Carbon Farm Plan

The Maples Farm

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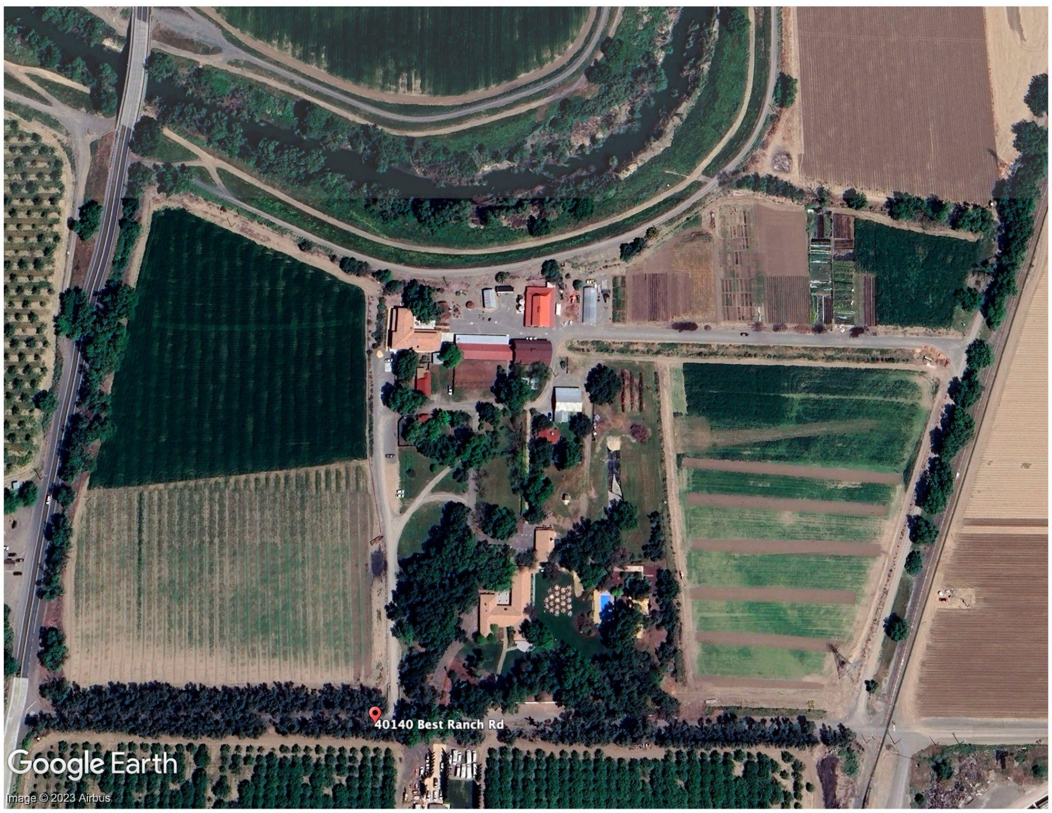
In collaboration with:

The



Yolo Carbon Farming Partnership
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The Maples Farm

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Introduction

Guide to document acronyms and abbreviations:

BIPOC – Black, Indigenous and People of Color
BOS - Board of Supervisors
CAAP – Climate Action and Adaptation Plan
CFP – Carbon Farm Plan
CCI – Carbon Cycle Institute
CLBL – Center for Land-Based Learning
CO2 - Carbon dioxide
CO2e - "carbon dioxide equivalent," a measurement of the total greenhouse gasses emitted, expressed in terms of the equivalent measurement of carbon dioxide.
GHG – Greenhouse gas
MT - Metric ton
NRCS – Natural Resources Conservation Service
SOC - Soil organic carbon
SOM - Soil organic matter
USFWS - United States Fish and Wildlife Service
YCCAC - Yolo County Climate Action Commission
Yolo RCD – Yolo County Resource Conservation District
YLT – Yolo Land Trust

The Center for Land-Based Learning

The Center for Land-Based Learning is a non-profit organization with a mission to inspire, educate, and cultivate future generations of farmers, agricultural leaders, and natural resources stewards. It began in 1993 with the FARMS Leadership program for high school students and has since grown to include multiple youth programs and a California Farm Academy (CFA) with a suite of training and outreach programs for prospective farmers. CFA programs include a farm business incubator program, a 7-month new farmer training course, an introductory training course, and an apprenticeship program for future farm managers. CLBL's farm "campuses" include Maples Farm and several small urban farms in West Sacramento. Produce grown on these farms supplies our Mobile Farmers' Market truck which makes regular stops at low-income communities in West Sacramento. A second Mobile Farmers Market truck will provide a similar service in Woodland beginning in June 2024.

CLBL's statewide diverse youth programs, including FARMS and SLEWS, allow high school students to explore and experience a variety of careers and college pathways in the fields of agriculture and environmental sciences. Since 2001, over 8000 students in the SLEWS program have planted over 140 miles of hedgerows, over 300,000 native grass plugs, and 80,000 trees.

CLBL's Farm and Climate Program addresses the dual challenges of climate change and declining biodiversity by promoting measures that increase the rate at which CO2 and other greenhouse gasses are sequestered in agricultural soils while improving other measures of ecological health such as native habitat, biodiversity, and drought resilience. The Yolo Carbon Farming Partnership is one of our flagship initiatives.

The Yolo Carbon Farming Partnership

Yolo County has been a leader in agricultural land conservation for decades and is poised to become a leader in climate change mitigation as well. In 2020, the Yolo County Board of Supervisors passed an emergency resolution declaring a climate emergency and calling for an urgent mobilization of resources to initiate a just transition to an inclusive, equitable, sustainable, and resilient economy. With 85 percent of Yolo County lands designated for agricultural use, farm and ranch lands are arguably our most valuable resource for increasing carbon sequestration and mitigating climate change.

In response to the emergency declaration, the County formed the Yolo County Climate Action Commission in 2021 which identified a set of Early Action projects that could be implemented in the short-term while preparing a new Climate Action and Adaptation Plan (CAAP). The Yolo Carbon Farming Partnership, a collaborative effort between the Center for Land-Based Learning, the Yolo County Resource Conservation District, the Carbon Cycle Institute, Yolo Land Trust, and the County, is one of those Early Actions. The Partnership is working to rapidly increase the pace and scale of Carbon Farming and carbon sequestration in Yolo County over the next two years by delivering:

- 3 Carbon Farm Plans that can serve as models to Yolo County growers
- Training workshops on carbon farm planning and climate-beneficial practices tailored to Yolo County growers
- A replicable training curriculum in English and Spanish

What is Carbon Farming?

The term "carbon farming" refers to proven and measurable practices that increase the rate at which CO_2 and other greenhouse gasses (GHG) are removed from the atmosphere and stored over the long term in soil and plant material. Technically, all farming is "carbon farming," because all agricultural production depends on photosynthesis to move CO_2 out of the atmosphere and into plants, where it is transformed into products like food, flora, fuel or fiber. Carbon entering the farm from the atmosphere can end up in several locations: in the harvested portion of the crop, in the soil as root exudates and soil organic matter (SOM), in "waste" materials such as compost or manure, in standing carbon stocks, such as grassland vegetation or woody perennials (trees, vines, orchards, etc.), or in other permanent vegetation such as windbreaks, vegetated filter strips, or riparian forests and woodlands.

While all farming is completely dependent upon atmospheric CO_2, different farming practices, and different farm systems, can lead to very different amounts of on-farm carbon capture and storage. The Carbon Farm Planning (CFP) process differs from other approaches to land use planning by focusing on increasing the capacity of the farm to capture carbon and to store it beneficially; in the crop, as standing carbon stocks in permanent vegetation, and/or as SOM.

While agricultural practices often lead to a gradual loss of carbon from the farm system, a CFP is successful when it leads to a net increase in farm-system carbon. By increasing the amount of photosynthetically captured carbon stored, or "sequestered," in long-term carbon pools on the farm, carbon farming results in a direct reduction in the amount of CO_2 in the atmosphere, while supporting crop production and farm resilience to environmental stress, including flood and drought.

On-farm carbon in all its forms (SOM, perennial and annual herbaceous vegetation, plant roots, root exudates, and standing woody biomass), contains energy, which originated as the solar energy used by the plants in photosynthesis. The carbon in plants and SOM can thus be understood as the embodied solar energy that drives on-farm processes, including the essential soil ecological processes that determine water and nutrient holding capacity and availability for the growing crop. **Consequently, CFP places carbon at the center of the planning process and views carbon as the single most important element, upon which all other on-farm processes depend (Figure 1).**

The Carbon Farm Planning Process

A carbon farm plan is a living document through which a landowner or land manager identifies and evaluates the range of carbon-beneficial practices that make sense for a particular farm, ranch, company, or and/or family. Carbon Farm Planning is based upon the USDA NRCS Conservation Planning process, but uses carbon and carbon capture as the organizing principle around which the plan is constructed. This simplifies the planning process and connects on-farm practices directly with ecosystem processes, including climate change mitigation and increases in on-farm climate resilience, water holding capacity, soil health and biodiversity.

Like NRCS Conservation Planning, a CFP begins with a conversation with the land manager or owner and an overall inventory of natural resource conditions on the property. Unlike the classic NRCS conservation planning process, however, the focus is on identification of all on-farm opportunities for reduction of greenhouse gas emissions and enhanced carbon capture and storage by both plants and soil. Enhancing working land carbon, whether in plants or soils, results in beneficial changes in a wide array of system attributes, including; water holding capacity of soil and hydrological function, biodiversity, soil fertility, and resilience to drought and flood, along with increasing agricultural productivity.

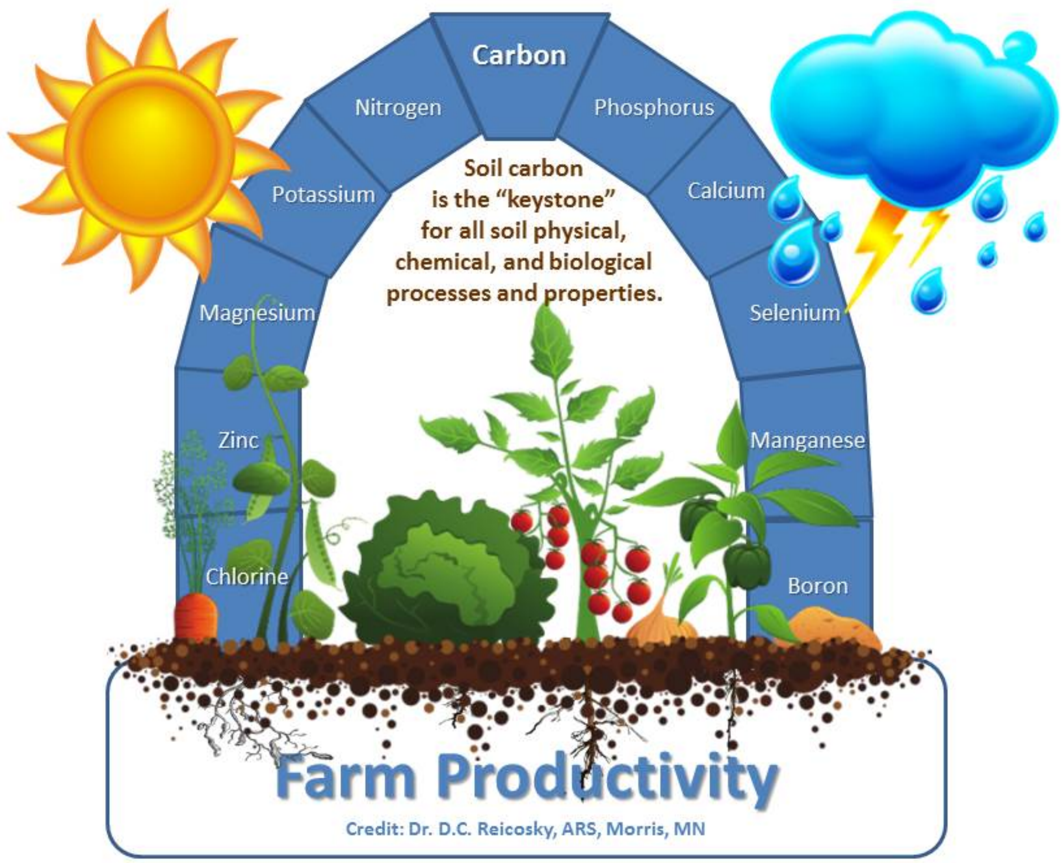

Figure 1. Carbon as the Key to Working Land Productivity and Resilience

History of Maples Farm

CLBL relocated its headquarters to Maples Farm in May of 2020. Located on 50 acres, the site includes 20 acres of prime farmland just north of the City of Woodland. The farm is bordered by a ¼ mile reach of Cache Creek to the north, which provides significant habitat value and carbon sequestration potential.

The property is owned by the Clark Collective which leases the land to CLBL through a long-term (25+ years) lease.

The Maples Farm was part of the Rancho Rio de Jesus Maria, a 26,637 acre Mexican land grant given in 1843 by Governor Manuel Micheltorena to Thomas M. Hardy. The name refers to Rio de Jesus Maria, now known as Cache Creek. In the late 1870s, the land known then and now as "The Maples" was purchased by Benjamin and Sophia Peart. The Pearts built a race track near Cache Creek in what we now call the Northeast field and also planted the majestic olive trees that line the main driveway. The land was sold to Camelia Nelson who ran a cattle and grain company that was later taken over by his son CQ Nelson who raised trotting horses. Eventually the land was sold to the Best Family which raised some of the finest 5 gaited horses in the area. For many years, the Best Family and their descendants ran short-horned cows in the pasture lands.

The property was purchased by Bob and Don Clark of Clark Pacific in 2010, who restored a portion of the property to be the Maples event center and leased the farmland to Rich and Steve Weiss who grew sunflower, alfalfa and other annual crops.

Current Land Use

The NRCS Conservation Plan for Maples Farm (2020) delineates five land units (fields 4 - 8) at the farm. However, for the purposes of this plan, the farmland at Maples is broken into six main fields/areas, according to their current and planned use (Table 1 and Figure 2)

Table 1. Current and planned land use Maples Farm fields

Field name	Land Unit	acres	Land use prior to CLBL (2011 - 2020)	Current/planned use
Southwest	7	5	alfalfa	Olive orchard/biochar research
Northwest	7	6	alfalfa	Incubator farmers/orchard
Northeast	4	3	pasture cover crop 2018-2020	Incubator farmers and training plot
Southeast	5	6	sunflower seed crop 2017-2018 Cover crop	Incubator farmers/grain
Riparian	8	11	Arundo treated in 2021-2	Cache creek riparian habitat
Human use	6	1.5	Construction completed 2020	Office building, barns, parking

Figure 2. Maples Farm main fields and riparian zone

Approximately 14 acres at Maples Farm is designated for incubator farmers who lease land to grow their nascent agricultural ventures. These farmers may lease from ¼ acre to 1 acre and can stay in the program for up to four years. They make all the decisions related to their operations including nutrient management, irrigation, weed control, crops grown, harvesting, and marketing. They are required to utilize cover cropping if fields are bare. To date, incubator farmers have grown mixed vegetables, cut flowers, heirloom grains, and mushrooms.

One acre at Maples Farm is dedicated to the new farmer training program, where trainees learn how to create beds, propagate plants, grow crops, harvest, and develop business plans. The remaining farmland (approximately 5 acres) has been converted to an olive orchard and research site for a CDFA Healthy Soils demonstration grant. Additional orchard crops or other perennial crops are also being considered in the Northwest and Southeast fields as well.

Maples Farm includes extensive "farm edges," many of which have already been planted with hedgerows and pollinator plantings. Some of these hedgerows include a native grass understory (i.e. conservation cover) and some are mulched with straw and/or wood chips. Finally, Maples Farm features a 0.06 acre native grass demonstration garden showcasing 12 species (11 grasses and 1 sedge) commonly used in restoration projects.

Buildings on site include CLBL's 5400 square foot headquarters building, a large historic barn, a wash-and-pack facility for the incubator program, a welding barn, and two additional small outbuildings.

Farm Goals and Objectives

1. Transform Maples Farm into an innovation hub to demonstrate carbon-beneficial practices to other growers, agricultural leaders, students, and the general public
2. Implement hedgerows and/or windbreaks on all field edges with specific attention to pollinator species
3. Increase soil organic matter compared to baseline in all farm fields and habitat sites
4. Successfully complete a CDFA Healthy Soils Demonstration project using biochar and compost in our planned olive orchard and share findings with other growers through field days and social media.
5. Restore 5 acres of riparian habitat on Cache Creek and recruit neighboring landowners to restore additional sections of the creek.
6. Maintain cover cropping and compost applications to the extent practicable on all crop and orchard fields
7. Explore alley cropping or other perennial crops in the Northwest, Southwest, and Southeast fields.
8. Continue to partner with CDFA's Healthy Soils Program, NRCS's EQIP program and agricultural ventures to develop new demonstration projects as opportunities arise.
9. Minimize tillage
10. Incorporate research findings and highlight carbon beneficial practices in CLBL's youth programs and Farm Academy training programs for beginning farmers and apprentices.

11. Share information and data about deep-rooted native perennial grasses through our Native Grass Demonstration Garden and hedgerow projects that incorporate conservation cover.

12. Partner with Yocha Dehe Wintun Nation and other indigenous peoples to showcase native land management practices through workshops and site tours.

Current Land Use and Resource Inventory

Climate and Topography

Located at the southern end of the Sacramento Valley, Maples Farm enjoys a Mediterranean climate with hot dry summers and cool wet winters. Woodland gets an average of 20 inches of rain a year and no snow, with approximately 67 days with precipitation each year. Temperatures range from summer highs of 94°F and winter lows of 39°F and are rarely below 30°F or above 102°F. Like the surrounding area, Maples Farm experiences occasional strong winds, especially between January and September with average wind speeds of more than 6.5 mph. July is typically the windiest month with an average hourly wind speed of 7.1 mph. Intense hot dry north winds in excess of 30 mph are not uncommon in summer months.

The elevation at Maples Farm is 59 feet above sea level and the topography is flat.

Soils

According to the NRCS Web Soil Survey, the majority of soil at Maples Farm is Reiff very fine sandy loam (Ra) with the riparian soils composed of riverwash (Rh) (See Figure 3). The full Web Soil Survey report is given in Appendix 4.

The primary goal of this Carbon Farm Plan is to increase soil organic matter throughout Maples Farm. Consequently, measuring and monitoring soil carbon according to a consistent protocol over time is very important. CLBL developed a soil monitoring protocol based on available sources. The full protocol is given in Appendix 3.

CLBL took baseline samples of soil organic carbon (SOC) in all of its fields and most of the current habitat projects in November 2021 We also took baseline samples specifically for the biochar and compost demonstration project in December 2022. We measured SOC using the dry combustion method, which is considered more accurate than the loss on ignition method.

Soil samples were analyzed by Ward Labs. The results of these soil tests are shown in Tables 2a and 2b. Soil organic matter (SOM) is calculated as 1.72 times the SOC measurement (Sullivan et. al 2019).

Figure 3. Soil Map (USDA Web Soil Survey)

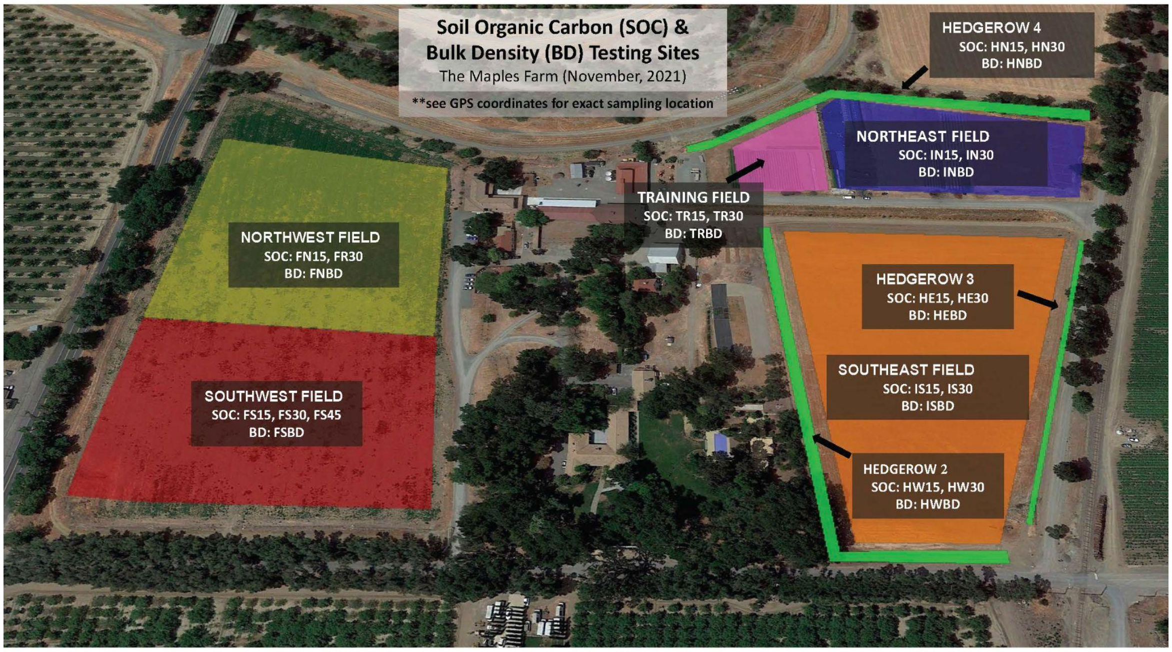

Figure 4. Soil Sampling Locations

Table 2a. Soil organic carbon (SOC), soil organic matter (SOM) and bulk density in Maples Farm fields (sampled November 2021)

Field	acres	bulk density g/L	depth cm	SOC %	SOM* %	Notes
South west	5	338.98	15	.996	1.71	Olive orchard field.
			30	.971	1.67	
North west	6	284.23	15	.977	1.68	Future incubator plots
			30	.864	1.49	
North east a	2	222.6	15	1.77	3.04	Current Incubator plots, sampled separately from the training field (see below)
			30	1.23	2.12	

North east b	1	247.18	15	2.406	4.14	Current training field, sampled separately from the incubator plots (see above)
			30	1.853	3.19	
South east	6		15	1.243	2.14	Current incubator plots and 4 acre grain field
			30	.889	1.53	

*SOM is calculated as 1.72 times the SOC measurement (Sullivan et. al 2019).

Table 2b. Soil organic carbon (SOC), soil organic matter (SOM) and bulk density at Maples Farm habitat projects (November 2021)

Field	linear feet/ acres	bulk density g/L	depth cm	SOC %	SOM* %	Notes
HR1 (2 row)	1400					"Bioswale". Planted fall/winter 2020 but no soil samples taken
HR2 (1 row)	910	291.24	15	1.277	2.2	Planted winter 2020/21. Single row hedgerow with conservation cover
			30	.531	0.96	
HR3 (1 row)	680	295.33	15	1.255	2.16	Planted January 2022. Single row hedgerow with wood mulch.
			30	0.936	1.61	
HR4 (2-3 row)	1860	288.28	15	1.385	2.38	Planted Feb-March 2022. 2-3 row hedgerow mulched with rice straw, native grass straw and woodchips.
			30	1.037	1.78	
Native grass garden	0.06 acre		15	2.406	4.14	Planted Feb 2022. Data are from the training field samples, which are very close to the Garden. Management of both areas was the same so we expect the results would be similar
			30	1.853	3.19	

*SOM is calculated as 1.72 times the SOC measurement (Sullivan et al, 2019).
**Linear feet is calculated as the sum of rows within the hedgerow.

Our target soil organic matter across the farm is 5%, which is considered at the higher end of SOM in productive agricultural soils. One percent is considered very low while 2-4% is considered average (Biernbaum, 2012). All of the practices in this Carbon Farm Plan will support this goal.

The results of these baseline soil samples show that the northeast field, which contains our training program plot and incubator farmers has the highest SOM on the farm at 4% and 3% respectively. This is not surprising considering these fields have been treated with compost application at a rate of 20 tons per acre each year on average since 2020. The south east field is lower at 2% SOM. The lowest soil organic matter measurements were taken in the northwest field and the southwest field at 1.7% SOM. Prior to planting the olive orchard, this field was farmed for alfalfa.

According to this Carbon Farm Plan, all of the fields will continue to receive compost treatments and cover cropping. We also expect that SOM in the southwest field will increase as the olive orchard matures. Consistent monitoring of soil organic matter over time will demonstrate the effectiveness of these measures (see Appendix 3 for CLBL's soil sampling protocol).

Wildlife

Wildlife seen at Maples Farm is in large part influenced by the wildlife corridor of Cache Creek, which offers significant habitat value. CLBL has been documenting wildlife's use of the farm and surrounding areas using wildlife cameras, bird surveys, and pollinator monitoring. Wildlife regularly documented by our wildlife cameras includes bobcats, coyotes, mule deer, jack rabbits, brush rabbits, and raccoons. Additional results of this monitoring are listed in Appendix 2.

Wildlife cameras at Maples Farm document use of hedgerows by bobcats

and coyotes

Riparian habitat and other native flora

Cache Creek borders the north side of Maples Farm for about ¼ mile, providing approximately 11 acres of native riparian habitat. The creek is deeply incised and banks are steep, but a significant stand of native woody vegetation remains on site. The overstory is dominated by Fremont cottonwood and valley oak. Understory shrubs include blue elderberry, California wild rose, coffeeberry, and wild grape. The herbaceous understory is dominated by non-native annual grasses and forbs including slender wild oat, Italian ryegrass, foxtail barley, soft chess, wild radish, field mustard, and milk thistle. Native herbaceous plants in the understory include mugwort, common fiddleneck and wild cucumber. The site is also invaded by giant reed and tamarisk. Most of the giant reed was treated in 2020-2022 through the Yolo RCD's Putah-Cache Creek Arundo removal project but will need follow-up treatment of resprouts. The tamarisk has not been treated to date, but will be as part of riparian restoration. Some of the native species found at the creek are also found in scattered small stands throughout the farm, especially elderberry, valley oak, coast live oak and black walnut.

Resource concerns

The primary resource concern with respect to this Carbon Farm Plan is the relatively low levels of soil organic matter in our farm fields, as measured by tests for soil organic carbon. Our southwest and northwest fields had the lowest levels of SOM while the northeast field had the highest levels. This disparity is likely due to the fact that compost has been added to the northeast field at a rate of approximately 20 tons/acre since 2020 through our incubator and training programs. As we implement more composting and cover cropping in all of the fields, as well as installing an olive orchard, we expect overall SOM numbers to increase.

Another resource concern is soil erosion due to wind. Maples Farm experiences occasional strong winds, especially between January and September with average wind speeds of more than 6.5 mph.

During high rain events, the southwest corner of our southwest field drains poorly and experiences significant ponding. We are considering installing a seasonal wildlife pond to capture some of that run-off. The installation of the olive orchard may also improve drainage.

The riparian area on Cache Creek supports a narrow band of native riparian trees along the creek itself. Giant reed (*Arundo donax*) has been treated by the Yolo RCD's Putah-Cache Creek Arundo Eradication project, however a significant amount of invasive tamarisk remains. The upper bank is heavily invaded by non-native annual grasses and forbs and there is little understory vegetation associated with the riparian forest. This results in significant erosion during high flow events.

Finally, we are aiming to increase on-farm biodiversity through a range of conservation practices. Because of proximity to Cache Creek, we have documented a fairly wide range of animal species on the farm (see appendix 2). We have added nest boxes for songbirds and installed two barn owl boxes to help control rodents. We upload data about the nest box success to the Cornell Lab of Ornithology's Nest Watch website. To date, however, we have little data on the diversity of pollinators at our farm. Consequently, we have deployed the Xerces Society's Streamlined Monitoring Protocol for Assessing Pollinator Habitat in several of our hedgerows to track numbers of native bees compared to honey bees. We are also monitoring one of our hedgerows (HR1) for monarch butterfly habitat.

Existing and historical carbon beneficial practices

Installation of carbon-beneficial practices at Maples Farm began even before the organization relocated to its new headquarters in May 2020. To mitigate flood risk due to the new construction, CLBL was required to install a large flood water retention basin. Funding from the USFWS and the Xerces Society allowed CLBL to install pollinator hedgerows and conservation cover on both sides of the swale. This early project became known as the "bioswale" (photo, right). In 2021 and 2022, CLBL installed additional hedgerows on three sides of the Southeast field as well as the north side of the Northeast field. As soon as CLBL took over management of the farm fields, it planted cover crops in all of the fields except the Southwest and Northwest fields which were leased to an alfalfa grower until spring of 2021. Cover crops were added to the Northwest field in fall 2022. Finally, CLBL installed an olive orchard in the SW field and will be tracking changes in soil carbon and other measures of soil health.

CLBL began implementing cover cropping in 2019

CLBL is currently conducting research in the olive orchard on biochar and compost as part of the CDFA Healthy Soils demonstration project. Existing practices are shown in Table 3.

Because CLBL leases part of its fields to participants in the Farm Business Incubator Program, it does not have total control over agricultural practices. Rather, the individual incubator farmers are encouraged to practice cultivation methods that maximize soil health. To date, all of the incubator farmers have added compost to their fields and they are required to plant a cover crop if the field is expected to be fallow during the winter.

Compost is applied in CLBL's training field (far right).

Native grass garden (right).

Table 3. Current carbon-beneficial practices at Maples Farm

Practices already implemented (NRCS CPS #)	**Field and acres or linear ft**	Description	Co-Benefits
Compost Application (336) - Training field 1 acre - Incubator fields 2 acres	NE field 3 acres	Actual application rates vary by incubator farmer.	Improved water holding capacity, soil quality and fertility, net primary productivity and forage production.
- Cover cropping (340) - Training field (1 acre) - Incubator Phase 1 (2 acres) - Incubator Phase 2 (6 acres) - Incubator Phase 3 (6 acres)	NW, NE and SE fields 15 acres	Cover cropping practices vary by incubator farmer. This estimate assumes all available fields are cover cropped every year	Decrease soil erosion from wind and water, better rainwater infiltration, and wildlife habitat
Hedgerows (422) HR1 2 row 1400 ft HR2 single row 925 ft HR3 single row 680 ft HR4 2-3 row 1860 ft -	NE, SE fields 4865 ft	Plant selection follows NRCS guidelines so that bloom time is staggered across the year. The bioswale (HR1) and HR2 utilized Xerces Society pollinator plant kits.	Wildlife habitat, pollinator habitat, carbon sequestration, improve microclimate stabilize soils, improve water quality, and reduce water loss.

Conservation cover (herbaceous understory) (327) HR1, HR2, portions of HR4, HR 5, native grass garden	NE, SE fields 2.2 acres	Native grasses were seeded in conjunction with two hedgerows and in preparation for a future hedgerow. Width of the seedings ranges from 10 to 20 feet	Stabilize soils and stream banks and channels, water capture, soil moisture and organic matter, wildlife habitat structural and species diversity
Mulching (484) HR3 and HR4	SE and NE 0.65 acres	Applied wood chips to mulch east hedgerow (HR3) and HR4. Mulch is 8 inches deep.	Improved efficiency of water. Improved plant productivity and health. Decreased soil erosion. Increased soil organic matter.
Olive orchard	SW field 5 acres	CLBL planted 777 olive trees in June 2023. The orchard is the site of our CDFA Healthy Soil Demonstration project looking at the effects of biochar and compost	Improved wildlife habitat, carbon sequestration, improved microclimate, stabilize soils, improve water quality, and reduce water loss.

Planned and Prospective Carbon-Beneficial Practices

Opportunities for carbon sequestration at Maples Farm have been identified and described below by NRCS Conservation Practice for agroforestry systems, the riparian system, and cropland systems. We used the CDFA Healthy Soils version of Comet Planner (www.comet-planner-cdfahsp.com), accessed in 2023, to calculate the sequestration benefits of these practices. The GHG benefits are shown in Tables 7a - 7c and discussed below for the individual practices.

Agroforestry systems

Agroforestry is the practice of integrating trees and woody shrubs into crop and animal production systems. Agroforestry practices can: increase on-farm biological and structural diversity; help control pests by providing habitat for beneficial insects and birds; protect crops and livestock by creating microclimates to reduce cold and heat stress on animals by providing shade and shelter; slow runoff to reduce flooding, soil erosion, and water pollution while increasing water infiltration; reduce crop evapotranspiration by reducing wind speed; and provide multiple products, including forage, fruit, nuts, timber, fence posts and wildlife habitat (Table 6).

Agroforestry practices currently in place or under consideration at Maples Farm include: hedgerows, a windbreak, tree and shrub establishment (olive orchard), and alley cropping.

Hedgerows (CPS 422)

Hedgerows are single or multiple rows of woody and semi-woody vegetation planted in linear configurations, usually along field edges. These plantings can increase carbon storage in biomass and soils, reduce soil erosion and loss of soil moisture from wind, protect infrastructure, pastures and crops from wind and sun-related damage, improve the microclimate for buildings and plant growth, provide shelter for livestock, enhance wildlife habitat, provide noise and visual screens, improve irrigation efficiency, and increase biodiversity. Hedgerows can provide habitat for a wide variety of native wildlife, including nectar and host plants for native pollinators and other beneficial insects. To date, CLBL has installed 4 hedgerows of varying length and width and plans to install 4 more (see Table 4 and Figure 5).

The species mix chosen for the hedgerow is based on NRCS guidelines to ensure there are some trees, shrubs, or forbs blooming throughout the year. Each hedgerow varies slightly in its planting palette due to site conditions. A master list of hedgerow species is shown in


CLBL hedgerows support several species of milkweed which serve as host plants for monarch butterfly caterpillars.

Appendix 1. All of our hedgerow plantings have been augmented by "pollinator kits" from the Xerces Society to provide a suite of pollinator friendly species, especially milkweed. These milkweeds began attracting monarch butterflies the same year they were planted (photo, above right). Four new hedgerows will be installed in fall-winter 2023, also augmented by Xerces kits.

Table 4 and Figure 5 show all implemented and planned hedgerows and one windbreak (HR7). Once all the hedgerows have been planted at Maples Farm, the total CO2e sequestered is estimated to be 16 MT annually and 320 MT CO2e over twenty years (see Tables 7a-7c).

Windbreak (CPS 380)

Like the surrounding area, Maples Farm experiences occasional strong winds, especially between January and September with average wind speeds of more than 6.5 mph. July is typically the windiest month with an average wind speed of 7.1 mph. Intense, hot dry north winds in excess of 30 mph are not uncommon in summer months.

Windbreaks differ from hedgerow plantings primarily in their objective, but also in structure and design. The objectives of a windbreak are to reduce soil erosion from wind, enhance plant health and productivity by protecting plants from wind-related damage, improve moisture management by reducing transpiration and evaporation losses and improving irrigation efficiency. Like hedgerows, windbreaks can increase carbon storage in biomass and soils.

While hedgerows planted for beneficial insects and wildlife habitat can also serve as windbreaks, when planning a windbreak more consideration is given to the location, size, spacing and phenology of the species to maximize their ability to intercept wind. CLBL has added a fourth row to its 2-3 row hedgerow along the north side of the NE field (HR4). These trees (mostly valley oak and coast live oak) are planted in line with existing black walnut trees to widen the hedgerow and when mature, to provide a windbreak. In addition, CLBL is planning a windbreak/hedgerow on the north side of its NW field (HR7). This will be a two row windbreak using native trees and shrubs with an emphasis on evergreen species to maximize wind protection year round.

Because the greenhouse gas benefits of a windbreak as quantified via COMET-Planner are similar to a hedgerow, we have included the windbreak in our hedgerow calculations. The single windbreak at HR7 will sequester 2 MT CO2e in one year and 80 MT over twenty years.

Figure 5. Current (green) and planned (pink) hedgerows at Maples Farm 2023

Table 4. Current and planned hedgerows and windbreak at Maples Farm

#	Rows	Location and description	Date planted	Length *
HR1	2	On the floodwater retention basin between the NE and SE field - the"Bioswale." Low stature shrubs and Xerces Society pollinator kits. Seeded with native grasses and forbs.	Dec 2019	1400 ft.
HR2	1	Along the west and south sides of the SE field. Medium to tall stature trees and shrubs, seeded with native grass.	Jan 2021	925 ft.
HR3	1	On the east side of the SE field. Low statured shrubs and milkweed with some volunteer elderberries. Mulched with wood chips.	Jan 2022	680 ft.
HR4	2-3	On the north side of the NE field. Ranges from a single row section to 2-3 rows with a fourth row of oak trees added between existing black walnuts.	Jan-Feb 2022	1860 ft.
HR5	2	On the east side of the NE field. Planned as a two row planting. Seeded with native grasses. Xerces Society pollinator kit.	Dec 2023 planned	440 ft.
HR6	1	On the east side of the NW and SW fields. Low-statured plants with some sycamore trees along the split rail fence. Some plants on the north end were planted in 2020. Xerces Society pollinator kit.	2020 Dec 2023 planned	780 ft.
HR7/ WB	1	On the north side of the NW field. Planned as a windbreak. Will be seeded with native grasses. Xerces Society pollinator kit.	Jan 2024 planned	1072

HR8	2	On west side of SW and NW fields along fence line on Hwy 113. Will be mulched with wood chips. Xerces Society pollinator kit.	Jan 2024 planned	1026 ft.
Total				8183 ft.
	MT CO2e sequestered annually, beginning in 2023**			16
	MT CO2e sequestered by year 20			320

*for multi-row hedgerows, the length is the sum of the total row lengths

** GHG estimates derived from CDFA version of COMET Planner, accessed April, 2023. See also Chiartas, et. al 2022

Tree and shrub establishment - olive orchard (CPS 612)

CLBL has converted a 5 acre field, formerly in alfalfa, into an olive orchard. While tree and shrub establishment is a conservation practice typically associated with establishing native forest, a farm woodlot, or riparian cover, many of the benefits apply to an orchard planting as well. The most significant benefit with respect to a carbon farm plan is the amount of carbon that will be captured and stored by the olive trees. We also expect the orchard to improve water infiltration and water holding capacity in the field.

The olive orchard is part of the CDFA Healthy Soils Demonstration project that is measuring the impacts of using compost and biochar, alone and in combination, on soil health and productivity. The orchard spacing is 20 feet between rows and 14 feet between trees which is considered a medium density planting. The planting density is 155 trees per acre. This medium density will allow CLBL to consider additional conservation practices. If feasible, we will pursue alley cropping (see below) and/or cover cropping between the rows.

Studies of olive orchards have shown that olive trees can sequester a high level of greenhouse gasses (see for example Lopez-Bellido et. al, 2016). According to COMET-Planner, once mature this five acre orchard will sequester an average of 97 MT of CO2e per year and 1940 MT CO2e over twenty years (see Tables 7a and 7c).

Alley cropping (CPS 311)

Alley cropping refers to the planting of trees and shrubs in rows or corridors with alleys of agronomic crops or forage between. CLBL is considering alley cropping in its NW, SW, and SE fields. In the olive orchard (SW field), we are working with a grower of heritage grains to explore the feasibility of growing perennial grains in between the rows of olive trees. Alley cropping is also being considered in the NW field where stone fruit trees or semi-woody herbs such as lavender and rosemary might be planted in rows running from east to west. This alley cropping will yield marketable crops (e.g. chestnuts, stone fruits, herbs) while also providing training opportunities for CLBL's new farmer training course. Alley cropping would also provide an aesthetically pleasing way to delineate fields of individual incubator farmers. The main drawbacks of alley cropping for these purposes is increased time and costs for maintaining the alleys and reduced flexibility in terms of overall field management.

Alley cropping in our 6 acre NW field and 6 acre SE could sequester 10 MT of CO2e annually and 200 MT CO2e over 20 years.

Riparian Systems

Riparian vegetation is not only critical for wildlife and healthy waterways, it is incredibly adept at sequestering CO_2 and other greenhouse gasses due to the presence of long-lived woody vegetation with deep roots. The Center for Biological Diversity estimates that riparian habitats in California could store 325.7 metric tons of carbon per acre in their biomass and soils while accumulating about 0.81 metric tons of carbon per acre per year.

Cache Creek flows from west to east along the northern boundary of Maples Farm. The creek here is contained by levees managed by the Central Valley Flood Control District. The riparian area sequesters significant amounts of carbon through the existing established riparian vegetation. However, the riparian corridor is also invaded by tamarisk, *Arundo* and non-native annual grasses. Carbon beneficial practices CLBL is considering include prescribed burning or prescribed grazing with goats and/or sheep to remove non-native annual grasses, planting riparian shrubs on the upper terrace of the creek, plug planting on the upper banks to reduce erosion, and replacing the non-native annual grasses with perennial native species.

Riparian forest buffer (CPS 391)

A riparian forest buffer consists of trees and shrubs located adjacent to and up-gradient from a watercourse or water body. Along with a riparian herbaceous buffer, this practice reduces transport of sediment to surface water, and reduces transport of pathogens, chemicals and nutrients to surface and groundwater. Riparian forest buffers improve the quantity and quality of terrestrial and aquatic habitat for wildlife, invertebrate species, fish, and other organisms and maintain or increase total carbon stored in soils and/or perennial biomass to reduce atmospheric concentrations of greenhouse gasses. By shading the watercourse, this practice also lowers stream water temperatures to improve habitat for aquatic organisms.

The riparian vegetation along Cache Creek near Maples Farm supports a suite of native riparian tree and shrub species including Fremont cottonwood, valley oak, blue elderberry, wildrose, wild grape, and willow. However, the site is also invaded by giant reed (*Arundo donax*) and tamarisk. Most of the giant reed was treated in 2020-2022 through the Yolo RCD's Putah-Cache Creek Arundo removal project but will need follow-up treatment of resprouts.

CLBL will treat the remaining resprouts and the tamarisk as part of a larger riparian restoration project. The project will also plant additional trees and shrubs to widen the riparian corridor.

Riparian herbaceous buffer (CPS 390)

A riparian herbaceous buffer consists of grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, that are established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats. In addition to reducing erosion and improving streambank stability, this practice provides wildlife habitat (including habitat for pollinators), restores native riparian vegetation, improves water quality, and increases net carbon storage in the biomass and soil.

Near Maples Farm, the upper terrace of Cache Creek has a small amount of native herbaceous vegetation (including wild cucumber and mugwort) but it is largely invaded by non-native annual grasses and forbs, especially ripgut brome, wild oats, Italian ryegrass, and foxtail barley. These invasive grasses are shallow-rooted and provide little benefit in reducing erosion, providing wildlife habitat, or storing carbon in the soil. Therefore, as part of a larger riparian restoration project, CLBL will replace the non-native vegetation with a mix of deep-rooted native grasses, sedges, and forbs that will provide a diversity of plant species for pollinator habitat as well as deep-rooted species to reduce erosion and store carbon.

Critical area planting (CPS 342)

This practice is used to establish permanent vegetation on sites that have (or are expected to have) high erosion rates or that have physical, chemical, or biological conditions that prevent establishment of vegetation with normal practices. This practice applies to highly disturbed areas such as road construction areas, conservation practice construction sites, areas needing stabilization before or after natural disasters, eroded banks of natural channels, banks of newly constructed channels, and other areas degraded by human activities or natural events. Benefits include stabilized soils, improved water capture, water quality, habitat structure, and species diversity, and an increase in soil and biomass carbon capture on protected sites.

Creeping wildrye is a rhizomatous native grass that can armor creek banks against erosion.

As part of a riparian restoration, we plan to plant large patches of creeping wildrye (*Elymus triticoides*) and white root sedge (*Carex barbarae*) on the banks of Cache Creek. Both of these species are rhizomatous and spread easily and thoroughly on creek banks, thus helping to armor the banks against erosion. Because the plantings themselves might be susceptible to high flows, we plan to do the plantings early in the fall with supplemental irrigation so that they can get established quickly.

Together, the "stacked" practices of riparian forest buffer, riparian herbaceous cover and critical area planting on this reach of Cache Creek could sequester 15 MT of CO2e annually and 300 MT over 20 years (Table 7b).

Cropland Systems

Compost Application (Soil Carbon Amendment CPS 336)

Compost application entails the use of amendments derived from plant or animal residues to improve the physical, chemical, and biological properties of the soil. Such applications enable increasing soil carbon stocks above what could otherwise be achieved through management of vegetation and soils on a given site. Over time, the carbon content of soils under consistent management will tend to reach equilibrium, where annual carbon inputs and losses tend to balance out. The addition of offsite sources of carbon, such as compost, can elevate soil carbon levels and enable increased carbon capture above that of equilibrium conditions (Ryals and Silver 2013).

Compost application can maintain, increase, or improve soil organic matter quantity and quality, maintain or improve soil aggregate stability and improve habitat for soil organisms, improve plant productivity and health, improve moisture management and enhance the efficient use of irrigation water, and improve air quality by reducing emissions of particulate matter (PM) and PM precursors, GHGs, ozone precursors and airborne reactive nitrogen (NRCS).

Compost is an important part of CLBL's ongoing cropland management. Compost is applied annually to our one acre training field by our new farmer trainees at a rate of approximately 20 tons/acre. In our Farm Business Incubator Program, compost is applied by the individual incubator farmers according to their individual crops and farm needs. Thus, there is no one universal compost application rate. For the purposes of this carbon farm plan, we used a low and high range compost application for all incubator fields.

Currently we are in Phase 2 of our Farm Business Incubator with approximately 9 acres utilized by incubator farmers in the NE and SE fields. Once Phase 3 is in place, incubator farms will take up 14 acres at Maples Farm with the addition of the NW field. In addition, compost has been and will be applied to our olive orchard according to the research design of our Healthy Soils Program grant. In that, half of the 16 research plots (about 2.5 acres total) receive compost every year at a rate of 10 dry tons per acre per year. Once the 3 year research project is completed, we will continue to add compost to the olive orchard, so we included that acreage in our calculations for carbon sequestration.

Table 5. Carbon sequestration (MT CO2e) potential at 5% SOM at Maples Farm, cropland soils = Reiff very fine sandy loam

Fields	cropland acres	Baseline SOM%*	Gap to 5%	Additional MT/C acre at 5% OM	total additional MT CO2e at 5% OM	MT compost/ acre needed for 5% SOM	Total MT compost needed for 5% SOM

NW, SW, NE, SE	20	2.54	2.46	11.18	41.04	44.72	894.4

Assumptions:
1% SOM = 0.5% SOC = 10 short tons = 9.09 metric tons (MT) SOM per acre (plow layer only)
Compost = 50% OM or 25% C
1" compost = 70 short tons/acre x .25 = 17.5 x 3.67/1.1 = 58.39 MT CO2e/acre
Approximately ½ of compost C is assumed lost annually under tillage
*Baseline is an average of soil tests completed in 2022

Application of 44.72 short tons of compost (at 25% C) to each acre of cropland would represent approximately 41 metric tons (MT) of CO2e per acre, or over 820 MT CO2e across all 20 acres, and bring all 20 acres up to 5% SOM, assuming no carbon losses from these soils (Table 6). The rate at which this could be achieved is dependent upon rates of compost addition and implementation of other carbon-beneficial practices on cropland at Maples Farm. How well this increase in soil SOM could be retained would depend on implemented farming practices, including future additions of compost.

Maintaining 5% SOM on cropland subject to cultivation can be assumed to require periodic reapplication of compost, reduced tillage, cover cropping and implementation of other carbon beneficial conservation practices..

Finally, CLBL does have an on-farm windrow composting operation that composts on-site farm waste, such as field residues and trimmings from individual farmers. Since we don't have an on-site animal operation, there are no manures added to the compost. To date, the operation is too small to produce significant amounts of compost so it is likely the final product will be used primarily as mulch for our hedgerow plantings.

Cover Crops (CPS 340)

A cover crop is a planting that is used primarily to slow erosion, improve soil health, enhance water availability, smother weeds, help control pests and diseases, and increase biodiversity. Cover crops that include legumes (clovers, vetches and beans) help "fix" nitrogen through symbiosis with nitrogen-fixing soil bacteria. Cover crops build soil health by increasing soil organic carbon and nitrogen, while reducing soil compaction. Planting a cover crop with a diversity of species promotes diversity in the soil biology which creates a healthier, more resilient medium for plant growth year-round.

CLBL utilizes cover cropping in all of its fields with the exception of the SW field with the 5 acre olive orchard (cover cropping between the rows of olive trees will begin in fall 2023). The amount of CO_2e sequestered when all available fields are cover cropped will be 4 MT annually and 80 MT over 20 years.

Table 6. Carbon Beneficial Practices by field as mapped (see Figure 6)

Location	Field/acres	Practices
1.Incubator Phase 1	NE/2 acre	Compost, cover crop
2. Incubator Phase 2	SE/6 acres	Compost, cover crop, alley cropping
3. Incubator Phase 3	NW/6 acres	Compost cover crop, alley cropping
4. Training field	NE/1 acre	Compost, cover crop
5. Olive orchard	SW/5 acres	Tree and shrub establishment, compost, biochar, cover crop, alley cropping
6. Native grass garden	NE/0.06 acre	Conservation cover
7. Riparian area	5 acres	Riparian forest buffer, riparian herbaceous cover, critical area planting
8. Field edges	all fields	Hedgerows and windbreak (HR1-HR8)

Figure 6. Maples Farm Carbon Farm Practice Map

Additional Carbon Beneficial Practices for Consideration

Biochar

Biochar is a granular carbon substance produced by pyrolysis or thermal decomposition of organic matter in an oxygen starved chamber. It is commercially produced from a variety of feedstocks from forest thinning to agricultural residues. It can also be produced on a small scale using a technique called “conservation burning.” The charcoal-like byproduct resists further decomposition and may have beneficial properties in soil. Biochar is not pure carbon, but a mix of carbon, hydrogen, oxygen, nitrogen, sulfur and ash in varying proportions. The central quality of biochar that makes it attractive as a soil amendment is its highly porous structure, potentially responsible for improved water retention and increased soil surface area.

Demonstrated benefits of biochar include increased yields, higher water holding capacity in soils, pathogen and disease suppression, stimulation of soil microbial activity, and increasing soil carbon sequestration (Gelardi and Parikh, 2021). In 2018, the Intergovernmental Panel on Climate Change (IPCC) characterized biochar as “a leading natural climate solution.” In a review published in the Proceedings of the National Academy of Sciences (PNAS), Griscom et al. (2017) assert: “The addition of biochar to soil offers the largest maximum [climate] mitigation potential among agricultural pathways." However, this is only true if a full lifecycle analysis reveals that the specific biochar being used has a net negative carbon impact.

While biochar is exploding in popularity, its agronomic and environmental benefits are not consistently realized across different climates, soil types, and cropping systems. It is important to remember that the choice of feedstock and the distance the feedstock has to travel to get to a biochar facility will factor into whether biochar has a net negative effect on carbon emissions. For example, some agricultural wastes might be better suited to on-site composting or mulching. A full life cycle assessment should be performed in order to determine the overall impact of biochar.

Comparatively, the benefits of compost application are more thoroughly demonstrated, including the ability of compost to decrease GHG emissions (Favoino and Hogg 2018). There is potential that biochar and compost would interact synergistically, amplifying the benefits of these two soil amendments. For example, Sanchez-Garcia (2016) found that combined biochar and compost application in olives increased biologically based nitrogen processing by the soil food web, without a corresponding increase in emissions.

While the effects of biochar on GHG emissions will vary with environmental conditions and soil types, research suggests that substantial reductions are possible. In a perennial crop, Miscanthus, biochar applied at 49 tons per hectare suppressed CO_2 emissions by 33 percent compared to unamended soil, with these reductions lasting up to two years (Case et al. 2014). A recent meta-analysis of 129 published papers found that biochar decreased soil N2O emissions by an average of 38 percent, but tended to slightly increase CH4 and emissions by an average of 15 percent and 16 percent respectively (Zhang et al. 2020). The authors suggest that outcomes are dependent on local site factors such as soil pH, the biochar C:N ratio, and the biochar application rate (Zhang et al. 2020).

In 2021, CLBL received a Healthy Soils Program grant from the California Department of Food and Agriculture to study the effects of biochar and compost, alone and in combination, in an olive orchard. The three year demonstration project is investigating the extent to which biochar and compost treatments can increase soil carbon sequestration, decrease GHG emissions, improve biological indicators of soil health, and ultimately improve yields.

The research endeavors to demonstrate that biochar application combined with compost application is a potential climate solution well-suited to large-scale implementation in olive orchards in California. Biochar has been shown to slow the respiration loss of organic carbon and stimulate increased photosynthetic carbon capture. Soil-biochar amendments commonly increase agricultural production on marginal and degraded lands, but may have little or no yield impact on well managed, high quality soils. Laboratory experiments have shown that biochar reduces bulk density and improves aeration in poorly drained soils while also increasing nutrient and water holding capacity in sandy, low-organic matter and otherwise degraded soils. Biochar can be added to compost for greater porosity and aeration for gas exchange, reduce emissions, and to house beneficial microbial communities.

CLBL will share the results of the project with producers through a series of on-farm outreach events and publication of research findings. Once completed, the research results will inform whether CLBL will continue to use biochar as a carbon beneficial practice.

Agrivoltaics

Agrivoltaics is the practice of using the same area of land to obtain both solar energy and agricultural products. In agrivoltaic systems, solar panels coexist with crops on the same surface with a goal of maintaining high efficiency in both systems. Initially, efforts focused on simply growing forage for grazing animals or pollinator habitat among solar panels but more recently the focus has shifted to producing cash crops.

According to a recent study by Oregon State University (Proctor et. al 2021), co-developing land for both solar photovoltaic power and agriculture could provide 20% of total electricity generation in the United States, with an investment of less than 1% of the annual U.S. budget.

The study found that wide-scale installation of agrivoltaic systems could lead to an annual reduction of 330,000 tons of carbon dioxide emissions in the U.S – the equivalent of 75,000 cars off the road per year – and the creation of more than 100,000 jobs in rural communities, while minimally impacting crop yield.

Research is ongoing to determine which crop types are best suited for AV conditions and what the optimal panel infrastructure and configuration may be. CLBL is considering a small scale demonstration project at Maples Farm to support further research into this promising technology.

Orchard-Livestock Integration (Prescribed grazing CPS 528)

Small livestock like sheep, goats, and chickens can be integrated into orchard systems to manage understory vegetation, minimize pest and disease outbreaks, and maintain uniform water distribution. Other benefits include greater economic returns, more diversified farming operations, reduction in fuel and chemical inputs and enhanced erosion control, water quality, water use efficiency, soil fertility, and nutrient cycling (Wilson et. al, 2006).

Currently, CLBL does not have the capacity to keep grazing animals on site, but is interested in hiring a contract grazer to provide weed control in the olive orchard. This will especially be true once cover crops are integrated between the rows of olive trees.

The carbon impact of such targeted grazing on a small parcel (5 acres) may be small but the reduction in inputs of fuel and herbicide are worth considering. According to COMET-Planner, prescribed grazing on 5 acres could provide a carbon benefit of 0.10 MT of CO2e per year

Table 7a. Summary table - Implemented practices

Practices already implemented (NRCS CPS#)	**Field/ length or area**	**Description**	**CO2e sequestered annually**	**CO2e sequestered 20 years**	**Co-benefits**	**References**
Olive grove installation - Tree and shrub establishment (612)	SW field 5 acres	777 trees total	97 MT	1940 MT		COMET-Planner CDFA version, accessed April 2023 Tree and Shrub establishment
Compost Application (336) - Olive orchard research plots	SW field 2.5 acres	Compost applied to 8/16 plots at a rate of 10 (dry) tons per acre/year	12 MT	240 MT	Improved water holding capacity, soil quality and fertility and crop production	COMET-Planner CDFA version, accessed April 2023
Biochar - Olive orchard research plots	SW field 2.5 acres	Biochar applied to 8/16 research plots at a rate of 10 (dry) tons per acre	71 MT *	71 MT**	Increased yields, higher water holding capacity in soils, pathogen and disease suppression, stimulation of soil microbial activity	Jeffrey Creque, personal communication 05/25/2023
Compost application 336) - Training field 1 acre - Incubator fields 2 acres (NE)	NE field 3 acres	Compost application in the training field is 20 tons/acre. Actual application rates vary by incubator farmer but we estimate it is close to 20 tons/acre/year overall.	13 MT	260 MT	Improved water holding capacity, soil quality and fertility and crop production	COMET-Planner CDFA version, accessed April 2023

Cover cropping (340) - Training field 1 acre - Incubator Phase 1 - - -Incubator Phase 2 - Incubator Phase 3	15 acres	Cover cropping practices vary by incubator farmer. This estimate assumes all available fields are cover cropped every year	3 MT	60 MT	Decrease soil erosion from wind and water, better rainwater infiltration, and wildlife habitat	COMET-Planner CDFA version, accessed April 2023
Hedgerows (422) - HR1 2 row 1400 ft - HR2 1 row 925 ft - HR3 1 row 680 ft - HR4 2-3 row 1860 ft	4865 linear ft	To date, hedgerows have been installed along four field edges and the bioswale. Plant selection follows NRCS guidelines so that bloom time is staggered across the year.	9 MT	180 MT	Wildlife habitat, pollinator habitat, carbon sequestration, improve microclimate stabilize soils, improve water quality, and reduce water loss.	COMET-Planner CDFA version, accessed April 2023 Chiartas et al. 2022
Conservation cover (herbaceous understory) (327) HR1, HR2, portions of HR4, native grass garden	2.2 acres	Native grasses were seeded in conjunction with two hedgerows and in preparation for a future hedgerow. Width of the seedings ranges from 10 to 20 feet wide	1 MT	20 MT	Stabilize soils and stream banks and channels, water capture, soil moisture and organic matter, wildlife habitat structural and species diversity	COMET-Planner CDFA version, accessed April 2023
Mulching (484)	.65 acres	Applied wood chips to mulch HR3 and a portion of HR4 . Applied annually	.21 MT	4.2 MT	Improved efficiency of irrigation water. Improved plant productivity and health. Decreased soil erosion. Increase soil organic matter.	COMET-Planner CDFA version, accessed April 2023
TOTAL FOR PRACTICES ALREADY IMPLEMENTED			206.21 MT***	2775.2 MT		

*estimated CO_2e sequestered for biochar application is based on C content of the biochar at 85% applied at a rate of 10 dry tons/acre to 2.5 acres

**because little is known about the long term impacts of biochar we are only counting the CO_2e reduction for the year it was applied.

***Annual rate, beginning in 2023 for all practices

Table 7b. Summary table - planned practices

Planned practices (NRCS CPS#)	Field/ total length or area	Description	CO2e sequestered annually	CO2e sequestered 20 years	Co-benefits	References
Cover cropping (340)	SW field 2.5 acres	Between rows of olive orchard- annually	1 MT	20 MT	Reduce erosion from wind and water, increase soil health and organic matter content, suppress weeds, improve soil moisture use efficiency, minimize soil compaction	COMET-Planner CDFA version, accessed April 2023
Alley cropping (311) with stone fruits or low-stature perennial herbs (rosemary, lavender).	NW and SE fields 12 acres	Plant stone fruit trees and/or chestnuts or low stature perennial herbs in strips to divide NW and SE field into discrete incubator plots	10 MT	200 MT	Enhance microclimatic conditions. Reduce surface water runoff and erosion. Improve soil health by increasing utilization and cycling of nutrients. Enhance wildlife and beneficial insect habitat. Increase crop diversity. Increase carbon storage in plant biomass and soils.	COMET Planner describes as replacing 20% of annual crop with single row of trees

Compost application (336)	NW, SW, and SE fields 14.5 acres	Includes additional 2.5 acres in olive orchard after 3 year research project is completed. Annual applications @ 10 tons/acre	64 MT	1280 MT	Improved water holding capacity, soil quality and fertility and crop production	COMET-Planner CDFA version, accessed April 2023
Additional Hedgerows (422) -HR5 900 ft -HR6 780 ft -HR7 (windbreak) 1072 ft. HR8 1026 ft	SW, NW and NE fields 3778 feet	Single row hedgerows on the western and eastern side of the SW and NW field. A 3 row hedgerow will be planted on the east end of the NE field.	7 MT	140 MT	Wildlife habitat, pollinator habitat, carbon sequestration, improve microclimate stabilize soils, improve water quality, and reduce water loss.	COMET-Planner CDFA version, accessed April 2023
Mulching (484)	NW and SW fields 0.5 acre	Mulch will be generated on site from woody debris applied 8 inches deep/10 ft wide on HR6 and 8. Annually	0.21 MT	4.2 MT	Improved efficiency of irrigation water. Improved plant productivity and health. Decreased soil erosion from wind and water. Increase soil organic matter.	COMET-Planner/CSU 2017
Conservation cover under windbreak (327)	NW field 0.5 acres	Native grass understory for windbreak (HR7)	0.38	7.6 MT	Stabilize soils and stream banks water capture, soil moisture and organic matter, wildlife habitat structural and species diversity	COMET-Planner/CSU 2017

Riparian restoration on Cache Creek (390/391) -riparian herbaceous cover -riparian forest buffer	5 acres	replace weedy invasive grasses with native grasses. plant trees and shrubs	14 MT	280 MT	Stabilize soils and stream banks and channels, water capture soil moisture and organic matter, wildlife habitat structural and species diversity.	COMET-Planner/CSU 2017
Critical area planting on Cache Creek	1 acre	plug plant rhizomatous herbaceous species	1 MT	20 MT	Stabilize soils and stream banks water capture soil moisture and organic matter, wildlife habitat structural and species diversity.	COMET-Planner/CSU 2017
TOTAL FOR PLANNED PRACTICES			97.59* MT	1951.8 MT		

Table 7c Summary table - Implemented and planned projects combined (see Tables 7a and 7b for descriptions and references)

Practice	Acreage/ Length	CO2e sequestered annually (MT)	CO2e sequestered over 20 years (MT)
Alley cropping	12 acres	10	200
Biochar	2.5 acres	71	71*
Compost application (annual)	20 acres	89	1780
Conservation cover	2.7 acres	1.38	27.6
Cover cropping (annual)	17.5 acre	4	80
Critical area planting	1 acre	1	20
Hedgerows	8183 feet	16	320

Mulching (annual)	1.15 acres	.42	8.4
Riparian restoration	5 acres	14	280
Tree and shrub establishment	5 acres	97	1940
TOTAL		**302.42**	**4727**

*biochar CO2e reduction taken in the first year only

Soil, Water, and Carbon

NRCS suggests that a 1% increase in SOM results in an increase in soil water holding capacity of approximately 1-acre inch, or 27,152 gallons of increased soil water storage capacity per acre. A 1% increase in SOM represents roughly 20,000 pounds (10 short tons) of organic matter, or 5 short tons of organic carbon. Table 9 shows estimated additional water storage capacity associated with soil carbon increases on Maples Farm resulting from implementation of the CFP. Total estimated additional soil water storage capacity associated with soil carbon increases on Maples Farm resulting from implementation of the CFP is estimated to be 16.39 acre-feet by year 20. This analysis is assumed to be conservative, yet reveals the potential significance of even small increases in soil carbon for overall farm dynamics.

Table 8. Estimated Additional Soil Water Holding Capacity (WHC) Maples Farm with Carbon Farm Plan Implementation, Year 20 (see Appendix 4 for WHC calculations)

Practice	Description	20 year SOM Increase (MT)	Soil WHC Increase by Year 20 (AF)
Alley cropping	Orchard trees or perennial herbs in SE and NW fields 12 acres	54.50	0.50
Biochar	2.5 acres in SW field	38.69	0.35
Compost application	All farm fields 20 acres	970.03	8.89
Conservation cover	Under HRs 1, 2, 4 and 7 plus native grass garden	10.9	0.10
Cover cropping	All farm fields minus rows with olive trees 17.5 acres	43.60	0.40
Critical area planting	Associated with riparian restoration 1 acre	5.45	0.05
Hedgerows/ Windbreak	Total of 8 measuring 8183 ft.	87.19	0.80
Mulching	Associated with hedgerows	4.58	0.04

Riparian restoration	5 acres on Cache Creek	76.29	0.70
Tree and shrub establishment	Olive orchard	528.61	4.85
TOTALS		1823.98	16.72

In addition, there is some additional water catchment potential on the farm through diversion of roof runoff from farm buildings to possible future water storage tanks. As shown in Table 10, with Woodland's average annual rainfall of 21.38 inches, total average yearly roof runoff catchment potential is estimated to be 0.57 acre feet, or 184,883 gallons. If all or most of this water could be stored, it would provide a significant source of water that could be used, for example, to irrigate carbon beneficial practices such as hedgerows and riparian restoration or to irrigate landscape plantings.

Structure	Roof area (sq. feet)	Volume in acre feet at 21.38" rainfall/year
Headquarters building	4031	0.16
Main barn	5025	0.21
Wash and pack barn	3418	0.14
Storage shed	568	0.02
Welding shop	830	0.03
Total	**13,872**	**0.57**

Table 9. Roof rainfall catchment potential at Maples Farm

Conclusion

Quantification of GHG Benefits

CLBL began implementing carbon-beneficial practices at Maples Farm in 2019, even before moving to the new headquarters. Table 7a, above, lists those conservation practices that have already been implemented. Table 7b lists those carbon beneficial practices identified through the carbon farm planning process as of June 2023. Table 7c lists both implemented and planned practices. Quantification of the carbon capture potential of these practices was derived from the on-farm carbon sequestration planning tool, COMET-Planner (www.comet-planner-cdfahsp.com) or other sources as noted.

With full implementation of this carbon farm plan, the overall total potential carbon sequestered at Maples Farm is estimated to be 298 MT CO2e[1] in the first year and 4727 MT CO2e over 20 years*

According to the U.S. EPA Greenhouse Gas Equivalencies Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator) , this is equivalent to: 1052 gasoline powered vehicles driven for one year or 596 homes' energy use for one year.

Summary of plan goals

Maples Farm is a working farm that has an educational mission. Therefore, all of the carbon-beneficial practices identified in this Carbon Farm Plan serve as demonstration sites for visitors, new farm trainees, apprentices, students and the general public. Indeed, CLBL is in the process of transforming Maples Farm into an innovation hub to demonstrate carbon farming principles.

A primary goal is to increase soil organic matter from current levels to 5 percent across the farm and increase water holding capacity. We conducted baseline monitoring of all of the farm

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[1] CO2e = "carbon dioxide equivalent". CO2e is a measurement of the total greenhouse gasses emitted, expressed in terms of the equivalent global warming potential of carbon dioxide. Common GHG equivalencies include: 1 MT methane = 84 MT CO2e (over the 12 year life span of CH4 in the atmosphere ; 1 MT of nitrous oxide = 298 MT CO2e (over 100 years or more).

fields and habitat areas in 2021 and 2022 (see table 2a and 2b). The Northeast field where our Phase 1 incubator farmers and the training program have their fields is closest to the 5% level now. This is not surprising as we estimate compost has been added at a rate of 20 tons/acre/year over the past two years.

The majority of working farmland at Maples Farm is dedicated to our Farm Business Incubator program through which new farmers are able to lease land at below market rates and develop their farm businesses. By emphasizing carbon beneficial practices through our Farm and Climate Program, CLBL is able to "grow" new farmers who consider the carbon impacts of their practices for years to come. While decisions of how to manage the farmland are up to the individual incubator farmer, the learning environment promotes carbon farming. At a minimum, all incubator farmers are encouraged to utilize compost and cover cropping to maintain or increase soil organic carbon.

At the time this plan was developed, CLBL had already implemented hedgerows around approximately half of the acreage of the farm and secured funding to put in three additional hedgerows and a windbreak in the near future. Once this second round of hedgerows is in place, virtually all of the farm edges that can support hedgerows will be planted accordingly.

Also at the time this plan was developed, CLBL was in the process of installing a new olive orchard on 5 acres of the southwest field. As part of a CDFA demonstration project monitoring the effects of compost and biochar, the orchard will yield important data not only on soil health impacts of those soil amendments, but on the impacts of the orchard itself on soil carbon over time.

One of the most exciting future projects is a riparian restoration project on Cache Creek, which at the time this plan was developed was in its planning phase. Once funding is secured and appropriate permits are obtained, the project will enhance the riparian habitat on this section of the creek with native trees and shrubs. Herbaceous vegetation now dominated by non-native annual grasses will be restored to native perennial grasses, sedges and forbs. These planting will improve the habitat value while also sequestering greenhouse gasses.

FInally, all of these carbon-beneficial practices are being integrated into CLBL's existing education programs for youth and adults. Students who participate in our FARMS and SLEWS program are introduced to the concept of carbon sequestration as a way to mitigate climate change and enhance farm resilience to extreme weather events. They are also given the opportunity to help with this strategy through field days in which they plant native vegetation both here at Maples Farm and at other sites throughout California. We have integrated carbon farm planning into our new farmer training course and the plant sciences course for the Apprenticeship program.

This plan should be viewed as a living document. It should evolve as practices are implemented and new information and new tools become available. Additional carbon-beneficial practices may be considered for inclusion in the plan in the future. GHG values presented here as associated with specific practices are considered to be both conservative and based upon the best available information at the time of this plan's preparation (June 2023).

Short term action plan and timeline

Objectives	2023		2024				2025				2026
	sum	fall	win	spr	sum	fall	win	spr	sum	fall	
Carbon Farming trainings			x	x							
Install 3 additional hedgerows		x	x			x	x				
Install windbreak		x	x								
Initiate riparian restoration											x
Seed native grasses on Cache Creek											x

Monitoring and record keeping

Regular monitoring of the impacts of these practices on soil health and biodiversity at our farm is very important to CLBL's educational mission. Our aim is to document and communicate ecological changes over time with respect to soil organic carbon, native pollinators, wildlife, and vegetation composition.

To that end, we took baseline soil samples in all of our main farm fields and initial habitat projects in fall 2021. Our baseline soil samples were analyzed for soil organic carbon by Ward

Laboratories using the dry combustion method. Baseline soil samples were collected in our SW field (olive orchard) for the CDFA demonstration project in December 2022 and analyzed at U.C. Davis using the loss on ignition (LOI) method. Additional soil samples will be collected in fall 2023 for new habitat projects (hedgerows, windbreak, and riparian restoration.

CLBL monitors a variety of indicators of biodiversity. We have established permanent transects in four hedgerows to monitor bees using the Xerces Society's Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat. We are also monitoring monarch habitat in our "bioswale" (HR1), using the Monarch Butterfly Habitat Quantification Tool. We track the success of our milkweed plantings using the Western Monarch Milkweed Mapper (https://www.monarchmilkweedmapper.org/). We track nest success in our birdbox program using the Cornell Lab of Ornithology's Project Nestwatch (https://nestwatch.org).

Ecological monitoring at Maples Farm

Indicator	Method	References
Soil organic carbon - all fields	Dry combustion method (Ward Laboratory)	Donovan, P. (2013) Measuring soil carbon change CLBL Soil Sampling Protocol (Appendix 3)
Pollinator diversity	Xerces Society Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat	www.xerces.org/publications/id-monitoring/streamlined-bee-monitoring-protocol
Vegetation cover (riparian)	Line intercept method	Herrick et. al (2005) Monitoring manual for grassland, shrubland and savanna ecosystems
Nest box productivity	Project nestwatch monitoring protocol	nestwatch.org
Monarch habitat quality	Monarch Butterfly Habitat Quantification Tool	Monarch butterfly habitat quantification tool

Bird diversity	Point counts	Bibby et. al 2000. Bird Census Techniques, second edition.
Milkweed abundance	mapping	Western Monarch Milkweed Mapper
Wildlife presence/absence	game camera monitoring	

Funding Opportunities

The Center for Land-Based Learning has benefitted from funding opportunities at the local, state, and federal level and encourages other landowners to seek resources and technical assistance to implement the recommended practices in their Carbon Farm Plans. The following is a non-exhaustive list of funding programs that are available to private landowners. Other funding programs exist through state or federal agencies, such as the Wildlife Conservation Board, California Department of Fish and Wildlife, or the California Coastal Conservancy, however, private individuals may need to partner with a sponsor (e.g., a local Resource Conservation District or nonprofit) to submit an application.

California Department of Food and Agriculture (CDFA)

Healthy Soils Program (HSP) Incentives Program- covers many carbon farm practices including cover cropping, hedgerows, mulching, riparian forest buffer, range seeding, compost application, and prescribed grazing. Funding is based on a fixed rate reimbursement depending on the practice. The reimbursement typically does not cover the full amount. Technical assistance is provided free of cost to the HSP incentives Program applicants and grant awardees.

https://www.cdfa.ca.gov/oefi/healthysoils/incentivesprogram.html

State Water Efficiency & Enhancement Program (SWEEP) - funds implementation of irrigation systems that reduce greenhouse gasses and save water. Funding is based on a fixed rate reimbursement depending on the practice. The reimbursement typically does not cover the full amount.

https://www.cdfa.ca.gov/oefi/sweep/

Natural Resources Conservation Service (NRCS)

Environmental Quality Incentives Program (EQIP) - covers most to all practices in a typical carbon farm plan including supporting practices such as fencing and water development. Funding is based on a fixed rate reimbursement depending on the practice. Landowners typically expect out of pocket expenses of 10% or more.

General information can be accessed at: https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives. However, interested producers should contact their local NRCS office directly

Conservation Stewardship Program (CSP) - includes multiple enhancement activities and conservation practices to address resource concerns such as soil health, pollinators, changing weather patterns, western forest health, efficient irrigation, and rangeland health. Funding is based on fixed payment rates for conservation activities. CSP payments occur annually.

https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program

U.S. Fish and Wildlife Service (USFWS)

Partners for Fish and Wildlife - funds conservation projects on private lands with a focus on migratory birds, anadromous fish and/or threatened and endangered species. Priority habitats are riparian, wetlands, and native grasslands. Funding is based on a 1:1 cost share. Matching funds are preferred but not always required.

https://www.fws.gov/program/partners-fish-and-wildlife

Xerces Society For Invertebrate Conservation

Xerces Society Pollinator Kits - are curated collections of native species specifically chosen as nectar or host plants for pollinator species and awarded to qualified projects. In California qualifying projects include those on working lands, public lands, tribal lands, and private/non-working lands recovering from wildfires. Project proposals are due between February 21 - April 3, 2023. If the proposal is accepted, plants are free of charge but require the recipient to pick up the plants at a designated location and report on project progress.

https://xerces.org/pollinator-conservation/habitat-kits

Zero Foodprint

Restore California - provides funding for implementation of carbon farming practices. Proposals are scored according to the GHG benefits of the project. Grants for up to $25,000. Applicants are required to partner with a Technical Assistance Provider.

https://www.zerofoodprint.org/

References

Biernbaum, J. 2012. Organic Matters: Feeding the Soil and Building Soil Quality. Organic Matters, Michigan State University.

Case et al. 2014. Can biochar reduce soil greenhouse gas emissions from a Miscanthus bioenergy crop? Bioenergy 6: 76-89.

Chiartas, J. L., Jackson, L. E., Long, R. F., Margenot, A. J., & O'Geen, A. T. 2021. Hedgerows on Crop Field Edges Increase Soil Carbon to a Depth of 1 meter. Sustainability, 14(19), [12901]. https://doi.org/10.3390/su141912901

Favoino & Hogg. 2008. The potential role of compost in reducing greenhouse gasses. Waste Management Research 26: 61-69.

Gelardi & Parikh. 2021. Soils & Beyond: Optimizing Sustainability Opportunities for Biochar. Sustainability 13: 10079.

Griscom et al. 2017. Natural Climate Solutions. Proceedings of the National Academy of Sciences 114(44): 11645-11650.

Lopez-Bellido, Pedro, Luis Lopez-Bellido, Purificacion Fernandez-Garcia, Veronica Muñoz-Romero & Francisco J. Lopez-Bellido. 2016. Assessment of carbon sequestration and the carbon footprint in olive groves in Southern Spain, Carbon Management, 7:3-4, 161-170, DOI: 10.1080/17583004.2016.1213126

Oladele. 2019. Changes in physicochemical properties and quality index of an Alfisol after three years of rice husk biochar amendment in rainfed rice-Maize cropping sequence. Geoderma 353: 359–371.

Pandit et al. 2018. Multi-year double cropping biochar field trials in Nepal: Finding the optimal biochar dose through agronomic trials & cost-benefit analysis. Sci. Total Environment: 1333-1341.

Proctor, et. al. 2021. Agrivoltaics Align with Green New Deal Goals While Supporting Investment in the US' Rural Economy Sustainability 2021, 13(1), 137
https://doi.org/10.3390/su13010137

Proietti, Stefania, Paolo Sdringola, Umberto Desideri, Francesco Zepparelli, Antonio Brunori, Luana Ilarioni, Luigi Nasini, Luca Regni, Primo Proiettim. 2014. Carbon footprint of an olive tree grove. Applied Energy, Volume 127, pages 115-124.
https://doi.org/10.1016/j.apenergy.2014.04.019

Ryals , L. and W. L. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecological Applications 23 (1): 46-59. https://doi.org/10.1890/12-0620.1.

Sanchez-Garcia. 2016. Compost vs biochar amendment: a two-year field study evaluating soil C build-up & N dynamics in an organically managed olive crop. Plant & Soil 408(1): 1-14.

Sofo, Adriano, Vitale Nuzzo, Assunta Maria Palese, Cristos Xiloyannis, Giuseppe Celano, Paul Zukowskyj, Bartolomeo Dichio. 2005. Net CO2 storage in Mediterranean olive and peach orchards. *Scientia Horticulturae*, Volume 107, Issue 1, Pages 17-24.
https://doi.org/10.1016/j.scienta.2005.06.001

Sullivan, D.M., A.D. Moore, and L.J. Brewer. 2019. Soil organic matter as a soil health indicator: Sampling, testing, and interpretation. Oregon State University Extension Service, E. M. 9251.

Wilson, L.M. and L. H. Hardestry. 2006. Targeted Grazing with Sheep and Goats in Orchard Settings. Chapter 11 in Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement, University of Idaho.

Zhang et al. 2020. Quantifying the Effects of Biochar Application on Greenhouse Gas Emissions from Agricultural Soils: A Global Meta-Analysis. Sustainability 12(8): 3436.

Appendices

Appendix 1. Hedgerow Species and Bloom Times at Maples Farm

Common Name	*Scientific Name*	Size/Type	Early Jan-Mar	Middle Apr-Jun	Mid/late Jul-Sep	Late Oct-Nov
valley oak*	*Quercus lobata*	Tree				
coast live oak	*Quercus agrifolia*	Tree				
mule-fat*	*Baccharis salicifolia*	Tall Shrub	X	X	X	X
common manzanita	*Arctostaphylos manzanita*	Tall Shrub	X	X		
whiteleaf manzanita	*Arctostaphylos viscida*	Tall Shrub	X	X		
Vine hill manzanita	*Arctostaphylos densiflora*	Shrub	X	X		
buckbrush	*Ceanothus cuneatus*	Shrub	X	X		
blue blossom	*Ceanothus thyrsiflorus*	Shrub	X	X		
western redbud*	*Cercis occidentalis*	Sm. Tree	X	X		
gumplant	*Grindelia camporum*	Forb		X	X	X
coffeeberry*	*Frangula californica*	Shrub		X		
CA flannelbush	*Fremontodendron californicum*	Tall Shrub		X		
toyon*	*Heteromeles arbutifolia*	Tall Shrub		X		
silver bush lupine	*Lupinus albifrons*	Low Shrub		X		
fragrant sumac*	*Rhus aromatica/trilobata*	Shrub		X		
California rose*	*Rosa californica*	Low Shrub		X		
blue elderberry*	*Sambucus nigra*	Tall Shrub		X	X	
yarrow	*Achillea millefolium*	Forb		X	X	
narrow-leaf milkweed	*Asclepias fascicularis*	Forb		X	X	
showy milkweed	*Asclepias speciosa*	Forb		X	X	
Indian hemp	*Apocynum cannabinum*	Forb		X	X	
CA buckwheat*	*Eriogonum fasciculatum*	Low Shrub		X	X	X
Cleveland sage*	*Salvia clevelandii*	Shrub		X	X	
CA goldenrod	*Solidago velutina*	Forb			X	X
Pacific aster	*Symphyotrichum chilense*	Forb			X	X
coyote brush*	*Baccharis pilularis*	Tall Shrub			X	X
California fuschia	*Epilobium canum*	Low Shrub			X	X

deergrass	*Muhlenbergia rigens*	Grass				X

Appendix 2. Wildlife at Maples Farm

Common name	Scientific name
Mammals	
Bobcat	*Lynx rufus*
Botta's pocket gopher	*Apodemus sylvaticus*
Brush rabbit	*Sylvilagus bachmani*
Coyote	*Canis latrans*
Field mouse	*Apodemus sylvaticus*
Gray Fox	*Urocyon cinereoargenteus*
Jackrabbit	*Lepus californicus*
Meadow vole	*Microtus pennsylvanicus*
Mule deer	*Odocoileus hemionus*
Racoon	*Procyon lotor*
Skunk	*Mephitidae*
Birds	
American crow	*Corvus brachyrhynchos*
American robin	*Turdis migratorius*
Anna's hummingbird	*Calypte anna*
Ash-throated flycatcher	*Myiarchus cinerascens*
Barn owl	*Tyto alba*
Belted kingfisher	*Megaceryle alcyon*
Black phoebe	*Sayornis nigricans*
Brewer's blackbird	*Euphagus cyanocephalus*
Bullock's oriole	*Icterus bullokii*
Bushtit	*Psaltriparus minimus*
California quail	*Callipepla californica*
California scrub jay	*Aphelocoma californica*
California towhee	*Melozone crissalis*

Cliff swallow	*Petrochelidon pyrrhonota*
Dark-eyed junco	*Junco hyemalis*
Double-crested cormorant	*Phalacrocorax auritus*
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Great horned owl	*Bubo Virginianus*
House finch	*Haemorpous mexicana*
House wren	*Troglodytes aedon*
Lesser goldfinch	*Spinus psaltria*
Loggerhead shrike	*Lanius ludovicianus*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes chrysoides*
Northern mockingbird	*Mimus polyglottos*
Nuttall's woodpecker	*Dryobates nuttallii*
Pacific slope flycatcher	Empidonax difficilis
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoenicus*
Swainson's hawk	*Buteo swainsoni*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Western bluebird	*Sialia mexicana*
Western kingbird	*Tyrannus verticalis*
Wild turkey	*Meleagris gallopavo*
Yellow-rumped warbler	*Setophaga coronata*

Appendix 3. CLBL Soil Sampling Protocol

Soil organic carbon & bulk density monitoring protocol for The Maples Farm

This protocol was prepared by **Alex M. Lintner** during her GrizzlyCorps service term (2021–2022) for the **Center for Land-Based Learning**.

Motivation for designing this monitoring protocol

The Center for Land-Based Learning (CLBL) recently moved to The Maples Farm. CLBL hopes to transform this 30-acre parcel into an education, research, and demonstration hub for regenerative agriculture in the Sacramento Valley. Shortly after their arrival at The Maples Farm, **CLBL identified the need to establish baseline data that captures a snapshot of soil organic carbon (SOC) stocks on the farm before starting active management** (see Appendix A for background information on SOC). These baseline data will be included in The Maples Farm Carbon Farm Plan. As carbon farming practices are deployed across the farm, these baseline data will be invaluable for quantifying the impact of the diverse regenerative land management practices CLBL implements. To track long-term trends in SOC, CLBL will periodically measure SOC stocks after this initial baseline assessment (ideally monitoring will occur once every three years). **This protocol was developed to facilitate baseline SOC monitoring (which took place in November 2021) and future monitoring efforts at The Maples Farm.** By adhering to this protocol, CLBL will reduce noise in the data and ensure confidence in the observed SOC trends across time.

Necessary sampling tools

- **Soil Probe and hammer** (CLBL's AMS Hammerhead Soil Probe is stored with the Farm and Climate Program equipment in the barn)
- **Bulk Density (BD) core** (a metal or plastic tube with a 6–8 cm diameter and 12–15 cm height)
- **Wooden block** (that can cover the top of the BD core)
- **Hand trowel** (to dig the BD core out of the ground)
- **Flat blade knife** (to ensure integrity of BD core)
- **Thee plastic buckets** (for combining soil cores)
- **Measuring tape** (to measure soil core depth increments)
- **Meter stick** (to measure the sampling grid and transect)
- **Flags** (for marking the center of the sampling grid)
- **Data collection sheet** (CLBL specific data sheet can be found in the *Soil Organic Carbon Monitoring* folder; see Appendix B for an example data sheet)
- **One-quart plastic bags** (for storing the soil samples)
- **Sharpies** (for labeling the bags) **and pens** (for recording data)

Delineating sampling regions and subplots

When selecting sampling locations it is important that all soils come from the same uniform soil type (soil type can be determined using the NRCS's Web Soil Survey). The Maples Farm's dominant soil series is Reiff very fine sandy loam – this soil dominates the entire property with the exception of the riparian zone which is dominated by the Riverwash series.

For baseline SOC sampling at The Maples Farm in 2021, we selected eight sites based on current and projected future management. For instance, we separated the front field into two sampling regions – Front North Field and Front South Field – since the southern portion will be converted into an olive grove as of spring 2023 whereas the northern portion is reserved for incubator plots. For baseline sampling, five of the eight sites are agricultural production and/or education fields and the remaining three sites are conservation hedgerows. Future baseline sampling should include the riparian region along Cache Creek and the borders of the front field. The eight baseline regions sampled in 2021 are delineated on the map below.

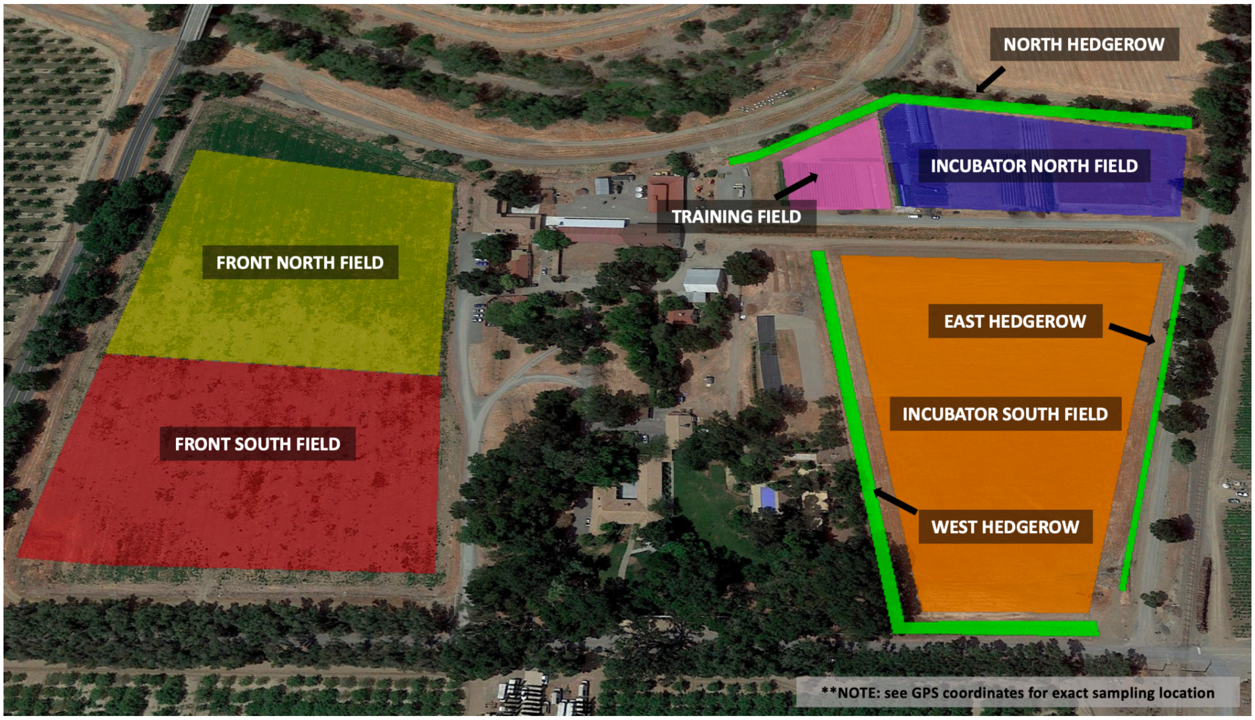

Figure 1. A map of the eight SOC and BD sample collection regions. Each site has a distinctive management history and projected future management plan. Baseline samples collected November 2021.

Since SOC is highly variable across space, we randomly selected a subplot of each of the eight sample collection regions to reduce noise. For the agricultural fields, the subplots were four by four meters and randomly located within each region. For the hedgerows, the subplots consisted of a 24 meter long transect randomly positioned in the hedgerows. The center of the subplots were GPS located. It is important to stress that in order to accurately measure SOC change over time, you must record the GPS coordinate for all your sampling subplots. GPS coordinates for the center of the eight subplots are recorded below (these coordinates are also found in the SOC and BD datasheet).

Table 1. GPS coordinates for SOC and BD sampling subplots. Future resampling endeavors must return to these GPS located subplots.

Region Description	Site Latitude	Site Longitude
Incubator South Field	38.7177769	-121.759823
Incubator North Field	38.7193585	-121.7587538

Training Field	38.7193203	-121.760390
Front North Field	38.7188667	-121.7631359
Front South Field	38.7178015	-121.7631282
West Hedgerow	38.7182614	-121.7603682
North Hedgerow	38.7197893	-121.7588212
East Hedgerow	38.7183629	-121.758602

Timing of SOC and BD sampling

It is common practice to sample soils in the fall. The baseline SOC and BD samples were collected on November 7, 2021. Future resampling of SOC and BD should take place in the fall season, ideally in November. Future resampling should occur once every three years – the next sampling will take place in November 2024, then November 2027, etc. By sampling fields as close to the same time of year for each subsequent resampling events will help reduce noise and ensure the most accurate estimates of SOC change over time.

Additionally, to ensure the most accurate SOC stock estimates, do not sample after a major weather event. For example, do not sample if the soil is wetter than normal after a heavy rainfall. Wait at least three days after a major weather event before sampling.

Do not sample immediately after soil amendments are added (such as compost etc.). Wait at least 1–2 weeks after adding soil amendments.

Choosing SOC and BD sampling depth

Depth increments for SOC sampling vary substantially. SOC change over time tends to be most noticeable at shallow depths; in agricultural fields, the top 15 cm of the soil profile are typically most impacted by management (this soil strata has the greatest root density, microbial activity, and amendment additions). It is therefore highly important to include the 0 cm to 15 cm increment when testing SOC levels. However, carbon dynamics in deeper increments of the soil profile are also important for tracking changes in SOC stocks (but these SOC levels are slower to change with management and more difficult to sample).

For this monitoring protocol, we chose to sample the 0 cm to 15 cm depth increment and the 15 cm to 30 cm depth increment across all regions. In the Front

South Field region, we also sampled the 30 cm to 45 cm depth increment because CLBL plans on installing an olive grove in this area. Since olives are perennials with deep root systems, it is important to test deeper strata in the soil profile to get a more complete picture of SOC storage dynamics.

When using the soil probe, it is critical to carefully separate soil core samples into discrete depths. Carefully measuring and separating the soil core is another way to reduce noise across sampling events.

When measuring BD, the dimensions of the BD core will determine the soil depth increment. For this protocol, we recommend using a core with a 12–15 cm depth.

SOC sampling process in the field

STEP 1:

Assemble all the necessary sampling tools listed on page 2.

STEP 2:

When first taking baseline samples, you must randomly select a subplot in your region of interest. Record the GPS coordinates for the center point in the subplot. When resampling after the baseline sampling event, return to the exact GPS located subplot.

STEP 3:

Once you arrive at the proper GPS located subplot, record your metadata and field data on the data sheet (see Appendix B). Then place a flag at the center point of the subplot.

STEP 4:

For the agricultural fields, **a fixed plot grid** is constructed around this center point. There are 25 possible subsample locations in this grid. Each possible subsample location is exactly one meter apart from neighboring subsample locations. The grid is alway oriented so that if you were to trace a line from subsample location 13 (the center point) to subsample location 3, the line would be pointing due North (see image below).

For hedgerows, **a fixed line transect** is constructed around this central GPS located point. There are 25 possible subsample locations in this transect. Each possible subsample location is exactly one meter apart from the neighboring subsample location. The line is alway oriented with the angle of the hedgerow (see image below).

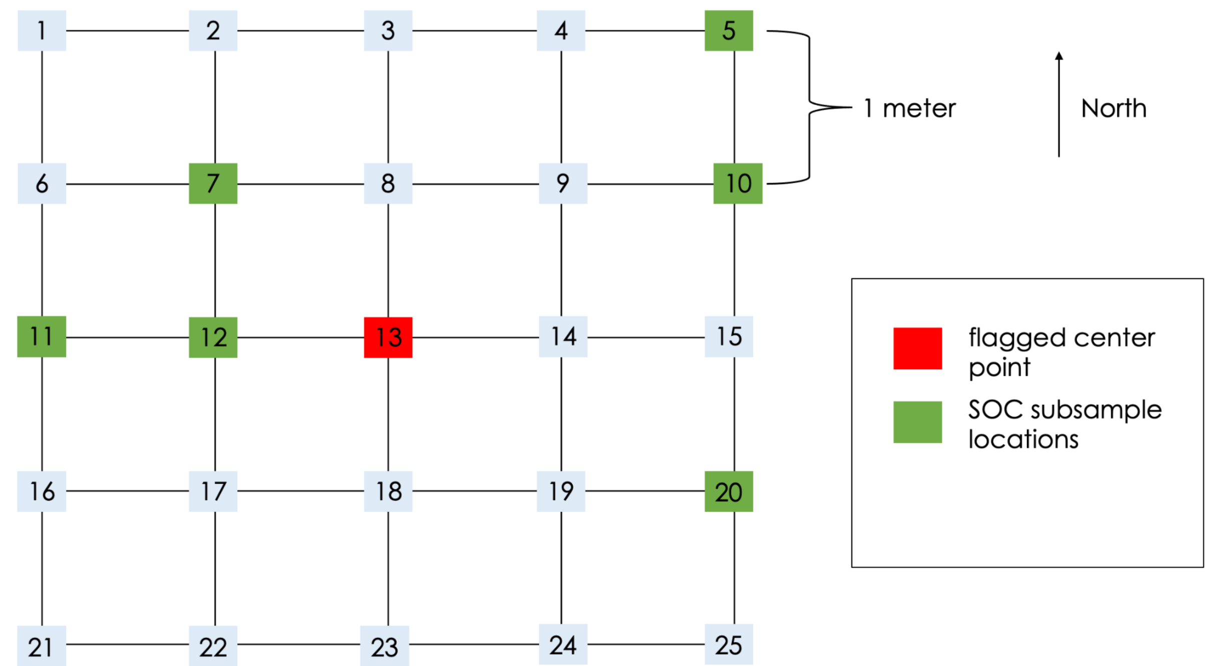

Figure 2. A fixed plot grid layout is used in agricultural fields. SOC sample collection occurs at six random subsample locations within the grid.

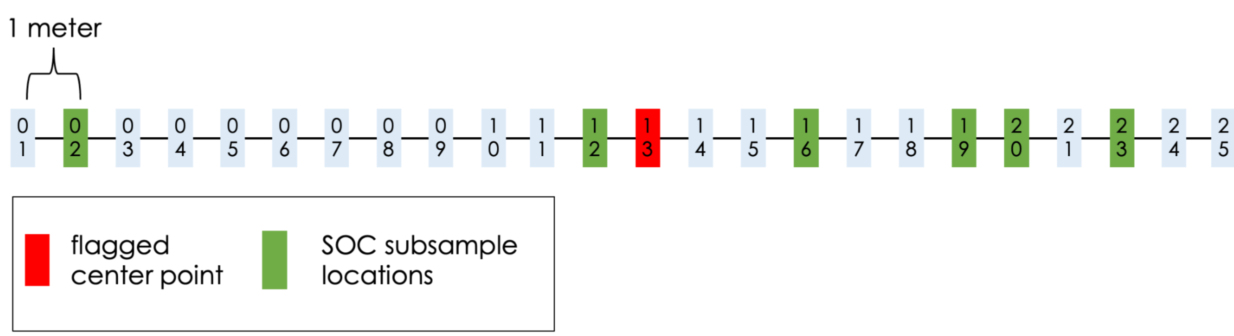

Figure 3. A fixed line transect is used in hedgerows. SOC sample collection occurs at six random subsample locations along the transect.

STEP 5:

Use a random number generator to produce six unique digits between one and twenty-five. Note these numbers on your data sheet. These randomly generated numbers inform the location of your six subsamples. Each number corresponds to a point in your fixed plot grid or line transect. Use the meter stick or measuring tape to arrive at each of the proper subsample locations, always starting at the flagged center point.

STEP 6:

At each of the six subsample locations, expose the bare soil surface without disturbing the soil surface. If necessary, gently remove any vegetation or litter covering the soil surface.

STEP 7:

Once the soil surface is exposed, use the soil probe to take soil cores at your six randomly selected locations within the grid plot or line transect. Use the soil probe to collect a subsample of each depth increment at each of the randomly selected subsample locations.

STEP 8:

At each subsample location, place the 0 cm to 15 cm section of the soil core into a bucket labeled 0–15 cm. Place the 15 cm to 30 cm section of the soil core into a bucket labeled 15–30 cm. For the Front South Field region, place the 30 cm to 45 cm section of the soil core into a bucket labeled 30–45 cm.

STEP 9:

Once you have taken soil cores from all six subsample locations, transfer the soil from the buckets into plastic bags.

STEP 10:

Using a sharpie, label the plastic bags with the date, time of sampling, sampler name(s), type of sampling (SOC), region name (Incubator South Field, Incubator North Field etc.), soil depth increment (0–15 cm, 15–30 cm, or 30–45 cm), and GPS coordinates for the plot or transect center point (latitude, longitude).

BD sampling process in the field

STEP 1:

BD sampling will occur in the same fixed grid plots (for agricultural fields) or fixed line transects (for hedgerows) where you took soil cores for SOC sampling (see above section).

STEP 2:

Use a random number generator to produce a number between one and twenty-five (make sure it is not one of the numbers you used for SOC monitoring above). Note this number on your data sheet. Similar to the SOC protocol above, this randomly generated number informs the location of your BD sampling site. Use the meter stick or measuring tape to arrive at the proper BD sampling location, always starting at the flagged center point.

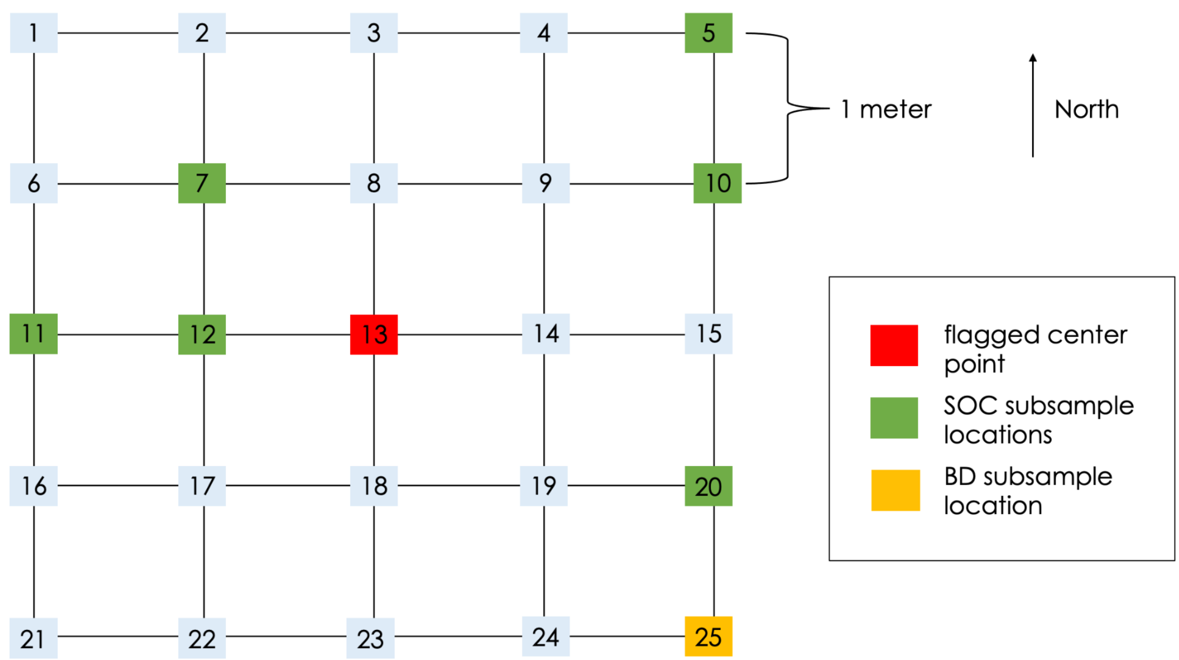

Figure 4. A fixed plot grid layout is used in agricultural fields. BD sample collection occurs at one random subsample location within the grid.

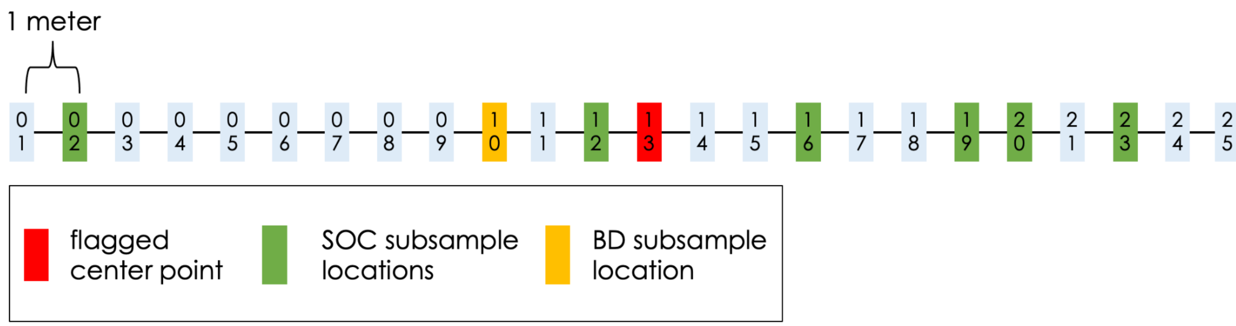

Figure 5. A fixed line transect is used in hedgerows. BD sample collection occurs at one random subsample location along the transect.

STEP 3:

At the sampling location, expose the bare soil surface without disturbing the soil surface. If necessary, gently remove any vegetation or litter covering the soil surface.

STEP 4:

Once the soil surface is exposed, place the BD core on top of the soil surface. Place the wooden block on top of the BD core. Using the hammer, evenly drive the BD core into the soil until the top of the core is level with the ground.

STEP 5:

Use the hand trowel to dig around the edge of the BD core. Carefully lift the BD core out of the soil, making sure not to let any soil escape from the bottom of the BD core when lifting it out of the ground.

STEP 6:

Use the flat blade knife to remove any excess soil on the bottom of the BD core. Ensure that the soil sample is flat with the edges of the BD core.

STEP 7:

Transfer the soil in the BD core into a plastic bag.

STEP 8:

Using a sharpie, label the plastic bag with the date, time of sampling, sampler name(s), type of sampling (BD), region name (Incubator South Field, Incubator

North Field etc.), BD core dimensions (diameter, height), and GPS coordinates for the plot or transect center point (latitude, longitude).

Sending SOC and BD samples to the lab and recording results

STEP 1:

Once you have sampled all the regions for SOC using the soil probe and BD using the BD core, store your labeled bags of soil somewhere safe (room temperature, not in direct sun). For the baseline monitoring that took place in November 2021, there were a total of 25 labeled plastic bags (17 SOC samples and 8 BD samples).

STEP 2:

As soon as possible after you complete sampling, prepare your samples for shipment. Ship soil samples to Ward Laboratories in Kearney, Nebraska. This lab was selected since they offer both tests of interest and have competitive pricing. You need to fill out their soil sample information sheet (see Appendix C). For the SOC samples, select the Total Organic Carbon (Combustion Method) option. For the BD samples, select the Basic Bulk Density option (not the Comprehensive Bulk Density option).

STEP 3:

After filling out necessary paperwork, ship your samples to Ward Laboratories (4007 Cherry Ave, Kearney, Nebraska 68847). You can expect results within 1–4 months.

STEP 4:

Once you receive the results, record the data and metadata in the spreadsheet titled *Data for Soil Organic Carbon and Bulk Density at The Maples Farm* in the *Soil Organic Carbon Monitoring* folder (see Appendix D).

References

*** All references can be found in PDF form in the folder titled References SOC and BD in the Soil Organic Carbon Monitoring folder. References also listed below.*

Billings et al., Ecological Applications, *Soil organic carbon is not just for soil scientists: measurement recommendations for diverse practitioners*, published in 2021.

Bossio et al., Nature Sustainability, *The role of soil carbon in natural climate solutions*, published in 2020.

Donovan, *Measuring Soil Carbon Change: A Flexible, Practical, Local Method*, published in 2013.

Fibershed, *Citizen Science Soil Sampling Protocol*, published in 2016.

Janzen et al., Soil Biology and Biogeochemistry, *The 'soil health' metaphor: Illuminating or illusory?* published in 2021.

Lal, Journal of Soil and Water Conservation, *Conceptual basis of managing soil carbon: Inspired by nature and driven by science*, published in 2019.

Moebius-Clune et al., Cornell University, *Comprehensive Assessment of Soil Health: The Cornell Framework,* published in 2016.

Norris et al., Agronomy Journal, *Introducing the North American project to evaluate soil health measurements*, published in 2020.

NRCS, *Bulk Density Test*.

NRCS, *Bulk Density: Soil Quality Indicators*.

NRCS, Oster, *Sampling Soils for Organic Carbon*, published in 2016.

Point Blue, *The Rangeland Monitoring Network: Handbook of Field Methods*, published in 2018.

Magdoff and van Es, SARE, *Building Soils for Better Crops: Ecological Management for Healthy Soils*, published in 2021.

Smith et al., Global Change Biology, *How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal,* published in 2019.

Sokol et al., Nature Microbiology, *Life and death in the soil microbiome: how ecological processes influence biogeochemistry*, published in 2022.

UN FAO, *Measuring and modeling soil carbon stocks and stock changes in livestock production systems,* published in 2019.

Appendix 4. Water Holding Capacity Calculations

Carbon Cycle Institute

NRCS suggests that a 1% increase in SOM (SOM) results in an increase in soil water holding capacity (WHC) of an approximately 1-acre inch, or 27,152 gallons of increased soil WHC per acre. A 1% increase in SOM represents roughly 20,000 pounds (10 short tons) of organic matter or 5 short tons of organic carbon. The WHC table below shows estimated additional WHC associated with soil carbon increases on a landscape resulting from the implementation of the CFP. For simplicity, only practices resulting in WHC increases greater than one-acre foot are shown in the Table.

Add your Carbon Farm Practice from Drop Down Menu. Choose "Blank" as a space filler.	Add the individual carbon farm practice Mg/CO2e 20 year value only from the overall CFP summary table. Remember, COMET will only give you and annual value so you will need to come up with the 20 year value. https://docs.google.com/spreadsheets/d/1GturZTy_o	(20 year Mg CO2e) / (3.67) = Mg Organic Carbon (SOC)	Soil Factor: some practices store 100% of their carbon in the soil, some, such as agroforestry practices, and riparian, store only a percentage below ground. This factor attempts to account for that.	(Mg SOC) x (2) =Mg Soil Organic Matter (SOM)	Conversion: metric ton to short ton 10 short tons = 9.09 metric tons	10 short tons of SOM/ acre inch (AI) increase WHC	Convert acre inch to acre feet (/12)	
Carbon Farm Practices (use dropdown)	**Mg CO2e 20 yr**	**Mg SOC**	**Soil Factor**	**Mg SOM**	**Mg SOM/AI**	**Acre Inches (AI)**	**Acre Feet (AF)**	
Alley Cropping (CPS 311)	200.00	54.50	0.50	54.50	9.09	5.99	0.50	
Compost Application on Cropland	1780.00	485.01	1.00	970.03	9.09	106.70	8.89	
Conservation Cover (CPS 327)	27.60	7.52	1.00	15.04	9.09	1.65	0.14	
Cover Crops (CPS 340)	80.00	21.80	1.00	43.60	9.09	4.80	0.40	
Critical Area Planting (CPS 342)	20.00	5.45	0.50	5.45	9.09	0.60	0.05	
Hedgerow Planting (CPS 422)	320.00	87.19	0.50	87.19	9.09	9.59	0.80	
Riparian Restoration	280.00	76.29	0.50	76.29	9.09	8.39	0.70	
Tree/Shrub Establishment (CPS 612)	1940.00	528.61	0.50	528.61	9.09	58.15	4.85	
Mulching (CPS 484)	8.40	2.29	1.00	4.58	9.09	0.50	0.04	
	71.00	19.35	1.00	38.69	9.09	4.26	0.35	bioch
Blank								
TOTAL	**4727.00**	**1288.01**		**1823.98**		**200.64**	**16.72**	

Appendix 5. Web Soil Survey