



HUICHICA CREEK SUSTAINABLE DEMONSTRATION VINEYARD

CARBON FARM PLAN



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Huichica Creek Sustainable Demonstration Vineyard Carbon Farm Plan

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Introduction

In response to the rapid pace of global climate change, the North Coast Regional Resource Conservation Districts in partnership with other local resource organizations are working to engage agricultural producers as ecosystem stewards to provide on-farm ecological benefits, improve agricultural productivity, enhance agroecosystem resilience, and mitigate global climate change through a planning and implementation process known as “Carbon Farming.”

Carbon can be beneficially stored long-term (decades to centuries or more) in soils and vegetation through biological carbon sequestration. Carbon Farming involves implementing on-farm practices that are known to improve the rate at which a given land area can support photosynthetically-driven transfer of carbon dioxide (CO₂) from the atmosphere to plant productivity and/or soil organic matter. Enhancing agroecosystem carbon, whether in plants or soil, results in beneficial changes in other system attributes, including soil water holding capacity, hydrologic function, soil fertility, biodiversity, ecosystem resilience and agricultural productivity.

Carbon entering the farm from the atmosphere ends up in one of three locations: in the harvested portion of the crop, in the soil as soil organic matter, or in standing carbon stocks on the farm, such as woody perennials or other permanent vegetation such as windbreaks or riparian vegetation or other perennial vegetation. While all farming is completely dependent upon atmospheric carbon dioxide in order to produce its products, different farming practices, and different farm designs, can lead to very different amounts of carbon capture on the farm.

The Carbon Farm Planning Process

The Carbon Farm Planning (CFP) process differs from other approaches to agriculture by focusing on *increasing* the capacity of the farm or ranch to capture carbon and to store it beneficially as soil organic matter and/or standing carbon stocks in permanent vegetation. While most modern agriculture results in a gradual loss of carbon from the farm system, CFP works when it leads to a *net increase* in farm-system carbon. By increasing the amount of photosynthetically captured carbon held, or sequestered, in long-term carbon pools on the farm or ranch, such as soil organic matter, perennial plant roots and standing woody biomass, carbon farming results in a direct reduction in the amount of carbon dioxide in the atmosphere.

On-farm carbon in all its forms (soil organic matter, living and dead plant and animal material), represents embodied solar energy. As such, carbon provides the energy needed to drive on-farm processes, including the essential soil ecological processes that determine water and nutrient availability for the growing crop. Consequently, the CFP process views carbon as the single most important element, upon which all other on-farm processes depend. Carbon Farm Planning (CFP) is similar to Conservation Planning, but uses carbon and carbon capture as the organizing principle around which the Plan is constructed. This both simplifies the planning process and connects on-farm practices directly with ecosystem processes, including climate change mitigation and increases in on-farm climate resilience, soil health and farm productivity.

Like the NRCS Conservation Planning Process, CFP begins with an overall inventory of natural resource conditions on the farm or ranch. Through that process, opportunities for enhanced carbon capture by both plants and soils are identified. Building this list of opportunities is a brainstorming process and is as extensive as possible, including everything the farmer and the planners can think of that could potentially sequester carbon on the farm. Financial considerations should not limit the brainstorming process. A map of the ranch is then developed, showing all potential carbon capture opportunities and practices and their locations on the ranch.

Next, needs and goals for the farm and economic considerations are used to filter the comprehensive list of options. The carbon benefits of each practice, if actually applied at the farm scale, are quantified using the USDA greenhouse gas model, COMET-Farm, COMET-Planner, or similar tool, and data sources, to estimate tons of carbon dioxide equivalent (CO₂e) that would be 1) avoided or 2) removed from the atmosphere and sequestered on farm by implementing each practice. A list of potential practices and their on-farm and climate mitigation benefits is then developed.

Finally, practices are prioritized based on needs and goals of the farm or ranch, choosing high carbon-benefit practices wherever possible. Economic considerations may be used to filter the comprehensive list of options, and funding mechanisms are identified, including; cap and trade, CEQA, or other greenhouse gas mitigation offset credits, USDA NRCS and other state and federal programs, and private funding. Projects are implemented as funding, technical assistance and farming allow. Over time, the CFP is evaluated, updated, and altered as needed to meet changing farm objectives and implementation opportunities, using the fully implemented plan scenario as a goal or point of reference.

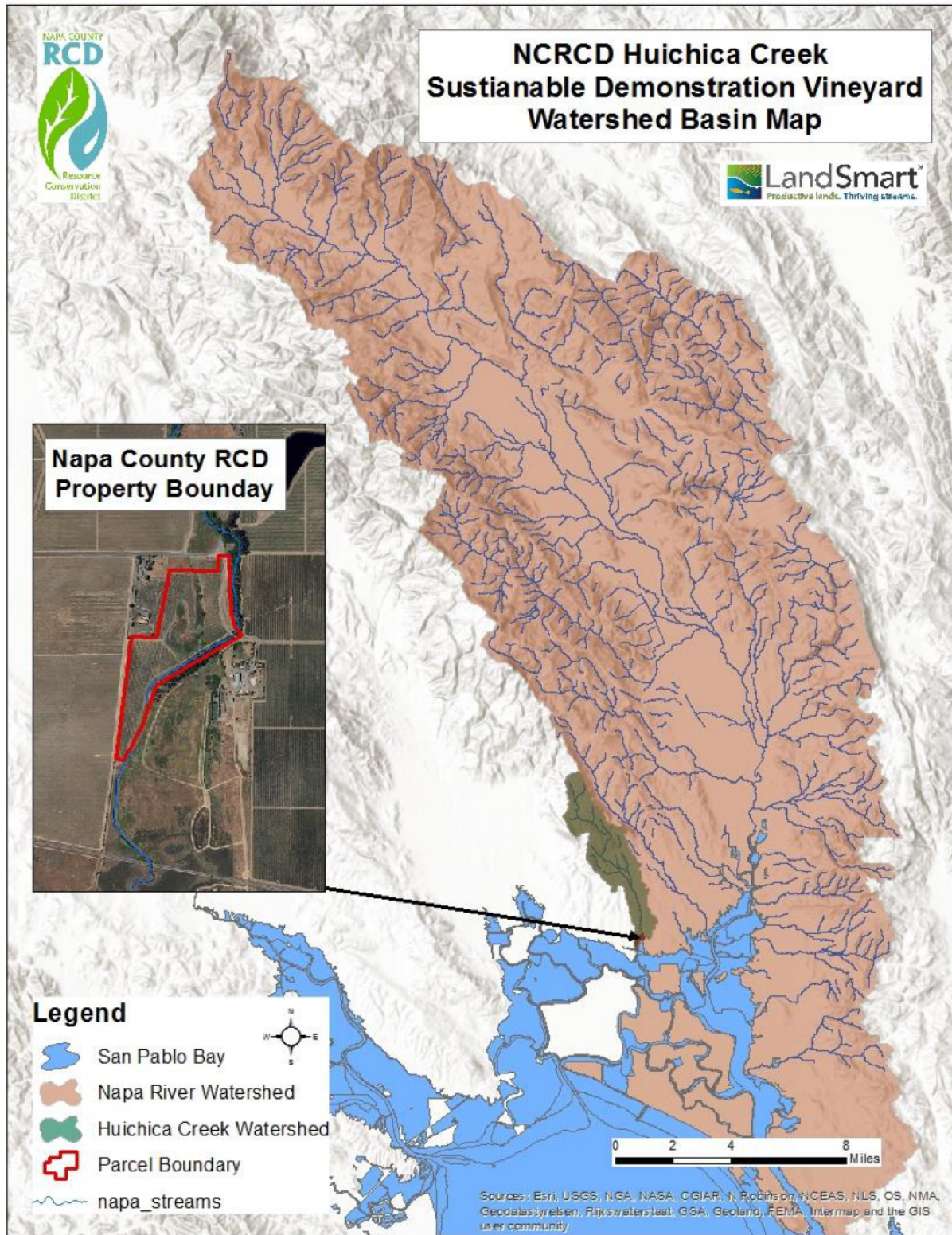
Huichica Creek Sustainable Demonstration Vineyard

Huichica Creek Sustainable Demonstration Vineyard (HCV) is located in the Carneros AVA in southwest Napa County. The property is in the Huichica Creek Watershed, Huichica Creek flows through the property. Huichica Creek is a Chinook salmon-bearing stream, and is home to many water fowl and migratory birds. HCV borders the Napa Marsh State Wildlife Area. The parcel is 21 acres. 14 acres contain vineyard planted to Pinot Noir and Chardonnay and 6 acres contain riparian and wetland habitat. Napa County Resource Conservation District purchased HCV in 1990 via a grant from the State Coastal Conservancy and the State Wildlife Conservation Board. The original goal was to demonstrate cost effective vineyard practices that protect water quality and produce high quality wine grapes, to encourage broad adoption of such practices, and to provide education and assistance to growers and landowners. The management plan combines sustainable conservation farming techniques with wetland enhancement and riparian restoration. In 2015, RCD began developing the property as a demonstration site for drought resilient and climate beneficial farming.

Prior to RCD acquisition, the land had been intensively grazed and farmed for hay production for more than a generation. Adjacent reaches of Huichica Creek and seasonal wetland habitat within the parcel had been impacted significantly. Stream channelization, removal of riparian vegetation, and draining and modification of the wetlands accompanied the historical agricultural operations within the Lower Huichica Creek Watershed. Since RCD purchased the property, we have planted a demonstration vineyard, utilized conservation farming practices recommended by

NRCS, and restored 1/2 mile of riparian habitat and over 4 acres of wetland. The vineyard served as a demonstration for diverse cover cropping systems and conservation tillage practices that have been adopted around the Napa Valley and has demonstrated the compatibility of riparian and wetland habitat in a productive vineyard setting.

Map 1. Huichica Creek Vineyard Watershed Basin



Soil

The primary goal of investigating the soil within the carbon farm planning framework is to measure the soil organic carbon (SOC) content and the condition of the soil physical properties, as measured by bulk density in the top 40 cm of the soil profile. SOC is measured for two main reasons: SOC influences a range of soil properties that enhance environmental and crop health, and increases in SOC may offset global greenhouse gas emissions (Baldock et al, 2010). In addition, increasing SOC content enhances the capacity of the soil to store plant available water (da Silva and Kay, 1997). With increasing SOC, we assume increases in crop health and farm ecology resiliency to both drought and large storm events.

Huichica Creek Soil Types and Properties

The soil series at Huichica Creek Vineyard is Haire Loam, soil mapping unit 145 in the Napa County Soil Survey, USDA-SCS, 1978. The Haire soil is an Ultisol, a soil that is characteristic of a moist-warm climate, with an accumulation of clay minerals in the B horizon. The Haire loam soil at the vineyard property is characterized by silt loam and silty-clay loam in the top 18-24 inches, and heavy clay-argillic B horizons from 24 – 40 inches, and sandy clay loam 40+ inches in the C horizons. Soil analysis conducted in block F of the ranch resulted in a pH range from 6.6-7.0. Soil structure is sub-angular blocky to blocky in the A-horizons and columnar to prismatic in the B horizons.

Permeability is generally slow in Haire loam soils. The effective rooting depth is generally 60 inches or more. The available water holding capacity is 3-6 inches. The soil gravel content varies throughout the property. Areas that have a high to extremely high gravel content will have greater permeability and a reduction in water holding capacity, compared to the areas with no gravel. In general, the water holding capacity is at the higher range as a result of abundant organic matter and a high clay content. The site frequently floods during large winter storm events, however, anaerobic soil conditions and mottling were not found in two soil pit analyses.



Soil Lab Analysis and Soil Pit Descriptions

Soil health metrics will be monitored at HCV, and measured every 3-5 years. Sampling began in 2015, and a regionally established protocol will be followed, which has been developed by the North Coast Soil Health Hub project. Since 2011, various data collection has occurred for measuring soil organic matter, soil organic carbon, microbial communities, and soil physical properties by UC Davis and USDA-ARS Davis. Some of this data has not been peer reviewed and not published yet.

In 2017, the North Coast Soil Health Hub identified a protocol to sample the top 6 inches, as a standard depth for monitoring soil health in farmlands. Standard academic and international protocols for measuring soil carbon are relatively consistent, with much smaller sample depth intervals, of 0-10 cm, 10-20 cm, etc. T

The Napa County RCD began sampling for soil organic matter and soil organic carbon in 2015 based on horizon identification. The Ap horizon was identified to be 6 inches deep, and therefore the sampling depth for the top horizon is consistent with the North Coast Soil Health Assessment and other soil health protocols around the U.S. Samples were collected in the cover crop-mid row and within the vine row/ under the vine (view table 1 and 2). HCV will continue to collect soil health data in the 0-6 inch depth, however, a carbon analysis protocol will be adopted in the future, in collaboration with UC Davis, and multiple sampling depths will conduct down to 1 meter throughout the ranch.

Table 1. Measurements of Soil Organic Matter (SOM), Soil Organic Carbon (TOC), and Soil Texture in Block F at Huichica Creek Sustainable Demonstration Vineyard.

Block F Soil Horizons	Location	Depth (in)	SOM (%)	SOC (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class
Ap	Cover Crop	0-6	4.81	2.80	23	54	23	Silt Loam
A1&2	Cover Crop	6-23	2.29	1.33	21	52	27	Clay Loam
Bt	Cover Crop	23-36	3.77	2.19	16	31	53	Clay Loam
C	Cover Crop	36-60	2.80	1.63	38	40	22	Loam
Ap	Vine row	0-6	3.68	2.14	23	54	23	Silt Loam
A1&2	Vine row	12-24	2.51	1.46	21	52	27	Clay Loam

Percent organic matter content ranges from 4.8% to 2.8% throughout the soil profile, and organic carbon ranges from 2.8 % to 1.33%. The Bt horizon, sampled a depth between 23-36 inches has a higher SOM and SOC than the A1&2 because the large increase in clay content. Under the vine SOM and SOC is lower under the vine than in the cover crop, however, under the vine SOM and SOC is slightly higher in A1&2 horizon.

Data for all other areas of the ranch will be updated once a comprehensive soil sampling and monitoring program has been established. Anticipated sampling will begin in winter-spring 2018.

Soil Texture

Soil texture in the top 36 inches includes Silt loam, Clay Loam, and Clay. These 3 textural classes are classified as fine textured soils.

Soil Organic Carbon (SOC)

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM). Total organic carbon is also referred to as soil organic carbon (SOC) in the scientific literature. Organic carbon enters the soil through the decomposition of plant and animals, root exudates, and living and dead microorganisms. Inorganic carbon is common in calcareous soils in the form of calcium and magnesium carbonates.

SOM influences the physical, chemical, and biological properties of soils, and therefore, plant growth, far more than suggested by its relatively small proportion in most soils. It increases soil aggregation, structure, and porosity, and lowers bulk density. Because the soil structure is improved, water infiltration rates increase. SOM has a high capacity to adsorb and exchange cations, and can facilitate pesticide and contaminant binding. It furnishes energy to microorganisms in the soil. As SOM is decomposed by soil microbes, nitrogen, phosphorous, sulfur, and many micronutrients are released and become available for plant growth. SOM is a heterogeneous, dynamic substance that varies in particle size, carbon content, decomposition rate, and turnover time. In general, SOM is most concentrated at the surface—where plant, animal, and microbial residue inputs are greatest—and concentrations decrease with depth (USDA-NRCS, 2014).

SOM and SOC

Many viticulturists and grape farmers strive to stress the vines; they desire a lower organic matter content to create a less fertile soil. A primary goal within the carbon farm planning framework is to achieve the maximum carbon storage potential of the soil within the agricultural system, while maintaining desirable grape quality and yield. Achieving maximum soil health and soil carbon (organic matter) while maintaining desirable grape production should be compatible, with the assumption that over time the farmer may have to alternate their management practices. For example, upon improving soil health, farmers may need to reduce irrigation and fertilizer inputs to maintain the desired vine growth and vigor. Once a ranch wide sampling protocol has been developed, all data will be included and updated in this report.

The Cornell Soil Health Assessment suggests that optimal soil health for a fine textured soil is achieved when SOM of 4-5% is present in the plow layer (0-15 cm) (Figure 1). Although the Cornell Soil Health Index was developed for soils from New York State, it is consistent with research conducted world-wide that suggests similar soil health standards. The top soil of the Haire Loam soil at Huichica Creek is in the fine textural class (silt loam). Figure 1 shows that fine textured soils will attain maximum soil health in the light to dark green portion of Figure 1, assuming 4%-5+% SOM as a target.

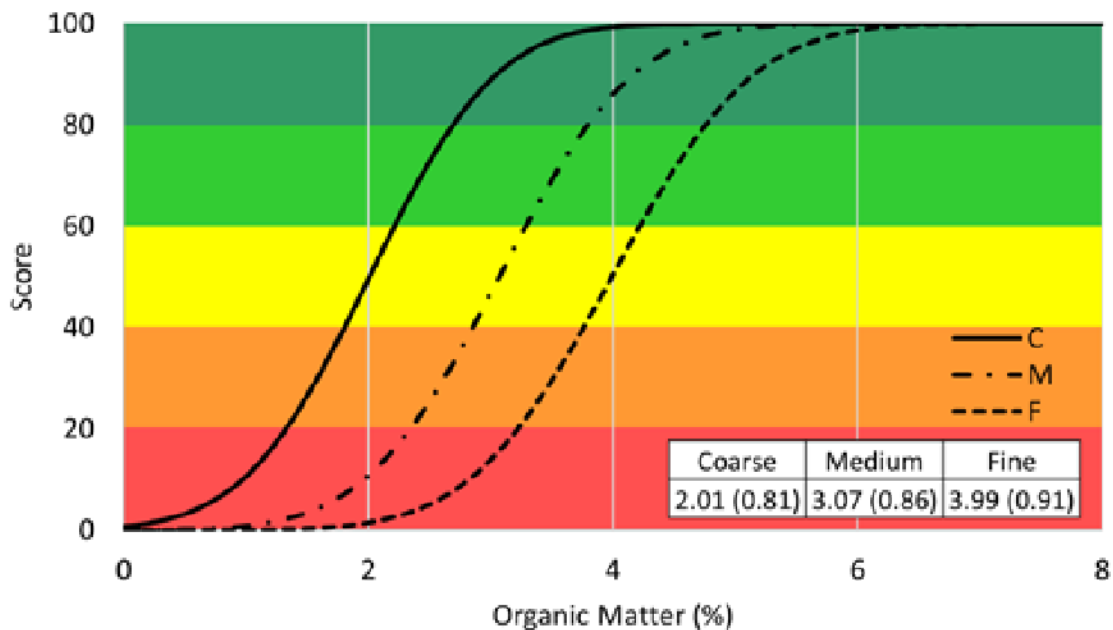


Figure 1. Soil Organic Matter (OM) scoring functions and upper value limits for Coarse (C), Medium (M) and Fine (F) textural classes. Mean and standard deviation (in parenthesis) for each class are provided. Soils with higher OM scores generally require lower inputs of nutrients and are more resilient to drought and extreme rainfall. (Comprehensive Assessment of Soil Health – The Cornell Framework Manual, 2016)

In the cover crop area, or mid row, SOM was measured at 4.81%. Based on the Cornell Rating, this soil’s organic matter is in the “good” range for soil health. Block F sits in the floodplains for Huichica Creek, so there may be much more potential to raise the OM, although it may already be in a “good” health state. Under the vine SOM was measured at 3.68%. We can assume that under the vine soil health is not optimal. We would expect this, given this blocks has been sprayed with herbicides for over 20 years, and little to no organic matter or organic fertilizers has been inputted into the system since the inception of the vineyard.

Although the SOM% and SOC% is relatively high for the cover crop area, and relatively high under the vine for industry standards, there are significant soil health/quality issues problematic

to crop health and ecologically functioning. View section ‘**Soil quality issues resulting from vineyard management**’ below.

Bulk Density

Bulk density is one of several indicators of soil health. It is also an indicator for soil compaction and root restriction. It influences water movement in the soil, root growth penetration, and seed germination. Bulk density is affected by soil cover, amount of organic matter, soil structure, and porosity (USDA, 2008).

Factors Affecting Bulk Density

Bulk density is dependent on soil texture and the packing arrangement and densities of soil mineral particles (sand, silt, and clay) and organic matter. Generally, loose, porous soils and those rich in organic matter have lower bulk density. Sandy soils have relatively high bulk density compared to silty or clay soils because total pore space in sandy soils is relatively low. Finer-textured soils that have good structure, such as silt and clay loam, have higher pore space and lower bulk density compared to sandy soils.

Bulk density is changed by crop and land management practices that affect soil cover, organic matter, soil structure, or porosity. Cultivation can result in compacted soil layers with increased bulk density. Livestock and the use of agricultural and construction equipment exert pressure that compacts the soil and reduces porosity, especially on wet soils. Freezing and thawing in the soil can lower bulk density (USDA-NRCS, 2014).

Some of the practices that can improve bulk density include increasing organic matter content, reducing soil disturbance when the soil is wet, and maintaining soil surface protection with cover crops, especially multi-species mixes that can provide a wide range of root penetration.

Table 2. General relationship of soil bulk density to root growth based on soil texture

Soil Texture	Ideal bulk densities for plant growth (g/cm³)	Bulk densities that restrict root growth (g/cm³)
Sandy	Less than 1.60	More than 1.80
Loamy	Less than 1.40	More than 1.65
Clayey	Less than 1.10	More than 1.47

Bulk Density at HCV

Bulk Density was measured in 2016 in block F at two locations (Table 3.), within the cover crop middle, that had been non-tilled for 25 years. The bulk density measurements indicate that compaction is not severe, or a problem. A1-Pit 1 may have slightly high BD. This depth is a silt loam, and an ideal BD for silt loam can range from 1.25-1.40 g/cm³. When BD samples were

taken during this sampling event, it was not documented whether the location was directly within the tractor wheel tracks, or outside of them, within the permanent no-till cover crop. Once a soil health monitoring protocol has been established at the HCV, BD will be sampled both within and outside of the tire tracks. Based on in the field water infiltration tests, it has been found that compaction in the tire tracks is severe at HCV, and must be addressed.

Table 3. Bulk Density Measurements, Block F at Huichica Creek Sustainable Demonstration Vineyard.

Pit 1	Depth (cm)	g/cm ³	Pit 2	Depth (cm)	g/cm ³
A1	11	1.40	A1	12	1.30
A2	17	1.12	A2	20	1.18

Soil Quality Issues Resulting from Vineyard Management

Currently, throughout the majority of the vineyard, the soil within the drip zone, has high pH (7.9), moderately-high Sodium Adsorption Ratio (SAR - 5.3), and higher than desirable sodium percentage (6.7%) occupying the cation exchange sites. These issues are caused by the well water quality, which has high pH, 8.2, and a very high adjustable SAR of 10.0. These issues are high enough to negatively impact plant growth. Low yields and poor plant health are notable throughout the vineyard, and many of the symptoms are characteristic of plant stress due to sodium. When SAR is high (generally 12+), soil physical problems arise and crops have difficulty absorbing water. In addition, there is substantial compaction issues in the non-tillage alleyways (cover crop middles).

Existing and Historical Carbon Beneficial Practices

Since the inception of the Huichica Creek Sustainable Demonstration, the Napa County RCD has restored and planted riparian vegetation on 1/2 mile of Huichica creek and allowed natives to establish naturally. Many non-native plants exist within the riparian zone, and the vineyard cover crop alleys and under the vine have many non-native weed species intermixed with the intentional cover crop. Below is an inventory of native riparian species provided by the Napa NRCS.

Herbaceous

<i>Artemesia douglasiana</i>	Mugwort
<i>Bromus carinatus</i>	California brome
<i>Conium maculatum</i>	Poison hemlock
<i>Elymus triticoides</i>	Creepign wild rye
<i>Foeniculum vulgare</i>	Fennel
<i>Galium aparine</i>	Bedstraw
<i>Juncus balticus</i>	Baltic rush
<i>Lepidium latifolium</i>	Perennia pepperweed

Tree

<i>Aesculus californica</i>	California buckeye
<i>Fraxinus latifolia</i>	Oregon ash
<i>Juglans hindsii</i>	Black walnut
<i>Populus fremontii</i>	Fremont cottonwood
<i>Quercus lobata</i>	Valley oak
<i>Salix exigua</i>	Sandbar willow
<i>Salix laevigata</i>	Red willow
<i>Salix lasiolepis</i>	Arroyo willow

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<i>Phalaris aquatica</i>	Harding grass		
<i>Poa annua</i>	Annual blue-grass	Shrub	
<i>Raphanus sativa</i>	Wild radish	<i>Sambucus mexicana</i>	Blue elderberry
<i>Rumex crispus</i>	Curly dock		
<i>Salicornia pacifica</i>	Pickleweed		
<i>Schoenoplectus acutus?</i>	Common tule		
<i>Scrofularia californica</i>	Bee plant		
<i>Sonchus oleraceus</i>	Annual sow thistle		
<i>Typha sp.</i>	Cattail		

Four acres of wetland habitat was restored from pastureland to native woody and herbaceous perennial cover. There is also a large population of non-native herbaceous vegetation that has colonized sections of the wetland.

Tree		Herb	
<i>Salix laevigata</i>	Red Willow	<i>Eleocharis macrostachya</i>	Creeping spike-rush
<i>Salix lasiolepis</i>	Arroyo willow	<i>Elymus triticoides</i>	Creeping wild rye
Shrub		<i>Epilobium brachycarpum</i>	Willow herb
<i>Baccharis pilularis</i>	Coyote brush	<i>Frankenia salina</i>	Alkali heath
		<i>Pleuropogon californicus</i>	Annual semaphorgrass

Approximately 1700 square feet of native shrubs, sedges, forbs and wildflowers have been established as a hedgerow in the Northern corner of the property. Native species include, Redbud, Ceanothus, CA Coffeeberry, Toyon, Elderberry, Santa Barbara Sedge, Ribes, Sages, Penstemon, Santa Barbara Sedge, CA Yarrow, and CA Poppy.

Since the inception of the project in 1991, fourteen acres of pastureland has been planted to vineyard. Initially, the RCD attempted to farm all 14 acres under non-tillage practices. Due to poor vigor issues in some blocks, tillage was incorporated in every other row over a portion of the property. Approximately 11 acres are farmed in alternate row tillage, where the tillage rows are annually tilled and the permanent no-till rows remain untilled. The tillage rows are annually seeded with a standard plow-down green manure cover crop, which is disked and incorporated into the soil each spring. A diverse permanent ground cover has been established in the non-tillage rows. Many species include Zorro Fescue, Blando Brome, clovers native CA annuals, and CA perennial bunch grasses were attempted with limited success. Approximately 3 acres of vineyard has been under non-tillage practices for the lifetime of the vineyard and the permanent cover cropping efforts were very similar to the non-tillage rows in the alternate tilled vineyard blocks.



Left Photo: Huichica Creek riparian corridor in 1991 when the RCD purchased the property.

Right Photo: Huichica Creek riparian corridor from the same angle in December 2016.

Considering the carbon benefits of the restoration efforts and implemented soil health farming practices, using metrics from COMET-PLANNER and research, an estimated potential of 117.97 tons of CO₂e has been sequestered or mitigated as a greenhouse gas per year. Table 1. below breaks down each practice and the estimated carbon dioxide reduction equivalent in metric tons per acre.

Table 4. Estimated Carbon Sequestration and Greenhouse Gas Emission Reductions per year, 1991 – 2015

Huichica Creek Sustainable Demonstration Farm Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions 1991-2015 (tons CO ₂ equivalent per year)						
NRCS Conservation Practice	Acres	Carbon Dioxide (CO ₂)	Nitrous Oxide (N ₂ O)	Methane (CH ₄)	1yr - Metric tons CO ₂ e Reduction	20yrs - Metric Tons of CO ₂ e Reduction
		Per Acre Per Year				
* Riparian Restoration (CPS 390)	4.70	*n/a	*n/a	0.00	76.80	1535.96
Conventional Tillage to Reduce Tillage (CPS 345)	11.00	0.13	0.07	0.00	2.20	44.00
Conventional Tillage to No Tillage (CPS 329)	3.00	0.42	-0.11	0.00	0.93	18.60
Cover Crop Establishment (CPS 340)	14.00	0.32	0.05	n/a	5.18	103.60
Nutrient Management - Replace Synthetic N Fertilizers with Soil Amendments (CPS 590)	14.00	1.75	n/a	0.00	24.50	490.00
Wetland Restoration (CPS 657)	4.00	1.81	0.28	n/a	8.36	167.20
Totals					117.97	2359.36

* Values generated from "Mitigating Greenhouse Gas Emissions through Riparian Revegetation", Lewis et al 2015. 16.34 MT CO₂e/acre
All other values estimated by COMET-Planner USDA, 2014

Farm Goals and Objectives

- Increase soil organic carbon to improve the following:
 - Improve cover crop productively and rooting depth
 - Aggregate stability (by converting tillage areas to non-tillage)
 - Improve soil available water holding capacity
 - Reduce compaction and improve soil infiltration
 - Potentially buffer pH and Na issue in the drip zone (along with water treatment)
 - Enhance drought resiliency of vineyard and reduce irrigation inputs
- Enhance riparian, wetland vegetation, and insectary habitat
- Increase grapes yields to an average 4 ton/acre.

Planned Carbon Beneficial Practices and Anticipated Outcomes

1. Riparian Restoration (NRCS Practice 390)

Locations along the creek banks that are devoid of large riparian trees and shrubs will be planted and composed of species that are currently existing and thriving within the

property riparian corridor. An estimated 2.76 acres of additional riparian acreage will be planted. At a rate of 16.34 tons of CO₂e per acre per year, implementation of these practices provides for an estimated 901.97 tons of CO₂e sequestered over a 20-year period (Lewis et al, 2015).

2. Hedgerow Planting (NRCS Practice 422)

Approximately 0.15 acres of hedgerow planting is proposed along the main vineyard access road and Block F. At rate of 1.7 tons of CO₂e per acre per year, an estimated 0.19 tons per year could be sequestered. Over a 20-year period there is a potential to sequester a total of 3.8 tons CO₂e (COMET-Planner USDA, 2014).

3. Conventional tillage to Non-tillage (NRCS Practice 329)

Currently 4 acres of vineyard are tilled annually. Current tillage practices include 2-3 disk cultivations to a depth of 10 inches for incorporating a green manure cover crop and reducing weed competition. At a rate of 0.31 tons of CO₂e per acre per year for the practice of converting 4 acres from reduced tillage to non-tillage, an estimated 24.80 tons of CO₂e could be sequestered over a 20-year period (COMET-Planner USDA, 2014).

4. Compost Application (NRCS Practices 484)

Application of ¼ “ of compost to 14 acres of vineyard. With the assumption that ¼ inch per acre is roughly 17 tons/ acre of compost, and 25% of the compost mass is composed of carbon, we estimate a potential 15.6 tons of CO₂e will be sequestered as result of each application. Application will occur every 3 years, with a total of 6 applications in 20 years, results in a total potential of 1310.4 tons of CO₂e sequestered. (17 tons compost is approximately 4.25 tons of carbon. One metric ton of soil carbon is equal to 3.67 metric tons of CO₂e).

5. Permanent Cover Crop Establishment (NRCS Practice 327)

Conservation Cover metrics are used to quantify the transition from a plow down cover crop to a permanent no-till cover crop. The use of this metric also assumes enhanced productivity of the permanent cover crop that is already established. At a rate of 1.26 tons of CO₂e per acre per year, a potential of 100.8 tons of CO₂e could be sequestered in a 20-year period (COMET-Planner USDA, 2014).

6. Mulch Application (NRCS Practice 484)

All vine row strips, the base of orchard trees, and hedgerows will be mulched with wood-based or straw based material. All vines that are extracted for replant, will be chipped, composed for one year, and applied as mulched throughout the property. We estimate approximately 4 acres of land will receive mulch application. At rate of 0.32 tons of CO₂e per acre per year, an estimated 25.60 tons CO₂e will be sequestered over a 20-year period (COMET-Planner USDA, 2014).

7. Multistory Cropping (NRCS Practice 379)

Approximately $\frac{3}{4}$ acre of grapes is being converted to a mixed apple orchard which will have an understory managed to replicate an oak-woodland savanna. Native plant populations will be established to the highest degree feasible. At rate of 1.71 tons of CO₂e per acre per year, on $\frac{3}{4}$ acre an estimated 26.1 tons CO₂e will be sequestered over a 20-year period (COMET-Planner USDA, 2014).

8. Windbreak / Shelterbelt Establishment (NRCS Practice 380)

Remove one $\frac{1}{4}$ mile length row of vines in replant and establish a shelterbelt on at the windward fence line. At a rate of 2.09 tons of CO₂ per acre per year, an estimated 20.90 tons of CO₂ could be sequestered over a 20-year period (COMET-Planner USDA, 2014).

9. Wetland Restoration and Enhancement (NRCS Practice 657)

The restoration proposal includes incorporating large shrubs and small trees of the perimeters, and planting wetland grasses in the more prominent inundated locations. Using windbreak (CPS 380) metrics, at rate of 2.09 tons of CO₂ per acre per year, an estimated 167.20 tons of CO₂ could be sequestered over a 20 – year period.

Summary of Planned Practices

Figure 2 summarizes carbon sequestration and GHG emission reduction potential from the implementation of the NRCS Conservation Practices listed above (see Map 2 for location of practice implementation). Using COMET-PLANNER and published regional research, we estimate a potential of 282.02 tons of CO₂ equivalent sequestered or mitigated as greenhouse gas emissions per year for the entire property upon implementing the plan.

The most effective conservation practices for capturing carbon at HCV is compost application (Figure 3). Riparian restoration has the second greatest potential, wetland restoration has the third greatest potential.

Table 5. Estimated Annual Carbon Sequestration and Greenhouse Gas Emission Reductions Associated with Implementation of Suggested Conservation Practices.

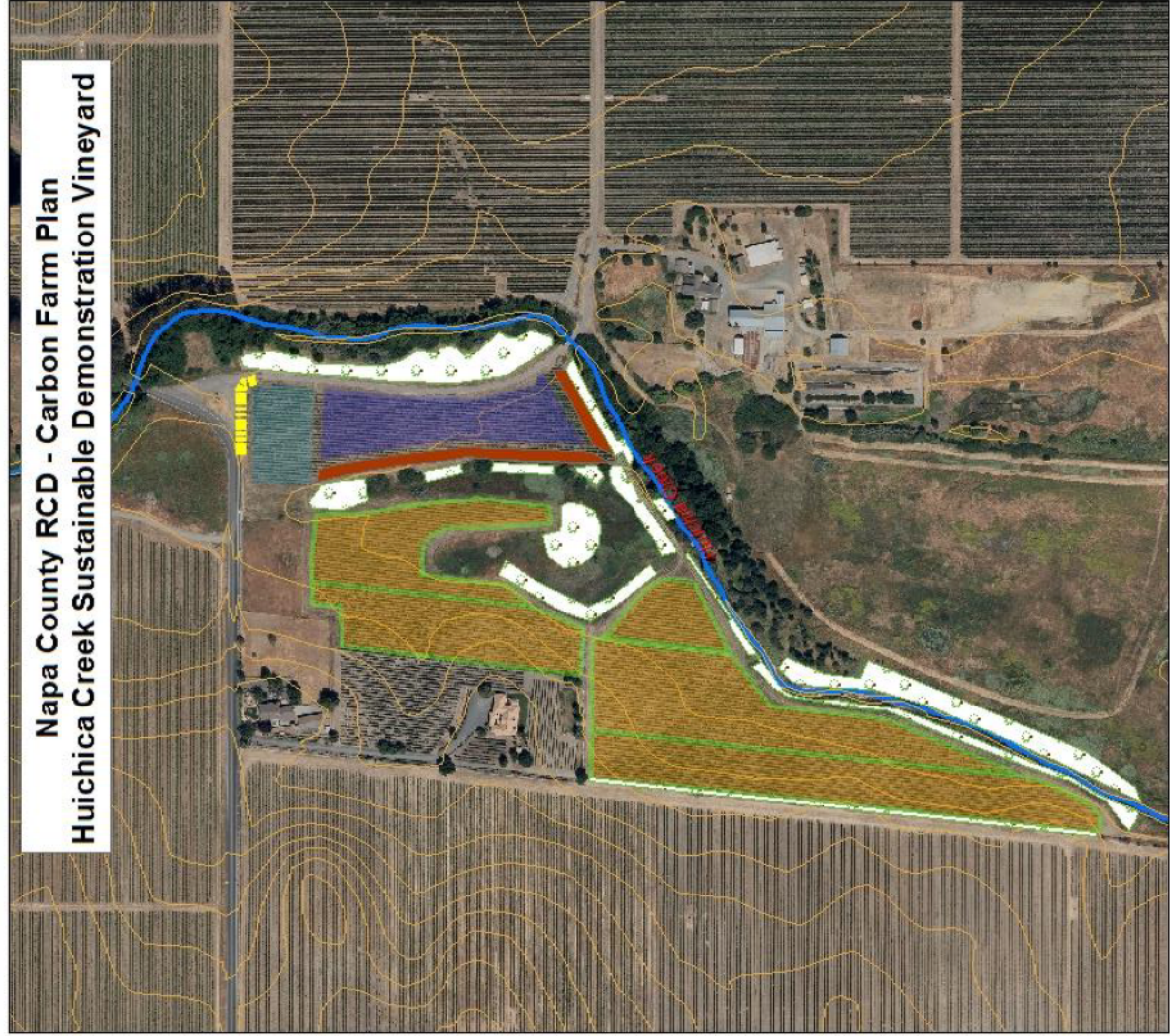
Huichica Creek Sustainable Demonstration Farm Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions 2016 - Future (tons CO₂ equivalent per year)						
		Carbon Dioxide (CO ₂)	Nitrous Oxide (N ₂ O)	Methane (CH ₄)	1yr - Metric tons CO ₂ e Reduction	20yrs - Metric Tons of CO ₂ e Reduction
NRCS Conservation Practice	Acres	Per Acre Per Year				
* Riparian Restoration (CPS 390)	2.76	*n/a	*n/a	0.00	45.10	901.97
Hedgerow Planting (CPS 422)	0.15	1.42	0.28	0.00	0.26	5.10
Conventional Tillage to No Tillage (CPS 329)	4.00	0.42	-0.11	0.00	1.24	24.80
Permenant Cover Crop Establishment (CPS 327)	4.00	0.98	0.28	n/a	5.04	100.80
**Compost Application (CPS 484)	14.00	15.60	n/a	0.00	218.40	1310.40
Mulching (CPS 484)	4.00	0.32	n/a	n/a	1.28	25.60
Multistory Cropping (CPS 379)	0.75	1.71	0.03	0.00	1.31	26.10
Windbreak/ Shelterbreak Establishment (CPS 380)	0.50	1.81	0.28	n/a	1.05	20.90
Wetland Restoration (CPS 657)	4.00	1.81	0.28	n/a	8.36	167.20
Totals					282.02	2582.87

* Values generated from "Mitigating Greenhouse Gas Emissions through Riparian Revegetation", Lewis et al 2015. 16.34 MT CO₂e/acre

** Assumption: 6 application of 1/4 inch compost in 20 yrs. 17 tons compost = 15.6 MT CO₂e reduction/acre/yr

All other values estimated by COMET-Planner USDA, 2014

Map 2. Carbon Farm Plan Map






Napa County RCD - Carbon Farm Plan
Huichica Creek Sustainable Demonstration Vineyard

Current Practices

-  Blocks A-E: Alternate Row Till
-  Block G - No Till
-  Replant Block F - No Till
-  5 Foot Contour
-  Huichica Creek

Planned Conservation Practices

Compost Application in all vineyard blocks

-  Riparian, Wetland, and Windbreak Planting
-  Alternate-Row Tillage to No-Till
-  Multistory Cropping

Carbon Farm Practices (NRCS Practice)

1. Riparian Restoration (390)
2. Hedgerow Planting (422)
3. Conventional Tillage to No Tillage (329)
4. Compost Application Mulching (484)
5. Cover Crop Establishment (340)
6. Multistory Cropping (379)
7. Windbreak Establishment (380)
8. Wetland Restoration (657)



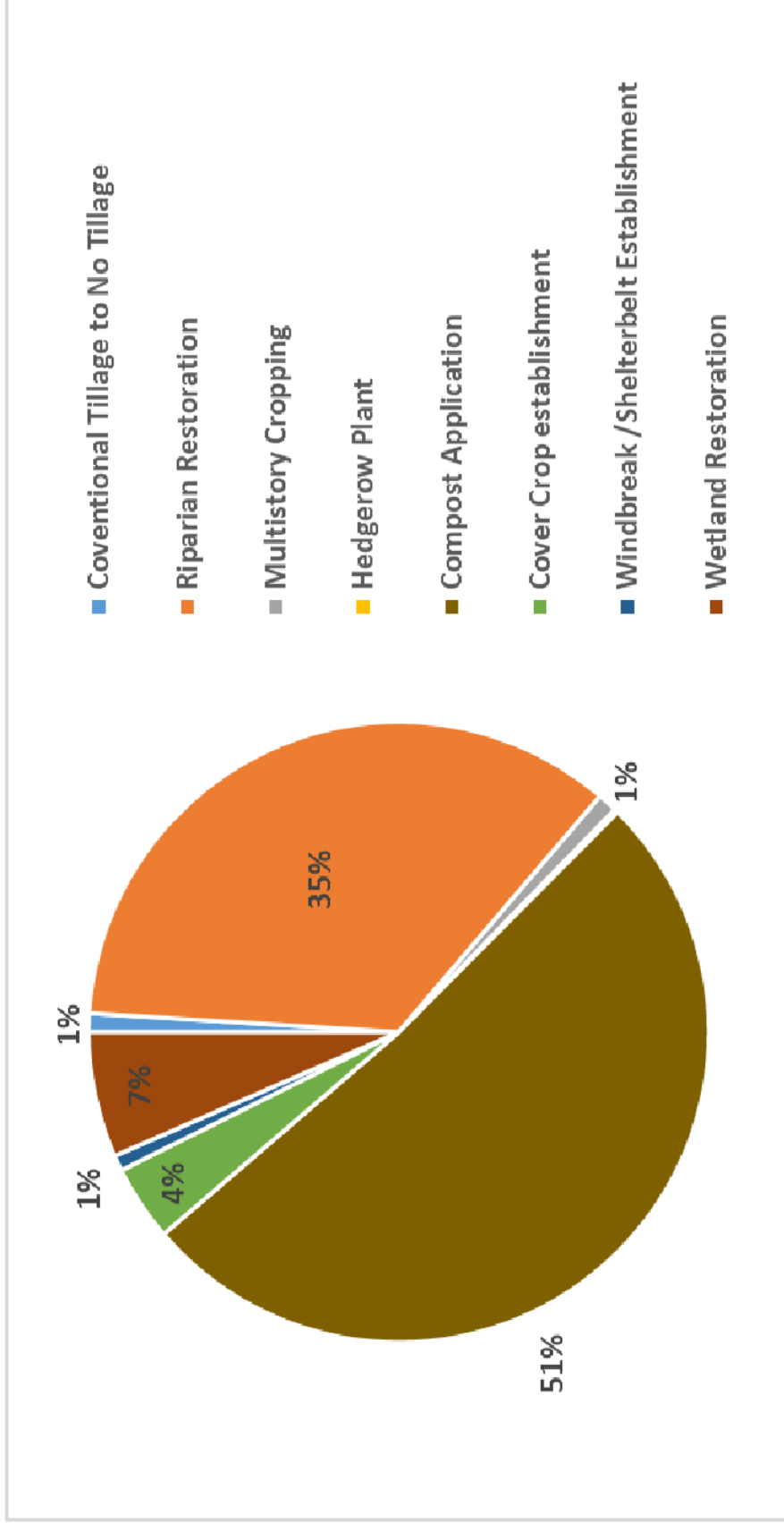




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Figure 2. Relative Impact of Proposed NRCS Conservation Practice Standards



The Soil-Water and Carbon Connection

NRCS estimates that a 1% increase in soil organic matter (SOM) results in an increase in soil water holding capacity of approximately 1-acre inch, or 27,152 gallons per acre. A 1% increase in SOM equals approximately 20,000 pounds of organic matter, or 5 short tons of organic carbon. Therefore, the implementation of the Carbon Farm Plan at HCV will potentially result in 7 acre feet of additional water storage capacity associated with soil carbon increases.

Additional Climate Beneficial Practices

Biochar

Six tons of biochar has been applied within the vine row and incorporated to a depth of 6 inches in 1.5 acres in block F. Although there is no accepted C-sequestration or CO₂e reduction quantification of biochar, many farmers, agencies, resources organizations, and scientists are recognizing biochar as a soil amendment that has benefits to soil health and may lead to additional soil carbon sequestration for decades. If biochar is applied to all 14 acres of agricultural area at HCV at a rate of 4 tons per acre, then CO₂e reduction per year would be 26.5 metric tons (CAPCOA GHG Rx Protocol).

Sheep grazing management plan

Grazing sheep throughout the vineyard during the vine dormancy season can have many beneficial impacts to reducing carbon emissions, and potentially contribute to building organic matter in the soil, enhancing soil carbon storage. The sheep grazing would reduce the need for mowing, herbicide application under the vine, and under the vine mechanical weed cultivation at HCV. Currently, 2-3 tractor passes are made each year to mow the vineyard cover crop, one pass for herbicide application under the vine, and an additional 1-2 passes with in under the vine cultivator for organic weed management. Therefore, sheep could potential eliminate the need for 4-6 tractor passes per year. Additionally, using sheep would eliminate the carbon footprint associated with production and shipping of herbicide. Lastly, sheep excrement applied throughout the vineyard may reduce the need for compost and fertilizer applications, further reducing the carbon footprint of the operation.

DISCUSSION

Values presented in Table 5 are best understood as gross CO₂e sequestered through implementation of the various on-farm practices at the spatial and temporal scales outlined in the table and the Carbon Farm Plan as a whole. Average annual CO₂e reduction values in Table 5 are for illustrative purposes only. Actual sequestration of CO₂ in response to management and conservation practice implementation is not expected to be linear over time, rather, it is expected to vary annually (J. Creque and Fibershed 2016). Length of time during which practices will sequester carbon also varies among practices. Terrestrial carbon sequestration resulting from each practice tends to increase cumulatively to maturity and then tends to decline, though remaining net positive relative to baseline conditions for many years (Ryals et al 2015). As such, periodic reapplication of compost and long-term maintenance of all carbon beneficial practices are important for maintaining high levels of carbon sequestration on the farm.

GHG emissions associated with the practices specified in this Plan are generally accounted for in the models used (COMET-Farm, COMET-Planner, etc.). Exact emission reductions and carbon sequestration achieved from implementing practices at Huichica Creek Vineyard cannot be determined precisely, however sequestration values presented here are based on conservative estimates and are likely to be exceeded in real world application (J. Creque and Fibershed 2016).

In some cases, rates of accumulation of CO₂e may fall below emission rates, resulting in temporary net increases of GHG. For example, initial GHG costs of compost production or riparian restoration may exceed first year sequestration rates. Net sequestration associated with a single compost application to grazed grassland may also decline over time. Models suggest soil nitrous oxide, (N₂O) emissions may gradually overtake reductions in CO₂ associated with this practice, some three decades after initial compost application. This suggests reapplication of compost sometime before the third decade after initial application may be warranted for sustained GHG reduction benefits from this practice (J. Creque and Fibershed 2016).

Improved soil hydrologic status, porosity, and micronutrient status that typically result from compost amendment (Ryals and Silver 2013) are not currently accounted for in the models used to estimate climate benefits of practices. The ecosystem carbon team at CSU-NREL is in the process of updating the model to account for these important soil quality factors. Meanwhile, models will tend to undervalue the combined benefits of carbon sequestering practices. As with positive feedbacks to productivity associated with compost applications, total additional water storage capacity associated with soil carbon increases at Huichica Creek Vineyard, can be expected to provide further feedback to higher productivity, and increased carbon capture potential, increasing soil water holding capacity over both the near and long term (J. Creque and Fibershed 2016).

References

Baldock JA, Sanderman J and Farquharson R (2010) Capturing carbon in Australian soils: potential and realities. In *Soil Solutions for a Changing World* (eds RJ Gilkes and N Prakongkep), Proceedings of the 19th World Congress of Soil Science, Congress Symposium no. 7, International Union of Soil Sciences, Brisbane (pdf on DVD).

CAPCOA GHG Rx Protocol: Biochar Production Project Reporting Protocol, GHG Emission Reduction Accounty. 2015. Version 3.4.

da Silva AP, Kay BD (1997) Estimating the least limiting water range of soils from properties and management. *Soil Science Society of America Journal* **61**, 877-883.

J. Creque, and Fibershed. Bare Ranch Carbon Farm Plan. Carbon Cycle Institute, 2016.

Lewis, D.J., M. Lennox, A. O'Green, J. Creque, V. Eviner, S. Larson, J. Harper, M. Doran, and K. W. Tate. 2015. Creel Carbon: Mitigating greenhouse gas emissions through riparian restoration. University of California Cooperative Extension in Marin County. Novato, California. 26 pgs

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H. A. Shayler, M. B. McBride, D.W. Wolfe, and G.S. Abawi, 2016. Comprehensive Assessment of Soil Health – The Cornell Framework Manual, Edition 3.1, Cornell University, Geneva, NY.

Ryals, R, and W.L. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grassland ecosystems. *Ecological Applications* 23:46-59.

United State Department of Agriculture, Natural Resources Conservation Service. 2008. Soil Quality Indicators – Bulk Density.