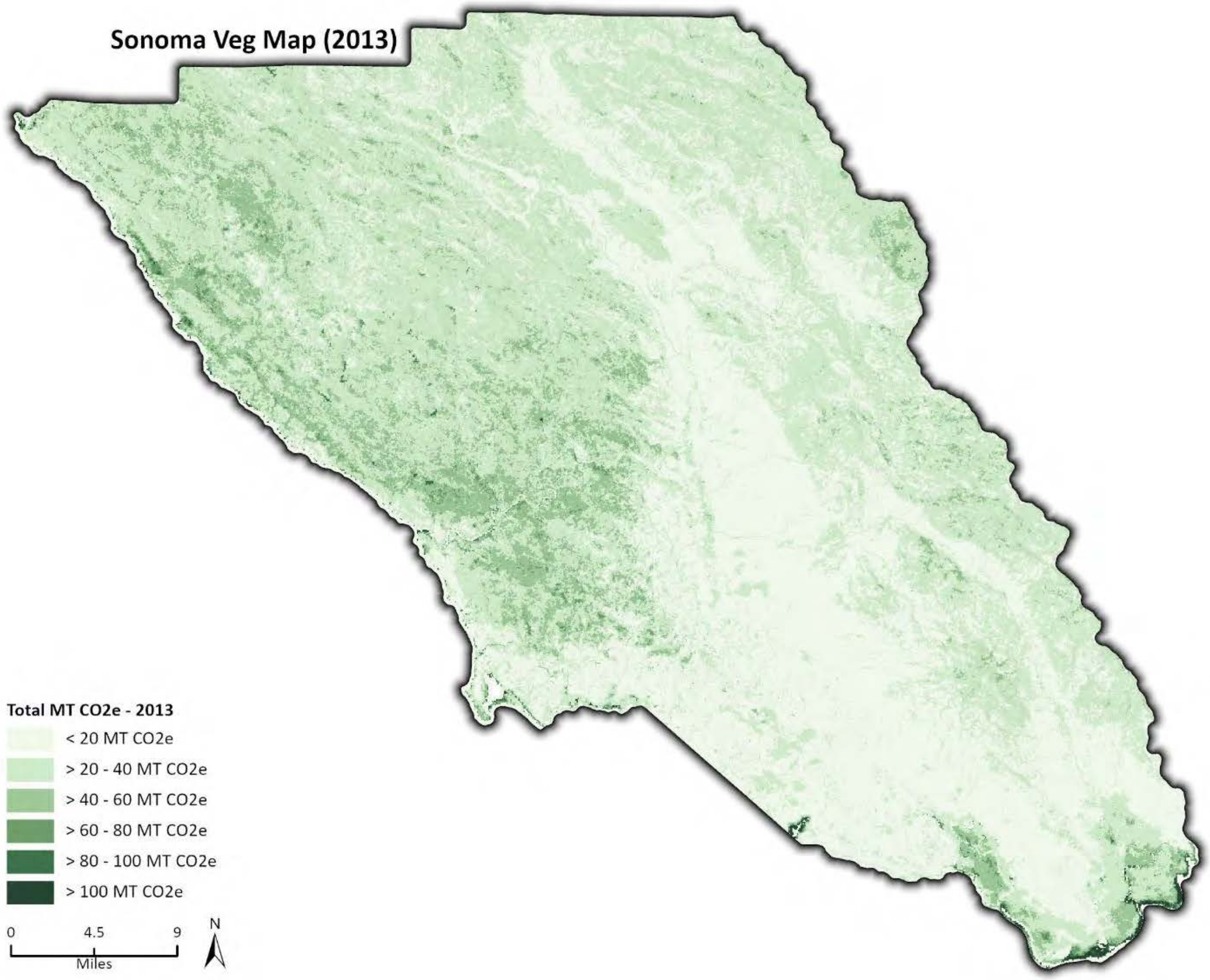
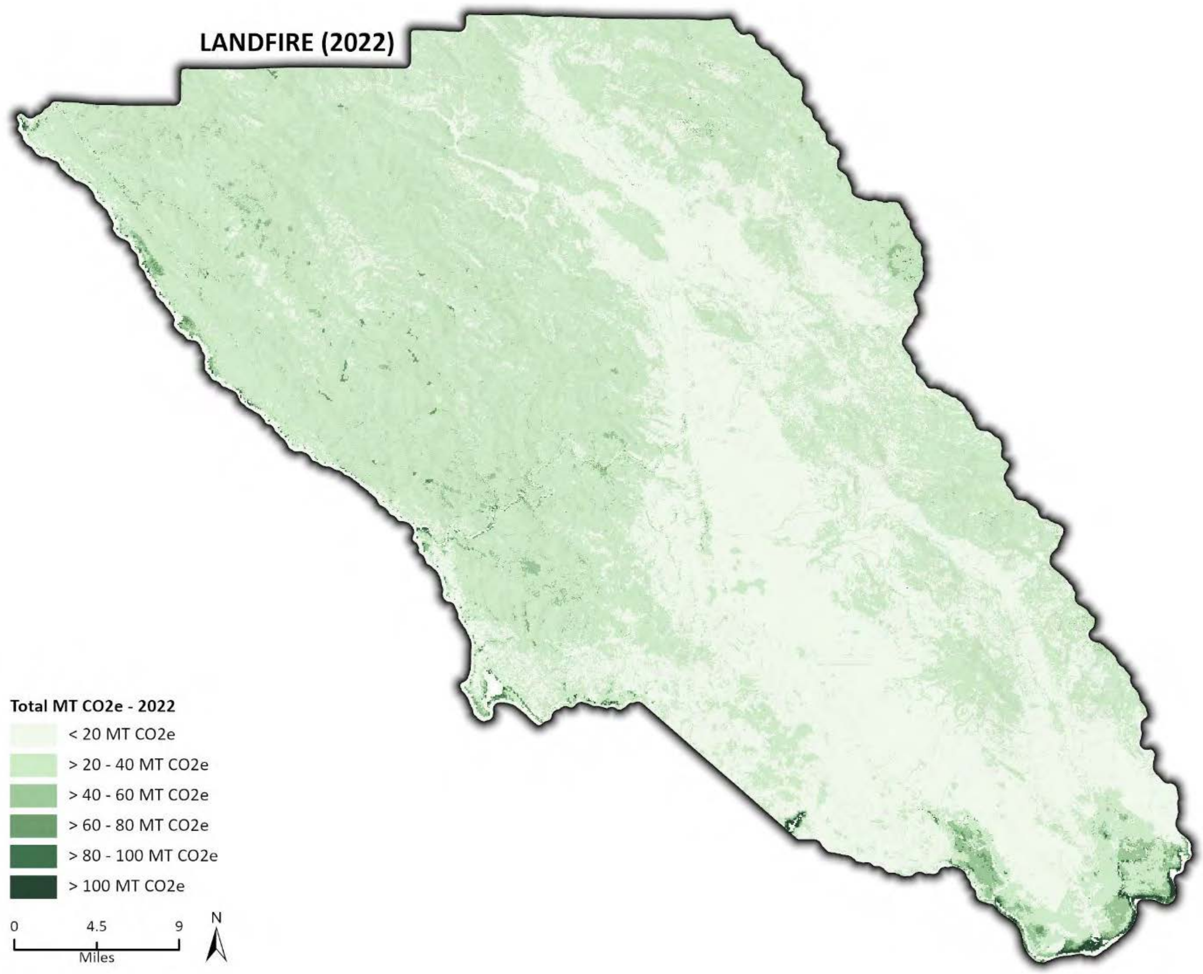


Figure 12 2022 Total Carbon Stock

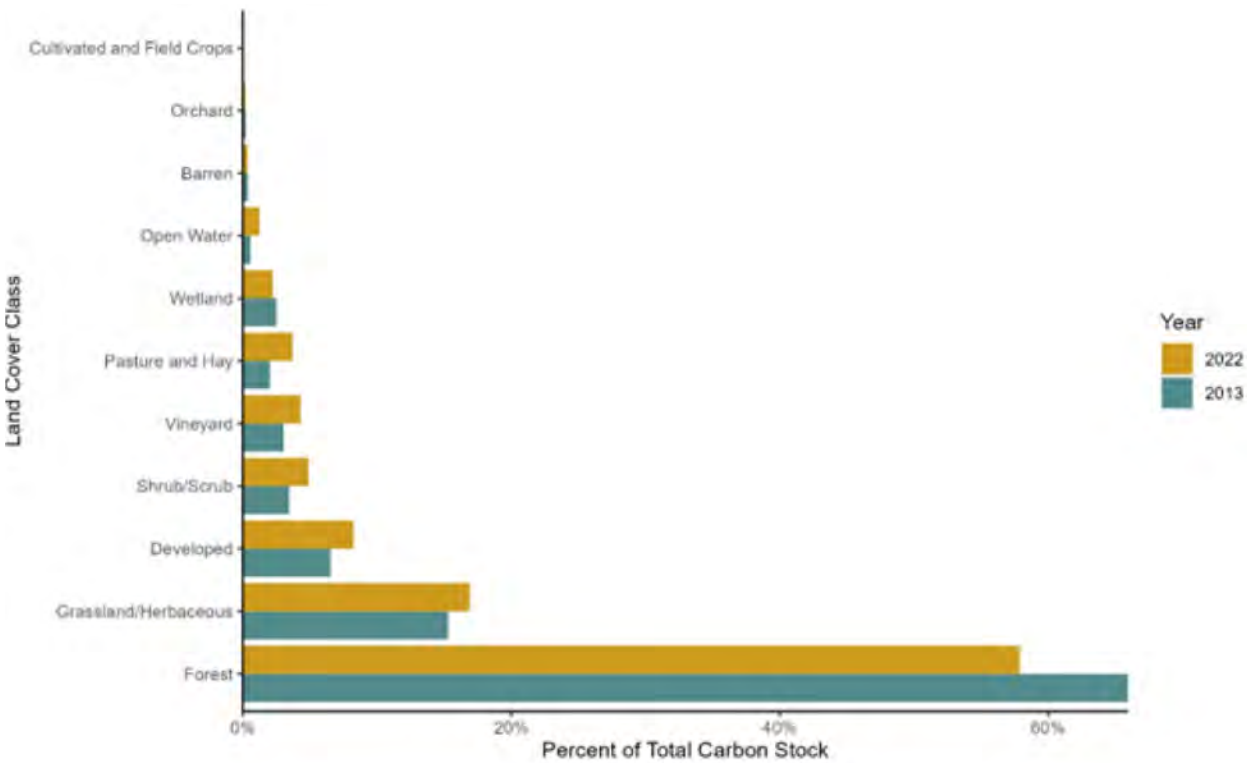


As described and illustrated in the Land Cover Classification section above, three landcover types (development, grassland/herbaceous, and forests) cumulatively accounted for 83 percent of all landcover types in 2022 (development: 7 percent; forests: 58 percent; grassland/herbaceous: 17 percent). Accordingly, changes in development, grassland/herbaceous, and forest acreage accounted for the most significant changes in landcover type in Sonoma County between the two years, also discussed above. This change in land cover acreage is reflected in the carbon stock values. Changes in carbon stock are due not only to changes in vegetation type (e.g., loss of forestland, shrub/scrub to grassland) but also vegetation height and cover. The paragraphs below describe the connections between increases/decreases to landcover, and corresponding increases/decreases to carbon stocks.

The forest land cover class encompassed approximately 51 percent of the total land cover area in 2013, whereas it accounted for 48.5 percent in 2022. The data shows a 16,456,946 MT CO_2e decrease (21 percent) in carbon stock held in forests between the two years, the largest decrease in total carbon stocks across Sonoma County. The second most significant decrease in carbon stocks comes from wetlands total carbon stock, which decreased by 20 percent (591,866 MT CO_2e) between 2013 and 2022. Between 2013 and 2022, development acreage increased slightly from 9 percent to 10 percent of total land cover, with a corresponding slight increase in carbon stock. Pasture and hay, when considered collectively with grassland/herbaceous, experienced a loss of 14,300 acres between years, but increased in carbon stock by 1,425,709 MT CO_2e. This could be due to differences in map classifications.

Agricultural land acreage in Sonoma County differed between the two years. Compared to 2013, 2022 shows 19 percent less cultivated and field crops, 15 percent less orchard, 118 percent more pasture and hay, and 26 percent more vineyards. Agricultural land acreage differences are also reflected in the carbon stocks for those land cover classes. Compared to 2013, 2022 shows a 15 percent decrease in orchard carbon stock. Total carbon stock for cultivated and field crops increased by 450 MT CO2e, less than 1 percent, between 2013 and 2022. As described above, pasture and hay experienced a 65 percent increase between the two datasets, while grasslands saw a 1 percent decline. This increase in pastureland and hay, and decrease in grasslands is likely due to differences in map classification between the two years. Considered collectively (pasture and hay plus grassland/herbaceous), the combined land types stored approximately 1,425,709 MT CO_2e more carbon in 2022 compared to 2013, and declined in total landcover type by 14,300 acres, or about 5 percent. Vineyards also experienced growth in both acreage and carbon stock, increasing acreage by 26 percent, and containing 988,842 more MT CO_2e carbon in 2022 compared to 2013. Figure 13 shows the proportional carbon stock changes between 2013 and 2022 for each land classification.

Figure 13 2013 and 2022 Sonoma County Proportional Carbon Stocks



Carbon Stock by Land Ownership

The pace and scale of future implementation of nature-based solutions (NBS) will differ depending on land ownership. Public and private landowners both play critical roles in the implementation of NBS. Private lands make up 88 percent of Sonoma County and play a large goal in carbon sequestration and emissions reductions. Implementing widespread NBS on privately held land requires coordination with many individual landowners with costs shared across participating landowners and supporting agencies. The County has an important role to play in both arenas (public, and private land), as implementing NBS across these land types require overcoming shared challenges of planning, permitting, funding, and implementation hurdles.

For example, the County can establish policies and incentives needed to facilitate land management shifts on privately owned land, the implementation of which will ultimately be up to the time, resources, motivation, and knowledge of the private landowner. Publicly owned lands may have greater potential to implement NBS in the near-term and at a larger scale, if available funding can be leveraged and cooperation across agencies coordinated to minimize planning and implementation hurdles. County or other public policy changes can catalyze new conservation easements and provide support to stakeholders like Resource Conservation Districts (RCDs) in implementing specific land management practices that can maximize NBS outcomes. For example, the County could explore means to support implementation of conservation practices through actions including generation of funding sources, tax incentives for good stewardship, and provide additional support to help RCDs overcome potential hurdles to implementation.

County-owned lands are broken out as a subsection of publicly owned land, and include Sonoma County, Ag + Open Space, and Sonoma County Water Agency. There are over 300 owners of public land in Sonoma County. The County of Sonoma owns the majority of the land, followed by the State of California, City of Santa Rosa, Sonoma County Water Agency, City of Petaluma, and City of Rohnert Park. Of the County-owned land, County of Sonoma owns the most land, followed by Ag + Open Space, and Sonoma County Water Agency. In Sonoma County 88 percent of land is privately owned, while 12 percent of land is publicly owned. Among publicly owned land types, County land ownership through Sonoma County, Ag + Open Space, and the Sonoma County Water Agency account for 24 percent of total publicly owned land acreage, with Sonoma County owning the largest total share of acres. Table 8 and Figure 14 depict landcover types by property owner, showing where lands are privately, or publicly owned.

Table 8 Total Metric Tons of Carbon and Acreage by Landownership Category

Landowner	2022 Total Acres	2022 Total $MTCO_2e$*
Privately Owned	881,225	88,841,962
Publicly Owned	111,974	12,513,728
Total	**993,199**	**101,355,691**
County Land Ownership Summary**		
Sonoma County	18,831	1,837,223
Ag + Open Space	6,972[1]	126,405
Sonoma County Water Agency	2,400	202,888
Total	**28,202**	**2,166,515**

Source: Sonoma County Ag + Open Space, 2023.

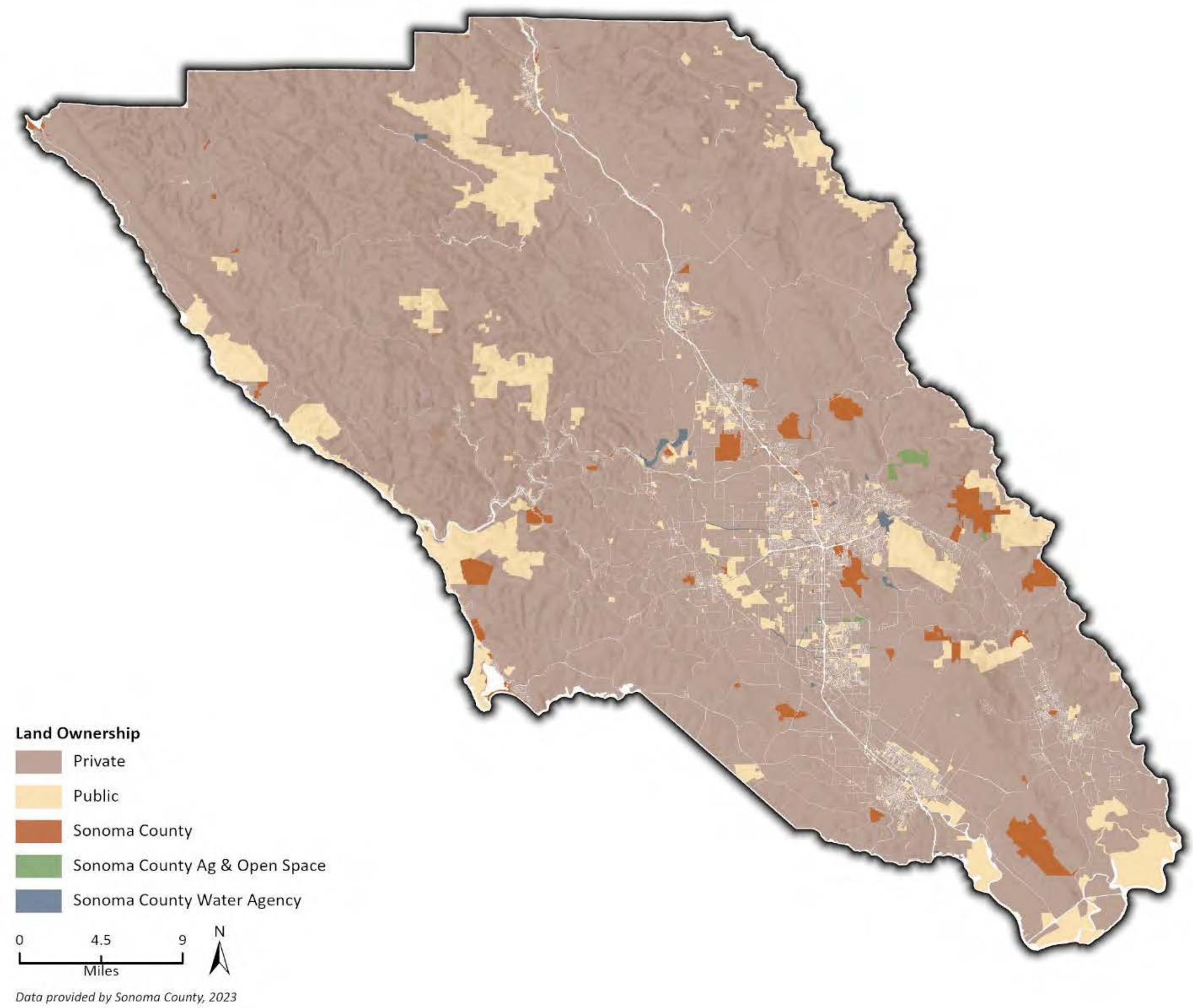
Notes: Acres have been rounded to the nearest whole number therefore sums may not match.

* The total acreage for this analysis is 1,044,416 for Sonoma County, which is 5% larger than the countywide acreage calculated from the landownership data provided by County of Sonoma Ag + Open Space. This difference in total acreage flows through to the carbon stock estimates in this table. LANDFIRE data is in raster format we needed to include a 1,000 ft buffer to ensure all areas of the County were captured.

**Subsection of Publicly Owned land, County lands

[1] In addition, Ag + Open Space holds 251 conservation easements on over 122,400 acres, which preserve agricultural lands, open space, and natural resources. Potential for nature-based solutions implementation on these lands will also be considered in the Carbon Inventory and Sequestration Potential Study.

Figure 14 2022 Public & Private Ownership Categorization



Wetlands Emissions

Emissions from wetlands are estimated for 2013 and 2022. Sonoma County wetlands occur along the San Francisco Estuary, the coast, and inland. There are no emission factors that may be applied to the inland wetland acreages and there is insufficient data about those wetlands available to use a more complex model to estimate emissions, therefore they are excluded from this report. To determine wetland acreages the 2013 and 2022 wetlands data was sorted uses the Coastal Zone GIS layer from the California Coastal Commission to determine the extent of coastal wetlands, the BAARI GIS data layer to determine the extent of SF Bay Estuary wetlands, and the remaining wetlands were determined to be inland. Table 9 below shows the wetland acreages, emission factors, and total annual emissions estimates for the coastal and San Francisco Bay wetlands in the Sonoma County. The total annual emission factors provided by SFEI are negative, indicating that SF Bay Estuary wetlands and coastal wetlands sequester more carbon dioxide equivalent than they emit in a given year. This is reflected in the total annual emissions values.

Table 9 Sonoma County Wetland Carbon Stock and Emissions

Year	SFEI Wetland Region	CH_4 Emission Factor (MT CO_2e/Acre/Year)	CH_4 Annual Emissions (MT CO_2e)	Total Emission Factor (MT CO_2e/Acre/Year)	Total Annual Emissions (MT CO_2e)
2013	SF Bay	0.1	1,236.0	-1.39	-17,180.69
	Statewide Coastal	0.1	104.5	-1.26	-1,316.44
	Inland	N/A	N/A	N/A	N/A
2022	SF Bay	0.1	842.0	-1.39	-11,704.29
	Statewide Coastal	0.1	83.0	-1.26	-1,045.75
	Inland	N/A	N/A	N/A	N/A

Conclusion and Next Steps

This memorandum provides an overview of the data used for the land classification analysis, the results for the County's land classification analysis for 2013 and 2022, a summary of the methodology, the results for the land-based carbon inventories, and the limitation of the data and results. The carbon inventories provide a quantitative estimate of historical and existing carbon stored countywide.

TerraCount is a scenario analysis tool which was piloted for the Resilient Counties Guide, to develop scenarios of change in land use and land management and evaluate future impacts on carbon stocks. The tool was developed by the Department of Conservation and The Nature Conservancy. Recently, it was determined by the Department of Conservation that TerraCount could not run for counties other than Merced County without substantial customizations, including modifications to the code base. The carbon sequestration potential and complementary benefits analysis for Sonoma County will be completed outside of the TerraCount model following the TerraCount methodology provided in the TerraCount activity sheets, which detail equations for calculating carbon sequestration potential and a qualitative assessment for complementary benefits, as well as COMET-Planner calculations for agricultural practices, as that is the tool used for estimating benefits and payments to farmers for the Healthy Soils Program.[22]

The following land management activities were assessed as part of the Resilient Counties Guide. These practices may be assessed to help develop and prioritize policies to prevent future loss of carbon stocks and increase carbon sequestration:

- Oak woodland restoration
- Cover crops
- Mulching
- Riparian restoration
- Urban forestry
- Hedgerow planting
- Avoided conversion to croplands
- Avoided conversion to urban
- Compost application to grasslands
- Native grassland restoration

Upon review of this memorandum and approval from the County, Rincon will begin refining and assessing land management and carbon sequestration strategies in consultation with the County of Sonoma's Climate Action and Resiliency Division (CARD) in the County Administrator's Office, Ag + Open Space, Sonoma Water, Permit Sonoma, the Regional Climate Protection Authority, University of California Cooperative Extension, Gold Ridge Resource Conservation District, Sonoma Resource Conservation District and Carbon Cycle Institute. Please let us know if you have any questions, comments or concerns with results described in the Sonoma County land-based carbon inventories.

Sincerely,
Rincon Consultants, Inc.

Camila Bobroff
Sustainability Planner/Assistant Project Manager

Lexi Journey
Senior Planner/Project Manager

Erik Feldman, MS, LEED AP
Principal

[22] The TerraCount model will not be run for Sonoma County as it is not set up to be transferrable to counties other than Merced County without substantial modifications to the code base. Instead, TerraCount activity sheets will be used to calculate carbons sequestration potential. TerraCount. N.d. Appendix L Activity Sheets. Available: <https://maps.conservation.ca.gov/TerraCount/downloads/>. Accessed May 9, 2022.

Sonoma County

Carbon Sequestration Analysis of Climate Smart Practices

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Introduction

This memorandum describes carbon sequestration potential analysis of climate smart practices for Sonoma County's natural and working lands This carbon sequestration potential analysis is intended to illustrate opportunities for increasing the carbon stocks (i.e., through carbon sequestration) and mitigation of potential carbon stock losses on natural and working lands countywide, through land management activities, such as urban forestry, fuels reduction, prescribed grazing, and native grassland restoration, etc.). This study builds on the analysis completed in the *Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum*. That analysis evaluated the acreage classified under various land cover types (the physical description of what is on a piece of land) and the associated carbon stocks in the soil and biomass for each land cover type. This memorandum details the Sonoma County carbon sequestration potential for natural and working lands and complementary benefits, providing a summary of the results of the quantitative analysis. The results of this analysis will be included in the Sonoma County Carbon Sequestration Potential Study currently being developed by the County of Sonoma. These results can then be used to identify a suite of potential strategies for increasing carbon sequestration and protecting carbon stocks in the county. Additionally, the results of this analysis and the related co-benefits analysis demonstrate the significant potential that application of climate smart management practices to Sonoma County's natural and working lands can have for reducing or avoiding emissions, sequestering carbon, and bringing numerous agroecological and social co-benefits to the community.

This study is intended to provide a starting point for further analysis informed by local climate smart practice planning and implementation activities. The County, along with many regional partners, has embarked on the Sonoma-Marin Ag and County Climate Coalition (SMACCC) project, funded by the USDA Climate Smart Commodities grant program. SMACCC project implementation and monitoring efforts within Sonoma County will be led by the Gold Ridge Resource Conservation District and the Sonoma Resource Conservation District (RCDs). The RCDs will leverage their local expertise and ongoing relationships with the agricultural community to increase the pace and scale of carbon farm planning and climate smart practice implementation. Data gathered from these efforts will be used to refine the sequestration and co-benefits analysis, further localized climate smart agricultural planning, and evaluate realistic adoption targets for practices given the sequestration potential, logistics, costs, and numerous co-benefits associated with each practice. Future planning for climate smart practice implementation should incorporate RCD data based on local implementation activities as much as possible and be guided by the work of the Sonoma-Marin Ag and County Climate Coalition. Additionally, future analysis could elaborate on how the land use categories utilized for the purposes of this study equate to local zoning designations, to aid decision makers in incorporating these findings into general plan policies and goals. What is Carbon Sequestration?

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide.[1] Natural and working lands play a critical role in sequestering carbon. Biological carbon sequestration occurs as part of the carbon cycle. The carbon cycle is the exchange of carbon between the atmosphere, biosphere (plants, animals, and other life forms), hydrosphere (water bodies), pedosphere (soils), and lithosphere (Earth's crust and mantles, including rocks and fossil fuels). Carbon moves between

[1] United States Geological Survey (USGS). N.d. What is carbons sequestration? Available <https://www.usgs.gov/faqs/what-carbon-sequestration>. Accessed October 2022.

land types (e.g., forests and grasslands) and carbon pools (e.g., wood, roots, and soils) due to natural processes (growth, decay, and succession) and disturbances (e.g., wildfire) or human-induced disturbances like land use change from natural lands to development or greenhouse gas (GHG) emissions from burning fossil fuels.[2]

Regulatory Context

As a global leader in the effort to combat climate change, the State of California has enacted legislation, regulations, and executive orders (EO) that put the state on course to achieve robust emissions reductions and address the impacts of a changing climate. Below is a brief overview of a subset of state legislation that addresses emissions reductions targets and plays a role in setting the standards for how natural and working lands will help to achieve the State's climate goals.

- **Assembly Bill 32.** On September 27, 2006, the California legislature signed Assembly Bill (AB) 32 – the Global Warming Solutions Act – into law, requiring a reduction in statewide GHG emissions to 1990 levels by 2020 and the California Air Resources Board (CARB) preparation of a Scoping Plan that outlines the main State strategies for reducing GHGs to meet the 2020 deadline.
- **Senate Bill 1386.** Signed into law on September 23, 2016, SB 1386 directs State agencies to consider the carbon sequestration potential of natural and working lands "when revising, adopting, or establishing policies, regulations, expenditures, or grant criteria related to their protection and management."
- **Senate Bill 32.** On September 8, 2021, the California legislature signed Senate Bill (SB) 32 into law, extending AB 32 by requiring further reduction in statewide GHG emissions to 40 percent below 1990 levels by 2030.**Executive Order N-82-20 to Achieve 30 Percent Land Conserved by 2030 (30 by 30).** On October 7, 2020, Governor Newsom issued EO N-82-20, which established a new statewide goal of conserving 30 percent of the state's lands and coastal waters by the year 2030. The order directs The California Natural Resources Agency (CNRA) , the California Department of Food and Agriculture, the California Environmental Protection Agency, the Governor's Office of Planning and Research, and other state agencies, to identify and implement near- and long-term actions to protect and restore the state's biodiversity, accelerate natural removal of carbon, and build climate resilience in our forests, wetlands, urban greenspaces, agricultural soils, and land conservation activities in ways that serve all communities. The executive order further directed the state agencies to develop the Natural and Working Lands Climate Smart Strategy which serves as a framework to advance the State's carbon neutrality goal and guide for natural and working lands strategies and actions.
- **Senate Bill 27.** On September 23, 2021, Governor Newsom signed SB 27 into law, which requires the CNRA to develop a registry of natural and working lands projects that are seeking funding. CNRA must also adopt regulations governing how projects may be listed and what methodologies are used to account for carbon reductions. The bill also required the California Air Resources Board (CARB), as part of its 2022 scoping plan, to establish specific carbon dioxide removal targets for 2030 and beyond.

[2] California Air Resources Board (CARB). 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands. Available: <https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf>. Accessed October 27, 2021.

- **Assembly Bill 1279.** On September 16, 2022, Governor Newsom signed AB 1279 into law, which codifies the State goal to achieve statewide carbon neutrality as soon as possible, no later than 2045, and establishes an 85 percent direct emission reduction target as part of that goal.
- **Assembly Bill 1757.** On September 16, 2022, Governor Newsom signed AB 1757 into law, which requires the State to develop an achievable carbon removal target for natural and working lands.
- **2022 Scoping Plan for Achieving Carbon Neutrality (2022 Scoping Plan).** In December of 2022, CARB formally adopted the 2022 Scoping Plan which lays out a path to achieve targets for carbon neutrality and reduce anthropogenic greenhouse gas (GHG) emissions by 85 percent below 1990 levels no later than 2045, as directed by Assembly Bill 1279. The plan sets targets and establishes strategies for increased action on natural and working lands to reduce emissions and sequester carbon.

Natural and working lands are a key sector in the State's climate change strategy. California's natural and working landscapes, such as forests and farms, are home to the most diverse sources of food, fiber, and renewable energy in the country. These lands underpin the state's water supply and support clean air, wildlife habitat, and local and regional economies. They also comprise a significant carbon stock and the potential to store even greater quantities of carbon. However, they are often the first to experience the impacts of climate change. Thus, it is important to deploy strategies to effectively manage natural and working lands, minimize loss due to climate change impacts, and maximize opportunities for increased sequestration.

Though carbon sequestration does not directly reduce a community's GHG emissions, it can complement GHG reduction strategies being implemented in other sectors like energy use and transportation and contribute to achieving carbon neutrality. All sources of emissions will not be able to be reduced entirely and some sequestration will be required to reach the County's 2030 carbon neutrality target.

Evaluating and Increasing Carbon Sequestration Potential

Sonoma County includes large areas of natural and working lands and a diversity of land cover types, ranging from developed land (cities, towns, roads) to forested lands. Achieving success in protecting the existing land based carbon stock and natural and lands involves developing and implementing programs that protect and enhance natural and working lands, establishing a baseline carbon stock, and measuring and monitoring progress through landscape carbon inventories.[3] While community GHG inventories provide estimates of anthropogenic GHG emissions in a jurisdictional boundary, such as energy use and transportation emissions, a landscape carbon inventory provides an estimate of ecosystem carbon stored in the land.[4] Landscape carbon inventories focus on carbon stored and released from the land, whereas community GHG inventories estimate GHGs emitted from human activities.

Evaluating carbon sequestration potential using landscape carbon inventories and developing feasible sequestration strategies (e.g., restoration and tree planting) complement and support the achieving the targets of AB 1279 to achieve carbon neutrality as soon as possible, no later than 2045, and maintain negative emissions thereafter. The CARB 2022 Scoping Plan found that natural and working lands are likely to be a net source of GHG emissions due to increased extent and frequency of wildfires through the end of the century, mostly occurring in forests and shrublands. Wildfire presents a risk of releasing carbon from existing carbon stocks. Climate change is likely to increase wildfire occurrences, extent and severity. Thus, it is important to take action to prevent wildfire, preserving existing carbon stocks, and fostering increased sequestration in biomass (above and below ground vegetation) and soils as much as possible through climate smart practices. This appendix includes a Carbon Sequestration Potential analysis for appropriate natural and working land sequestration activities, methodology, and results of the carbon sequestration potential and co-benefits analysis for Sonoma County.

State guidance used to complete the carbon sequestration potential analysis include California's 2022 Climate Change Scoping Plan, the State's Natural and Working Lands Inventory, TerraCount scenario planning tool developed by the Department of Conservation (DOC) and The Nature Conservancy for the purpose of estimating the benefits of land management activities at the County level and COMET-Planner HSP developed to support the Healthy Soils Program and other programs coordinated by the California Department of Food and Agriculture and CARB.[5,6,7,8,9]

Some terminology may be helpful to define before delving further into the methodology and results.

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3 CARB. 2017. Scoping Plan. Available <https://ww2.arb.ca.gov/sites/default/files/classic/cc/scopingplan/scoping_plan_2017.pdf>. Accessed April 14, 2022.

4 CARB. 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands. Available: <https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf>. Accessed October 27, 2021.

5 CARB. 2017. California's 2017 Climate Change Scoping Plan. Available: <https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf>. Accessed May 26, 2021.

6 Note: The CARB 2022 Draft Climate Change Scoping Plan was not used as it is still at the draft stage and has not been finalized. Therefore, the CARB 2017 Scoping Plan is still the most current Scoping Plan available. The Draft 2022 Scoping Plan was reviewed, but the 2017 Scoping Plan was the primary Scoping Plan referenced in the production of this memorandum.

7 CARB. 2018. An Inventory of Ecosystem Carbon in California's Natural & Working Lands. Available: <https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf>. Accessed May 26, 2021.

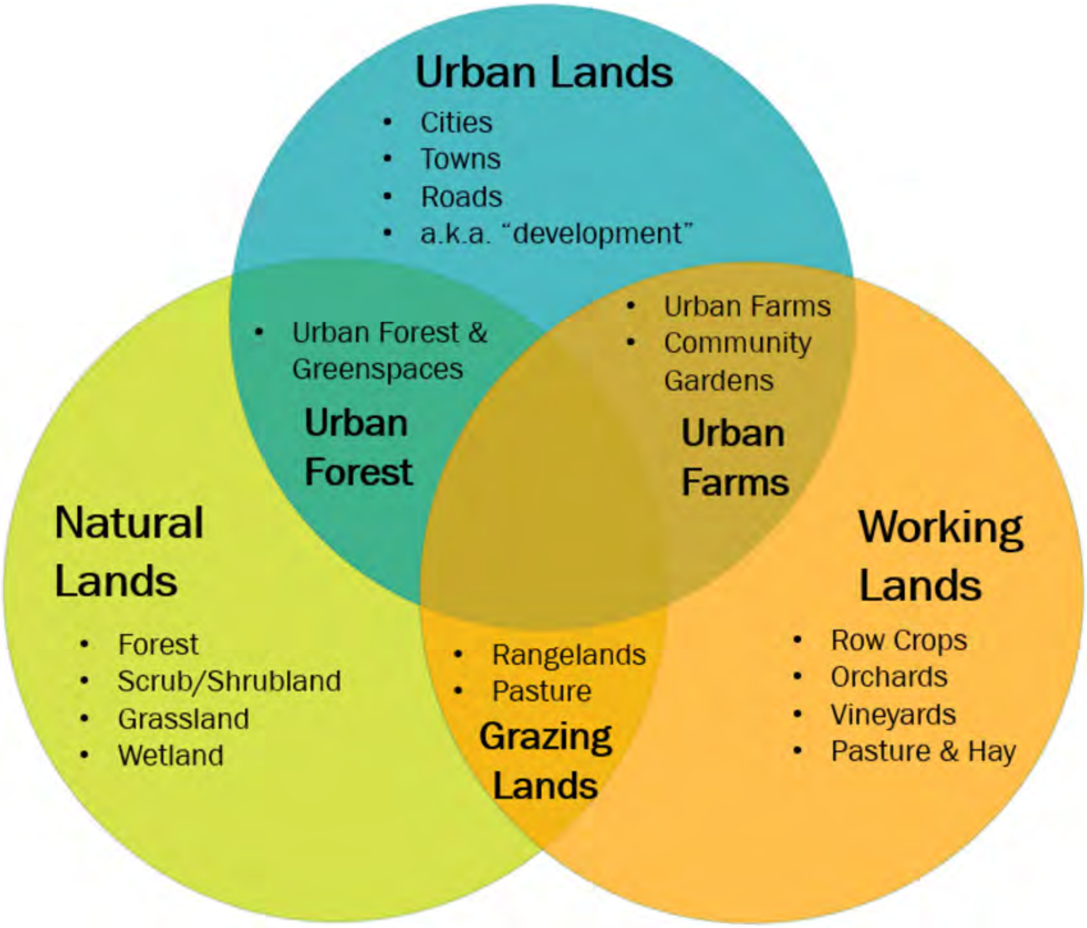
8 Department of Conservation (DOC). TerraCount. <https://maps.conservation.ca.gov/terracount/>. Accessed August 24, 2023.

9 COMET-Planner. < http://comet-planner-cdfahsp.com/>.

- **Climate Smart Practices** are land management activities that leverage natural processes to sequester carbon from the atmosphere into and avoid carbon stock losses from natural and working lands through practices like vegetation management, compost application, and ecosystem restoration.
- **Land Cover** class or type refers to the physical description of what is on the land. The classes include development, wetland, forest, scrub/shrubland, grassland, pasture/hay, orchard, vineyard, and row crops, and can be grouped into overarching land use categories (natural, working, etc.) These are the land cover classes quantified in the *Sonoma County Land Cover, Carbon Stock, and Natural GHG Emissions Inventory Results Memorandum* analysis upon which this analysis builds.
- **Natural and Working Lands** include natural ecosystems of different types, lands used for agricultural production and urban green spaces. Natural land types found in Sonoma include wetlands, forests, shrublands, and grasslands. Working land types found in Sonoma include pasture, vineyards, and croplands. Natural land types found in Sonoma include wetlands, forests, and oak woodlands.
- **Urban Lands** include all developed areas.
- **Urban Forests** include urban parks, street trees, landscaped boulevards, gardens, river and coastal promenades, greenways, river corridors, nature preserves, shelter belts of trees.
- **Urban Farms** include field crops, orchards, and vineyards cultivated in an urban environment.
- **Grazing Lands** include rangelands and pastures, which are both used for grazing.

Some of the terms are similar and some practices are described by the land cover they are applied to while others may be grouped into a more overarching land use category. Some land uses and the associated climate smart practices fall in between the natural and working lands categories, or natural and urban lands categories as illustrated in Figure 1.

Figure 1 Land Use Categories and Land Cover Classes



Carbon Sequestration Potential and Complementary Benefits

The carbon sequestration potential and complementary benefits (co-benefits) analysis for Sonoma County natural and urban lands was completed following the TerraCount methodology provided in the TerraCount Activity Sheets, which is based on National Resource Conservation Service Conservation practices and COMET-Planner HSP, which assesses NRCS practices. The TerraCount Activity Sheets were developed as part of the Resilient Counties Guide in collaboration between Merced County, The Nature Conservancy, and the California Department of Conservation. These Sheets detail equations for calculating carbon sequestration potential and provide a qualitative assessment of complementary benefits.[10] COMET-Planner provides estimated sequestration based on conservation practices, agricultural land cover, and implementation acreage. The following sections describe the methodology and results of this analysis. These two tools provide per acre annual GHG reduction rate and leakage discount[11] (if applicable) to calculate estimated GHG reductions. Users provide total acreage upon which the activity is to be implemented (i.e., "implementation acreage") and the duration of the activity (if applicable). Activities were selected based on their appropriateness for application across relevant land cover types in the county with estimated implementation acreages derived through GIS analysis, averages based on farm HSP applications, and stakeholder input in order to estimate the maximum carbon sequestration potential for application of various practices.

Determining Climate Smart Practices

Climate Smart Practices were sourced primarily from COMET-Planner and TerraCount, both of which are based largely on United States Department of Agriculture NRCS conservation management practices and provide the information necessary to quantify estimated carbon sequestration. These tools were developed to allow for consistent replication and estimation of the GHG benefits of various land management practices across the country and state, respectively. County stakeholders also reviewed the list of potential practices to determine which practices were most locally relevant to Sonoma County farmers and natural and working lands. There are additional practices which may provide carbon sequestration benefits, enhance the carbon sequestration benefits of practices included in this analysis, or provide necessary support for these practices, but they are not quantifiable at this time. Some practices are emerging, such as beaver assisted restoration, application of biochar, application of crushed basalt and other mineral soil amendments, and do not as of yet have a reliable protocol or tool for quantifying the sequestration benefit. Examples of practices that compliment or enhance the sequestration benefits of other practices include fencing projects to support prescribed grazing and oak woodland restoration in grazing lands, forest fuel reduction using goats, forest slash treatments, and conservation of lands for future wetland upland migration to preserve wetland carbon sequestration and biodiversity benefits despite rising sea levels. The carbon sequestration and environmental benefits of these practices may be described

[10] The TerraCount model was not run due to technical constraints, and instead, TerraCount Activity Sheets were used to calculate carbon sequestration potential, similar to other jurisdictions, including the San Diego Association of Governments (SANDAG) region. TerraCount. N.d. Appendix L Activity Sheets. Available <https://maps.conservation.ca.gov/TerraCount/downloads/>. Accessed March 26, 2022.

[11] The leakage definition used in the TerraCount Activity Sheets is: "Carbon leakage refers to the displacement of greenhouse gas (GHG) emissions from one place to another due to emission reduction activities. It is caused by a direct or indirect shift of activities that create those emissions from within an emissions accounting system to out of that system." This definition is from Henders and Ostwald (2012) in their review of leakage accounting mechanisms from both the published literature and existing project accounting standards.

qualitatively but are not currently quantifiable given the available tools, protocols, and data. Practices that are not currently quantifiable are not included in this analysis, though they are nonetheless valuable and are recommended for inclusion in the suite of potential climate smart practices in the Carbon Sequestration Potential Study to be considered by the County.

The climate smart practices analyzed in this study are listed below in Table 1 along with the activity source, expected lifespan of the practice, and the sequestration/emissions reduction coefficient and are organized by land use category.

Table 1 Carbon Sequestration Activities

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Natural Lands	Forest	Avoided conversion to row crops	The activity case is the avoided conversion of a forested landscape to annual row crops. The activity area is permanently protected through zoning changes (e.g., to open space) or conservation easements that dedicate the site to natural conditions. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	114.76	1****
Natural Lands	Forest	Avoided conversion to urban	The activity case is the avoided conversion of a forested landscape to urban use, such as urban residential, commercial, or industrial use. The activity area is permanently protected through zoning changes, Williamson Act designation (new), or conservation easements that dedicate the site to natural conditions. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	159.35	1****
Natural Lands	Forest	Forest Slash Treatment (CPS 384)	Woody plant residues managed (chipped, scattered, etc.) on-site will increase soil carbon and soil organic matter. Forest slash that is removed can serve as a renewable fuel and feedstock.	NRCS GHG and Carbon Sequestration Ranking Tool	NA***	NA***
Natural Lands	Forest	Fuel reduction	Activity reductions are the result of the removal of excess biomass contributing to unhealthy forest fuel conditions. Reductions are based on changes in on-site biomass over time and probabilistic emissions from future wildfires after fuel reduction treatments have been performed on the site, per the California Climate Investments methodology for forest health projects, assuming treatments under the activity are effective for a period of 20 years.	TerraCount Activity Sheets	1.00	20

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Natural Lands	Forest	Improved forest management thinning from below	Activity reductions are the result of committing to 'thin from below' silviculture activities that retain co-dominant and dominant trees at harvest and reduce ladder fuels. Growth rates are managed at a high level while reducing risks of catastrophic carbon loss through wildfires that burn through tree crowns. Practitioners must indicate intent to perform one of the following: 1) Harvest commercially within 5 years of Activity implementation with at least one successive commercial harvest; 2) Harvest commercially within 5 years of Activity implementation with no subsequent plans to for commercial harvest; 3) Only remove ladder fuels within 5 years of Activity implementation.	TerraCount Activity Sheets	1.80	50
Natural Lands	Forest	Riparian restoration	Activity reductions are the result of woody plantings on degraded streambanks, which are characterized by lack of vegetation, allowing the movement of heavy runoff through the riparian zone directly into stream channels. Management is based on NRCS COMET-Planner description for Riparian Restoration.	TerraCount Activity Sheets (leakage rate); Matzek et al. 2020 (sequestratio n coefficient and practice lifespan)	6.80	45
Natural Lands	Grassland	Avoided conversion to row crops	The activity case is the avoided conversion of a grassland landscape to annual row crops. The activity area is permanently protected through zoning changes or conservation easements that dedicate the site to natural conditions. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	18.04	1****
Natural Lands	Grassland	Native grassland restoration	Activity reductions are the result of restoration of native grasses to a site currently dominated by non-native grasses.	TerraCount Activity Sheets	0.60	50
Natural Lands	Grassland	Oak woodland restoration	Activity reductions are the results of the restoration of grasslands to native oak woodland cover in ecologically appropriate areas.	TerraCount Activity Sheets	1.45	50

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Natural Lands	Grassland	Riparian Restoration	Restoration of woody riparian vegetation in areas near streams and rivers	TerraCount Activity Sheets (leakage rate); Matzek et al. 2020 (sequestratio n coefficient and practice lifespan)	6.80	45
Natural Lands	Shrub/ Scrub	Avoided conversion to row crops	The activity case is the avoided conversion of a shrubland landscape to annual row crops. The activity area is permanently protected through zoning changes or conservation easements that dedicate the site to natural conditions. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	83.24	1****
Natural Lands	Shrub/ Scrub	Avoided conversion to urban	The activity case is the avoided conversion of a shrubland landscape to urban use, such as urban residential, commercial, or industrial use. The activity area is permanently protected through zoning changes or conservation easements that dedicate the site to natural condition. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	79.07	1****
Natural Lands	Wetland	Conservation of Lands for coastal wetland upland migration with sea level rise	Conserving lands expressly for wetland upland migration to preserve wetlands despite sea level rise which may otherwise “drown” these habitats. Wetlands may require assistance in migrating upland via restoration and sediment control activities if sea level rise is outpacing natural upland migration.	San Francisco Estuary Institute Resilience Atlas	NA***	permanent

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Natural Lands	Wetland	Avoided conversion to row crops	The activity case is the avoided conversion of wetlands to annual row crops. The activity area is permanently protected through zoning changes or conservation easements that dedicate the site to natural conditions. The activity area may be used for a variety of purposes that maintain natural land cover and a carbon density equal to or greater than the density present when activity is initiated.	TerraCount Activity Sheets	5.72	1****
Natural Lands	Wetland	Restoration (from agricultural uses)	Returning a wetland and its functions to a close approximation of its original condition as it existed prior to disturbance on a former or degraded wetland site.	CARB, NRCS - CPS 657	NA***	permanent
Urban Forest	Development	Urban forestry	Activity reductions are the result of committing to the maintenance and increase of CO_2e in trees within the urban land cover. Reductions can occur from sequestration on existing trees and/or newly planted trees. Benefit is attributed to increase in urban canopy cover.	TerraCount Activity Sheets	133.14	50
Urban Farms	Cultivated & Field Crops Orchards & Vineyards	Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA
Urban Farms	Cultivated & Field Crops	Compost Application & Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments (compost) derived from plant materials or treated animal byproducts.	NRCS/COMET -Planner	1.03	6
Urban Farms	Orchards & Vineyards	Compost Application & Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments derived from plant materials or treated animal byproducts.	NRCS/COMET -Planner	1.55	6
Urban Farms	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	Conservation crop rotation is growing a planned sequence (i.e., the rotation cycle) of various crops on the same piece of land for a variety of conservation purposes.	NRCS/COMET -Planner	0.22	1

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Urban Farms	Cultivated & Field Crops	Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/COMET -Planner	0.40	1
Urban Farms	Orchards & Vineyards	Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/COMET -Planner	1.64	1
Urban Farms	Cultivated & Field Crops	Field Border (CPS 386)	A strip of permanent vegetation established at the edge or around the perimeter of a field. This practice is applied around the inside perimeter of fields.	NRCS/COMET -Planner	1.23	20
Urban Farms	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.	NRCS/COMET -Planner	8.41	34
Urban Farms	Orchards & Vineyards	Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.	NRCS/COMET -Planner	8.20	34
Urban Farms	Cultivated & Field Crops	Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface.	NRCS/COMET -Planner	0.32	5
Urban Farms	Orchards & Vineyards	Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface.	NRCS/COMET -Planner	0.34	5
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/COMET -Planner	0.22	1

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Urban Farms	Orchards & Vineyards	Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/COMET -Planner	0.35	1
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/COMET -Planner	0.12	1
Urban Farms	Orchards & Vineyards	Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/COMET -Planner	0.12	1
Urban Farms	Cultivated & Field Crops	Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/COMET -Planner	8.41	80
Urban Farms	Orchards & Vineyards	Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/COMET -Planner	8.20	80
Working Lands	All agricultural land covers	Riparian Forest Buffer (CPS 391)	Apply riparian forest buffers on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands where channels and streambanks are sufficiently stable. This practice creates an area predominantly covered by trees and/or shrubs located adjacent to and up-gradient from a watercourse or water body.	NRCS/COMET -Planner (practice); Matzek et al. 2020 (sequestration coefficient and practice lifespan)	9.06	45

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Working Lands	All agricultural land covers	Riparian Herbaceous Cover (CPS 390)	This practice creates an area with grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats.	NRCS/COMET -Planner	0.21	10
Working Lands	Cultivated & Field Crops	Alley Cropping (CPS 311)	Alley cropping is an agroforestry practice where agricultural or horticultural crops are grown in the alleyways between widely spaced rows of woody plants. By combining annual and perennial crops that yield varied products and profits at different times, a landowner can more effectively use available space, time, and resources. Replace 20% of annual cropland with woody plants-tree-planting/single row.	NRCS/COMET -Planner	1.74	15
Working Lands	Cultivated & Field Crops	Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost C/N <= 11, 3 tons per acre.	NRCS/COMET -Planner	2.07	6
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost C/N > 11, 6 tons per acre.	NRCS/COMET -Planner	4.34	6
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) & Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Application of carbon-based amendments derived from plant materials or treated animal byproducts. Reduce fertilizer rate by 15% and apply compost - 3 tons per acre C/N <= 11.	NRCS/COMET -Planner	2.05	6
Working Lands	Cultivated & Field Crops	Conservation Cover (CPS 327)	Convert Irrigated Cropland to Permanent Unfertilized Grass/Legume Cover-can use native, introduced, pollinator, or monarch supporting species.	NRCS/COMET -Planner	0.63	permanent
Working Lands	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	Conservation crop rotation is growing a planned sequence (i.e., the rotation cycle) of various crops on the same piece of land for a variety of conservation purposes. Decrease fallow frequency or add perennial crops to rotations.	NRCS/COMET -Planner	0.22	1

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Working Lands	Cultivated & Field Crops	Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/COMET -Planner	0.40	1
Working Lands	Cultivated & Field Crops	Field Border (CPS 386)	A strip of permanent vegetation established at the edge or around the perimeter of a field. This practice is applied around the inside perimeter of fields.	NRCS/COMET -Planner	1.23	20
Working Lands	Cultivated & Field Crops	Filter Strip (CPS 393)	Establishment of an area of herbaceous vegetation situated between cropland, grazing land, or disturbed land (including forestland) and environmentally sensitive areas that removes contaminants from overland flow of water or runoff.	NRCS/COMET -Planner	1.23	10
Working Lands	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose. Replace a strip of cropland with one row of woody plants.	NRCS/COMET -Planner	8.41	34
Working Lands	Cultivated & Field Crops	Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface. May use natural materials or wood chips.	NRCS/COMET -Planner	0.32	5
Working Lands	Cultivated & Field Crops	Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce fertilizer rate by 15%.	NRCS/COMET -Planner	-0.02	1
Working Lands	Cultivated & Field Crops	Pasture & Hay Planting (CPS 512)	Conversion of annual cropland to irrigated grass/legume forage/biomass crops-non-native species, standard seeding rate, with or without fertilizer.	NRCS/COMET -Planner	1.22	5
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	Switch from Intensive Till to No Till or Strip Till on Irrigated Cropland. The residue and tillage management no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned.	NRCS/COMET -Planner	0.22	1

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	Switch from Intensive Till to Reduced Till on Irrigated Cropland. Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	NRCS/COMET -Planner	0.12	1
Working Lands	Cultivated & Field Crops	Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations. Replace a strip of cropland with one row of woody plants-one-row/tree or shrub/wind protection fence.	NRCS/COMET -Planner	8.41	80
Working Lands	Orchard & Vineyard	Biochar Application (CPS 336)	Application of carbon-based amendments (biochar) derived from plant materials or treated animal byproducts.	NRCS – CPS 336	NA	NA
Working Lands	Orchard & Vineyard	Compost Application (CPS 808)	Application of carbon-based amendments derived from plant materials or treated animal byproducts. May be purchased from a certified compost facility or produced on-farm. (C/N </=11), 3 tons/acre	NRCS/COMET -Planner	1.55	6
Working Lands	Orchard & Vineyard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce Fertilizer Application Rate by 15% . Application of carbon-based amendments derived from plant materials or treated animal byproducts. Compost may be purchased from a certified compost facility or produced on-farm. (C/N </=11), 3 tons/acre.	NRCS/COMET -Planner	1.55	6
Working Lands	Orchard & Vineyard	Cover Cropping (CPS 340)	Cover crops include grasses, legumes, and forbs for seasonal cover and other conservation purposes. Can be applied to all lands requiring vegetative cover for natural resource protection and or improvement. Add legume/legume mix cover crop to orchard/vineyard alleys - basic or multi-species, organic or non-organic cover crops will be terminated by frost, tillage, mowing, crimping, and/or herbicides in preparation for the following crop. Cover crop residue will not be burned.	NRCS/COMET -Planner	1.64	1

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Working Lands	Orchard & Vineyard	Filter Strip (CPS 393)	A strip or area of herbaceous vegetation that removes contaminants from overland flow. Filter strips are established where environmentally sensitive areas need to be protected from sediment, other suspended solids, and dissolved contaminants in runoff. Convert idle land near orchards/vineyards to permanent unfertilized grass cover. May include native or introduced species.	NRCS/COMET -Planner	0.60	10
Working Lands	Orchard & Vineyard	Hedgerow Planting (CPS 422)	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose. Plant one row of woody plants on border of orchard or vineyard-single row.	NRCS/COMET -Planner	8.20	34
Working Lands	Orchard & Vineyard	Mulching (CPS 484)	Applying plant residues or other suitable materials to the land surface. May use wood chips or natural materials.	NRCS/COMET -Planner	0.34	5
Working Lands	Orchard & Vineyard	Nutrient Management (CPS 590)	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts. Reduce fertilizer application rate by 15%.	NRCS/COMET -Planner	0.00	1
Working Lands	Orchard & Vineyard	Windbreak/ Shelterbelt Establishment (CPS 380)	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	NRCS/COMET -Planner	8.20	80
Working Lands	Orchard & Vineyard	Residue and Tillage Management - No Till (CPS 329)	The residue and tillage management, no till practice limits soil disturbance to manage the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop. Residue shall not be burned. Conventional Till to No Till in Orchard/Vineyard Alleys-No-till or Strip-till.	NRCS/COMET -Planner	0.35	1
Working Lands	Orchard & Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting. Conventional Till to Reduced Till in Orchard/Vineyard Alleys.	NRCS/COMET -Planner	0.12	1
Working Lands	Orchard	Whole Orchard Recycling (CPS 808)	Using carbon-based amendments (orchard materials) to increase soil carbon and improve the physical, chemical, and biological properties of the soil. Whole orchard recycling followed by orchard replant within 3 years.	NRCS/COMET -Planner	0.04	20

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Grazing Lands	Rangelands & Pasture	Compost Application to Rangelands (CPS 808)	Using carbon-based amendments to increase soil carbon and improve the physical, chemical, and biological properties of the soil. Compost C/N > 11, 6 tons/acre.	NRCS/COMET -Planner (practice); Ryals et al. 2015 (sequestration coefficient)	1.49	20
Grazing Lands	Rangelands	Native Oak Restoration/ Silvopasture (CPS 381)	Establishment and/or management of desired trees (native oaks) and forages on the same land unit.	NRCS/COMET -Planner	1.34	50
Grazing Lands	Pasture	Prescribed Grazing (CPS 528) (Pasture)	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.	NRCS/COMET -Planner	0.10	10
Grazing Lands	Rangelands	Prescribed Grazing (CPS 528) (Rangelands)	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.	NRCS/COMET -Planner	0.09	10
Grazing Lands	Rangelands	Range Planting (CPS 550)	The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals. May include native or non-native species, broadcast or drilled planting, high or low forb mixes, and shrub plugs.	NRCS/COMET -Planner	0.50	10
Grazing Lands	Rangelands	Riparian Forest Buffer (CPS 391)	Apply riparian forest buffers on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands where channels and streambanks are sufficiently stable. This practice creates an area predominantly covered by trees and/or shrubs located adjacent to and up-gradient from a watercourse or water body.	NRCS/COMET -Planner (practice); Matzek et al. 2020 (sequestration coefficient and practice lifespan)	9.06	45

Land Use Category	Land Cover	Climate Smart Activity	Description	Source	Sequestration/ Emissions Reduction Coefficient* (MT CO_2e/AC/year)	Expected Practice Lifespan** (Years)
Grazing Lands	Rangelands	Tree/Shrub establishment (CPS 612)	Conversion of grasslands to a Farm Woodlot. Establishing woody plants by planting, by direct seeding, or through natural regeneration.	NRCS/COMET -Planner	18.89	20

* Reduction/Sequestration coefficient factors in leakage rates where provided by TerraCount

** Expected or maximum practice lifespan in years per the NRCS standard and specifications, TerraCount Activity Sheets, or typical practice

*** Not currently quantifiable due to lack of site-specific parameters, quantification protocol, etc. - but practice does provide carbon sequestration and other benefits

**** Permanent conservation - 1 time sequestration benefit in MT CO_2e/AC

Estimating Implementation Acreage

It is important to note that in order to estimate potential sequestration implementation acreage must first be estimated. Determining implementation acreage for climate smart agricultural and natural lands management practices is typically done at the project or site level. Generating site-specific implementation acreages and plans for implementing climate smart practices is a time consuming and resource intensive process that takes many additional site-specific factors into consideration when planning on a per-farm or per-project basis that are not possible to include in estimations at the county level. For example, when Resource Conservation Districts (RCDs) assist with developing a carbon farm plan, planners would visit the farm and interview the farmer to determine implementation needs, consider available resources and property characteristics. Restoration projects for natural landscapes would be similarly complex planning endeavors. This time and resource-intensive effort cannot be replicated at the county level for the purposes of this analysis. However, estimating the potential implementation acreage of each climate smart practice is key to this analysis and estimates can be further refined with follow-up analysis in the future. Several methods and numerous data sets were utilized to assist in developing countywide estimates as a basis for general target setting and later site-specific analysis and project planning. The methods used for estimating implementation acreage are outlined below.

Implementation Coefficients

One method of estimating the potential implementation acreage of each climate practice throughout the county is to develop an average implementation coefficient based on current implementation levels. This coefficient is a ratio of how many acres of the climate smart practice is being implemented on compared to the total area of the land being managed (e.g., farm, ranch). This analysis used a few different methods to derive implementation coefficient based on existing available data. The forthcoming SMACCC coalition project will include extensive outreach and research on climate smart implementation on agricultural lands, which may be used to refine these implementation coefficients in the future.

Utilizing Regional Data

Another Bay Area county to the east, Contra Costa County, recently developed the *Contra Costa County Healthy Lands, Healthy People: A Carbon Sequestration Feasibility Study*. Appendix F of that study is the *Contra Costa County Carbon Sequestration Potential on Agricultural Lands Report*.[12] For some climate smart practices, a set of implementation acreage coefficients were developed using historical California Department of Food and Agriculture (CDFA) Healthy Soils Incentives Program applications in the county. The implementation coefficients represent the ratio between implementation acreage of climate smart practices and total farm acreage. iThe CDFA applications used for this purpose included specific implementation acreages for each practice, and these acreages were then divided by the total farm acreage to get crop specific implementation coefficients. Coefficients then were averaged across crop type to arrive at the management practice implementation coefficient (for Cover Cropping, Mulching, Compost Application, Hedgerow Installation, and Windbreaks). In addition to application data, the conservation practice standards for each practice were also used to help determine implementation coefficients for Field Borders, Conservation Crop Rotation, Reduced Till, No-Till, Whole Orchard Recycling, and Alley Cropping.

[12] This report was produced by the Carbon Cycle Institute and the Contra Costa Resource Conservation District.

Contra Costa County and Sonoma County are both located in the Bay Area. It was considered reasonable to use the implementation coefficients produced as part of a carbon feasibility study for that Contra Costa County in 2022 to estimate implementation acreages for this analysis. The same methodology described above could be utilized to determine Sonoma County specific management practice implementation coefficients as part of the analysis conducted during the SMACCC coalition project, or in future follow up studies.

The management practice implementation coefficients are included Table 2 below, reproduced from the *Contra Costa County Carbon Sequestration Potential on Agricultural Lands Report*.

Table 2 Implementation Acreage Proportions (Implementation Coefficients)

Climate Smart Management Practice	Implementation Acreage Proportion (Row Crops)	Implementation Acreage Proportion (Orchards/Vineyards)	Implementation Acreage Proportion (Urban Farms)
Cover Cropping	0.7017	0.7458	0.2206
Mulching	0.4557	0.7309	0.3188
Compost Application (C/N > 11)	0.7017	0.7301	0.2942
Hedgerow Installation	0.0189	0.0276	0.0176
Windbreak Installation	0.0269	0.0269	0.0649
Field Border	0.09	0.09	0.28
Biochar	0.7017	0.7458	0.2942
Conservation Crop Rotation	1.0	n/a	1.0
Reduced Till	1.0	0.6-0.7	1.00
No Till	1.0	0.6-0.7	1.00
Whole Orchard Recycling	n/a	1.0	n/a
Alley Cropping	1.0	n/a	n/a

Utilizing Sonoma County Data

Carbon farm plan data for Sonoma County ranches was provided by the Gold Ridge RCD. The data was pulled from the Gold Ridge and Sonoma RCD project trackers and included total ranch acreage and implementation acreage for range planting and tree/shrub establishment. There were a total of 8 ranches that implemented range planting and for which total ranch acreage was also available. There were 3 ranches that implemented tree/shrub establishment, and had total farm acreage available. It would be preferable to have a larger subset of data for tree/shrub establishment, and this is a potential area for further refinement of implementation estimates in future analysis. From the available data, Sonoma County-specific implementation coefficients were derived for these two practices using the same methodology as the implementation coefficients derived for Contra Costa County. The implementation coefficients were then applied to the total rangeland and pasture acreages determined by GIS analysis to estimate potential implementation acreages for these practices. Table 3 lists the implementation acreage for these practices.

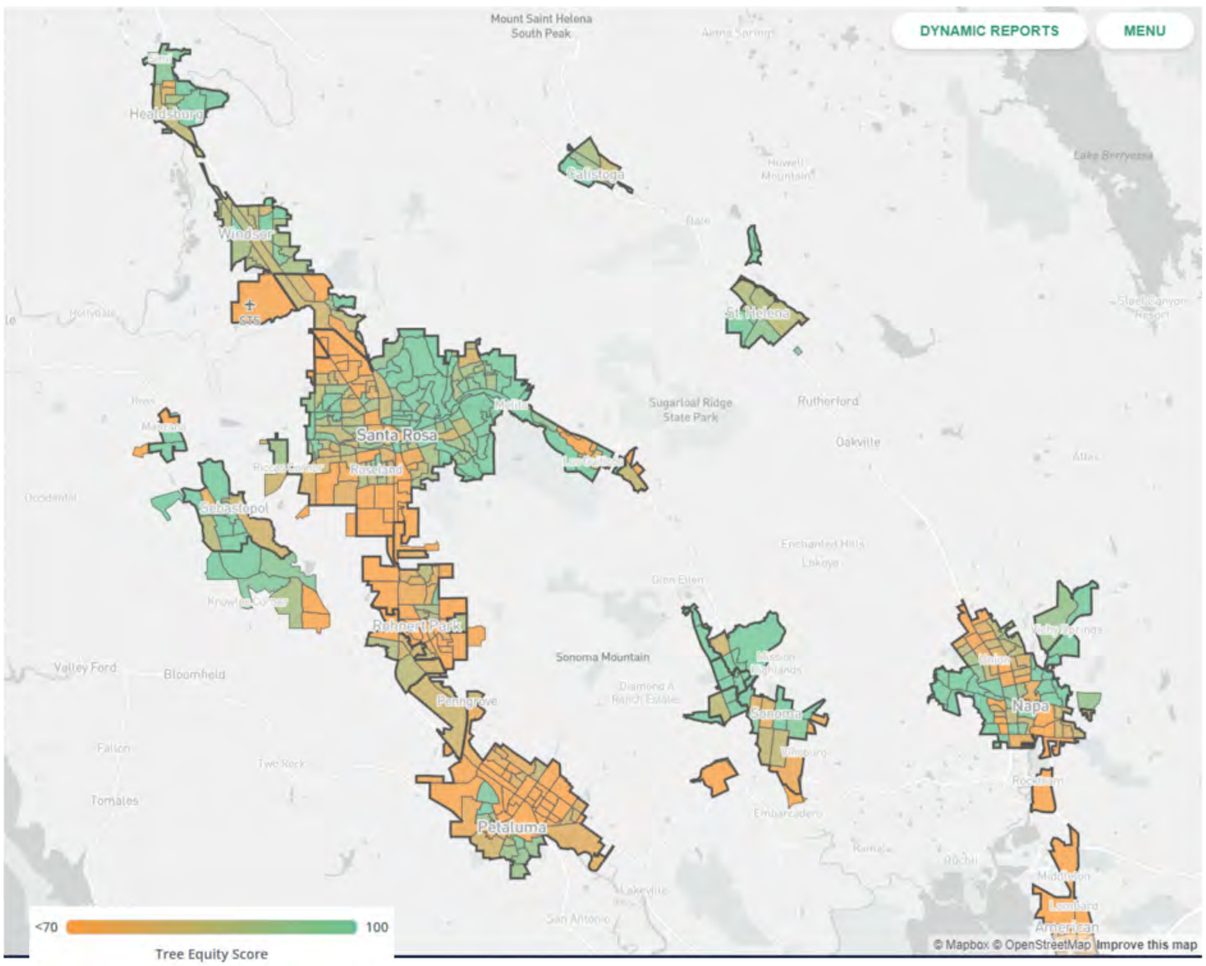
Table 3 Implementation Coefficients for Range Planting and Tree/Shrub Establishment

Climate Smart Management Practice	Implementation Acreage Proportion (Grazing Lands)
Range Planting	0.312
Tree/Shrub Establishment	0.02

Utilizing State Data

Lastly, the estimated implementation acreage for urban forest tree canopy expansion was derived by multiplying an implementation coefficient provided by TerraCount for that activity. The maximum increase allowed for tree canopy cover is 5 percent, or an implementation coefficient of 0.05. This is a reasonable maximum implementation acreage for Sonoma County given that many cities within the county have less than 30 percent tree canopy cover.[13] Figure 2 shows a map of the major cities and town in Sonoma County, subdivided into census blocks, and color-coded based on the tree equity score which factors in total canopy cover and demographic factors to rate how equitable access to trees is across cities.

Figure 2 Tree Equity Map of Major Cities in Sonoma County



[13] Tree Equity Score. 2023. https://www.treeequityscore.org/map#10.04/38.4039/-122.6771

GIS Analysis

The potential implementation acreages for some climate smart practices were determined using GIS analysis of available raster and vector data layers from numerous sources. The data sources used are described for each climate smart practice and accompanying land type below. This approach was used for practices that have some constraints to applicability that can be mapped using geospatial data and tools to create a primary set of biophysical filters to determine potential implementation acreage. The maps included for each set of practices reflects this initial set of biophysical constraints, shows areas that are potentially eligible for implementation of the practice in question, and should be considered as a starting point from which additional analysis wherein funding, equipment, land ownership, incentive programs, presence of wildlife, cultural significance, updated or site-specific data, and alternative practices or uses are considered. While these implementation acreages are a reasonably good estimate using the best available data, there are inevitably some inaccuracies in the data sets, and the true maximum potential implementation acreage can be expected to vary from these estimates. The detailed methodology for each implementation acreage and map follows below.

Urban Farm Acreage

For the purposes of this analysis indoor farms (hydroponic, aquaponic, greenhouse, and vertical farms) are excluded. Those types of urban farms would require a lifecycle analysis to determine the emissions reduction benefits. Furthermore, there is not currently a methodology for estimating indoor farm acreage or emissions benefits at the county scale. Urban farms are defined for this study as traditional agricultural systems (cultivated and field crops, orchards, and vineyards) taking place within the urban borders. Urban farm acreage was determined through GIS analysis. The GIS team utilized LANDFIRE land cover classes for orchard, vineyard, and cultivated and field crops, then clipped this layer to the jurisdictional boundaries of cities within Sonoma County. The resulting acreages were then subtracted from the county-wide totals for those land covers to avoid double-counting. The appropriate implementation coefficients were applied to the urban farm acreages to estimate implementation acreage for various urban farm climate smart practices, as outlined in greater detail in the previous section. Table 4 shows the resulting urban farm acreages by land cover type. For the purposes of calculating carbon sequestration benefits orchard and vineyard acreages were combined due to their small total acreage, and because in COMET-Planner the climate smart practices are typically applied to both and have the same sequestration/emissions reduction coefficient.

Table 4 Urban Farm Acreage in Sonoma County

Urban Farm Land Cover Type	Acres in Sonoma County
Cultivated & Field Crops	24
Orchard	29
Vineyard	147

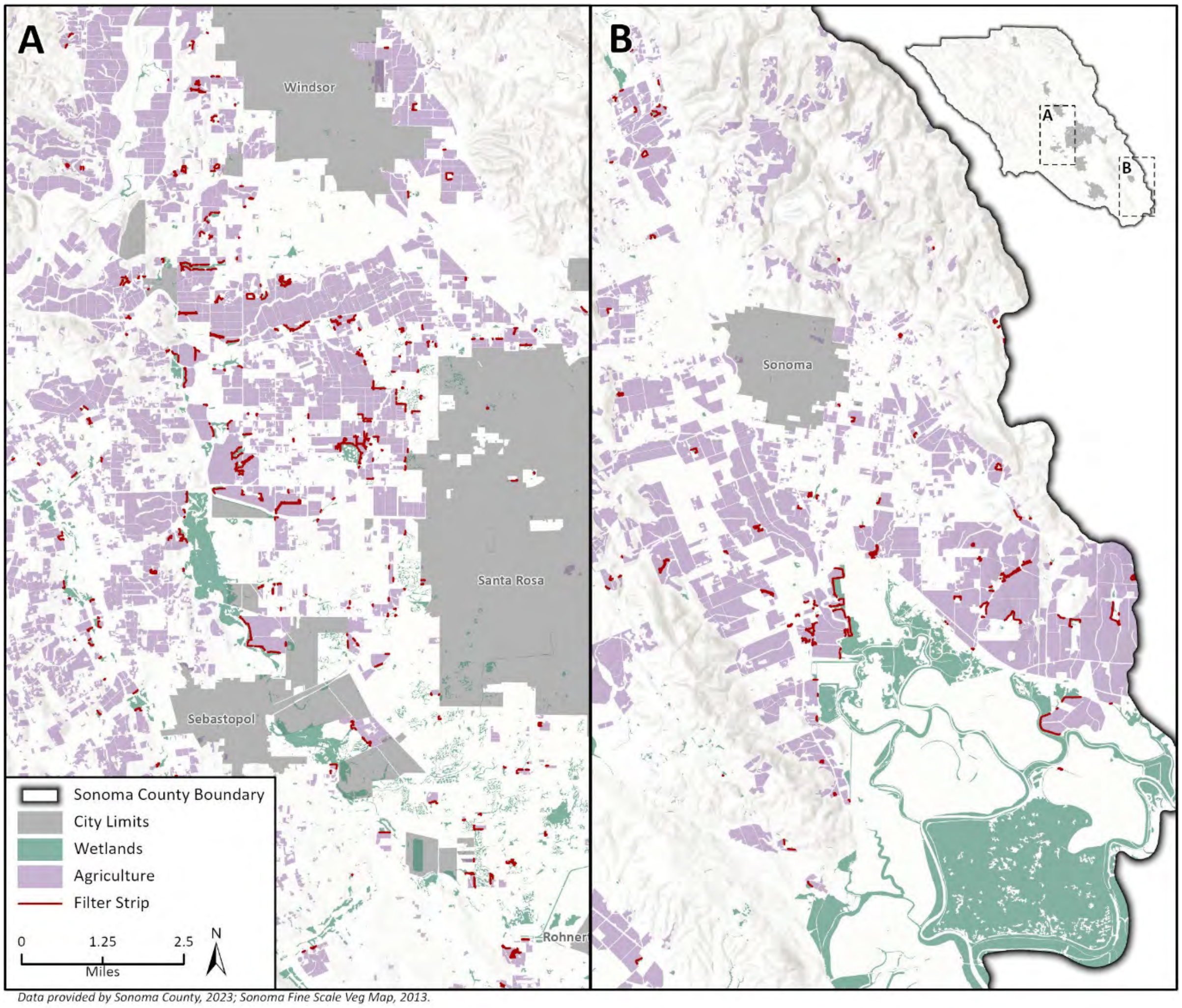
Filter Strips on Vineyards, Orchards, and Croplands

Filter strips (CPS 393) are a strip or area of herbaceous vegetation that removes contaminants from overland surface water flow. Filter strips are established where environmentally sensitive areas need to be protected from sediment, other suspended solids, and dissolved contaminants in runoff. The analysis to determine implementation acreage for filter strips began with the Sonoma Fine Scale Vegetation Map. The first layer was created using the “Lifeform” attribute to include “Annual

Cropland," "Orchard or Grove," "Vineyard," "Nursery or Ornamental Horticultural Area," and "Vineyard Replant" to create an initial Agricultural Lands layer. Next, a second layer was created to delineate wetlands and water bodies that may be sensitive to contaminants in farm runoff. This layer included "*Carex serratodens* Provisional Alliance," "Dry Stock Pond," "*Juncus arcticus* (var. *balticus, mexicanus*) Alliance," "North American Pacific Coastal Salt Marsh Macrogroup," "Tidal Panne," "Western North America Vernal Pool Macrogroup," "Western North American Freshwater Aquatic Vegetation Macrogroup," "Western North American Freshwater Marsh Macrogroup." Next, the "Polygon to Line" tool was used to convert the Agriculture polygons to lines. A 100-foot buffer was created around the wetland/water polygons. Next, the Agriculture Lines were clipped to the 100-foot buffer to calculate the linear feet of how much agricultural land abuts wetlands, totaling 435,751 linear feet for vineyards and orchards and 25,340 linear feet for croplands. The NRCS practice standard for filter strips specifies that the minimum flow length is 30 feet in order to remove dissolved contaminants and pathogens in runoff. The linear feet found previously were multiplied by 30 to get potential implementation area in square footages, which were divided by 43,560 square feet to determine the acreage. This resulted in potential filter strip implementation of 300 acres for vineyard/orchard and 17.5 acres for other croplands.

Figure 3 shows the potential implementation areas for filter strips in two subsections (labeled A and B) of the county with the greatest acreage of implementable areas. The subsections are labeled A and B to identify where they are located in the full county map subset into the top right corner of the figure. Agricultural land covers are shown in purple, adjacent wetlands are shown in teal, and the potential location for filter strips to protect the sensitive natural resources form agricultural runoff is shown in dark purple.

Figure 3 Filter Strips (CPS 393) on Agricultural Lands



Riparian Forest Buffer and Herbaceous Cover on Agricultural Lands

The analysis to determine implementation acreage for the establishment of riparian forest buffer (CPS 391), started with the LANDFIRE land cover data for vineyard, row crop, pasture and hay, orchard, and cultivated field crops (i.e., all agricultural lands). This layer was then overlayed with the California Fish and Wildlife California Streams layer and a 24-meter buffer was added to delineate the riparian corridor, consistent with the methodology developed by Matzek et. al in a study[14] reviewing the increases in soil and biomass carbon stocks as a result of riparian restoration. Following this, the Conservation Lands Network vegetation data was used to exclude areas with woody cover and include all other vegetation types. This resulted in a map layer that included 4,503 acres within the riparian buffer zone that lacked woody vegetation, but often included herbaceous vegetation, where woody cover could be established.

The analysis to estimate the potential implementation acreage for establishing riparian herbaceous cover (CPS 390) started with the LANDFIRE land cover data for vineyard, row crop, pasture and hay,

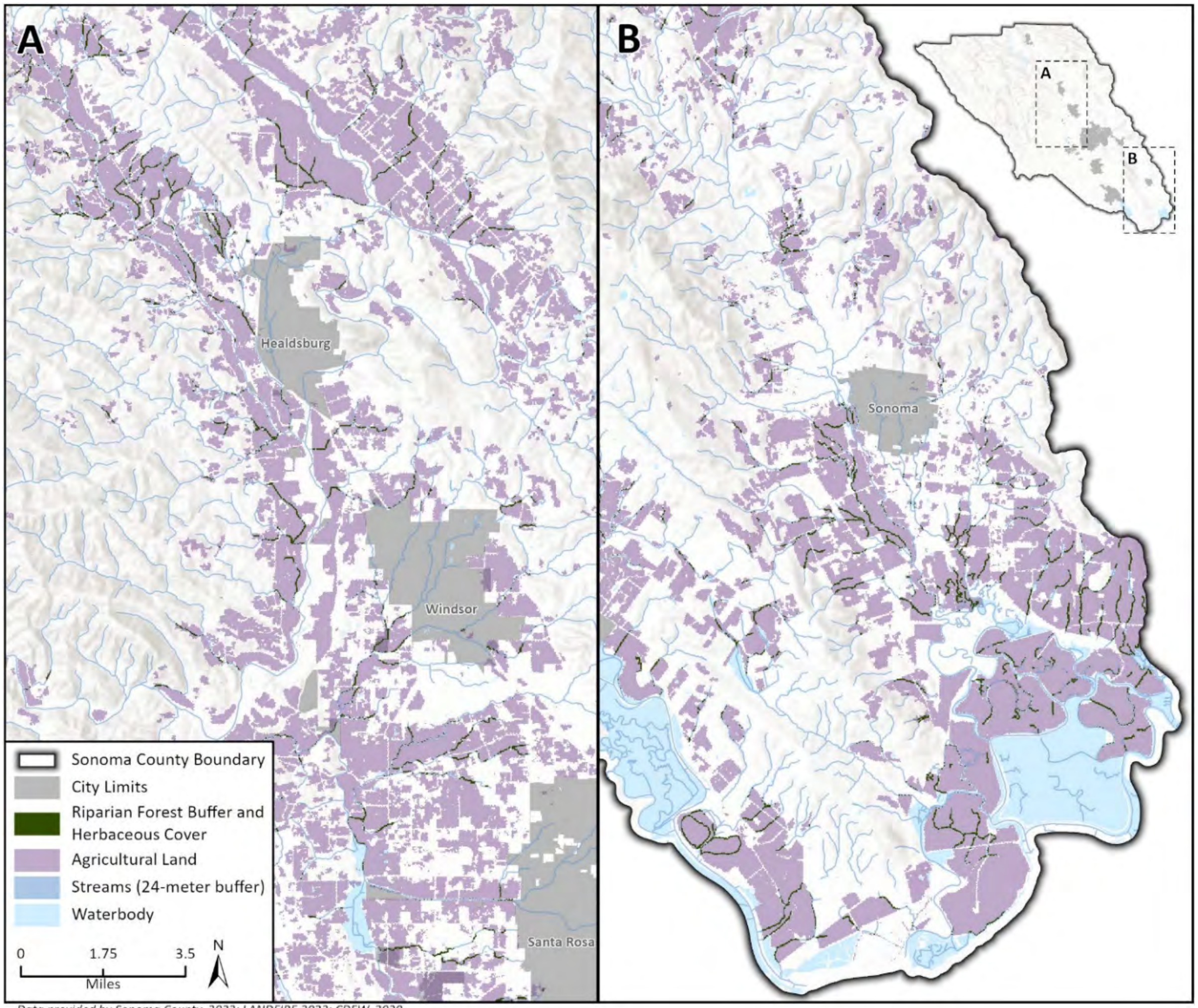
[14] Matzek, V., Lewis, D., O'Geen, A. et al. Increases in soil and woody biomass carbon stocks as a result of rangeland riparian restoration. Carbon Balance Manage 15, 16 (2020). https://doi.org/10.1186/s13021-020-00150-7

orchard, and cultivated field crops (i.e., all agricultural lands). This layer was then overlayed with the California Fish and Wildlife California Streams layer and a 24-meter buffer was added to delineate the riparian corridor. Following this the Conservation Lands Network vegetation data was used to exclude areas with native grasses, woody vegetation, permanent marsh, and vernal pools. This resulted in areas with non-native herbaceous vegetation within the riparian buffer zone in agricultural areas that could potentially be managed or planted with native herbaceous cover tolerant of intermittent flooding. Though slightly different land types were included/excluded from the biophysical constraints for herbaceous riparian cover and forest buffer, the resulting implementation acreages were the same, 4,503 acres, indicating an overlap in the potential implementation areas for these practices.

Because these practices occur on agricultural lands with available irrigation, the streams layer was not clipped to stream valleys, as farmers implementing this practice could provide supplemental irrigation for plantings until there is adequate establishment. Farms may not always be able to provide supplemental water at all the locations identified, especially with larger properties. This may reduce the area suitable for riparian forest buffer and herbaceous cover.

Figure 4 shows two close-up sections (sections A &B) of the county map layer depicted potential implementation areas for these practices. Streams are shown in dark blue, agricultural lands in purple, and potential implementation areas in dark green. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 4 Riparian Forest Buffer (CPS 391) and Riparian Herbaceous Cover (CPS 390) on Agricultural Lands



Data provided by Sonoma County, 2023; LANDFIRE 2022; CDFW, 2020.

Riparian Restoration on Natural Lands and Grazing Lands

To determine implementation for riparian restoration practices on natural and grazing lands, the California Fish and Wildlife California Streams layer was clipped to include only streams found in stream valleys, identified by the Conservation Lands Network 2.0 Stream Valley data layer, in order to select for streams with persistent enough moisture to facilitate riparian restoration without additional irrigation. A 24-meter buffer was added to these streamlines to delineate the riparian corridor area. The resulting riparian areas were then clipped to the LANDFIRE grassland land cover. The DOC Farmland Mapping and Monitoring Program (FMMP) farmland map was overlaid onto this, and the grazing suitable lands category was used to differentiate between riparian restoration on grasslands considered part of the County’s natural lands versus those considered grazing lands. The resulting riparian area was then overlaid with Conservation Lands Network 2.0 vegetation layer to exclude riparian areas covered in woody vegetation. Riparian area under herbaceous vegetation, but lacking woody vegetative cover, is considered appropriate for potential establishment of woody riparian vegetation for riparian restoration purposes. The resulting potential implementation acreages for riparian restoration were 1,400 acres on grazing lands and 339 acres on grasslands.

A similar process was utilized for forest riparian restoration. First the California Fish and Wildlife California Streams layer was clipped to include only streams found in stream valleys, identified by the Conservation Lands Network 2.0 Stream Valley data layer and a 24-meter buffer was added to delineate the riparian corridor area. The riparian layer was clipped to LANDFIRE forest lands cover to select for streams located within forested areas. The resulting riparian area was then overlaid with Conservation Lands Network 2.0 vegetation layer to exclude riparian areas covered in woody vegetation. There were 970 acres of riparian areas with non-woody vegetative cover within the forested lands that may be suitable for riparian restoration with woody vegetation establishment.

Figure 5 shows a close-up of an area within the county that depicts areas for potential riparian restoration on grazing lands in yellow, and natural lands (grasslands) in green. Where city limits are shown, that indicates the jurisdictional border and not land cover that is considered developed.

Figure 6 shows a two subsections (labeled A and B) within the county that include a higher concentration of areas potentially suitable for riparian restoration on natural lands (forest), shown in green. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 5 Riparian Restoration on Natural (Grasslands) and Grazing Lands

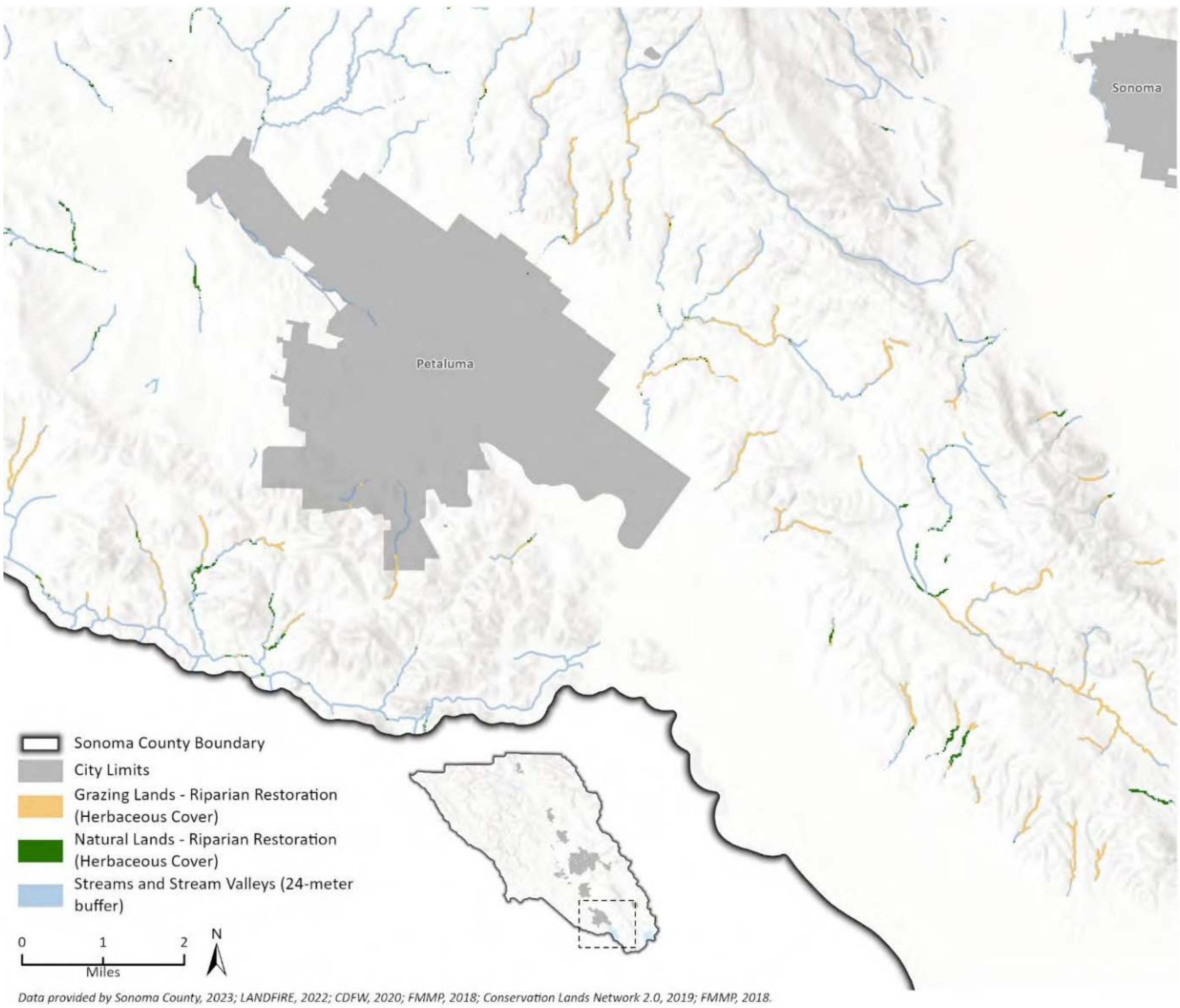
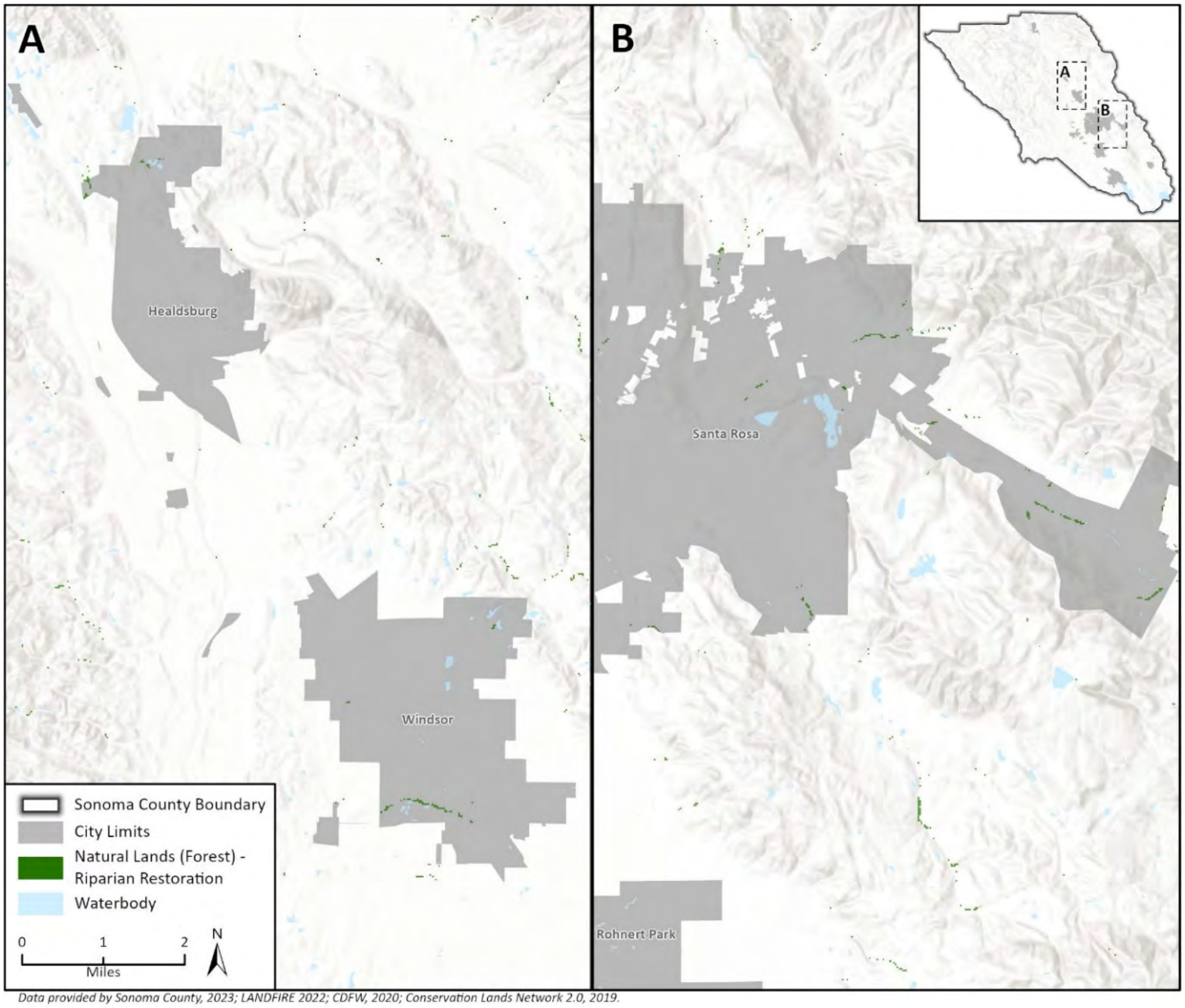


Figure 6 Riparian Restoration on Forested Lands

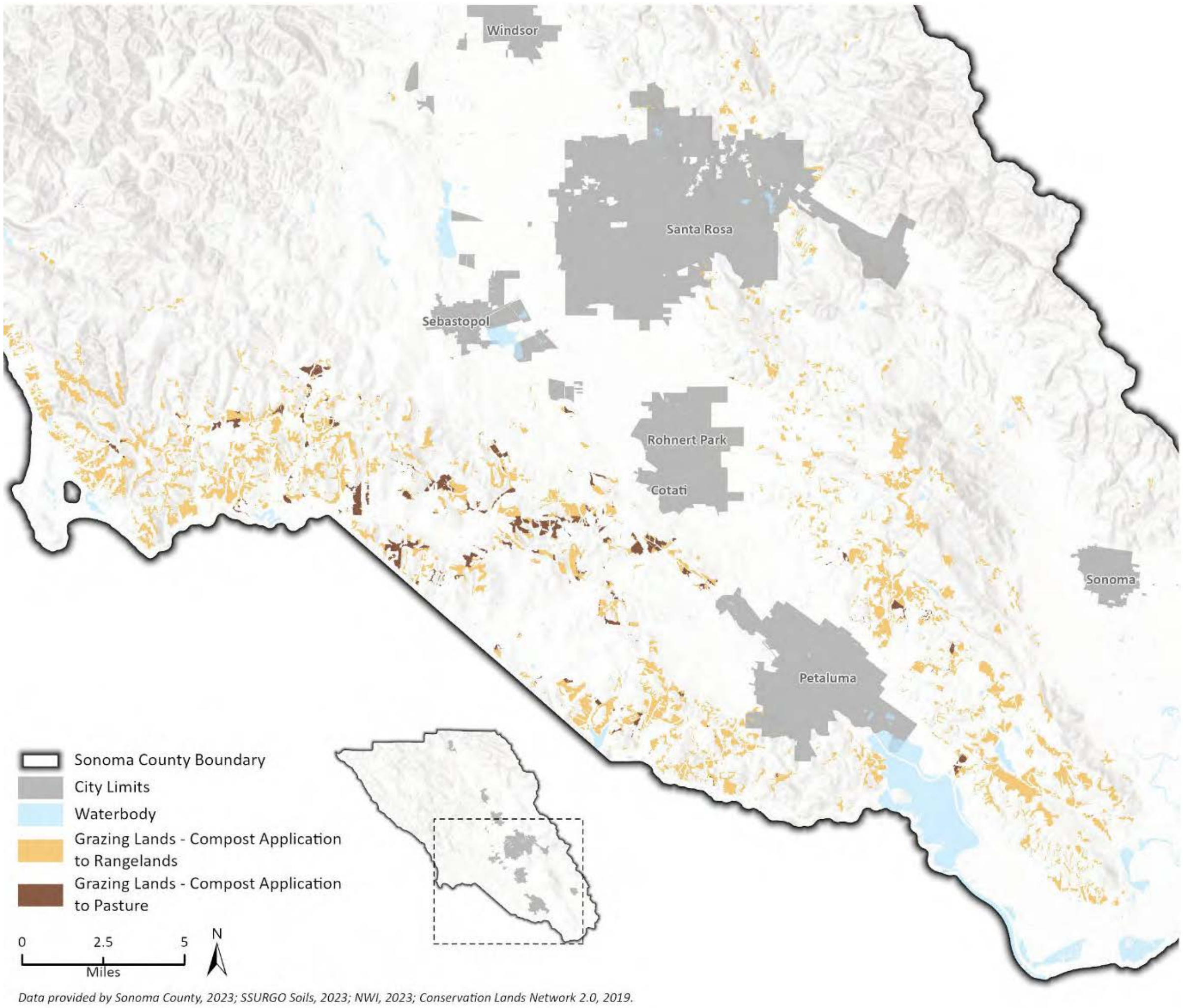


Compost Application on Grazing Lands

To determine potential implementation acreage for compost application to rangelands (CPS 808) in Sonoma County, LANDFIRE was used to map grassland and herbaceous cover, pasture and Department of Water Resources (DWR) pasture, which was then clipped to the FMMP grazing lands layer to delineate grazing lands. Because the CDFA Healthy Soils Program does not fund compost application to slopes greater than 15 percent, and due to practical considerations of compost application, areas with greater than 15 percent slope were removed using the SSURGO slope gradient data layer. Next, a 30-meter buffer was added to wetlands and water features and this was used to clip the data so compost would not be applied too close to water bodies. All areas with hydric soils were then removed using SSURGO's Hydric Rating field. The remaining acreage was overlaid with the Conservation Lands Network 2.0 Vegetation layer and all vegetation identified as perennial grasses and forbs, serpentine vegetation, and non-grassland vegetation types were removed. The remaining area has vegetation classified by the Conservation Lands Network 2.0 Vegetation layer as Non-Native/Ornamental Grass, Cool Grasslands, Hot Grasslands, Moderate Grasslands, and Warm Grasslands. This resulted in 21,437 acres of grazing lands, 19,148 acres of rangeland and 2,289 acres of pasture that fulfill the preliminary conditions for compost application.

Figure 7 shows a close up of part of the county with the greatest number of areas suitable for compost application within the county, rangelands suitable for compost application are shown in yellow, and pasture suitable for compost application is shown in brown. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 7 Compost Application on Grazing Lands



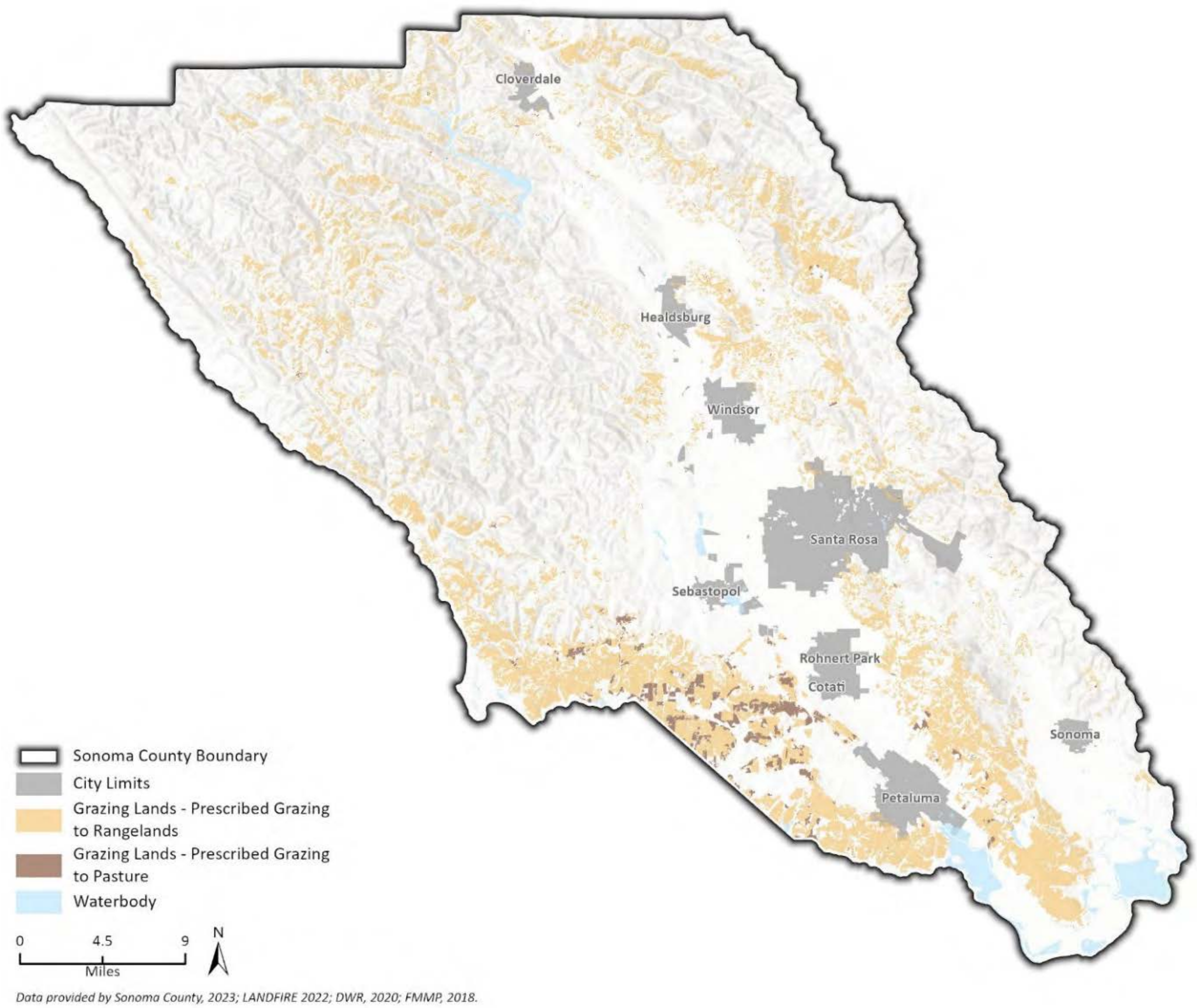
Prescribed Grazing on Grazing Lands

To determine potential implementation acreage for prescribed grazing (CPS 528) in Sonoma County, LANDFIRE was to map grassland/herbaceous land cover, excluded areas defined as pasture by DWR, and clipped this to the FMMP grazing lands layer to delineate rangelands. This resulted in an acreage of 142,371 acres of rangelands potentially suitable for prescribed grazing.

LANDFIRE's pasture/hay land cover was combined with DWR's pasture land cover and this layers was clipped to the FMMP grazing lands layer to delineate pasture used for grazing. This resulted in 8,200 acres of pasture potentially suitable for prescribed grazing.

Figure 8 shows areas in the county potentially suitable for prescribed grazing with rangelands depicted in yellow and pasture depicted in brown. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 8 Prescribed Grazing on Rangeland and Pasture (Grazing Lands)

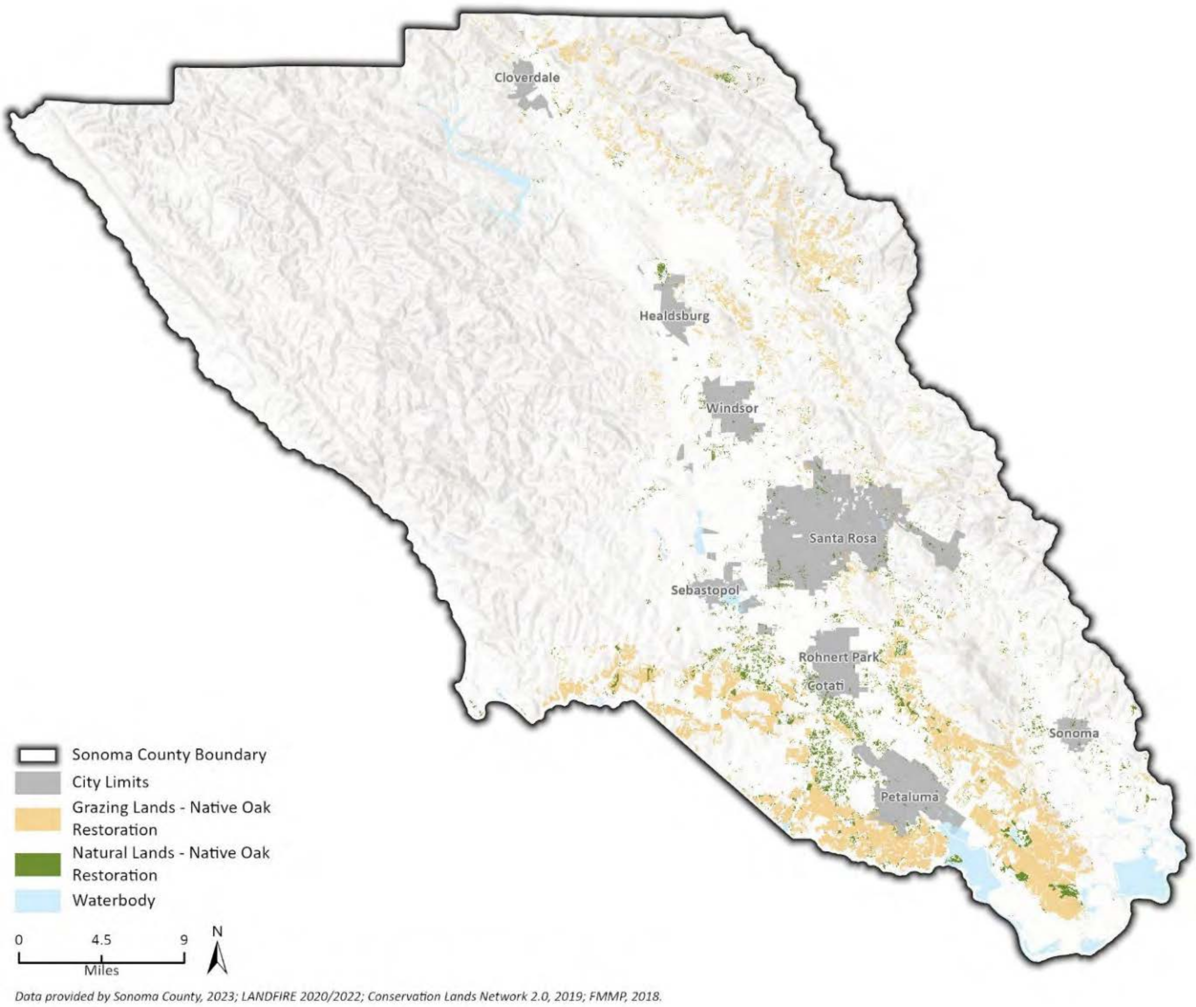


Native oak Restoration and Silvopasture on Natural and Grazing Lands

Oak woodlands and oak savannahs are important ecosystems in California, supporting immense biodiversity. For the purposes of this study, oak woodland restoration was considered analogous to silvopasture (CPS 381) on grazing lands, as the establishment of tree cover on grazing lands utilizing oaks can accomplish the same function as silvopasture while helping to restore and maintain key habitat. To determine potential implementation acreage for oak woodland restoration, LANDFIRE's Biophysical Setting database (BPS) was used to estimate potential areas for oak woodland re-establishment by mapping the four oak woodland and savannah categories. This was then clipped to the LANDFIRE grassland/herbaceous layer. This layer was clipped to the areas covered in grass vegetation according to the Conservation Land Network 2.0's vegetation layer. Finally, the resulting areas were delineated as either natural lands (grassland) or rangelands, by using the FMMP grazing suitable lands data layer. This resulted in potential implementation acreages of 51,655 acres for oak woodland restoration/silvopasture on grazing lands (rangelands), and 11,889 acres for oak woodland restoration on natural lands (grasslands).

Figure 9 shows the areas potentially suitable for oak woodland restoration, with grazing lands (rangelands) shows in yellow and natural lands (grasslands) shown in green. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 9 Oak Woodland Restoration/Silvopasture on Grasslands and Rangelands.



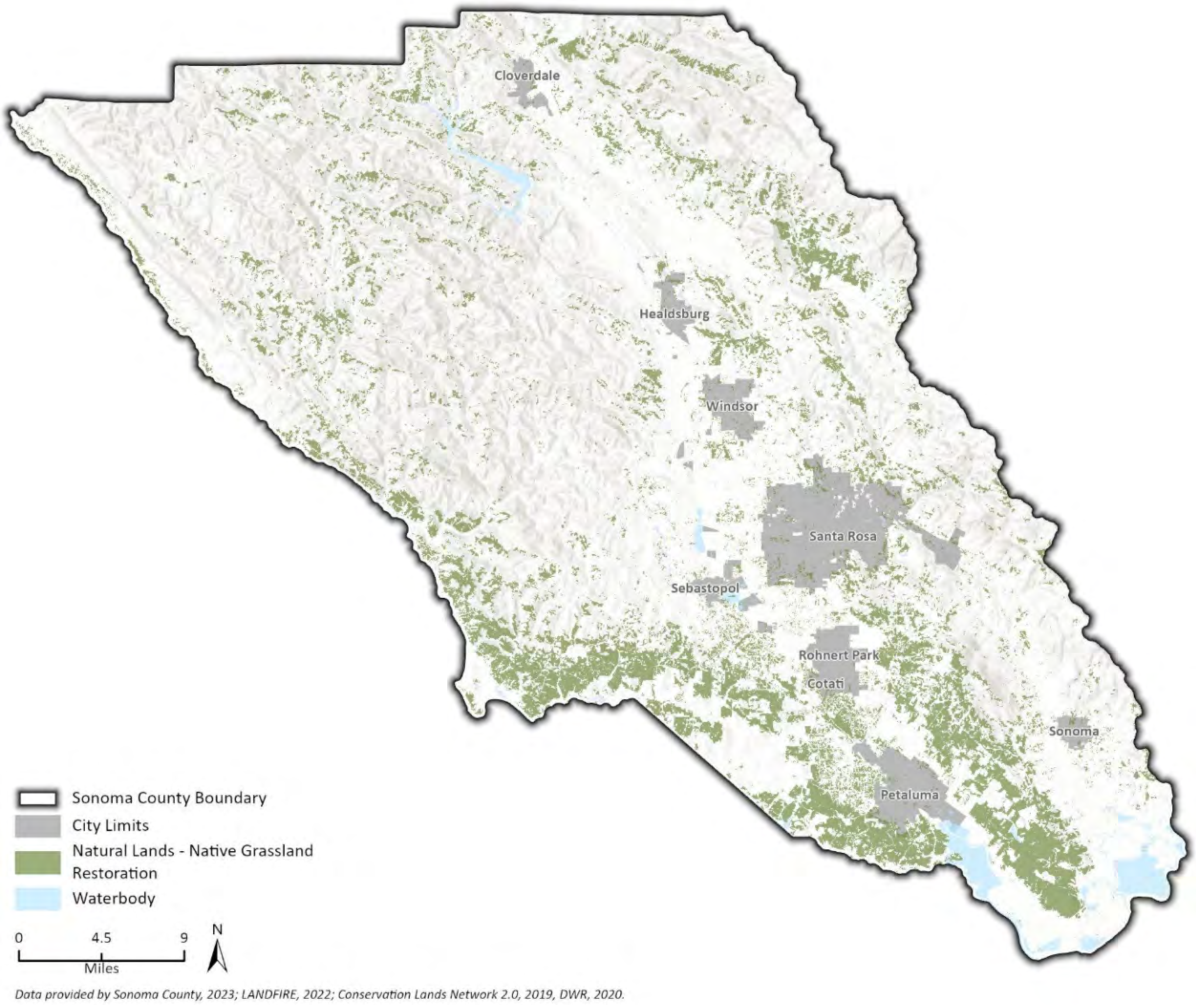
Native Grassland Restoration on Grasslands

To determine the potential implementation acreage for native grassland restoration, LANDFIRE's grassland/herbaceous land cover was overlaid with the Conservation Lands Network 2.0 Vegetation layer to remove all vegetation identified as perennial grasses and forbs, serpentine vegetation, and non-grassland vegetation types. The team checked that the remaining vegetation types under the Conservation Lands Network 2.0 Vegetation layer were Non-Native/Ornamental Grass, Cool Grasslands, Hot Grasslands, Moderate Grasslands, and Warm Grasslands. This was clipped to exclude Pasture/Hay from the DWR dataset. The implementation acreage does not further differentiate between grasslands used for grazing and those not used for grazing. The resulting

132,077 acres of grassland/herbaceous cover could potentially be suitable for restoration with native grassland species.

Figure 10 shows the grasslands potentially suitable for restoration with native grass species in green. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 10 Native Grass Restoration on All Grasslands



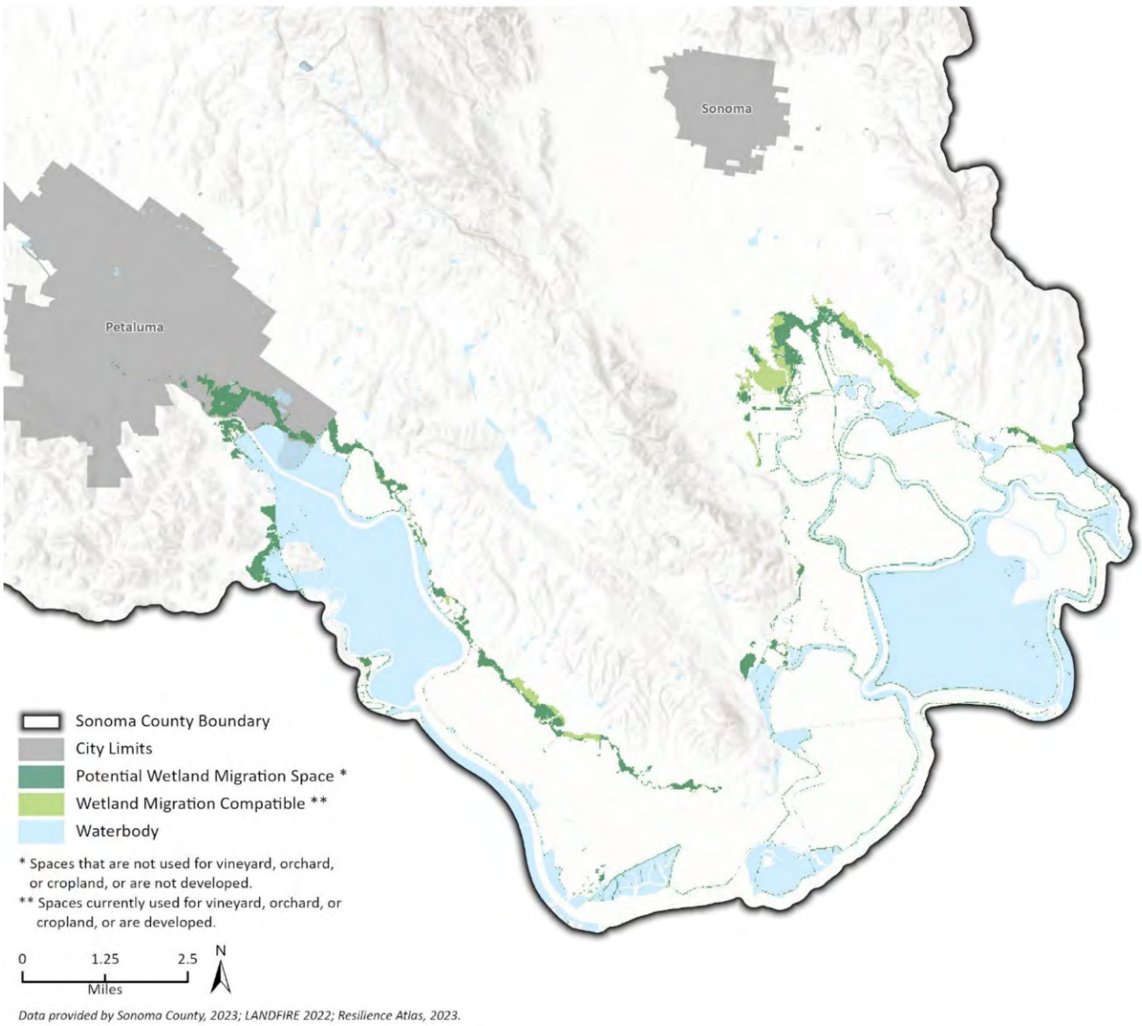
Wetland Upland Migration

While the carbon sequestration benefits of this activity are not currently quantifiable, the county's coastal wetlands provide important habitat for many plant and animal species, and sequester more carbon that they emit, making them an important land cover to protect for sequestration and biodiversity. Sea level rise threatens these ecosystems which may not be able to migrate upland at the pace of sea level rise, and particularly if lands are not preserved for such migration, they could be lost entirely over the course of the century. In order to preserve the future of coastal wetlands an essential step is to permanently conserve land for the purpose of future upland migration, which may need to be assisted in the future with additional restoration activities.

To determine the lands with potential for future upland migration of wetlands, the San Francisco Estuary Institute Resilience Atlas dataset was used, beginning with the migration space preparation layer. This layer was then clipped to only exclude LANDFIRE developed, vineyard, orchard, and row crop land covers. This resulted in 1,724 acres of undeveloped and non-agricultural lands that could potentially be conserved for future wetland upland migration.

Figure 11 shows the areas potentially suitable for conservation to allow for future upland wetland migration of coastal wetlands. This area is exclusively in the southeastern portion of the county bordering the San Francisco Bay. The areas suitable for upland wetland migration on undeveloped and non-agricultural lands (i.e., natural lands) are depicted in dark green. Areas that are wetland migration compatible but include developed or agricultural land covers are shown in light green for additional context. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 11 Wetland Upland Migration on Undeveloped and Natural Lands



Wildfire Fuel Reduction and Thinning from Below in forested Lands

The TerraCount Activity Sheets differentiate between two wildfire mitigation practices in forests, based on forest type and forest management. The practice referred to as thinning from below includes the removal of ladder fuels (i.e., the creation of shaded fuel breaks) in conifer forests managed for timber production. Fuel reduction refers to the removal of biomass in any forest type that could benefit from fuels reduction. The method of fuel reduction is not specified and could be conducted via mechanical thinning, herbivory, or other methods. In order to avoid double counting the GIS analysis needed to differentiate between forested lands that were suitable for each wildfire mitigation practice.

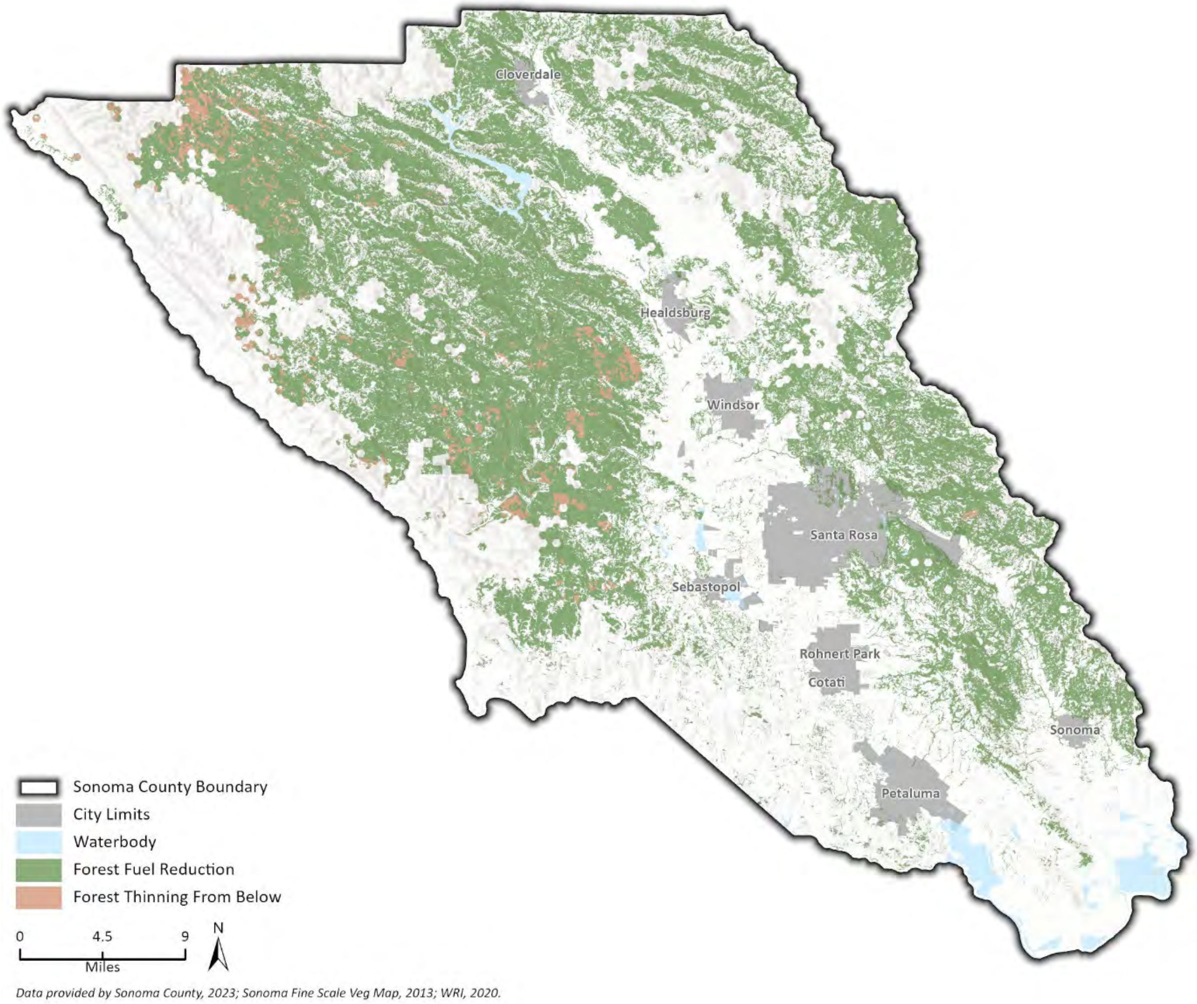
Thinning from below is applicable to conifer forests that are managed for timber production. Fuels reduction is applicable to all forest types where thinning may be beneficial for wildfire mitigation. First, the Sonoma Fine Scale Vegetation Map was utilized to determine whether forest type was conifer only or non-conifer only. To delineate forests that are managed for timber production, a timber production layer was created. This was done by mapping California Department of Forestry and Fire Protection (CAL FIRE) Timber Harvesting Plan data, including current and historical timber harvest plan polygons of all management types, and clipping this to the county boundaries, then merging all remaining polygons into a single layer. This initial layer was then merged with the "TP – Timber Production" zoned areas of Sonoma County, which were pulled from the Sonoma County Zoning and Land Use dataset. These forested areas were then clipped to the Sonoma County Wildfire Risk Index "high," "very-high," and "extreme" wildfire hazard zones to determine the forested areas at highest risk of wildfire. Due to the large acreage of forest in Sonoma County, utilizing this hazard risk layer helped to prioritize the forested lands at greatest risk of wildfire, for wildfire mitigation practices. Lastly, the California Vegetation Treatment Program (CalVTP) data was used to exclude areas recently treated for wildfire fuel reduction, by overlaying the CalVTP project area polygons (projects occurred from 2021-2023) and clipping the forest layer to exclude them, so forested areas that have not recently been treated could be prioritized.

For forest fuel reduction in all forests not managed for timber production, a similar methodology was used. First, the Sonoma Fine Scale Vegetation map was utilized to capture all non-conifer-only forest types in one layer. Another layer started with conifer-only forest types and was clipped to exclude (rather than include) forests that fell within the timber management layer. Remaining conifer-only forests were then combined with the non-conifer forests into a single layer that was clipped to the Sonoma County Wildfire Risk Index "high," "very high," and "extreme" wildfire hazard zones. Lastly, this layer was clipped to exclude the CalVTP fuel reduction project areas (projects occurred from 2021-2023).

The actual implementation of wildfire mitigation practices will be influenced by the location of infrastructure, proximity to residential areas, cost constraints, and other factors. This initial assessment is intended to provide a baseline implementation acreage for the purposes of estimating emissions reduction benefits of wildfire mitigation efforts for this study. The resulting areas of conifer-only forest managed for timber production within the high, very-high, and extreme wildfire hazard zones are potentially suitable for improved forest management through thinning from below, totaling 15,548 acres. The remaining forested areas within the high, very-high, and extreme wildfire hazard zones are potentially suitable for fuels reduction treatments, totaling 399,044 acres.

Figure 12 Depicts the forested lands that could benefit from fuel reduction and thinning from below. Non-conifer only forests with the highest risk of wildfire are shown in green, these forests are potentially suitable for fuels reduction. Conifer-only forests with the highest risk of wildfire are shown in brown, these forests are potentially suitable for improved forest management, thinning from below. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 12 Fuel Reduction and Thinning From Below on Forested Lands



Avoided Conversion to Urban Lands

The Greenbelt Alliance conducted an analysis to assess the natural and agricultural lands at risk of development using a myriad of development pressures and land protections to categorize land as permanently protected (parks and conservation easements), urban, high-risk of development, medium risk of development, or low risk of development. For a full methodology of the at-risk data please refer to the *At Risk: The Bay Area Greenbelt 2017 Methodology*[15] document. The LANDFIRE land cover types that would be at risk for development, specifically forest, shrub/scrub, grasslands, wetlands, and agriculture (orchard, vineyard, cultivated and field crops, pasture and hay), were clipped to the high risk and medium risk of development areas. Because planned development, Regional Housing Needs Allocations, adjacency to recent development and other factors contribute

[15] Greenbelt Alliance. At Risk: Bay Area Greenbelt 2017 Methodology. http://www.greenbelt.org/wp-content/uploads/2017/02/At-Risk-2017-Methodology-Greenbelt-Alliance.pdf

to the high-risk level, these areas were excluded from the lands for potential conservation as they are adjacent to existing development and are likely contributing to required development of housing and other needs. For reference there are 3,300 acres at high risk of development (2,473 acres of natural lands and 826 acres of agricultural lands). Instead, the medium risk area was determined to be suitable as potential areas for permanent conservation as they were much more extensive, are further from urban lands and would limit sprawl, and contribute to the infiltration of rain into local groundwater basins upon which Sonoma County relies heavily. These lands totaled 42,793 acres (31,147 acres of which were natural lands and 11,646 acres of which were agricultural lands).

Figure 13 shows the natural and agricultural lands at medium-risk of development across the entire county. Figure 14 shows the natural and agricultural lands at medium-risk of development in a subsection of the county. Agricultural lands are shown in magenta, shrub/scrub lands are shown in orange, grasslands are shown in light green, forest are shown in dark green, and wetlands are shown in blue. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 13 Avoided Conversion to Urban, Entire County

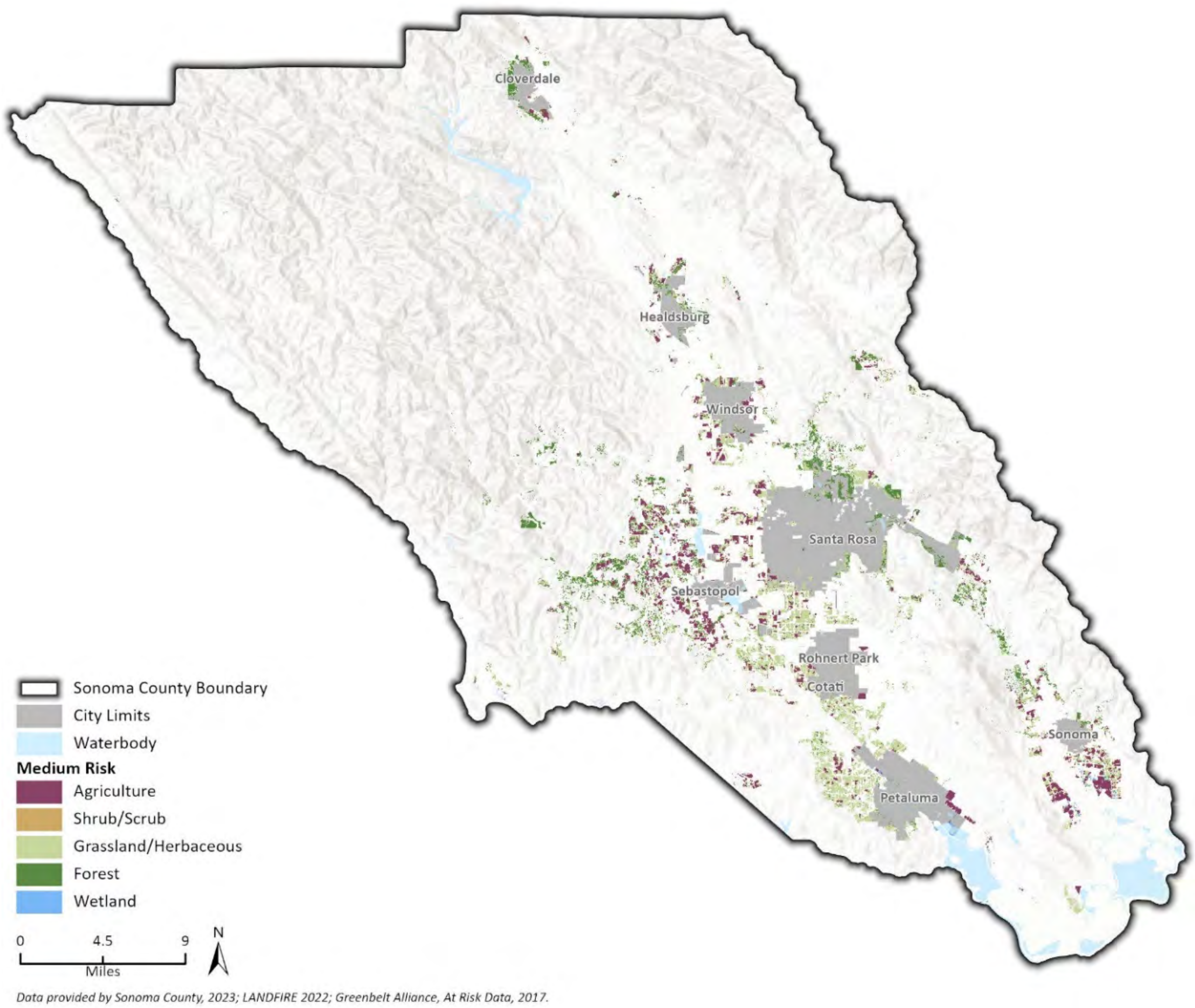
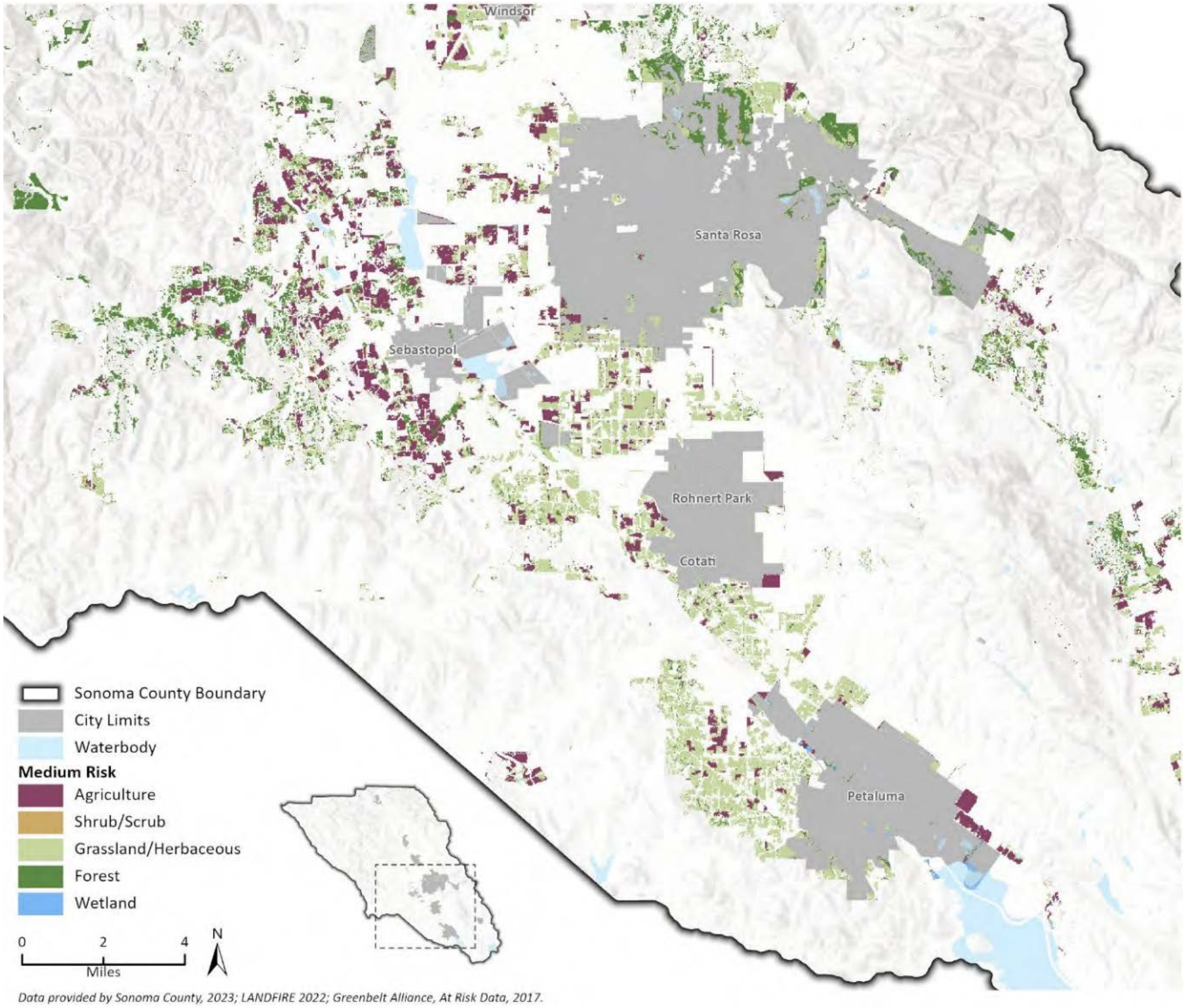


Figure 14 Avoided Conversion to Urban, Subsection



Avoided Conversion to Annual Crops/Vineyards

Several key assumptions were made for this analysis. First, it was assumed that conversion of natural lands to vineyards is the most likely conversion type given the large role of viniculture in the county. Second, the assumption was made that the GHG emissions associated with conversion of natural lands to vineyard was roughly comparable to the GHG emissions associated with conversion to row crops, which is the conversion type specified in the TerraCount activity sheet outlining the parameters for this climate smart practice. There will be slight differences in the carbon sequestration benefits of vineyards versus annual crops. However, the project team determined that the main carbon sequestration benefit was from avoided conversion of natural land covers and the carbon sequestered in their biomass and soils, which would be close to equivalently disturbed/lost with conversion to vineyard as compared to conversion to annual crops. Avoided conversion is a one-time activity and does not account for ongoing emissions or carbon stock losses related to agricultural activities after conversion. The final key assumption was that lands with the biophysical properties making them eligible for VESCO level 1 permits (less than 10 percent slope for highly-erodible soils and less than 15 percent slope for non-highly erodible soils) are at the highest risk of conversion to vineyard.

In order to determine the implementation acreage for avoided conversion to vineyards, LANDFIRE land cover data for forest, shrub/scrub, grassland, wetlands, and pasture/hay was utilized. Two biophysical filter layers were created. The first clipped areas of the county with highly erodible soils (SSURGO) to areas with less than 10 percent slope using SSURGO slope data. The second layer included all remaining areas with non-highly erodible soils and clipped that to areas with less than 15 percent slope using SSURGO slope data. The LANDFIRE land covers were then clipped to both of these screening layers to determine the areas potentially eligible for VESCO level 1 permits for vineyard development. This was further clipped to the Bay Area Greenbelt At-Risk medium-level of risk of development data layer to identify the areas with higher risk of development. This resulted in a total of 26,180 acres of natural lands and pasture/hay that could potentially be protected from conversion to vineyard.

Figure 15 shows the natural and agricultural lands at risk of conversion into vineyard across the entire county. Figure 16 shows the natural and agricultural lands at risk of conversion into vineyard in a subsection of the county. Pasture and Hay are shown in brown, shrub/scrub lands are shown in orange, grasslands are shown in light green, forest are shown in dark green, and wetlands are shown in blue. Where city limits are shown indicates the jurisdictional border and not land cover that is considered developed.

Figure 15 Avoided Conversion to Vineyard, Entire County

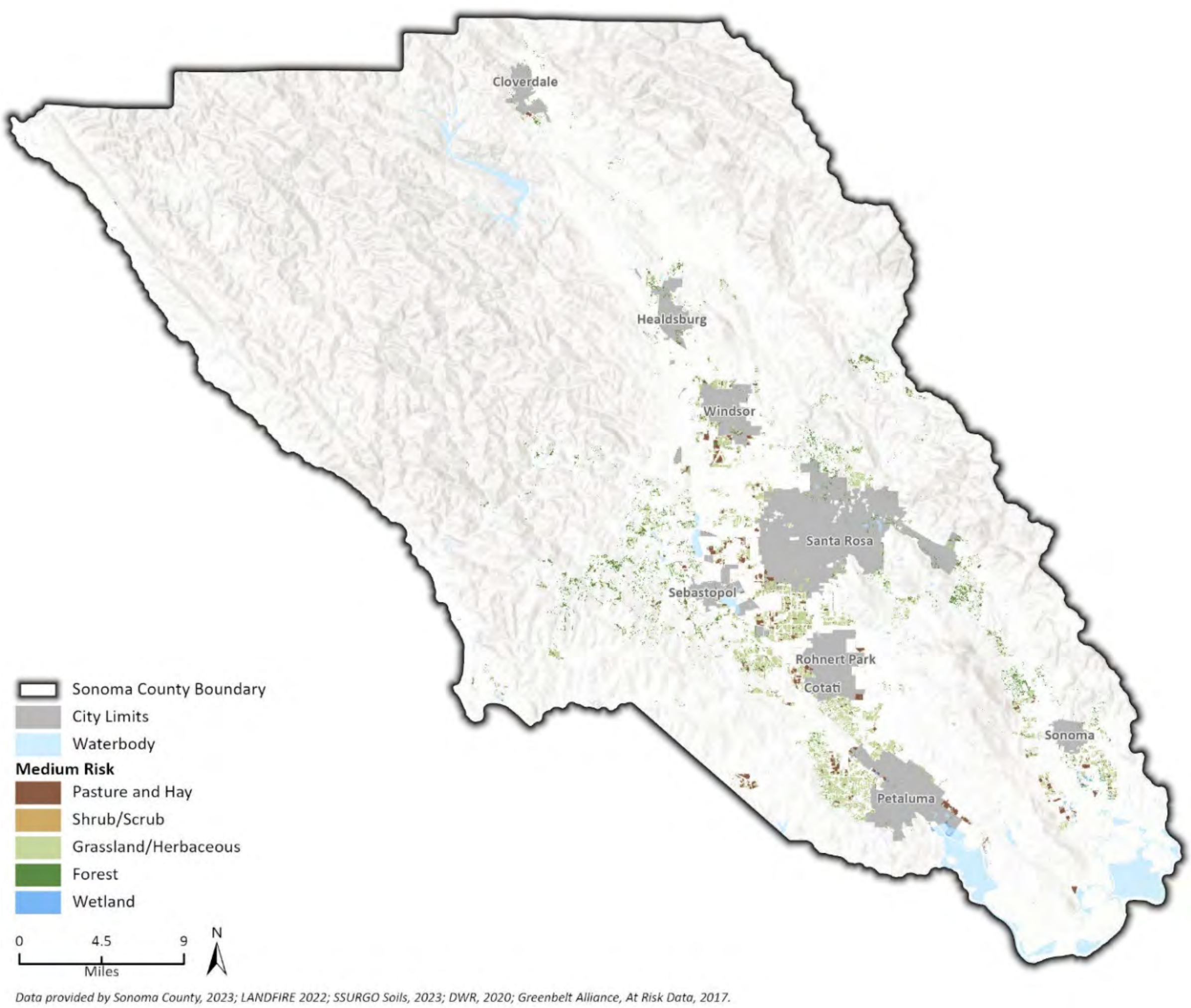
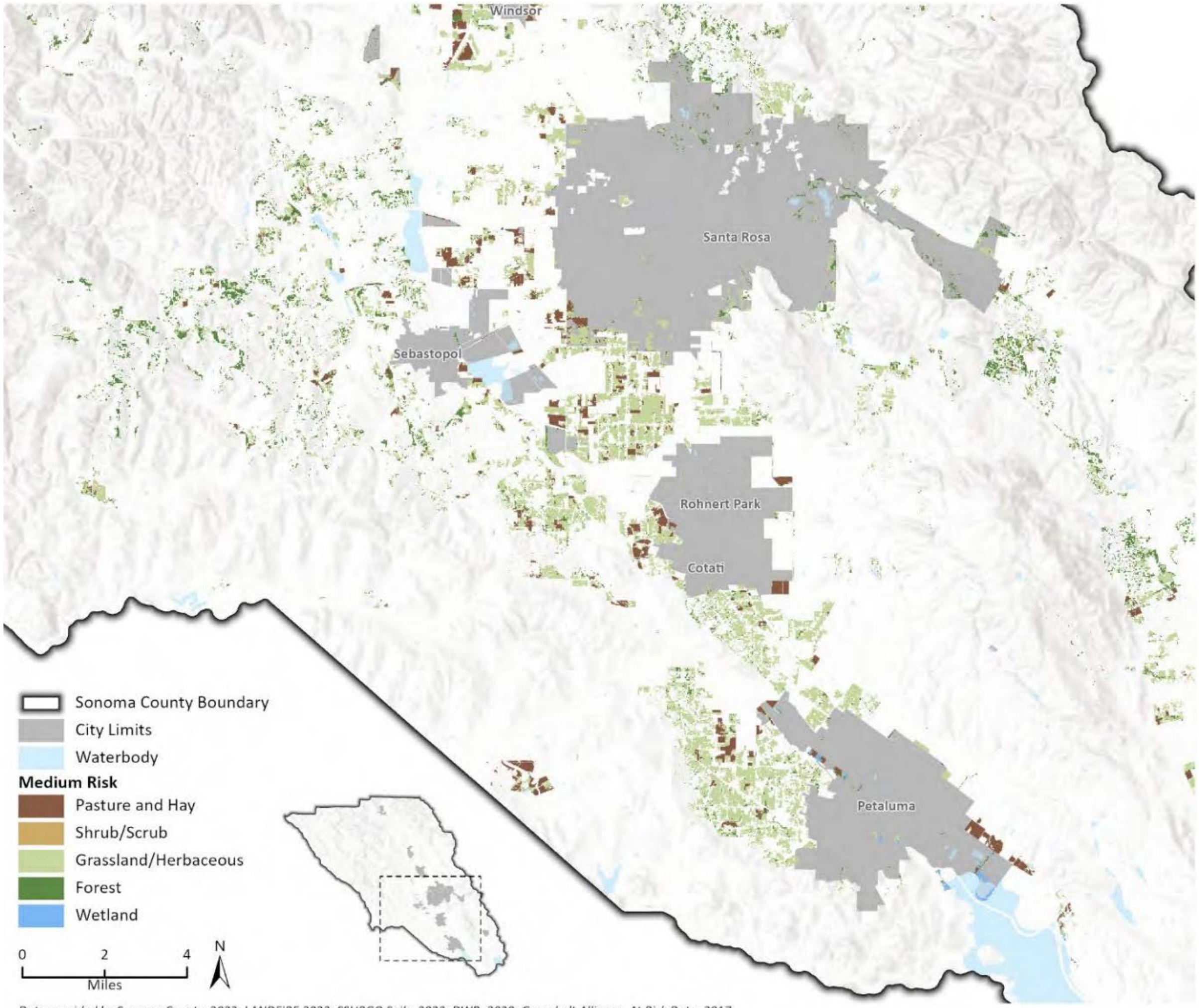


Figure 16 Avoided Conversion to Vineyard, Subsection of County



Data provided by Sonoma County, 2023; LANDFIRE 2022; SSURGO Soils, 2023; DWR, 2020; Greenbelt Alliance, At Risk Data, 2017.

Implementation Acreages for All Practices

Utilizing the methodologies outlined in the above sections, implementation acreages were estimated for all climate smart practices analyzed in this report. These estimations represent a maximum for the potential implementable area in the county for each practice. Likely implementation rates will be much lower than the maximum in most cases; however, it is instructive to consider the maximum possible implementation areas to quantify the maximum potential sequestration, to see which practices have the greatest potential for implementation at large scales and which ones are less relevant or only likely to be implemented at a smaller scale.

Table 5below lists the maximum potential implementation acreages for each climate smart practice, organized by land use category and land cover.

Table 5 Estimated Implementation Acreages for All Carbon Sequestration Activities

Land Use Category	Land Cover	Climate Smart Activity	Estimated Implementation Acreage (AC)
Natural Lands	Forest	Avoided Conversion to Row Crops	5,282
Natural Lands	Forest	Avoided Conversion to Urban	10,879
Natural Lands	Forest	Forest Slash Treatment (CPS 384)	414,591
Natural Lands	Forest	Fuel Reduction	399,044
Natural Lands	Forest	Improved Forest Management Thinning from Below	15,548
Natural Lands	Forest	Riparian Restoration	970
Natural Lands	Grassland	Avoided Conversion to Row Crops	16,085
Natural Lands	Grassland	Native Grassland Restoration	132,077
Natural Lands	Grassland	Oak Woodland Restoration	11,889
Natural Lands	Grassland	Riparian Restoration	339
Natural Lands	Shrub/Scrub	Avoided Conversion to Row Crops	521
Natural Lands	Shrub/Scrub	Avoided Conversion to Urban	818
Natural Lands	Wetland	Conservation of Lands for Coastal Wetland Upland Migration with Sea Level Rise	10,095
Natural Lands	Wetland	Avoided Conversion to Row Crops	1,724
Natural Lands	Wetland	Restoration (from Agricultural Uses)	30,731
Urban Forest	Development	Urban Forestry	5,266
Urban Farms	Cultivated & Field Crops Orchards & Vineyards	Biochar Application (CPS 336)	59
Urban Farms	Cultivated & Field Crops	Compost Application & Nutrient Management (CPS 590)	7.10
Urban Farms	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	24
Urban Farms	Cultivated & Field Crops	Cover Cropping (CPS 340)	5.30
Urban Farms	Cultivated & Field Crops	Field Border (CPS 386)	6.70
Urban Farms	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	0.40
Urban Farms	Cultivated & Field Crops	Mulching (CPS 484)	7.70
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	24
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	24
Urban Farms	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	1.60
Urban Farms	Orchard & Vineyard	Compost Application & Nutrient Management (CPS 590)	52
Urban Farms	Orchard & Vineyard	Cover Cropping (CPS 340)	39
Urban Farms	Orchard & Vineyard	Hedgerow Planting (CPS 422)	3.10
Urban Farms	Orchard & Vineyard	Mulching (CPS 484)	56
Urban Farms	Orchard & Vineyard	Residue and Tillage Management - No Till (CPS 329)	114

Land Use Category	Land Cover	Climate Smart Activity	Estimated Implementation Acreage (AC)
Urban Farms	Orchard & Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	114
Urban Farms	Orchard & Vineyard	Windbreak/Shelterbelt Establishment (CPS 380)	11
Working Lands	All agricultural land covers	Riparian Forest Buffer (CPS 391)	4,503
Working Lands	All agricultural land covers	Riparian Herbaceous Cover (CPS 390)	4,503
Working Lands	Cultivated & Field Crops	Alley Cropping (CPS 311)	1,210
Working Lands	Cultivated & Field Crops	Biochar Application (CPS 336)	849
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808)	849
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808)	849
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) & Nutrient Management (CPS 590)	849
Working Lands	Cultivated & Field Crops	Conservation Cover (CPS 327)	61
Working Lands	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	1,210
Working Lands	Cultivated & Field Crops	Cover Cropping (CPS 340)	849
Working Lands	Cultivated & Field Crops	Field Border (CPS 386)	109
Working Lands	Cultivated & Field Crops	Filter Strip (CPS 393)	17
Working Lands	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	23
Working Lands	Cultivated & Field Crops	Mulching (CPS 484)	551
Working Lands	Cultivated & Field Crops	Nutrient Management (CPS 590)	849
Working Lands	Cultivated & Field Crops	Pasture & Hay Planting (CPS 512)	121
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	1,210
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	1,210
Working Lands	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	33
Working Lands	Orchard	Biochar Application (CPS 336)	2,313
Working Lands	Orchard	Compost Application (CPS 808)	2,264
Working Lands	Orchard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	2,264
Working Lands	Orchard	Cover Cropping (CPS 340)	2,313
Working Lands	Orchard	Filter Strip (CPS 393)	300
Working Lands	Orchard	Hedgerow Planting (CPS 422)	86
Working Lands	Orchard	Mulching (CPS 484)	2,267
Working Lands	Orchard	Nutrient Management (CPS 590)	2,264
Working Lands	Orchard	Windbreak/Shelterbelt Establishment (CPS 380)	1,861
Working Lands	Orchard	Residue and Tillage Management - No Till (CPS 329)	1,861
Working Lands	Orchard	Residue and Tillage Management - Reduced Till (CPS 345)	3,101
Working Lands	Orchard	Whole Orchard Recycling (CPS 808)	83

Land Use Category	Land Cover	Climate Smart Activity	Estimated Implementation Acreage (AC)
Working Lands	Vineyard	Biochar Application (CPS 336)	58,233
Working Lands	Vineyard	Compost Application (CPS 808)	57,007
Working Lands	Vineyard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	57,007
Working Lands	Vineyard	Cover Cropping (CPS 340)	58,233
Working Lands	Vineyard	Filter Strip (CPS 393)	300
Working Lands	Vineyard	Hedgerow Planting (CPS 422)	2,155
Working Lands	Vineyard	Mulching (CPS 484)	57,069
Working Lands	Vineyard	Nutrient Management (CPS 590)	57,007
Working Lands	Vineyard	Windbreak/Shelterbelt Establishment (CPS 380)	54,657
Working Lands	Vineyard	Residue and Tillage Management - No Till (CPS 329)	54,657
Working Lands	Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	2,100
Grazing Lands	Rangelands & Pasture	Compost Application to Rangelands (CPS 808)	21,437
Grazing Lands	Rangelands	Native Oak Restoration/Silvopasture (CPS 381)	51,655
Grazing Lands	Pasture	Prescribed Grazing (CPS 528) (Pasture)	8,200
Grazing Lands	Rangelands	Prescribed Grazing (CPS 528) (Rangelands)	142,371
Grazing Lands	Rangelands	Range Planting (CPS 550)	44,420
Grazing Lands	Rangelands	Riparian Forest Buffer (CPS 391)	1,400
Grazing Lands	Rangelands	Tree/Shrub Establishment (CPS 612)	2,847

Carbon Sequestration Potential

The results from the implementation acreage estimation analyses were used to estimate the future carbon sequestration potential countywide.[16] This carbon sequestration potential and complementary benefits analysis used the estimated sequestration and GHG emissions reduction coefficients provided in the TerraCount Activity Sheets and COMET-Planner.[17,18] Below in Table 6 is the urban forestry example of the parameters and equation provided in the TerraCount Activity Sheets.

Table 6 TerraCount Activity Sheet Carbon Sequestration Equation Example

$$Total\ Estimated\ GHG\ Reductions = R * I * D * (100\% - L)$$

Parameter	Value	Unit
R = Per acre annual reduction rate	133.136	MT CO_2e/acre/year
I = Total increase in canopy cover acreage within activity area	[Different per activity]	Acres
D = Duration of activity	1	Years
L = Leakage discount	0	Percent

Notes: reproduction of an example equation and variables from the TerraCount Activity Sheets

[Different depending on the climate smart practice assessed] = To be determined by user. See Attachment A.

The duration of all activities (*D*) was assumed to be 1 year due to an assumed delay in implementation to allow for stakeholder engagement and a more extensive planning process. The annualized implementation duration allows for a comparison of practices across the marginal unit of 1 year of implementation. The County may then decide the target acreages and duration for actual implementation and adjust the estimated carbon sequestration benefits accordingly. See Attachment A for calculations.

Results and Next Steps

Adoption Levels, Target Setting, and Next Steps with SMACCC

The results of the potential carbon sequestration and emissions reduction analysis are provided in Table 7 below. The table is organized by land use category, land cover, and climate smart practice. The potential carbon sequestration or emission reduction value for the maximum potential implementation acreage is provided first. This can be thought of as the 100 percent adoption scenario for each practice to provide a sense of the total potential sequestration for a given practice in the county. Because 100 percent adoption is highly unlikely and targets for adoption have not yet been set, carbon sequestration potential is also provided for the 1 percent adoption scenario. The 1 percent adoption scenario is also unlikely and the preferrable adoption scenario would be greater than 1 percent for all practices; however, it is valuable as a marginal unit of change in practice implementation for evaluation and planning purposes. Both values, along with additional adoption level scenarios (5 percent, 8 percent, 10 percent, 15 percent, 25 percent, and 50 percent adoption level sequestration potentials) available in Attachment A, should be useful during stakeholder

[16] Countywide sequestration potential includes all lands including incorporated and unincorporated areas.

[17] TerraCount. N.d. Appendix L Activity Sheets. Available <https://maps.conservation.ca.gov/TerraCount/downloads/>. Accessed March 26, 2022.

[18] COMET-Planner for the CDFA Healthy Soils Program. http://comet-planner-cdfahsp.com/

engagement, follow up analysis with SMACCC, and later planning processes for setting county-wide adoption targets. The TerraCount model typically caps adoption levels between 5 percent and 20 percent above baseline adoption for a practice. It is recommended that the target setting for climate smart practices be developed through the SMACCC project where RCDs, local agricultural producers, community members, and other stakeholders will help assess the current adoption rates for various practices, the potential for increasing adoption rates, the sequestration potential for practices as refined through further work in the SMACCC project, and the agroecological and social co-benefits that practices provide over the expected practice lifetime.

Results

It should be noted that conservation climate smart activities that avoid land conversion from one type to another are considered one-time practices, with lands conserved permanently, therefore, the carbon sequestration benefit only being applied one time. The sequestration value provided for all other practices is for 1 year of implementing or maintaining that practice. Comparison of the relative benefits of practices should take into account the expected lifespan of the practice, the potential maximum implementation acreage in the county, and the annual sequestration potential among cost and other considerations. For the purposes of this analysis, activities that reduce or avoid emissions are compared to practices that actually sequester carbon. For example, avoiding the conversion of a natural or working landscape to development in effect reduces the emissions associated with that potential development and protects the carbon stocks of those lands from loss through development. Alternatively, planting trees in the urban landscape or implementing cover cropping on farms can increase the amount of carbon stored in biomass or soil through sequestration. Sequestration and emissions reduction activities are activities are combined for the purposes of comparison, but it may be helpful to understand this distinction.

Table 7 Estimated Annual Carbon Sequestration Potential by Climate Smart Practice

Land Use Category	Land Cover	Climate Smart Activity	Annual Carbon Sequestration – 100% Adoption Scenario (MT CO_2e)	Annual Carbon Sequestration – 1% Adoption Scenario (MT CO_2e)
Natural Lands	Forest	Avoided Conversion to Row Crops	606,173	6,062
Natural Lands	Forest	Avoided Conversion to Urban	1,733,590	17,336
Natural Lands	Forest	Forest Slash Treatment (CPS 384)	NA	NA
Natural Lands	Forest	Fuel Reduction	399,044	3,990
Natural Lands	Forest	Improved Forest Management Thinning from Below	27,986	280
Natural Lands	Forest	Riparian Restoration	6,591	66
Natural Lands	Grassland	Avoided Conversion to Row Crops	290,202	2,902
Natural Lands	Grassland	Native Grassland Restoration	79,147	791
Natural Lands	Grassland	Oak Woodland Restoration	17,239	172
Natural Lands	Grassland	Riparian Restoration	2,304	23
Natural Lands	Shrub/Scrub	Avoided Conversion to Row Crops	43,390	434
Natural Lands	Shrub/Scrub	Avoided Conversion to Urban	64,636	646
Natural Lands	Wetland	Conservation of Lands for Coastal Wetland Upland Migration with Sea Level Rise	57,693	577
Natural Lands	Wetland	Avoided Conversion to Row Crops	NA	NA
Natural Lands	Wetland	Restoration (from Agricultural Uses)	NA	NA
Urban Forest	Development	Urban Forestry	701,121	7,011
Urban Farms	Cultivated & Field Crops	Compost Application & Nutrient Management (CPS 590)	14	0.14
Urban Farms	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	5	0.05
Urban Farms	Cultivated & Field Crops	Cover Cropping (CPS 340)	2	0.02
Urban Farms	Cultivated & Field Crops	Field Border (CPS 386)	8	0.08
Urban Farms	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	4	0.04
Urban Farms	Cultivated & Field Crops	Mulching (CPS 484)	2	0.02
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	5	0.05
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	3	0.03
Urban Farms	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	13	0.13
Urban Farms	Orchard & Vineyard	Compost Application & Nutrient Management (CPS 590)	80	0.80
Urban Farms	Orchard & Vineyard	Cover Cropping (CPS 340)	64	0.64

Land Use Category	Land Cover	Climate Smart Activity	Annual Carbon Sequestration – 100% Adoption Scenario (MT CO_2e)	Annual Carbon Sequestration – 1% Adoption Scenario (MT CO_2e)
Urban Farms	Orchard & Vineyard	Hedgerow Planting (CPS 422)	25	0.25
Urban Farms	Orchard & Vineyard	Mulching (CPS 484)	19	0.19
Urban Farms	Orchard & Vineyard	Residue and Tillage Management - No Till (CPS 329)	40	0.40
Urban Farms	Orchard & Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	14	0.14
Urban Farms	Orchard & Vineyard	Windbreak/Shelterbelt Establishment (CPS 380)	94	0.94
Working Lands	All Agricultural Land Covers	Riparian Forest Buffer (CPS 391)	40,797	408
Working Lands	All Agricultural Land Covers	Riparian Herbaceous Cover (CPS 390)	946	9.5
Working Lands	Cultivated & Field Crops	Alley Cropping (CPS 311)	2,105	21
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) Compost C/N </= 11, 3 tons per acre.	1,758	18
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) Compost C/N > 11, 6 tons per acre.	3,685	37
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) & Nutrient Management (CPS 590)	1,741	17.4
Working Lands	Cultivated & Field Crops	Conservation Cover (CPS 327)	38	0.4
Working Lands	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	266	2.7
Working Lands	Cultivated & Field Crops	Cover Cropping (CPS 340)	340	3.4
Working Lands	Cultivated & Field Crops	Field Border (CPS 386)	134	1.3
Working Lands	Cultivated & Field Crops	Filter Strip (CPS 393)	21	0.2
Working Lands	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	192	1.9
Working Lands	Cultivated & Field Crops	Mulching (CPS 484)	176	1.8
Working Lands	Cultivated & Field Crops	Nutrient Management (CPS 590)	-17	-0.2
Working Lands	Cultivated & Field Crops	Pasture & Hay Planting (CPS 512)	148	1.5
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	266	2.7
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	145	1.5

Land Use Category	Land Cover	Climate Smart Activity	Annual Carbon Sequestration – 100% Adoption Scenario (MT CO_2e)	Annual Carbon Sequestration – 1% Adoption Scenario (MT CO_2e)
Working Lands	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	274	2.7
Working Lands	Orchard	Compost Application (CPS 808)	3,509	35
Working Lands	Orchard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	3,509	35
Working Lands	Orchard	Cover Cropping (CPS 340)	3,793	38
Working Lands	Orchard	Filter Strip (CPS 393)	180	2
Working Lands	Orchard	Hedgerow Planting (CPS 422)	702	7
Working Lands	Orchard	Mulching (CPS 484)	771	8
Working Lands	Orchard	Nutrient Management (CPS 590)	0	0
Working Lands	Orchard	Residue and Tillage Management - No Till (CPS 329)	651	7
Working Lands	Orchard	Residue and Tillage Management - Reduced Till (CPS 345)	223	2
Working Lands	Orchard	Whole Orchard Recycling (CPS 808)	124	1
Working Lands	Orchard	Windbreak/Shelterbelt Establishment (CPS 380)	684	7
Working Lands	Vineyard	Compost Application (CPS 808)	88,361	884
Working Lands	Vineyard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	88,361	884
Working Lands	Vineyard	Cover Cropping (CPS 340)	95,502	955
Working Lands	Vineyard	Filter Strip (CPS 393)	180	2
Working Lands	Vineyard	Hedgerow Planting (CPS 422)	17,671	177
Working Lands	Vineyard	Mulching (CPS 484)	19,404	194
Working Lands	Vineyard	Nutrient Management (CPS 590)	0	0
Working Lands	Vineyard	Residue and Tillage Management - No Till (CPS 329)	19,130	191
Working Lands	Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	6,559	66
Working Lands	Vineyard	Windbreak/Shelterbelt Establishment (CPS 380)	17,223	172

Land Use Category	Land Cover	Climate Smart Activity	Annual Carbon Sequestration – 100% Adoption Scenario (MT CO_2e)	Annual Carbon Sequestration – 1% Adoption Scenario (MT CO_2e)
Grazing Lands	Rangelands & Pasture	Compost Application to Rangelands (CPS 808)	31,941	319
Grazing Lands	Rangelands	Native Oak Restoration/Silvopasture (CPS 381)	69,218	692
Grazing Lands	Pasture	Prescribed Grazing (CPS 528) (Pasture)	820	8.20
Grazing Lands	Rangelands	Prescribed Grazing (CPS 528) (Rangelands)	12,813	128
Grazing Lands	Rangelands	Range Planting (CPS 550)	22,210	222
Grazing Lands	Rangelands	Riparian Forest Buffer (CPS 391)	12,684	127
Grazing Lands	Rangelands	Tree/Shrub Establishment (CPS 612)	53,788	538

Conclusion

The County of Sonoma is beginning a process of stakeholder engagement and long-term planning that will make use of the findings of this study to help set targets for climate smart practice adoption and implementation. The results of this study may be used to aid in stakeholder discussions and provide the foundation for future study. Target setting for climate smart management practices should consider a range of factors including the potential for practices to be implemented at scale, the rate of sequestration associated with a practice, and the expected lifespan of that practice. Additional discussion with stakeholders should use these findings to further conversations about likely implementation, and costs and funding for implementation, partnerships, and future feasibility studies for specific projects or actions. Additionally, as part of the planning process, the County will consider the resources required to maintain and monitor climate smart practice implementation. Implementation of climate smart practices will require a continual evaluation of local conditions, pursuit of available federal, state, and private funds, and coordination with key partners, to maximize practice adoption achieve the greatest climate resilience and community co-benefits possible. Partnerships with agricultural and natural landowners will be key in ensuring that any barriers to implementation are addressed.

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Attachment A

Carbon Sequestration Potential By Adoption Level

Land Use Category	Land Cover	Management Practice	Implementation Acreage Coefficient (if applicable)	Land Cover Type - Total Acreage	Maximum Implementation Acreage in Sonoma County	CO2	N2O	CH4	CO2e Sequestration and Emissions Reduction Coefficient (MT CO2e/ac/yr)	Leakage Assumed (if applicable - Terracount Provided)	CO2e Sequestration Coefficient after Leakage (MT CO2e/ac/yr)	Potential Annual CO2 Sequestered Estimate (Mg CO2e/yr), 100% Adoption	1% Adoption	5% Adoption	8% Adoption	10% Adoption	15% Adoption	25% Adoption	50% Adoption
Grazing Lands	Pasture	Prescribed Grazing (CPS 528) (Pasture)	NA	NA	8,200	0.05	0.05	0	0.1	0	0.10	820	8.20	41.00	65.60	82.00	123.00	205.00	410.00
Grazing Lands	Rangeland	Compost Application to Rangelands (CPS 808)	NA	NA	21,437	4.54	-0.05	0.01	1.49	0	1.49	31,941	319	1597.06	2555.29	3194.11	4791.17	7985.28	15970.57
Grazing Lands	Rangeland	Prescribed Grazing (CPS 528) (Rangelands)	NA	NA	142,371	0.04	0.05	0	0.09	0	0.09	12,813	128	640.67	1025.07	1281.34	1922.01	3203.35	6406.70
Grazing Lands	Rangeland	Tree/Shrub establishment (CPS 612)	0.0200	142,371	2,847	18.89	NA	NA	18.89	0	18.89	53,788	538	2689.39	4303.02	5378.78	8068.16	13446.94	26893.88
Grazing Lands	Rangeland & Pasture	Native Oak Restoration/Silvopasture (CPS 381)	NA	NA	51,655	1.34	NA	NA	1.34	0	1.34	69,218	692	3460.89	5537.42	6921.77	10382.66	17304.43	34608.85
Grazing Lands	Rangeland & Pasture	Range Planting (CPS 550)	0.3120	142,371	44,420	0.5	0	NA	0.50	0	0.50	22,210	222	1110.49	1776.79	2220.99	3331.48	5552.47	11104.94
Natural Lands	Forest	Avoided conversion to row crops	NA	506,840.00	5,282	NA	NA	NA	191.27	0.4	114.76	606,173	6,062	30308.64	48493.83	60617.29	90925.93	151543.22	303086.44
Natural Lands	Forest	Avoided conversion to urban	NA	506,840.00	10,879	NA	NA	NA	159.35	0	159.35	1,733,590	17,336	86679.52	138687.23	173359.04	260038.56	433397.60	866795.20
Natural Lands	Forest	Forest Slash Treatment (CPS 384)	NA	NA	414,591	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Natural Lands	Forest	Fuel reduction	NA	506,840.00	399,044	NA	NA	NA	1	0	1.00	399,044	3,990	19952.18	31923.48	39904.35	59856.53	99760.88	199521.75
Natural Lands	Forest	Improved forest management thinning from below	NA	506,840.00	15,548	NA	NA	NA	3	0.4	1.80	27,986	280	1399.28	2238.85	2798.57	4197.85	6996.42	13992.84
Natural Lands	Forest	Riparian restoration	NA	506,840.00	970	NA	NA	NA	9.06	0.25	6.80	6,591	66	329.56	527.29	659.12	988.67	1647.79	3295.58
Natural Lands	Grassland	Avoided conversion to row crops	NA	215,490.00	16,085	NA	NA	NA	24.06	0.25	18.04	290,202	2,902	14510.10	23216.16	29020.20	43530.30	72550.50	145100.99
Natural Lands	Grassland	Native grassland restoration	NA	215,490.00	132,077	NA	NA	NA	0.80	0.25	0.60	79,147	791	3957.36	6331.77	7914.71	11872.07	19786.79	39573.57
Natural Lands	Grassland	Oak woodland restoration	NA	215,490.00	11,889	NA	NA	NA	1.45	0.00	1.45	17,239	172	861.95	1379.12	1723.91	2585.86	4309.76	8619.53
Natural Lands	Grassland	Riparian Restoration	NA	215,490.00	339	NA	NA	NA	9.06	0.25	6.80	2,304	23	115.18	184.28	230.35	345.53	575.88	1151.75
Natural Lands	Shrub/scrub	Avoided conversion to row crops	NA	53,201.00	521	NA	NA	NA	110.98	0.25	83.24	43,390	434	2169.50	3471.19	4338.99	6508.49	10847.48	21694.96
Natural Lands	Shrub/scrub	Avoided conversion to urban	NA	53,201.00	818	NA	NA	NA	79.07	0	79.07	64,636	646	3231.82	5170.91	6463.64	9695.46	16159.11	32318.21
Natural Lands	Wetlands	Avoided conversion to row crops	NA	13,276.00	10,095	NA	NA	NA	7.62	0.25	5.72	57,693	577	2884.65	4615.43	5769.29	8653.94	14423.23	28846.46
Natural Lands	Wetlands	Conservation of Lands for coastal wetland upland migration with sea level rise	NA	NA	1,724	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Natural Lands	Wetlands/Croplands	Wetland Restoration (from agricultural uses)	NA	NA	30,731	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Urban Farms	Cultivated & Field Crops	Compost Application (CPS 808) & Nutrient Management (CPS 590)	0.2942	24	7.1	2.24	-0.19	0	2.05	0	2.05	14	0.14	0.72	1.16	1.45	2.17	3.62	7.24
Urban Farms	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	1	24	24.0	0.21	0.01	NA	0.22	0	0.22	5	0.05	0.26	0.42	0.53	0.79	1.32	2.64
Urban Farms	Cultivated & Field Crops	Cover Cropping (CPS 340)	0.2206	24	5.3	0.5	-0.1	0	0.40	0	0.40	2	0.02	0.11	0.17	0.21	0.32	0.53	1.06
Urban Farms	Cultivated & Field Crops	Field Border (CPS 386)	0.28	24	6.7	1.35	-0.12	0	1.23	0	1.23	8	0.08	0.41	0.66	0.83	1.24	2.07	4.13
Urban Farms	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	0.0176	24	0.4	8.28	0.13	NA	8.41	0	8.41	4	0.04	0.18	0.28	0.36	0.53	0.89	1.78

Land Use Category	Land Cover	Management Practice	Implementation Acreage Coefficient (if applicable)	Land Cover Type - Total Acreage	Maximum Implementation Acreage in Sonoma County	CO2	N2O	CH4	CO2e Sequestration and Emissions Reduction Coefficient (MT CO2e/ac/yr)	Leakage Assumed (if applicable - Terracount Provided)	CO2e Sequestration Coefficient after Leakage (MT CO2e/ac/yr)	Potential Annual CO2 Sequestered Estimate (Mg CO2e/yr), 100% Adoption	1% Adoption	5% Adoption	8% Adoption	10% Adoption	15% Adoption	25% Adoption	50% Adoption
Urban Farms	Cultivated & Field Crops	Mulching (CPS 484)	0.3188	24	7.7	0.32	0	NA	0.32	0	0.32	2	0.02	0.12	0.20	0.24	0.37	0.61	1.22
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	1	24	24.0	0.18	0.04	0	0.22	0	0.22	5	0.05	0.26	0.42	0.53	0.79	1.32	2.64
Urban Farms	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	1	24	24.0	0.09	0.03	0	0.12	0	0.12	3	0.03	0.14	0.23	0.29	0.43	0.72	1.44
Urban Farms	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	0.0649	24	1.6	8.28	0.13	NA	8.41	0	8.41	13	0.13	0.65	1.05	1.31	1.96	3.27	6.55
Urban Farms	Orchards & Vineyards	Compost Application (CPS 808) & Nutrient Management (CPS 590)	0.2942	176	51.8	1.66	-0.11	0	1.55	0	1.55	80	0.80	4.01	6.42	8.03	12.04	20.06	40.13
Urban Farms	Orchards & Vineyards	Cover Cropping (CPS 340)	0.2206	176	38.8	1.69	-0.05	0	1.64	0	1.64	64	0.64	3.18	5.09	6.37	9.55	15.92	31.84
Urban Farms	Orchards & Vineyards	Hedgerow Planting (CPS 422)	0.0176	176	3.1	8.2	NA	NA	8.20	0	8.20	25	0.25	1.27	2.03	2.54	3.81	6.35	12.70
Urban Farms	Orchards & Vineyards	Mulching (CPS 484)	0.3188	176	56.1	0.53	-0.19	0	0.34	0	0.34	19	0.19	0.95	1.53	1.91	2.86	4.77	9.54
Urban Farms	Orchards & Vineyards	Residue and Tillage Management - No Till (CPS 329)	0.65	176	114.4	0.32	0.03	0	0.35	0	0.35	40	0.40	2.00	3.20	4.00	6.01	10.01	20.02
Urban Farms	Orchards & Vineyards	Residue and Tillage Management - Reduced Till (CPS 345)	0.65	176	114.4	0.09	0.03	0	0.12	0	0.12	14	0.14	0.69	1.10	1.37	2.06	3.43	6.86
Urban Farms	Orchards & Vineyards	Windbreak/Shelterbelt Establishment (CPS 380)	0.0649	176	11.4	8.2	NA	NA	8.20	0	8.20	94	0.94	4.68	7.49	9.37	14.05	23.42	46.83
Urban Forest	Development	Increasing Urban Forest Canopy Cover	0.05	105,324.00	5,266	NA	NA	NA	133.136	0.00%	133.14	701,121	7,011	35056.04	56089.66	70112.08	105168.12	175280.20	350560.40
Working Lands	All Agricultural Lands	Riparian Forest Buffer (CPS 391)	NA	NA	4,503	1.85	0.13	NA	9.06	0	9.06	40,797	408	2039.86	3263.77	4079.72	6119.58	10199.30	20398.59
Working Lands	All Agricultural Lands	Riparian Herbaceous Cover (CPS 390)	NA	NA	4,503	0.08	0.13	0	0.21	0	0.21	946	9.5	47.28	75.65	94.56	141.84	236.41	472.82
Working Lands	Cultivated & Field Crops	Alley Cropping (CPS 311)	1	1,210.00	1,210	1.71	0.03	NA	1.74	0	1.74	2,105	21	105.27	168.43	210.54	315.81	526.35	1052.70
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) - Compost C/N </= 11, 3 tons per acre	0.7017	1,210.00	849	2.27	-0.2	0	2.07	0	2.07	1,758	18	87.88	140.60	175.75	263.63	439.39	878.77
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) - Compost C/N > 11, 6 tons per acre	0.7017	1,210.00	849	4.53	-0.19	0	4.34	0	4.34	3,685	37	184.25	294.79	368.49	552.74	921.23	1842.45
Working Lands	Cultivated & Field Crops	Compost Application (CPS 808) & Nutrient Management (CPS 590)	0.7017	1,210.00	849	2.24	-0.19	0	2.05	0	2.05	1,741	17.4	87.03	139.25	174.06	261.09	435.14	870.28
Working Lands	Cultivated & Field Crops	Conservation Cover (CPS 327)	0.05	1,210.00	61	0.61	0.02	0	0.63	0	0.63	38	0.4	1.91	3.05	3.81	5.72	9.53	19.06
Working Lands	Cultivated & Field Crops	Conservation Crop Rotation (CPS 328)	1	1,210.00	1,210	0.21	0.01	NA	0.22	0	0.22	266	2.7	13.31	21.30	26.62	39.93	66.55	133.10
Working Lands	Cultivated & Field Crops	Cover Cropping (CPS 340)	0.7017	1,210.00	849	0.5	-0.1	0	0.40	0	0.40	340	3.4	16.98	27.17	33.96	50.94	84.91	169.81
Working Lands	Cultivated & Field Crops	Field Border (CPS 386)	0.09	1,210.00	109	1.35	-0.12	0	1.23	0	1.23	134	1.3	6.70	10.72	13.39	20.09	33.49	66.97
Working Lands	Cultivated & Field Crops	Filter Strip (CPS 393)	NA	1,210.00	17	1.35	-0.12	0	1.23	0	1.23	21	0.2	1.07	1.72	2.15	3.22	5.37	10.73
Working Lands	Cultivated & Field Crops	Hedgerow Planting (CPS 422)	0.0189	1,210.00	23	8.28	0.13	NA	8.41	0	8.41	192	1.9	9.62	15.39	19.23	28.85	48.08	96.16
Working Lands	Cultivated & Field Crops	Mulching (CPS 484)	0.4557	1,210.00	551	0.32	0	NA	0.32	0	0.32	176	1.8	8.82	14.12	17.64	26.47	44.11	88.22
Working Lands	Cultivated & Field Crops	Nutrient Management (CPS 590)	0.7017	1,210.00	849	-0.03	0.01	0	-0.02	0	-0.02	-17	-0.2	-0.85	-1.36	-1.70	-2.55	-4.25	-8.49

Land Use Category	Land Cover	Management Practice	Implementation Acreage Coefficient (if applicable)	Land Cover Type - Total Acreage	Maximum Implementation Acreage in Sonoma County	CO2	N2O	CH4	CO2e Sequestration and Emissions Reduction Coefficient (MT CO2e/ac/yr)	Leakage Assumed (if applicable - Terracount Provided)	CO2e Sequestration Coefficient after Leakage (MT CO2e/ac/yr)	Potential Annual CO2 Sequestered Estimate (Mg CO2e/yr), 100% Adoption	1% Adoption	5% Adoption	8% Adoption	10% Adoption	15% Adoption	25% Adoption	50% Adoption
Working Lands	Cultivated & Field Crops	Pasture & Hay Planting (CPS 512)	0.1	1,210.00	121	1.26	-0.04	0	1.22	0	1.22	148	1.5	7.38	11.81	14.76	22.14	36.91	73.81
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - No Till (CPS 329)	1	1,210.00	1,210	0.18	0.04	0	0.22	0	0.22	266	2.7	13.31	21.30	26.62	39.93	66.55	133.10
Working Lands	Cultivated & Field Crops	Residue and Tillage Management - Reduced Till (CPS 345)	1	1,210.00	1,210	0.09	0.03	0	0.12	0	0.12	145	1.5	7.26	11.62	14.52	21.78	36.30	72.60
Working Lands	Cultivated & Field Crops	Windbreak/Shelterbelt Establishment (CPS 380)	0.0269	1,210.00	33	8.28	0.13	NA	8.41	0	8.41	274	2.7	13.69	21.90	27.37	41.06	68.43	136.87
Working Lands	Orchard	Compost Application (CPS 808)	0.7301	3,101.00	2,264	1.7	-0.15	0	1.55	0	1.55	3,509	35	175.46	280.74	350.93	526.39	877.32	1754.63
Working Lands	Orchard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	0.7301	3,101.00	2,264	1.66	-0.11	0	1.55	0	1.55	3,509	35	175.46	280.74	350.93	526.39	877.32	1754.63
Working Lands	Orchard	Cover Cropping (CPS 340)	0.7458	3,101.00	2,313	1.69	-0.05	0	1.64	0	1.64	3,793	38	189.64	303.43	379.29	568.93	948.22	1896.44
Working Lands	Orchard	Filter Strip (CPS 393)	NA	NA	300	0.6	0	0	0.60	0	0.60	180	2	9.00	14.40	18.01	27.01	45.02	90.03
Working Lands	Orchard	Hedgerow Planting (CPS 422)	0.0276	3,101.00	86	8.2	NA	NA	8.20	0	8.20	702	7	35.09	56.15	70.18	105.27	175.45	350.91
Working Lands	Orchard	Mulching (CPS 484)	0.7309	3,101.00	2,267	0.53	-0.19	0	0.34	0	0.34	771	8	38.53	61.65	77.06	115.59	192.65	385.31
Working Lands	Orchard	Nutrient Management (CPS 590)	0.7301	3,101.00	2,264	-0.04	0.04	0	0.00	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Working Lands	Orchard	Residue and Tillage Management - No Till (CPS 329)	0.6	3,101.00	1,861	0.32	0.03	0	0.35	0	0.35	651	7	32.56	52.10	65.12	97.68	162.80	325.61
Working Lands	Orchard	Residue and Tillage Management - Reduced Till (CPS 345)	0.6	3,101.00	1,861	0.09	0.03	0	0.12	0	0.12	223	2	11.16	17.86	22.33	33.49	55.82	111.64
Working Lands	Orchard	Whole Orchard Recycling (CPS 808)	1	3,101.00	3,101	0.11	-0.08	0.01	0.04	0	0.04	124	1	6.20	9.92	12.40	18.61	31.01	62.02
Working Lands	Orchard	Windbreak/Shelterbelt Establishment (CPS 380)	0.0269	3,101.00	83	8.2	NA	NA	8.20	0	8.20	684	7	34.20	54.72	68.40	102.60	171.00	342.01
Working Lands	Vineyard	Compost Application (CPS 808)	0.7301	78,081.00	57,007	1.7	-0.15	0	1.55	0	1.55	88,361	884	4418.04	7068.86	8836.08	13254.11	22090.19	44180.38
Working Lands	Vineyard	Compost Application (CPS 808) & Nutrient Management (CPS 590)	0.7301	78,081.00	57,007	1.66	-0.11	0	1.55	0	1.55	88,361	884	4418.04	7068.86	8836.08	13254.11	22090.19	44180.38
Working Lands	Vineyard	Cover Cropping (CPS 340)	0.7458	78,081.00	58,233	1.69	-0.05	0	1.64	0	1.64	95,502	955	4775.09	7640.14	9550.18	14325.27	23875.45	47750.90
Working Lands	Vineyard	Filter Strip (CPS 393)	NA	NA	300	0.6	0	0	0.60	0	0.60	180	2	9.00	14.40	18.00	27.00	45.00	90.00
Working Lands	Vineyard	Hedgerow Planting (CPS 422)	0.0276	78,081.00	2,155	8.2	NA	NA	8.20	0	8.20	17,671	177	883.56	1413.70	1767.13	2650.69	4417.82	8835.65
Working Lands	Vineyard	Mulching (CPS 484)	0.7309	78,081.00	57,069	0.53	-0.19	0	0.34	0	0.34	19,404	194	970.18	1552.29	1940.36	2910.54	4850.90	9701.80
Working Lands	Vineyard	Nutrient Management (CPS 590)	0.7301	78,081.00	57,007	-0.04	0.04	0	0.00	0	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
Working Lands	Vineyard	Residue and Tillage Management - No Till (CPS 329)	0.7	78,081.00	54,657	0.32	0.03	0	0.35	0	0.35	19,130	191	956.49	1530.39	1912.98	2869.48	4782.46	9564.92
Working Lands	Vineyard	Residue and Tillage Management - Reduced Till (CPS 345)	0.7	78,081.00	54,657	0.09	0.03	0	0.12	1	0.00	6,559	66	327.94	524.70	655.88	983.82	1639.70	3279.40
Working Lands	Vineyard	Windbreak/Shelterbelt Establishment (CPS 380)	0.0269	78,081.00	2,100	8.2	NA	NA	8.20	0	8.20	17,223	172	861.16	1377.85	1722.31	2583.47	4305.78	8611.55

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Carbon Inventory and Sequestration Potential Study

Analysis of Co-Benefits of Climate Smart Practices

prepared by

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1 Introduction

Carbon sequestration and emissions mitigation is a central benefit of climate smart practices; however, the benefits of these practices extend beyond climate change mitigation. Climate smart practices also offer a range of complementary benefits, or “co-benefits,” that contribute to broader environmental and socio-economic objectives. The evaluation of these co-benefits helps in prioritizing the target setting and implementation of practices to optimize carbon sequestration with broader goals and values in order to deliver the maximum cumulative advantage. The objectives of this analysis are to assess the co-benefits associated with a range of climate-smart practices applied to natural and working lands and to identify practices that offer the highest number of co-benefits with the least negative impacts.

This memorandum outlines the methodology and findings from the application of two evaluation tools: the Conservation Practice Physical Effects (CPPE) tool and TerraCount. The following sections describe the state of co-benefits analyses, the methodology employed, and the findings of the analysis. Long-term planning may incorporate these findings along with those from the carbon sequestration analysis to take a holistic approach to target setting and evaluation of the climate smart practices included in this Study.

1.1 Tools for Complementary Benefits Analysis

A key challenge in climate smart practice evaluation is a lack of a standardized and quantifiable approach to identify and account for the co-benefits associated with implementation of climate smart practices. The following tools provide a standardized way to evaluate and compare the potential co-benefits of implementing climate smart practices. The use of these tools mirrors the sourcing of the climate smart practices which were mostly drawn from Natural Resources Conservation Service (NRCS) conservation practices and TerraCount. The NRCS practices are the foundation for COMET-Planner, a California Department of Food and Agriculture (CDFA) Healthy Soils program tool which was utilized to conduct the carbon sequestration analysis for those practices. TerraCount provides a qualitative assessment of co-benefits for most of the practices included in this Study.

TerraCount

TerraCount, developed by the Department of Conservation and The Nature Conservancy, provides a qualitative assessment for the impact of each practice as positive (+), negative (-) or potentially positive or negative depending on site-specific factors (+/-), for a range of effects on human wellbeing and natural resources. This tool was used to assess the following co-benefits associated with the climate smart practices primarily applied to natural lands:

Human Wellbeing

- Air Quality – estimates air pollution (nitrogen dioxide - NO_2, sulfur dioxide - SO_2, carbon dioxide - CO_2, ozone - O_3, particulate matter 2.5 - PM2.5, and particulate matter 10 - PM10) removed by plants, mainly by uptake through the stomata of leaves
- Scenic Value – visibility of areas developed from public areas, parks, and roadways
- Flood Risk Reduction/Attenuation – tracks acreage of development in the 100-year floodplain

Water Quality

- Ag/Urban Water Conservation – changes in water use driven by land use change
- Water Quality – changes in the chemical, physical, and biological characteristics of water important for ecological and human health
- Groundwater Recharge/Banking Potential – changes in groundwater recharge from scenarios that convert natural lands to development, and/or net change in land cover on lands suitable for groundwater banking as rated by the Soil Agricultural Groundwater Banking Index
- Watershed Integrity – estimated based on the following metrics: riparian areas degraded, important riparian buffer, and natural catchment

Biodiversity and Ecosystem Resilience

- Habitat Stability – Net change in land cover (natural, agricultural or urban) in climate change refugia areas where habitat is more likely to be stable
- Climate Connectivity – Net change in land cover (natural, agricultural or urban) in linkages important for climate-driven species movement
- Terrestrial Connectivity – species movement potential
- Natural Habitat – area of natural habitat
- Priority Conservation Areas – landcover in priority conservation areas (The Nature Conservancy priority conservation areas, Audubon important bird areas, and California Department of Fish and Wildlife essential connectivity areas)
- Terrestrial Habitat Value – terrestrial habitat value for mammals, birds, amphibians, reptiles, and threatened and endangered species
- Aquatic Biodiversity Value/Richness – landcover in watersheds with important aquatic habitat (as defined by The Nature Conservancy's Freshwater Blueprint)

Conservation Practice Physical Effects (CPPE) Tool

The CPPE tool[1], developed by the Natural Resources Conservation Service (NRCS), provides a comprehensive evaluation of the physical effects of different conservation practices on natural resources and human-economic environments. Practices are scored from -5 to 5 depending on the level of positive or negative impact on the physical effect being assessed. This tool was used to assess the following co-benefits associated with the climate smart practices primarily applied to working and grazing lands:

Soil Quality

- Sheet and Rill Erosion - Soil loss caused by water runoff, with sheet erosion being the removal of a uniform thin layer of soil, and rill erosion involving small, shallow channels forming on the soil surface
- Wind Erosion - Soil loss caused by wind detaching, transporting, and depositing soil particles
- Ephemeral Gully Erosion - Erosion occurring in low points or depressions in a field
- Classic Gully Erosion - Deep channels or gullies formed due to water erosion

[1] NRCS. CPPE and RMS Planning Tools. 2022. https://www.nrcs.usda.gov/resources/guides-and-instructions/conservation-practice-physical-effects

- Bank Erosion from Streams, Shorelines or Water Conveyance Channels - Erosion occurring at the banks of streams, shorelines, or channels due to water movement
- Subsidence - The sinking or lowering of the ground surface due to various factors
- Compaction - Compression of soil, reducing its porosity and permeability
- Organic Matter Depletion - Loss of organic material in soil, reducing its fertility and structure
- Concentration of Salts or other Chemicals - Accumulation of salts or chemicals in the soil affecting its health and fertility
- Soil Organism Habitat Loss or Degradation - Loss or degradation of habitats for organisms living in the soil
- Aggregate Instability - Lack of soil particle cohesion, affecting soil structure and erodibility

Water Quality

- Ponding and Flooding - Accumulation of water on land, with ponding being smaller, temporary water pools, and flooding being a more extensive overflow of water
- Seasonal High Water Table - The highest level at which the groundwater occurs naturally during a specific season
- Seeps - Places where groundwater emanates from the ground
- Naturally Available Moisture Use - Utilization of the moisture naturally present in the soil
- Surface Water Depletion - Reduction in above-ground water resources
- Groundwater Depletion - Over-extraction leading to lowering or depleted groundwater levels
- Inefficient Irrigation Water Use - Wasteful or ineffective use of water for irrigation
- Nutrients Transported to Surface Water - Movement of nutrients from land to surface water bodies
- Nutrients Transported to Groundwater - Leakage of nutrients into the groundwater
- Pathogens and Chemicals from Manure, Bio-solids or Compost Applications Transported to Surface Water - Movement of harmful substances from organic matter applications to surface water
- Pathogens and Chemicals from Manure, Bio-solids or Compost Applications Transported to Groundwater - Leakage of harmful substances from organic matter applications into groundwater
- Sediment Transported to Surface Water - Movement of soil particles to surface water bodies
- Pesticides Transported to Surface Water - Movement of pesticides from land to surface water bodies
- Pesticides Transported to Groundwater - Leakage of pesticides into the groundwater
- Petroleum, Heavy Metals and Other Pollutants Transported to Surface Water - Movement of various pollutants from land to surface water bodies
- Petroleum, Heavy Metals and Other Pollutants Transported to Groundwater - Leakage of various pollutants into groundwater
- Salts Transported to Surface Water - Movement of salts from land to surface water bodies
- Salts Transported to Groundwater - Leakage of salts into groundwater
- Elevated Water Temperature - Higher than normal water temperatures

Air Quality

- Emissions of Particulate Matter (PM) and PM Precursors - Release of small particles that have negative human health impacts and substances that can form such particles into the air

- Emissions of Ozone Precursors - Release of substances that can form ozone, a harmful air pollutant, into the air
- Objectionable Odor - Unpleasant smells polluting the air
- Emissions of Airborne Reactive Nitrogen - Release of reactive forms of nitrogen into the air

Plants and Crops

- Plant Pest Pressure - The extent of infestation or threat from pests to plants
- Plant Productivity and Health - The growth rate, yield, and overall well-being of plants
- Plant Structure and Composition - The physical form, arrangement, and variety of plant species in an area
- Wildfire Hazard from Biomass Accumulation - Risk of wildfires due to the buildup of plant material and debris that can fuel fires

Rangeland and Habitat

- Feed and Forage Imbalance - Discrepancy between the availability of feed and forage for livestock and their nutritional needs
- Inadequate Livestock Shelter - Insufficient protection for livestock from adverse weather conditions
- Inadequate Livestock Water Quantity, Quality and Distribution - Lack of sufficient water, in terms of quantity, quality, and accessibility, for livestock
- Terrestrial Habitat for Wildlife and Invertebrates - Land-based habitats that support wildlife and invertebrate species
- Aquatic Habitat for Fish and other Organisms - Water-based habitats that support fish and other aquatic organisms

Energy Efficiency

- Energy Efficiency of Farming/Ranching Practices and Field Operations - The extent to which farming, ranching, and field operations are conducted in a manner that minimizes energy use

1.2 Considerations for Co-benefits Evaluation

Project-level Analysis Versus County-level Analysis

Co-benefit analyses typically yield the most accurate insights at the project or site-specific level. However, this Study takes a county-wide approach with the goal of prioritizing a range of climate smart practices that are both environmentally sustainable and socio-economically beneficial. The actual co-benefits pertaining to a specific project are best discerned at the site-level because the effects of climate smart practices may vary from one site to another due to project and site-specific attributes and resources. General evaluation of all practices considering both carbon sequestration and co-benefits will help with planning and engagement and should be followed up with site-specific analysis for individual projects.

Stacking and Scaling Climate Smart Practices

Climate smart practices are rarely applied in isolation, and utilizing a mix of practices can create a synergistic effect. When climate smart practices, such as composting, cover cropping, mulching, etc., are used in tandem, or stacked, both carbon sequestration and co-benefits are increased. For example, rotating plantings of cover crops between cash crops can add carbon to the soil. When compost is applied to land regularly, the overall capacity to store carbon in soil is increased. Thus, if composting and cover cropping practices are stacked together, the soil carbon storage capacity is increased from compost application, meaning that more carbon from cover crops can be sequestered. Additional soil health co-benefits of stacking climate smart practices may include increased water retention, decreased nutrient leaching, and reduced erosion. These co-benefits would actualizes at higher rate than implementing one soil health enhancing practice on its own. Some practices cannot be implemented in the same area for practical reasons, and those benefits cannot be stacked or summed. For example, reduced till and no till practices cannot both be applied to the same land. Therefore, the carbon sequestration and co-benefits of those two practices should not be considered “stackable.” The tools utilized for this analysis were scored to provide a rating of co-benefits for practices implemented individually, a rough approximation of enhanced benefits could be achieved by adding the benefits of other practices that may be co-implemented, as long as caution is taken to avoid summing practices that could not be applied to the same land.

Co-benefits may also have cumulative effects when assessed at a larger scale and when implemented across many individual sites. For example, implementing riparian buffers at a particular site can help reduce runoff and filter pollutants, improving the water quality of a nearby stream. And when riparian buffers are implemented across multiple sites within a watershed, the cumulative effect can significantly improve the overall water quality in the entire watershed, benefiting downstream ecosystems and communities. This underscores the importance of considering cumulative impacts from individual practices applied across many places, forming part of the county-wide approach to landscape-level planning, collaboration, and resource allocation.

1.3 Methodology

Conducting a co-benefit analysis of climate smart practices involves qualitatively evaluating and quantifying both the primary benefits and the additional co-benefits of such practices. Quantification of the primary (carbon sequestration or emissions reduction) benefit of climate smart practices was included in the Carbon Sequestration Analysis of Climate Smart Practices memorandum. This analysis aims to address the complementary benefits associated with climate smart practices. The co-benefits assessed are determined by the assessment tools available and does not represent an exhaustive list of all possible co-benefits or co-benefit categories.

Quantification of complementary benefits at the county or regional level is not possible with a high degree of accuracy given the currently available tools and data constraints. Therefore, the quantification of co-benefits is a summation of the qualitative improvement or worsening expected from application of practices to a range of effects. The improvement or worsening is assigned a positive or negative value and the sum of those values produces a total co-benefit score. The scores are comparable within the same comparison table (the NRCS CPPE-based tables or the TerraCount table) but not across tables because the scoring and effect categories are slightly different.

Tool Scoring

TerraCount

TerraCount assigns a value of +1 to positive impacts, -1 to negative impacts, and (+/-)[2] to impacts that could be positive or negative depending on site-specific factors. The scores were summed across all effects within effect categories (human wellbeing, water quality, and biodiversity and ecosystem resilience) to get the score for those categories. The score for each category was summed to get the total co-benefits score. The Scores may be used to compare the practices overall or for a specific category.

CPPE Tool

The CPPE tool based analysis utilized the scores provided within the tool for a range of effects organized into different effect categories. The numbers correspond to relative levels of the expected positive or negative impacts as follows:

5	Substantial Improvement	-1	Slight Worsening
4	Moderate to Substantial Improvement	-2	Slight to Moderate Worsening
3	Moderate Improvement	-3	Moderate Worsening
2	Slight to Moderate Improvement	-4	Moderate to Substantial Worsening
1	Slight Improvement	-5	Substantial Worsening
0	No Effect		

The scores were averaged for each effect category (soil, water, air quality, plant and crops, rangelands and habitat, and energy efficiency), and then the score for each category was summed to get the total co-benefits score for each practice. Scores may be used to compare practices overall or for a specific category.

Wildfire Prevention Climate Smart Practices

TerraCount did not provide an assessment of the co-benefits for the wildfire prevention practices utilized in this study, despite those practices being sourced from the TerraCount Activity sheets. These practices are “Thinning from Below” in conifer forests managed for timber production, and “Forest Fuel Reduction” in all other forests. The co-benefits analysis was not provided in the activity sheets because those practices were not utilized in the original project the model was developed for, and the co-benefit analysis was never conducted. Given the importance of these practices for carbon sequestration,

[2] Practices that could be positive or negative depending on site-specific factors are noted in the analysis as +/- and given a score of 0.

economic vitality, and human and ecosystem well-being, a research-based analysis of co-benefits for thinning from below and forest fuel reduction was conducted to provide an assessment of the co-benefits for these two climate smart wildfire mitigation practices. The qualitative results of that analysis follow the TerraCount and CPPE tool co-benefits quantification results.

To provide additional context alternate wildfire prevention practices included in the CPPE tool were included in the CPPE results table for reference. These practices (prescribed burning, fuel break (unshaded), and brush management) differ from the practices evaluated for carbon sequestration; however, they are still critical climate smart practices to optimize carbon sequestration. Therefore, understanding their potential co-benefits and impacts are needed in the overall consideration of practices and planning.

1.4 Results

TerraCount Co-Benefits Assessment

Utilizing the TerraCount, the practices with the highest co-benefit scores are all conservation-based practices. These following practices show the same number of co-benefits: avoided conversion of grassland to row crops/vineyard, avoided conversion of shrubland to urban, and avoided conversion of wetland to row crops/vineyard. Avoided conversion of forest and shrublands to row crops/vineyard and avoided conversion of forest to urban, were tied for the second highest number of co-benefits.

Table 1 summarizes the effect category and total co-benefit scores for each practice. Table 2 includes all results of the TerraCount co-benefits analysis by practice and land use category.

Table 1 TerraCount Co-benefits Assessment: Summary of Scores

Climate Smart Practice by Land Use Category	Total Co-Benefit Score	Human Wellbeing Score	Water Quality Score	Biodiversity and Ecosystem Resilience Score
Natural Land				
Avoided Conversion of Forest to Row Crop/Vineyard	11	2	3	6
Avoided Conversion of Forest to Urban	11	3	2	6
Avoided Conversion of Grassland to Row Crops/Vineyard	12	2	3	7
Avoided Conversion of Shrubland to Row Crop/Vineyard	11	2	3	6
Avoided Conversion of Shrubland to Urban	12	3	2	7
Avoided Conversion of Wetland to Row Crops/Vineyard	12	2	3	7
Oak Woodland Restoration/Silvopasture Establishment	7	2	2	3
Restoration of Native Grasses	7	1	2	4
Riparian Restoration	8	3	1	4
Urban Forest				
Increase Urban Forest Canopy Cover	6	2	1	3

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Table 2 TerraCount Co-benefits Assessment

Climate Smart Practice by Land Use Category	Total Co-Benefit Score	Human Wellbeing				Water Quality					Biodiversity & Ecosystem Resilience							
		Air Quality	Scenic Value	Improved Flood Protection/ Attenuation	Human Wellbeing Score	Ag/Urban Water Use/ Conservation	Improved Surface and Groundwater Quality	Groundwater Recharge/ Banking Potential	Watershed Integrity	Water Quality Score	Habitat Stability	Climate Connectivity	Terrestrial Connectivity	Natural Habitat Area	Priority Conservation Areas	Terrestrial Habitat Value/ Availability/ Quality	Aquatic Biodiversity Value/ Richness or Avail/ Quality	Biodiversity & Resilience Score
Natural Land																		
Avoided Conversion of Forest to Row Crop/Vineyard	11	(+/-)	(+)	(+)	2	(+)	(+)	(+/-)	(+)	3	(+)	(+)	(+)	(+)	(+)	(+)		6
Avoided Conversion of Forest to Urban	11	(+)	(+)	(+)	3	(+/-)	(+/-)	(+)	(+)	2	(+)	(+)	(+)	(+)	(+)	(+)		6
Avoided Conversion of Grassland to Row Crops/Vineyard	12	(+/-)	(+)	(+)	2	(+)	(+)	(+/-)	(+)	3	(+)	(+)	(+)	(+)	(+)	(+)	(+)	7
Avoided Conversion of Shrubland to Row Crop/Vineyard	11	(+/-)	(+)	(+)	2	(+)	(+)	(+/-)	(+)	3	(+)	(+)	(+)	(+)	(+)	(+)		6
Avoided Conversion of Shrubland to Urban	12	(+)	(+)	(+)	3	(+/-)	(+/-)	(+)	(+)	2	(+)	(+)	(+)	(+)	(+)	(+)	(+)	7
Avoided Conversion of Wetland to Row Crops/Vineyard	12	(+/-)	(+)	(+)	2	(+)	(+)	(+/-)	(+)	3	(+)	(+)	(+)	(+)	(+)	(+)	(+)	7
Oak Woodland Restoration/Silvopasture Establishment	7	(+)	(+)		2		(+)		(+)	2			(+)	(+)	(+)	(+/-)		3
Restoration of Native Grasses	7			(+)	1		(+)	(+)		2			(+)	(+)		(+)	(+)	4
Riparian Restoration	8	(+)	(+)	(+)	3	(-)	(+)		(+)	1			(+)	(+)	(+)	(+/-)	(+)	4
Urban Forest																		
Increase Urban Forest Canopy Cover	6	(+)	(+)		2				(+)	1			(+)	(+)		(+)		3

NRCS CPPE Tool Co-Benefits Assessment

Utilizing the CPPE analysis the top 5 practices for co-benefits are tree/shrub establishment, riparian forest buffer, prescribed grazing, windbreak/shelterbelt establishment, and alley cropping.

Table 3 provides a summary of the effect category scores and total co-benefits scores by practice and land use category.

Table 4 includes the co-benefit assessment for all of the effect categories except for water quality which is included in Table 5. The effect categories were divided this way to accommodate the large size of the tables. Both tables include the relevant category score(s) and the total co-benefit score for each practice.

Table 3 NRCS CPPE Tool Co-benefits Assessment: Summary of Scores

Climate Smart Practice by Land Use Category	Practice Code	Total Benefit Score	Soil Benefit Score	Water Benefit Score	Air Quality Benefit Score	Plant & Crop Benefit Score	Rangeland & Habitat Benefit Score	Energy Efficiency Benefit Score
Working Lands								
Alley Cropping	311	10.8	3.2	1.5	0.8	2.8	1.6	1.0
Conservation Cover	327	9.2	2.5	1.4	1.5	3.0	0.8	0.0
Conservation Crop Rotation	328	6.8	1.7	1.2	0.3	2.0	0.6	1.0
Cover Crop	340	7.7	1.7	0.8	1.0	1.8	0.4	2.0
Field Border	386	4.9	1.5	0.5	0.5	1.8	0.6	0.0
Filter Strip	393	3.1	0.7	1.3	0.3	0.3	0.6	0.0
Hedgerow Planting	422	5.4	0.4	0.2	1.5	2.8	0.6	0.0
Mulching	484	4.7	1.4	0.7	1.0	1.5	0.2	0.0
Nutrient Management	590	6.2	0.4	1.1	2.3	1.8	0.8	0.0
Pasture and Hay Planting	512	7.5	2.4	0.6	0.8	2.0	1.8	0.0
Prescribed Grazing	528	11.1	2.5	1.0	0.8	3.5	2.4	1.0
Range Planting	550	9.7	2.8	1.1	0.8	3.5	1.6	0.0
Residue and Tillage Management, No Till	329	10.1	2.1	0.8	2.5	0.5	0.2	4.0
Residue and Tillage Management, Reduced Till	345	7.5	1.6	0.7	1.5	0.5	0.2	3.0
Riparian Forest Buffer	391	11.6	2.6	2.1	0.5	3.3	2.2	1.0
Riparian Herbaceous Cover	390	9.1	1.7	1.7	0.3	3.3	1.2	1.0
Silvopasture	381	9.1	2.0	1.4	0.5	1.8	2.4	1.0
Soil Carbon Amendment	336	1.8	1.2	0.4	0.0	0.3	0	0.0
Tree/Shrub Establishment	612	12.2	3.2	1.3	0.8	3.8	2.2	1.0
Tree/Shrub Pruning*	660	6.1	0.7	0.4	0.5	3.5	1	0.0
Tree/Shrub Site Preparation*	490	3.6	-0.9	0.0	0.0	4.5	0	0.0
Windbreak/Shelterbelt Establishment and Renovation	380	11.0	2.2	1.0	2.5	1.8	2.6	1.0
Natural Lands								
Forest Slash/Woody Residue Treatment	384	5.7	0.3	0.2	1.5	3.0	0.8	0.0
Restoration and Management of Rare or Declining Habitats*	643	6.1	0.5	0.2	0.0	3.0	2.4	0.0
Wetland Creation*	658	4.5	0.2	0.7	-0.3	3.0	0.8	0.0
Wetland Restoration	657	4.4	0.1	0.7	-0.3	3.0	0.8	0.0
Brush Management*	314	7.2	0.8	0.3	0.0	4.8	1.4	0.0
Fuel Break (Unshaded)*	383	1.9	-0.7	-0.2	0.8	1.3	-0.2	1.0
Prescribed Burning*	338	7.7	0.5	0.3	-0.3	4.5	1.6	1.0

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Table 4 CPPE Co-benefits Assessment: Soils Quality, Air Quality, Plants and Crops, Rangeland and Habitat, and Energy Efficiency Effects

			Soil Quality												Air Quality					Plants and Crops					Rangeland and Habitat						Energy Efficiency	
Climate Smart Practice by Land Use Category	Practice Code	Total Benefit Score	Sheet and Rill Erosion	Wind Erosion	Ephemeral Gully Erosion	Classic Gully Erosion	Bank Erosion from Streams, Shorelines or Water Conveyance	Subsidence	Compaction	Organic Matter Depletion	Concentration of Salts or other Chemicals	Soil Organism Habitat Loss or Degradation	Aggregate Instability	Soil Benefit Score	Emissions of Particulate Matter (PM) and PM Precursors	Emissions of Ozone Precursors	Objectionable Odor	Emissions of Airborne Reactive Nitrogen	Air Quality Benefit Score	Plant Pest Pressure	Plant Productivity and Health	Plant Structure and Composition	Wildfire Hazard from Biomass Accumulation	Plant & Crop Benefit Score	Feed and Forage Imbalance	Inadequate Livestock Shelter	Inadequate Livestock Water Quantity, Quality and Distribution	Terrestrial Habitat for Wildlife and Invertebrates	Aquatic Habitat for Fish and other Organisms	Rangeland & Habitat Benefit Score	Energy Efficiency of Farming/ Ranching Practices and Field	Energy Efficiency Benefit Score
Working Lands																																
Alley Cropping	311	10.8	5	5	5	3	0	0	2	5	1	5	4	3.2	2	0	1	0	0.8	3	5	3	0	2.8	1	2	0	3	2	1.6	1	1.0
Conservation Cover	327	9.2	4	4	1	1	2	0	3	5	2	2	4	2.5	4	1	0	1	1.5	4	4	4	0	3.0	0	0	0	3	1	0.8	0	0.0
Conservation Crop Rotation	328	6.8	4	4	0	0	0	0	1	4	2	1	3	1.7	1	0	0	0	0.3	3	4	1	0	2.0	2	0	0	1	0	0.6	1	1.0
Cover Crop	340	7.7	4	4	3	0	0	0	2	2	0	2	2	1.7	3	0	0	1	1.0	4	2	1	0	1.8	1	0	0	1	0	0.4	2	2.0
Field Border	386	4.9	4	4	1	0	1	0	1	4	0	1	1	1.5	1	0	0	1	0.5	0	2	5	0	1.8	0	0	0	1	2	0.6	0	0.0
Filter Strip	393	3.1	2	1	0	0	1	0	1	1	0	1	1	0.7	1	0	0	0	0.3	0	0	1	0	0.3	0	0	0	1	2	0.6	0	0.0
Hedgerow Planting	422	5.4	0	1	0	0	0	0	1	2	0	0	0	0.4	2	0	2	2	1.5	4	2	5	0	2.8	0	1	0	2	0	0.6	0	0.0
Mulching	484	4.7	4	4	0	0	2	0	1	1	1	2	0	1.4	4	0	0	0	1.0	2	4	0	0	1.5	0	0	0	1	0	0.2	0	0.0
Nutrient Management	590	6.2	0	0	0	0	0	0	0	2	2	0	0	0.4	2	2	2	3	2.3	0	4	3	0	1.8	4	0	0	0	0	0.8	0	0.0
Pasture and Hay Planting	512	7.5	4	4	3	1	0	0	2	4	0	4	4	2.4	3	0	0	0	0.8	0	4	4	0	2.0	5	0	0	4	0	1.8	0	0.0
Prescribed Grazing	528	11.1	4	4	3	1	3	0	2	4	2	2	2	2.5	2	0	1	0	0.8	2	5	4	3	3.5	5	2	2	2	1	2.4	1	1.0
Range Planting	550	9.7	4	4	4	2	2	0	4	4	1	3	3	2.8	3	0	0	0	0.8	4	5	5	0	3.5	5	0	0	2	1	1.6	0	0.0
Residue and Tillage Management, No Till	329	10.1	5	5	-1	0	0	1	2	3	0	4	4	2.1	5	3	0	2	2.5	0	2	0	0	0.5	0	0	0	1	0	0.2	4	4.0
Residue and Tillage Management, Reduced Till	345	7.5	4	4	0	0	0	1	2	2	0	3	2	1.6	4	1	0	1	1.5	0	2	0	0	0.5	0	0	0	1	0	0.2	3	3.0
Riparian Forest Buffer	391	11.6	3	2	1	3	4	0	2	4	1	5	4	2.6	1	0	1	0	0.5	3	5	5	0	3.3	0	1	0	5	5	2.2	1	1.0
Riparian Herbaceous Cover	390	9.1	2	2	1	0	4	0	4	4	2	0	0	1.7	1	0	0	0	0.3	4	5	4	0	3.3	4	0	0	2	0	1.2	1	1.0
Silvopasture	381	9.1	4	3	3	2	2	0	0	3	0	3	2	2.0	1	0	1	0	0.5	2	5	-1	1	1.8	3	4	0	2	3	2.4	1	1.0
Soil Carbon Amendment	336	1.8	0	0	0	0	0	0	1	4	0	4	4	1.2	0	0	0	0	0.0	0	1	0	0	0.3	0	0	0	0	0	0	0	0.0
Tree/Shrub Establishment	612	12.2	5	5	4	2	2	0	2	4	1	5	5	3.2	1	0	2	0	0.8	5	5	5	0	3.8	0	2	0	5	4	2.2	1	1.0
Tree/Shrub Pruning*	660	6.1	1	1	1	1	0	0	0	1	0	2	1	0.7	0	0	1	1	0.5	2	5	4	3	3.5	2	0	0	2	1	1	0	0.0
Tree/Shrub Site Preparation*	490	3.6	-1	-1	-2	-1	0	0	-1	-2	0	-1	-1	-0.9	0	0	0	0	0.0	5	5	5	3	4.5	0	0	0	0	0	0	0	0.0
Windbreak/Shelterbelt Establishment and Renovation	380	11.0	1	5	2	0	0	0	2	4	1	5	4	2.2	4	0	3	3	2.5	1	5	1	0	1.8	1	5	0	3	4	2.6	1	1.0
Natural Lands																																
Forest Slash/Woody Residue Treatment	384	5.7	1	1	1	1	0	0	-2	-1	0	1	1	0.3	2	2	0	2	1.5	3	5	1	3	3.0	3	1	0	0	0	0.8	0	0.0
Restoration and Management of Rare or Declining Habitats*	643	6.1	2	2	2	0	0	0	0	0	-1	0	0	0.5	0	0	0	0	0.0	4	4	4	0	3.0	2	0	0	5	5	2.4	0	0.0
Wetland Creation*	658	4.5	0	0	0	0	0	0	0	2	0	0	0	0.2	0	0	-1	0	##	4	4	4	0	3.0	2	0	0	2	0	0.8	0	0.0
Wetland Restoration	657	4.4	0	0	0	0	0	0	0	1	0	0	0	0.1	0	0	-1	0	##	4	4	4	0	3.0	2	0	0	2	0	0.8	0	0.0
Brush Management*	314	7.2	3	3	3	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0.0	5	5	5	4	4.8	4	0	0	3	0	1.4	0	0.0
Fuel Break (Unshaded)*	383	1.9	-1	-1	-1	-1	0	0	-1	-3	0	0	0	-0.7	1	1	0	1	0.8	-1	1	0	5	1.3	1	-1	0	0	-1	-0.2	1	1.0
Prescribed Burning*	338	7.7	2	2	1	1	1	-1	0	1	-1	0	0	0.5	0	0	-1	0	##	4	5	4	5	4.5	5	-1	0	4	0	1.6	1	1.0

Table 5 CPPE Co-benefits Assessment: Water Quality Effects

Climate Smart Practice by Land Use Category	Practice Code	Total Benefit Score	Water Quality: Ponding and Flooding	Seasonal High Water Table	Seeps	Naturally Available Moisture Use	Surface Water Depletion	Groundwater Depletion	Inefficient Irrigation Water Use	Nutrients Transported to Surface Water	Nutrients Transported to Groundwater	Pathogens and Chemicals from manure, Bio-solids or Compost Applications Transported to Surface Water	Pathogens and Chemicals from Manure, Bio-solids or Compost Applications Transported to Groundwater	Sediment Transported to Surface Water	Pesticides Transported to Surface Water	Pesticides Transported to Groundwater	Petroleum, Heavy Metals and Other Pollutants Transported to Surface Water	Petroleum, Heavy Metals and Other Pollutants Transported to Groundwater	Salts Transported to Surface Water	Salts Transported to Groundwater	Elevated water temperature	Water Benefit Score
Working Lands																						
Alley Cropping	311	**10.8**	2	2	1	0	2	0	3	3	1	3	1	3	3	1	1	1	1	1	0	1.5
Conservation Cover	327	**9.2**	1	0	1	0	0	0	0	4	4	2	2	4	2	2	0	0	2	2	0	1.4
Conservation Crop Rotation	328	**6.8**	1	0	1	3	0	0	2	3	3	1	0	3	2	2	0	0	1	1	0	1.2
Cover Crop	340	**7.7**	1	1	1	2	0	0	1	2	1	1	1	2	2	1	0	0	0	0	0	0.8
Field Border	386	**4.9**	1	0	0	0	0	0	0	1	1	1	0	3	2	0	0	0	0	0	0	0.5
Filter Strip	393	**3.1**	1	0	0	0	0	0	0	5	1	4	1	5	2	1	2	1	1	1	0	1.3
Hedgerow Planting	422	**5.4**	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	1	0.2
Mulching	484	**4.7**	0	0	0	4	0	0	3	2	0	0	0	2	1	0	0	0	1	0	0	0.7
Nutrient Management	590	**6.2**	0	0	0	0	0	0	0	5	5	4	4	0	0	0	0	0	1	1	0	1.1
Pasture and Hay Planting	512	**7.5**	1	0	0	0	3	3	0	1	0	1	0	1	1	0	1	0	0	0	0	0.6
Prescribed Grazing	528	**11.1**	2	0	0	2	1	1	0	1	1	1	1	2	2	1	0	0	2	1	1	1.0
Range Planting	550	**9.7**	2	0	0	2	0	0	0	1	1	1	1	2	2	2	2	1	1	1	1	1.1
Residue and Tillage Management, No Till	329	**10.1**	1	0	0	2	0	0	2	2	-1	1	0	4	4	0	0	0	0	0	0	0.8
Residue and Tillage Management, Reduced Till	345	**7.5**	0	0	0	2	0	0	1	2	0	1	0	3	3	0	0	0	1	0	0	0.7
Riparian Forest Buffer	391	**11.6**	-1	2	1	0	3	0	0	5	5	3	1	5	3	1	3	1	1	1	5	2.1
Riparian Herbaceous Cover	390	**9.1**	-2	2	2	0	0	0	0	5	5	3	2	4	2	2	2	1	1	1	2	1.7
Silvopasture	381	**9.1**	2	1	1	2	3	0	0	3	2	1	1	3	2	1	1	1	1	1	1	1.4
Soil Carbon Amendment	336	**1.8**	0	0	0	2	0	0	0	1	1	0	0	1	1	0	1	0	0	0	0	0.4
Tree/Shrub Establishment	612	**12.2**	0	2	2	1	3	0	0	1	1	1	1	3	1	1	1	1	1	1	4	1.3
Tree/Shrub Pruning*	660	**6.1**	0	0	0	2	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0.4
Tree/Shrub Site Preparation*	490	**3.6**	1	0	0	2	0	0	0	0	0	0	0	-1	-1	-1	0	0	0	0	0	0.0
Windbreak/Shelterbelt Establishment and Renovation	380	**11.0**	1	2	2	3	3	0	1	1	1	0	0	1	3	0	1	0	0	0	0	1.0
Natural Lands																						
Forest Slash/Woody Residue Treatment	384	**5.7**	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.2
Restoration and Management of Rare or Declining Habitats*	643	**6.1**	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0.2
Wetland Creation*	658	**4.5**	1	-1	0	0	2	0	0	3	1	1	0	2	1	1	2	0	1	0	0	0.7
Wetland Restoration	657	**4.4**	1	0	0	0	1	0	0	3	1	1	0	2	1	1	2	0	1	0	0	0.7
Brush Management*	314	**7.2**	1	0	0	2	1	0	0	0	0	0	0	2	-1	0	0	0	0	0	0	0.3
Fuel Break (Unshaded)*	383	**1.9**	0	-1	0	0	0	0	0	0	0	0	0	-1	-1	-1	0	0	0	0	0	-0.2
Prescribed Burning*	338	**7.7**	1	0	0	0	0	0	0	2	1	0	0	1	0	0	1	0	0	0	0	0.3

Other Wildfire Prevention Practice Co-benefits Summary

Climate smart wildfire prevention/fuel reduction practices are a key strategy to optimize carbon sequestration in the County. However, both TerraCount and the CPPE Tool do not provide an evaluation of co-benefits associated with vegetation thinning. Therefore, the following discussions provide a high-level summary of some of the co-benefits associated with these practices.

HUMAN WELLBEING

A considerable amount (17%, 83,559 people) of the population in the county live within the High or Very Hire Fire Severity Zone in the State Responsibility Area. Wildfire prevention and reduction of wildfire intensity through thinning practices on commercial timberlands can reduce the immediate health, safety, and property damage risks associated with wildfire for the surrounding communities[3].

SOCIO-ECONOMIC

There is an existing need for more people who can effectively conduct fuel reduction work. Fuel reduction in forests is multifaceted and creates more jobs for sawyers, but also equipment operators, shepherds, and foresters. Repeated fuel reduction treatments will attract and help to develop an experienced and skilled wildfire mitigation workforce.

Fuel reduction on managed timber lands has the added benefit of employing Licensed timber operators (LTOs) during non-harvest treatments. This may increase local knowledge of a site, allow an LTO to be better prepared and conduct a more efficient commercial harvest in the coming years, and result in higher yields for the landowner. Alternatively, because these treatments are not commercial in nature, landowners are not obligated to use LTOs which will be cheaper and or allow other small-time operators the chance to get meaningful experience toward becoming an LTO.

Fuels reduction causes “release” in remaining timber. Release is a growth response to an increase in available resources. The timber isn’t necessarily of high(er) quality, but there will be more of it. A Registered Professional Forester will grade timber prior to harvest and may note this release of wood, but it is unlikely that such a note will affect the desirability of wood for mills.

WATER QUALITY/STORAGE/WATERSHED

Less understory growth increases water availability for the important vegetation species (commercial and non-commercial) in a stand. The relationship between increased water availability and increased growth rates is not infinite, so after the maximum increase in growth rates is achieved there are likely to be net benefits to groundwater and storm water infiltration.

Fuel reduction practices usually do not include root removal of cleared vegetation, so if the vegetation removed is not a sprouting species the root materials in the ground will begin to decay. The decaying structure leaves voids which may increase water infiltration rates and storage capacity in the short term.

Fuel reduction can also lead to increases in base flows in high order streams due to less vegetative uptake higher in the watershed, benefitting fisheries and riparian health.

Reducing the amount of vegetation on a site can in turn reduce interception (the process where rainwater is caught and held by leaves, branches, and other above-ground parts of plants,

[3] Sonoma County Community Wildfire Protection Plan. 2023. https://permitsonoma.org/sonomacountycwpp

preventing it from reaching the ground directly) of rainwater, potentially increasing infiltration and contributing to increased groundwater recharge[4].

BIODIVERSITY/HABITAT

Reducing non-commercially viable growth in the understory can increase the resources available for the commercial timber species. If the timber area has been previously harvested (and depending on the intensity of that harvest) it is likely that it isn't representative of forested space too far outside of its Fire Return Interval (FRI). Normal habitat structure would likely exist, but by opening up understory, it provides more access for larger animals to broaden their range[5].

Anecdotally while conducting nesting bird surveys for shaded fuel breaks in Cambria, reducing the density of fuels and disturbing the soils showed a major increase in bird activity almost immediately[6].

As opposed to forests managed for timber harvest, these other spaces are much more likely to be well outside of their historic FRI. This typically means very dense fuels with high horizontal and vertical fuel continuity. This density under the upper canopy layer can limit animal movement through the forest. Raptors cannot fly through it or see into it which makes it a haven for rodents which at too high of populations can have detrimental effects. Ecologically sound fuel reduction projects should result in a more open understory with clumps of dense vegetation and some open areas. The goal is to emulate conditions that would be present if fire were able to occasionally move through the site. This heterogeneity results in diverse habitat structure and increases species diversity on a site.

SOIL EROSION/HEALTH

Climate smart fuel reduction practices reduce the amount of above ground biomass without creating large areas devoid of vegetation. Rainfall interception will still occur in the overstory although minor mobilization of sediments in rainfall may now occur. More likely that the remaining chipped or masticated material will help intercept the impacts and result in water being held on the site as long or longer than prior to treatment which will result in an increased rate of decomposition. These smaller vegetative materials break down faster than a downed log would have, which results in bio-available micronutrients for soil biota, likely increasing overall microbial health.

Staging in areas of recent disturbance typically follows a pattern that shows smaller annual growth (ground cover) moving in first to prepare a habitat for brush, which gives way to larger trees over time. The available seed bank of a given area of land will likely result in a return of growth fairly rapidly after treatment. At that stage it can be more easily treated with prescribed fire[7] or prescribed herbivory. Both of which, when managed properly, can also increase soil health at a site.

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[4] Surfleet et al. Hydrologic Response of a Montane Meadow from Conifer Removal and Upslope Forest thinning. 2020. https://digitalcommons.calpoly.edu/phy_fac/603/

[5] Brown et al. The influence of different restoration thinning treatments on tree growth in a depleted forest system. 2019. https://www.ari.vic.gov.au/research/field-techniques-and-monitoring/restoration-thinning-to-recover-habitat

[6] Know Your Forest – Thinning My Forest. https://knowyourforest.org/learning-library/thinning-my-forest#:~:text=Thinning%20can%20reduce%20fire%20hazards,habitat%20conditions%20for%20widlife%20species

[7] DeBano, Leonard F. The Effect of Fire on Soil Properties. https://forest.moscowfsl.wsu.edu/smp/solo/documents/GTRs/INT_280/DeBano_INT-280.php

Hazard fuel reduction will likely result in a less intense wildfire at a site. High temperature wildfires can negatively affect soil health in many ways including reducing microbial life in upper layers and heat induced water repellence.

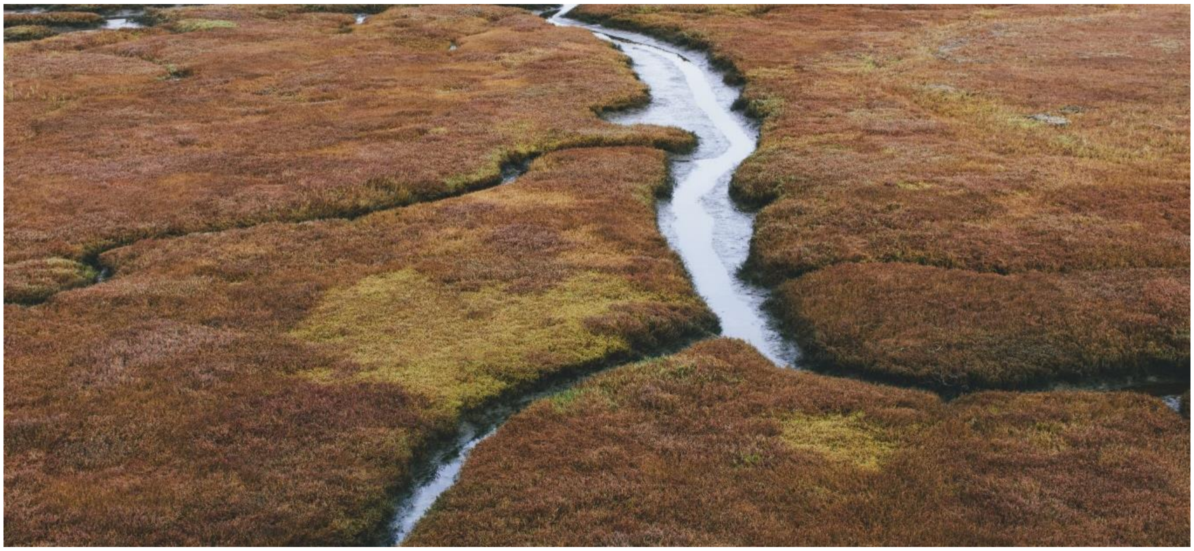
AIR QUALITY

Wildfires emit massive quantities of PM_{10} and $PM_{2.5}$ which are carcinogenic and can cause major health problems. Major reductions in productivity and periodic local economic downturns can also result. Reducing the wildfire hazard will likely have a net reduction in poor air quality associated with wildfires.

2 Conclusion

Sonoma County is beginning a process of stakeholder engagement and long-term planning that will make use of the findings of this co-benefits analysis and the Carbon Sequestration Analysis of Climate Smart Practices memorandum to help set targets for climate smart practice adoption and implementation. The co-benefits analysis using TerraCount and the CPPE tool highlighted the synergistic potential of climate smart practices in not only mitigating carbon emissions but also enhancing human wellbeing, water quality, soil health, and wildlife habitat. The results of this study may be used as starting point for subsequent efforts which may include:

- Engaging multi-sectoral stakeholders and fostering collaboration to leverage collective expertise and resources and increase interest in and implementation of practices
- Refining and localizing the co-benefits analysis to project- specific and site-level nuances
- Developing a monitoring and evaluation framework for tracking the efficacy of implemented practices and adapting strategies to meet evolving environmental challenges and stakeholders' needs



Compendium of Measures and Actions for Consideration

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October 2023

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1 Compendium of Measures and Actions for Consideration

The measures and actions proposed here provide a policy toolbox that can be referenced in establishing a plan to achieve County climate goals. These measures and actions build from County and local existing policies and programs and prescribe additional strategies based on this Study's carbon sequestration analysis. In its development of a master action plan, the County will use this carbon inventory and policy toolbox as a resource to develop a list of specific climate action strategies, targets, and performance metrics for setting and tracking carbon sequestration goals.

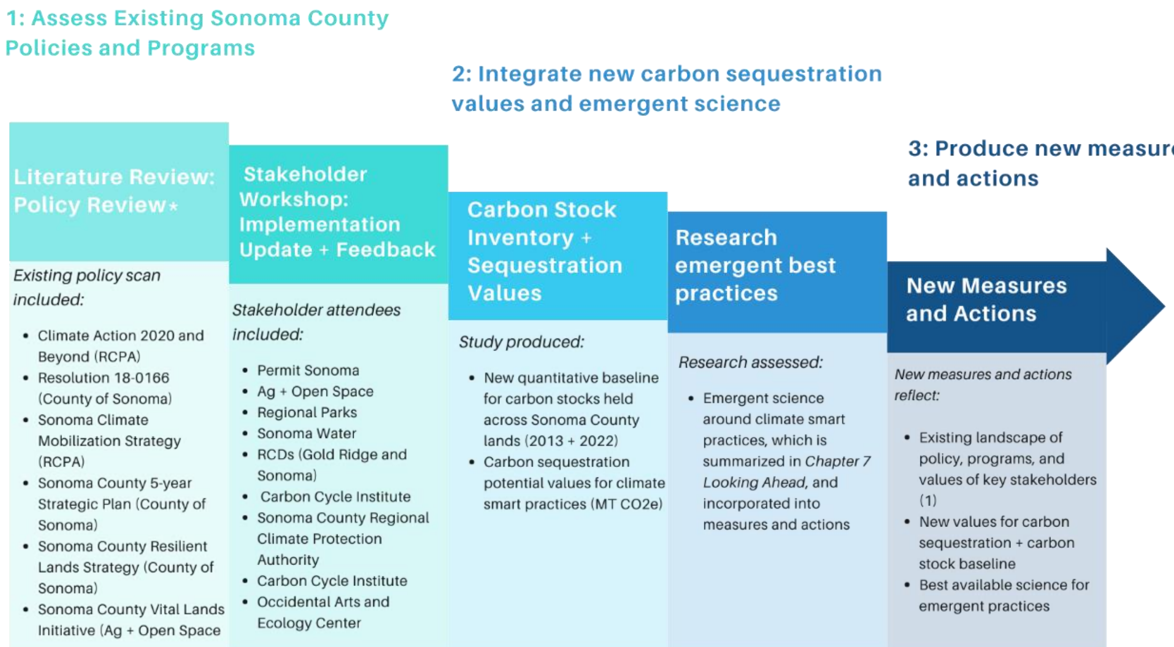
This compendium of measures and actions are provided here as an appendix for consideration by the County and all County partners. These are a result of the research and stakeholder input that went into this Study and can be used as a reference for future planning efforts. This list is proposed because of their potential positive impacts to preserving local carbon stocks and climate smart practice planning and implementation efforts regionally.

1.1 Measure and Action Development

The County has developed a strong foundation for carbon sequestration policy with the Sonoma County Resilient Lands Strategy (2022) and The Sonoma County 5-Year Strategic Plan (2021-2026). As the County, local agencies, and other partners put these plans, and their own initiatives, into action, this new collection of measures and actions provide refined actions that build off the existing policy and programs.

Figure 1 outlines the process of how measures and actions were developed. First, existing climate smart initiatives and policies in Sonoma County were assessed through a literature review (*Appendix A Data Evaluation and Literature Review Summary*), and two in-person stakeholder workshops. Second, this Study produced new information and data including a county-wide carbon stock inventory, carbon sequestration values for different climate smart practices by land cover, and a review of emergent best practices for climate smart practices. Together these quantitative values for carbon sequestration and qualitative policy insights were used to craft new measures and actions that the County and its partners may employ in furthering its carbon sequestration goals, which are described in this appendix.

Figure 1 How Measures and Actions Were Developed



1.1.1 How to Read This Section

As described above, these measures and associated actions incorporate the results of this study and new ideas generated by stakeholders to close existing implementation gaps, solve challenges that are currently being faced in implementing climate smart practices, and catalyze new, innovative carbon-prioritized actions based on best available science.

Foundational

Foundational strategies establish the long-standing policies and programs that will facilitate the achievement of all measures and actions for all land management types. These are not one-time strategies. These strategies are meant to endure and evolve as the County continues to advance its natural and working lands operations.

Land Management and Land Cover Classes

The measures and actions are organized under three broad land management types, which roughly encompass different land cover classes (see below).

Land Management Types	Land Cover Classes
Natural Lands	▪ Forest ▪ Grassland ▪ Shrub/Scrub ▪ Wetland
Working and Grazing Lands	▪ Cultivated and Field Crops ▪ Orchard ▪ Vineyard ▪ Rangelands ▪ Pasture
Urban Forest and Urban Farm	▪ Development ▪ Cultivated and Field Crops (Urban) ▪ Orchard and Vineyard (Urban)

Measures

The measures provide an overarching policy objective that supports climate smart practice implementation. Except for the foundational measure, all other measures are organized under the Land Management Types. These measures and actions encompass strategies to maintain existing carbon stocks, increase carbon stock, and/or increase community resilience.

Measures Summary

FOUNDATIONAL

- **Measure 1:** Support a Regional Collaborative focused on empowering community members, private landowners, tribes with land conservation, restoration activities, and climate smart practices that increase community resilience and optimize carbon sequestration on private lands

NATURAL LANDS

- **Measure 2:** Maintain existing carbon stock by bolstering the conservation of natural lands, leveraging conservation easements, new policies, and land acquisition to protect lands from development
- **Measure 3:** Restore and maintain natural systems to increase carbon stock
- **Measure 4:** Protect critical carbon-stocking landscapes and prevent increased GHG emissions through implementation of fuels treatment practices and other climate smart practices. Increase community resilience through implementation of fuels treatment practices at the Wildland Urban Interface (WUI)
- **Measure 5:** Increase community resilience and protect carbon-stock through water resource management strategies

WORKING AND GRAZING LANDS

- **Measure 6:** Support efforts to increase carbon sequestration by expanding compost application throughout the county
- **Measure 7:** Support carbon sequestration efforts related to the production and application of mulch
- **Measure 8:** Explore potential for carbon sequestration through piloting, expanding, and tracking the utilization of biochar
- **Measure 9:** Increase carbon sequestration by increasing the implementation of climate smart practices on working and grazing lands
- **Measure 10:** Support implementation of managed grazing to sequester carbon in rangeland and pasture, and use of grazing to reduce risk of wildfire through prescribed herbivory

URBAN FORESTS AND FARMS

- **Measure 11:** Increase carbon sequestration by expanding the County's urban forest and farms

Actions

Actions describe specific steps such as policies, programs, activities, and/or partnerships the County can leverage that work together to increase the implementation of climate smart practices. The actions were created utilizing a framework of pillars that work together to achieve measure objectives. Each pillar represents a critical aspect of measure implementation that is needed for success. In general, the actions under a single measure collectively address all the key pillars. These pillars have been tailored to reflect the concerns, values, and implementation experience brought forward by keys stakeholders during the stakeholder workshop, as shown below in Table 1.

Stakeholder-Generated Actions
Each action that is coded with a "*" indicates an idea that was directly brainstormed or generated by stakeholders during the stakeholder workshops described in Section 2 Regional Efforts held as part of this study, indicating where stakeholder input directly influenced the list of measures and actions.

Table 1 Pillar Description

Pillar Name	Description
Structural Change	Actions that improve governance through staffing, programs, policies, or ordinances.
Feasibility	Actions that provide additional context about the details, obstacles, or feasibility for implementation of a program. These include analysis necessary to identify the best path forward or the feasibility of implementing a specific measure.
Equity	Actions that prioritize investment in under-resourced communities, allocating time, funding, education, and other resources to these groups. Equity actions also equitably distribute the benefits from climate smart practices. In Sonoma County, key equity concerns include supporting small-holder landowners, BIPOC and low-income growers, and rural communities reliant on off-grid systems.
Funding	Actions that provide pathways for financial backing and adequate resources (e.g., equipment) to implement climate smart practices.
Partnership	Actions that focus on partnerships across other local agencies, and community based organizations (CBOs) to leverage expertise, capacity, relationships, and resources.
Education	Actions that support structural change by increasing community awareness and understanding, getting community buy in, and promoting the existence of programs.
Tracking and Monitoring	Actions that establish new mechanisms to track and monitor implementation climate smart practices, providing the data needed for adaptive management.

1.1.2 Sonoma County Policy Toolbox

Foundational Measures and Actions

Measure 1: Support a Regional Collaborative focused on empowering community members, private landowners, tribes with land conservation, restoration activities, and climate smart practices that increase community resilience and optimize carbon sequestration on private lands

Action		Pillar
1.1	Support regional collaboration for natural and working lands regionally to coordinate efforts with key implementors of climate smart practices to develop, fund, and track innovation, and land management best practices with a goal of increasing community resilience and optimization of carbon sequestration.	Partnership
1.2	Support efforts to expand a county-wide tracking program to monitor carbon sequestration and continue to identify priority lands for targeted conservation, restoration, and implementation of climate-smart practices.	Tracking and Monitoring
1.3	Support a funding working group to apply for existing state and federal funding for large-scale grant projects and implementation of identified key climate smart practices within the community.	Funding
1.4	Explore funding opportunities or opportunities to collaborate with nonprofit research entities for research and pilot programs related to existing gaps in carbon quantification data, land management practices, wetlands, and sources of blue carbon (coastal ecosystems), incorporating new best practices into future carbon sequestration and inventory efforts.	Funding
1.5	Support the North Coast Soil Hub’s long-term online forum for land stewards to connect, share, collaborate, ideate, and reinforce land-based practices that have been successful within the county. The forum is designed to educate land stewards on best practices.	Education

Action		Pillar
1.6	Share resources (e.g., Sonoma Veg Map and COMET planner) for the quantification of carbon sequestration and carbon stocks. These resources would provide landowners and other key stakeholders with Sonoma-specific, easy-to-use tools to visualize and assess the impact that shifting land management practices would have on the carbon stock and sequestration potential of their lands.	Education
1.7	Support development of a carbon sequestration outreach program (e.g., individual landowners, community based organizations, and the general public) to increase understanding of carbon sequestration contribution, and prioritized climate smart practices from this study. Outreach goals could include: ▪ Establishing a collective understanding on the value of land management and stewardship in achieving Sonoma County's climate goals ▪ Highlighting actions that individuals, community groups, and individual landowners can take to maximize carbon sequestration and other associated benefits on their land ▪ Increasing land-owner proficiency with using technology-based tools available for carbon sequestration	Education
1.8	Continue to develop equity criteria to evaluate and prioritize County investments on private lands. Include outreach to tribes, under-represented groups, and land-stewards (e.g., non-English speakers, small farmers, rural landowners) to develop the criteria.	Equity
1.**9**	Invite tribal partners to co-convene working sessions designed to achieve the following goals: ▪ Identify tribal priorities for climate smart land stewardship ▪ Determine long-term arrangements for shared stewardship and co-management ▪ Ensure tribal engagement is conducted throughout the lifespan of a project from inception, planning, design, and implementation ▪ Identify sources of funding and financing to advance joint priorities ▪ Include tribal experts and voices in climate resilience panels and other knowledge sharing forums" See: Sonoma County Climate Resilient Lands Strategy - Project Concept J	Partnership

Natural Lands Measures and Actions

Measure 2: Maintain existing carbon stock by bolstering the conservation of natural lands, leveraging conservation easements, new policies, and land acquisition to protect lands from development

Action		Pillar
2.1	Explore the potential to establish and update plans and policy mechanisms to facilitate the protection and establishment of conservation easements. Examples of potential options to explore include: ▪ Designate areas where conservation easements are encouraged or required ▪ Incorporate specific technical assistance for conservation easement applications and timeline for processing Strengthen evaluation of carbon sequestration potential and implementation of carbon sequestration practices as part of the conservation easement application process.	Structural Change
2.2	Partner with local tribes and explore arrangements promoting stewardship by Native American tribes of lands under conservation easements, particularly for lands of spiritual and cultural significance to Native American tribes in Sonoma County.	Partnership
2.3	Support development of dashboards to track conservation acreage and associated carbon sequestration potential. Continuously update as conservation easements get purchased and management practices are implemented and track progress in achieving 30 x 30 California conservation acreage goals.	Tracking and Monitoring
2.4	Support educational programming that promotes awareness of the cultural, ecosystem, and recreational value of conserved lands.	Education

Measure 3: Restore and maintain natural systems to increase carbon stock

Action		Pillar
3.1	Track specific landscape type conversions to understand where/how landscapes have changed over time and identify impacted landscapes, to determine scale of impacted lands in the County. Explore the utility of restoration targets for each landcover type and priority areas for restoration.	Structure change
3.2	Support programs to expand and track restoration and monitoring of deep-rooted native grasses on grasslands consistent with see California 30 x 30.	Partnership, Tracking and Monitoring
3.3	Explore potential pilot-projects for beaver-assisted restoration (North American Beaver, *Castor canadensis*).	Feasibility
3.4	Support riparian restoration planning for riparian corridors, wetlands, mesic meadows. As part of the restoration efforts consider “environmental watering” through diversion of stormwater on floodplains to wetlands.	Feasibility
3.5	Support working groups to restore oak woodland habitat through partnerships.	Partnership
3.6	Consider economic opportunities (end-markets) for potential agroforestry products resulting from reforestation that could be to help fund conservation initiatives.	Funding
3.7	Consider development of a silvopasture education and funding program for land stewards to understand the economic/environmental benefits of converting grass-dominated rangelands to mixed oak woodland/grassland for silvopasture grazing techniques. Consider providing financial resources to land stewards for silvopasture implementation.	Funding, Education
3.8	Support the improvement of water harvesting efforts to streamline subsidies and provide funding for rural water catchment systems. Consider amplifying efforts to provide education materials and support landowners.*	Equity

* Stakeholder workshop-generated idea(s)

Measure 4: Protect critical carbon-stocking landscapes and prevent increased GHG emissions through implementation of fuels treatment practices and other climate smart practices. Increase community resilience through implementation of fuels treatment practices at the Wildland Urban Interface (WUI)

Action		Pillar
4.1	Explore potential partnerships to use the Community Wildfire Protection Plan (CWPP) Project Entry Portal Project List and Map to track where fuel management projects are occurring and prioritize new areas and projects.	Partnership, Tracking and Monitoring
4.2	Explore opportunities for multilingual educational programming to promote increasing awareness of the techniques and benefits associated with of fuels treatment and climate smart practices.	Education
4.3	Support transitional adolescents (18- to 24-year-olds) develop job skills. Consider providing paid opportunities for youth who have experienced adversities that make career development more challenging.	Equity, Education
4.4	Explore innovative financing mechanisms to fund forest management practices through voter-approved tax measures, hazard abatement districts, or sources like the Forest Resilient Bond (https://www.blueforest.org/forest-resilience-bond).	Funding
4.5	Consider conducting a feasibility study for the development of forest management plans for all wooded/brush covered county-owned open space to promote long-term fuels reduction.	Feasibility
4.6	Consider establishing a budget or look into potential grant funding for implementation of the Sonoma County Wildfire Protection Plan. Consider including a reporting program to establish accountability with meeting the goals of the plan.	Funding, Structural Change
4.7	Support development of a publicly accessible GIS project tracking tool (incorporating data from the CWPP Project Entry Portal Project List) to track project implementation progress and assist with project prioritization, aligning with statewide efforts.*	Tracking and Monitoring
4.8	Consider potential applications for the CAL VTP for programmatic CEQA analysis and streamlining of environmental compliance efforts associated with vegetation treatment and mulching activities throughout the county.*	Structural Change
4.9	Explore opportunities to research potential conditions of approval related to fuel management and climate smart practices for all new subdivision and development projects (e.g., landscaping requirements, developer requirements for landscaping practices, tree and/or fuel removal), and/or the CWPP.*	Structural Change
4.10	Support programs that provide publicly accessible tools for monitoring vegetation stress and updating fine scale fuels and vegetation datasets. The tools could provide land managers, regulators, and policy makers with continually updated and indispensable information needed to allocate and prioritize fuel treatments, plan evacuation routes, and respond to and recover from wildfire.1	Tracking and Monitoring
4.11	Explore opportunities to identify existing resilient buffer zones (areas of reduced fire fuel surrounding development) and identify gaps and critical locations for additional buffer zones. Consider potential strategies to create and maintain resilient buffer zones throughout the County. (Sonoma County Climate Resilient Lands Strategy (Project Concept M).	Feasibility
4.12	Support forest management planning for all wooded/brush covered county-owned open space to promote long-term fuels reduction.	Feasibility
4.13	Consider future integrations with carbon stock, carbon sequestration, and frontline community considerations in regards to annual CWPP projects funding considerations and CWPP updates.	Equity, Structural Change

Action		Pillar
4.14	Support community wildfire planning efforts by considering a formal communication format, either as part of a Natural and Working Lands collaborative or the establishment of a County wildfire liaison to coordinate with all local wildfire planning organizations and communicate updates throughout the County. Coordination organization could include but are not limited to CAL FIRE, Northern Sonoma County Fire/CAL FIRE, Fire Safe Sonoma, Healdsburg Fire/So Co Fire Chiefs, Kashia Band of Pomo Indians, Santa Rosa Fire Department, Sonoma County Fire District, Sonoma Valley Fire District, and RCDs.*	Education, Partnerships, Structural Change
4.15	Support hazard fuel reduction projects in high and very high FHSZ areas in LRA and SRA on roadways by developing a roadside right of way vegetation clearance schedule for annual treatments with planned return intervals.	Structural Change, Partnerships
4.16	Consider a community chipping/curtain burner rotation program that chips/burns/hauls fuel reduction residue (slash piles) within one year of production.	Structural Change

* Stakeholder workshop-generated idea(s)

[1] Similar to a project being conducted by the San Mateo Resource Conservation District.

Measure 5: Increase community resilience and protect carbon-stock through water resource management strategies

Action		Pillar
5.1	Support restoration of upland watersheds in critical landscapes that have been impacted by wildfire.	Structural Change
5.2	Support projects that identify and address infrastructure areas contributing to soil instability and erosion. Consider prioritizing projects based on positive impacts to population centers and lands that have been historically vulnerable to floods.	Structure Change
5.3	Support projects that identify key areas for floodplain enhancement.	Feasibility
5.4	Encourage the evaluation of water supply, water use, and water quality into carbon farm plans to work towards understanding the relationship between water, carbon sequestration, and climate smart practice implementation.	Feasibility, Structural Change
5.5	Support programs that address where water quality issues occur and/or may occur due to the climate change impacts on aging water, wastewater, and flood protection system. Support implementation of climate smart practices and tracking of water quality improvement.	Feasibility, Structural Change
5.6	Support pilots for groundwater banking.	Structural Change
5.7	Support water resource management strategies and implementation goals and develop a publicly accessible GIS project tracking tool to track project implementation progress and assist with project prioritization.*	Tracking and Monitoring

* Stakeholder workshop-generated idea(s)

Working and Grazing Lands Measures and Actions

Measure 6: Support efforts to increase carbon sequestration by expanding compost application throughout the county

Action		Pillar
6.1	While considering guidance from SB 1383 explore establishing formal targets for compost application efforts to enhance access to compost to achieve target.	Structure Change
6.2	Support past and existing efforts to track volumes of compost applied across Sonoma County.	Tracking and Monitoring
6.3	Support planning efforts to identify gaps and prioritize compost application.	Feasibility
6.4	To maintain compost quality and increase carbon sequestration, support outreach events and meetings with key stakeholders using SB 1383 compost, discussing best practices for removing compost contamination.	Education, Partnership
6.5	Explore funding opportunities to support local compost production with the goal of reducing organic waste trucked from urban centers and out of county for compliance with SB 1383.	Funding
6.6	Support CBOs, RCDs, and existing soil health program work (e.g., North Coast Soil Hub) to assist producers with compost procurement. Support existing programs that aid producers with onsite production.	Partnership
6.7	Scale the 2022 Carbon Sequestration Pilot Project with Gold Ridge and Sonoma RCDs by expanding compost application.	Equity, Partnership, Funding
6.8	Support growers and RCDs, in efforts to seek long term feedback on compost quality and implementation of best practices for compost quality improvement.	Feasibility, Education and Partnership

Measure 7: Support carbon sequestration efforts related to the production and application of mulch

Action		Pillar
7.1	Consider land access for the generation and storage of mulch and compost. Learn from existing programs that provide collection areas for community members to deliver organic waste.	Structural Change
7.2	Support regional mulch production planning to create and distribute mulch locally.	Partnership
7.3	Support efforts to increase local mulch production, which will also help meet SB 1383 annual procurement targets.	Feasibility
7.4	Support partners and RCDs to implement multi-lingual trainings, resources, and educational opportunities for landowners to understand the benefits of applying mulch.	Education, Partnership
7.5	Explore funding opportunities to support the creation and distribution of mulch throughout the County.	Funding

Measure 8: Explore potential for carbon sequestration through piloting, expanding, and tracking the utilization of biochar

Action		Pillar
8.1	Support partners and producers ready to pilot new methods and programs that produce outreach and education events with the goal of information sharing related to best practices.	Education, Partnership
8.2	Support studies that expand understanding of potential applications of pyrolysis technology and industrial-scale composting for local biochar and compost production for crop residue and food waste.	Feasibility, Funding, Structural Change
8.3	Explore funding opportunities to support pilot programs for future studies.	Funding

Measure 9: Increase carbon sequestration by increasing the implementation of climate smart practices on working and grazing lands

Action		Pillar
9.1	Support creation of a plan to achieve these goals that includes outreach, funding, and capacity, and identification of priority areas and/or farm type.	Structural Change
9.2	Support existing programs that assist producers in enrolling for EQIP and Healthy Soils Program Funding. Support partners in meeting their enrollment goals.	Education, Tracking and Monitoring
9.3	Support established efforts aimed at developing a climate smart marketing campaign for iconic Sonoma products creating product premiums for farmers implementing carbon smart practices.	Feasibility, Education
9.4	Support programs that acquire and loan out low/no-cost specialty equipment for implementing climate smart practices (e.g., no-till seed drill).	Structural Change, Funding
9.5	Support post-wildfire recovery programs for working and grazing lands impacted by recent fires that provides funding and technical assistance to restore operations using climate smart practices.	Education, Partnership, Funding
9.6	Support programs and trainings related to residue and tillage management, and whole orchard recycling. Assist in long-term data collection efforts.	Education, Partnership
9.7	Consider supporting programs related to integrated sheep vineyard systems for new vineyard development.	Feasibility, Education
9.8	Support ongoing economic studies related to the feasibility of developing a local carbon credit program to support farmers in implementing the switch to climate smart practices.	Feasibility
9.9	Support programs that aggregate grant applications from different entities into one grant application for climate smart practices projects such as carbon farm plan development. This measure supports coordinated grant actions under Measure 1.	Funding
9.10	Support economic analysis exploring new markets for food and fiber products from Sonoma County producers implementing climate smart practices.	Feasibility, Funding

Measure 10: Support implementation of managed grazing to sequester carbon in rangeland and pasture, and use of grazing to reduce risk of wildfire through prescribed herbivory

Action		Pillar
10.1	Collaborate with partners to identify ways to expand start-up business opportunities in managed grazing, especially for those who are economically disadvantaged; support could include access to capital, equipment, training, mentoring, and other support.*	Structural Change
10.2	Support programs that improve understanding of perspectives of Homeowners Associations (HOAs) use of grazing cooperatives to improve functionality of grazing cooperatives accordingly.	Engagement
10.3	Support programs that promote grazing best practices and increase awareness of available funding (including grazing cooperatives).*	Education
10.4	Support grazing education for rural community members to increase resident-led managed grazing on their own properties, with their own animals (also known as do-it-yourself (DIY) grazing). This education program could target HOAs, Firewise communities, and smaller communities through targeted outreach.*	Education
10.5	Support programs that develop a collaborative County-wide grazing plan. The plan could include education and outreach programming for herder training, recruitment, and retainment programs, address the challenge of long-term land stewardship retention and shepherd recruitment.*	Feasibility, Education, Partnership
10.6	Support prescribed grazing/herbivory efforts led by RCDs by aiding in grant application efforts for additional RCD staffing, equipment (such as fencing), and/or workforce training programs.	Partnership, Funding
10.7	Support established and developing programs aimed at monitoring and tracking prescribed grazing/herbivory to understand the level of prescribed grazing that is occurring annually and the impacts or benefits.	Tracking and Monitoring

* Stakeholder workshop-generated idea(s)

Urban Forests and Farms Measure and Actions

Measure 11: Increase carbon sequestration by expanding the County's urban forest and farms.

Action		Pillar
11.1	Support projects that explore ways to streamline the use of vacant lots, rooftops, and other urban areas for food production.	Structural Change
11.2	Explore potential policy solutions to allow for husbandry of small animals and goat ownership.*	Structural Change
11.3	Support expansion of urban and peri-urban agriculture by assisting projects aimed at taking an inventory of suitable lands existing or acquirable that can be repurposed for urban farming.	Feasibility, Equity
11.4	Support existing and new programs that expand land access opportunities for under-resourced communities and community-based organizations for urban farming purposes. Provide long-term land tenure security to encourage investment and sustainable farming practices.	Funding, Equity, Structural Change
11.5	Support programs that explore circular economy end-market uses in urban farming efforts. (e.g. use of sawdust for edible mushroom cultivation) for woody debris removed as part of fuels management programs, as well as mandatory compost procurement targets for Cities as part of SB 1383 diversion.	Feasibility
11.6	Support projects related to county-wide urban forest management planning available space for managed, urban re-wilding, and incorporates key equity considerations of urban heat reduction and inequitable patterns of access to urban green spaces.	Feasibility
11.7	Consider development of an urban forest and farm implementation dashboard to monitor the increase of the urban forest canopy and urban farms. This tool could evaluate potential improvements to soil moisture, urban heat, and public health that occur due to tree planting.	Tracking and Monitoring, Equity
11.8	Support marketing programs for the urban forest and farm implementation dashboard for people to understand the tree equity of their community and educate the community on carbon sequestration and other co-benefits.	Equity, Education
11.9	Support education and outreach programs aimed at increasing the prevalence of water-smart native species in residential and commercial landscapes that also comply with defensible space regulations.	Education
11.10	Support urban infrastructure resilience planning that utilizes nature-based solutions (such as riparian restoration, bioswales, and resilient buffer zones) to improve infrastructure's ability to withstand extreme weather and natural disasters.	Feasibility

* Stakeholder workshop-generated idea(s)

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