CARBON FARM PLAN

Angels Farm

Photo: Belinda Xu

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CARBON FARM PLAN FOR ANGELS FARM

Content

Introduction and planning

The scope of the Carbon Farm Plan is to make recommendations on how a farm can implement practices that increase the potential for carbon sequestration in the soil and at the same time support the production and enterprise goals of the farmer. Lowering greenhouse gas (GHG) emissions from farms and increasing carbon storage in soil are part of the statewide efforts to mitigate climate change. From the farmer's perspective, carbon farming practices contribute to increase soil organic matter (SOM), which has several co-benefits. A higher SOM content improves soil structure and water holding capacity. Keeping moisture in the soil makes plant production more resilient to drought and increases water use efficiency. Ultimately these practices can potentially create higher yields.

Carbon beneficial practices are conservation practices that support mechanisms in which carbon is locked up in biomass. The underground biomass (plant roots and other plant material) is in close connection with the physical and biological properties of soil. Microorganisms decompose plant material to smaller organic compounds. These compounds can be encapsulated in soil aggregates and through different biological, physical and chemical processes, the soil has the potential to store the carbon in its underground biomass for a very long time. For more detail on carbon farming, visit Carbon Cycle Institute (carboncycleinstitute.org).

This Carbon Farm Plan (CFP) is the result of in-depth interviews and e-mail correspondence with Belinda Xu and Jackson Yang, the owners of Angels Farm. The online calculation tools COMET-planner, COMET-farm, and Compost-planner are used to calculate the amount of carbon a certain farming practice would potentially sequester.

The objective of this work is to produce a document directed to and for the farmer. It is a report that can be a source of inspiration and learning and a resource for further planning and funding opportunities.

Acknowledgement

Dr. Chandra Richards, Conservation Ecologist at Resource Conservation District of Greater San Diego County (RCD), has been my supervisor and creator of the maps made in ArcGIS (Figure 3 and 4).

I am grateful for Belinda Xu, owner of Angels Farm, having been very responsive to all my questions in person and by e-mail. Without good communication, this project would not be possible.

Jeffrey Creque (Director of the Carbon Cycle Institute), Lance Anderson (Agricultural Program Director at Mission Resource Conservation District), and Puja Batra (Batra Ecology) have all contributed with valuable input.

Property information

Farm Name:	Angels Farm, B&W Farm LLC
Farm owners:	Dr. Belinda Xu and Wilson Xu
Purchased:	February 2016
Farm Physical Address:	3131 La Posta Road, Campo, CA 91906, San Diego County
Mailing Address:	Angela Preschool & Kindergarten, 5708 N Muscatel Avenue, San Gabriel, CA, 91775
Email:	angelapreschool@hotmail.com
Phone:	626 286 0266
Web site:	https://www.angelesfarm.com
Operation Type:	Mixed vegetables and poultry
Assessor Parcel Numbers (APNs):	605-050-16-00
Watershed and region	Cottonwood-Tijuana watershed 18070305 Regional Water Board nr. 9*
Size	40.12 acres where 18 acres are farmed.

*Reference: Environmental Protection Agency (2018); California Water Board (2018)

Regulations and certificates

- Certifications: Producer, Egg handler, Organic Certification
- Monitoring of irrigation water is performed annually.
- No conservation plan has been made for this property.

Assessment of landscape

The total size of the property is 40.12 acres. About 15 acres are stony, hilly and not farmable, though it could be used for grazing. About 18 acres are farmed and mostly flat. There are no open streams on the property even though maps from Web Soil Survey (NRCS, 2018b) indicate this.

Climate

The climate at Angels Farm is semi-arid Mediterranean with warm dry summers and cold moist winters. The warmest month is July and August, with an average temperature of 73°F, though an average high of 94°F. The coldest month is December and January, with an average low of 34°F. The owners of the farm have experienced temperatures down to 20°F and up to 125°F. The wind usually derives from southwest and Santa Ana winds from the east. It is frequently experienced high and sustained winds. High winds and extreme temperatures seem to be a major growth limitation.

History

The land was purchased in 2016. In the previous 7–8 years, the land was leased out and used for grazing approximately 15 cows. The grazed area can be clearly seen in Figure 1A. Previously, the property also had a small apple orchard.

In the two maps below, it is apparent how the land use has changed. The left hand map, Figure 1A, is from Web Soil Survey, date unknown (NRCS, 2018b). Figure 1B is from Google Earth dated 2018 (Google, 2018). It is clear to see that how the land management has changed, assumingly (also based on information from Belinda Xu), from perennial grass cover to row crops.

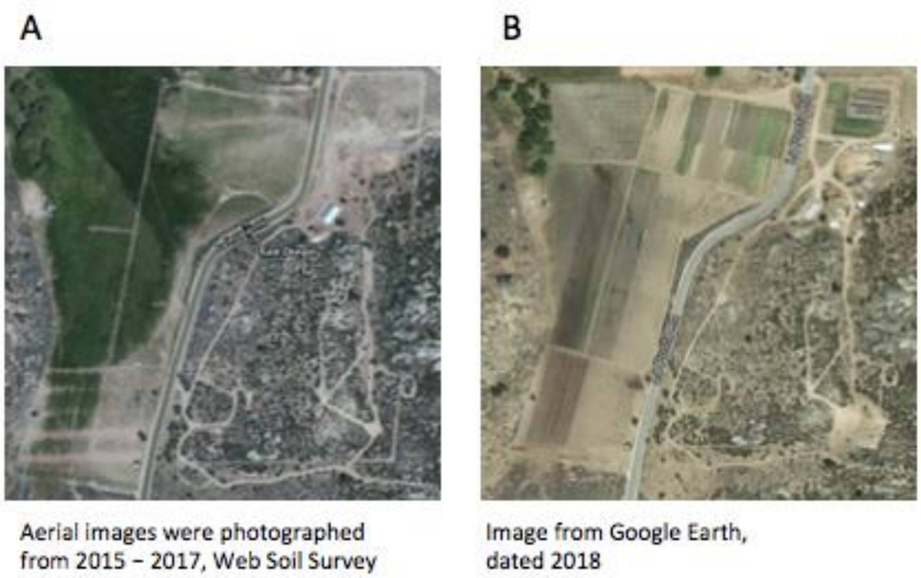

Figure 1*, two aerial photos of 3131 La Posta, Campo, CA showing different soil cover*

Infrastructure and resources

Along the east side of the road, there are 10 windmills that produce 20 kWh and power one of the water pumps. The plan is to install solar panels to power the main water pump. Currently, the windmills cannot power the main water pump north of the property because of prohibiting regulations regarding the intersecting road. The intersecting road is La Posta Road (see Figure 2).

- Two full time farm workers are managing the day-to-day productions.
- The owners, Belinda Xu and Jackson Yang, work on the farm every weekend.
- The owners have off-farm income and are therefore not dependent on income from the farm.
- The farmers own a John Deer tractor.

Figure 2 shows the elements of the farm. The irrigation water comes from two wells with pumps. There are no visible surface streams on the property. A pond is established and has recently been filled with fish. There is evidence of rill erosion on the road from runoff from the hill. Around the chickens there has been established pasture for the chickens, but due to birds of prey, the chickens are not willing to use the area. A rose garden is also being established. The water used in the washing station is directed down into the rose garden.

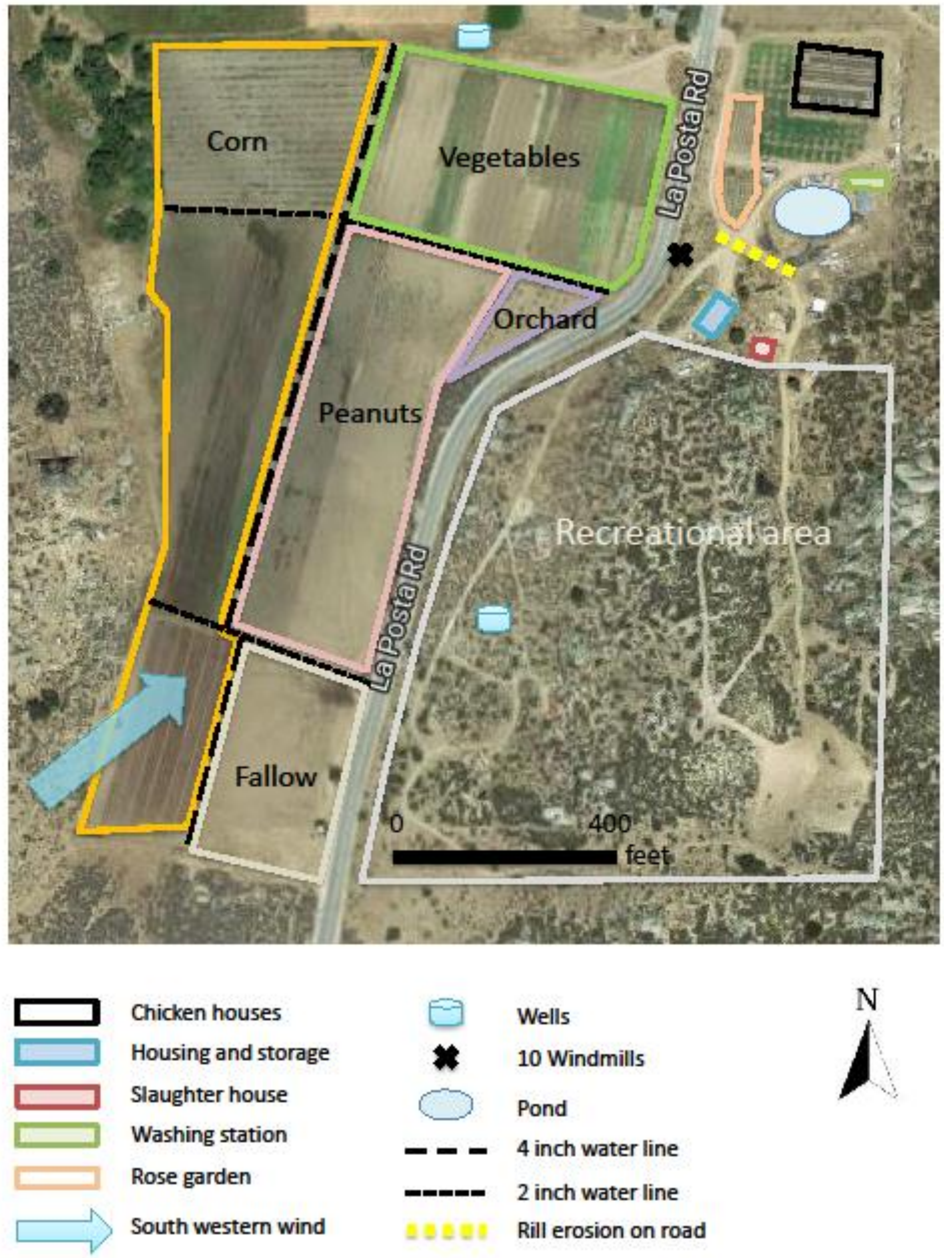

Figure 2, ***infrastructure elements on Angels Farm***

Figure 3 shows the aspect (the cardinal directions) of the slopes on the farm. Lighter colors represent north-facing slopes and darker colors are south-facing slopes. The black area is flat. The resolution is not quite detailed enough to give a good representation of such a small area. In the case of hills being used for production, this is an important feature to map.

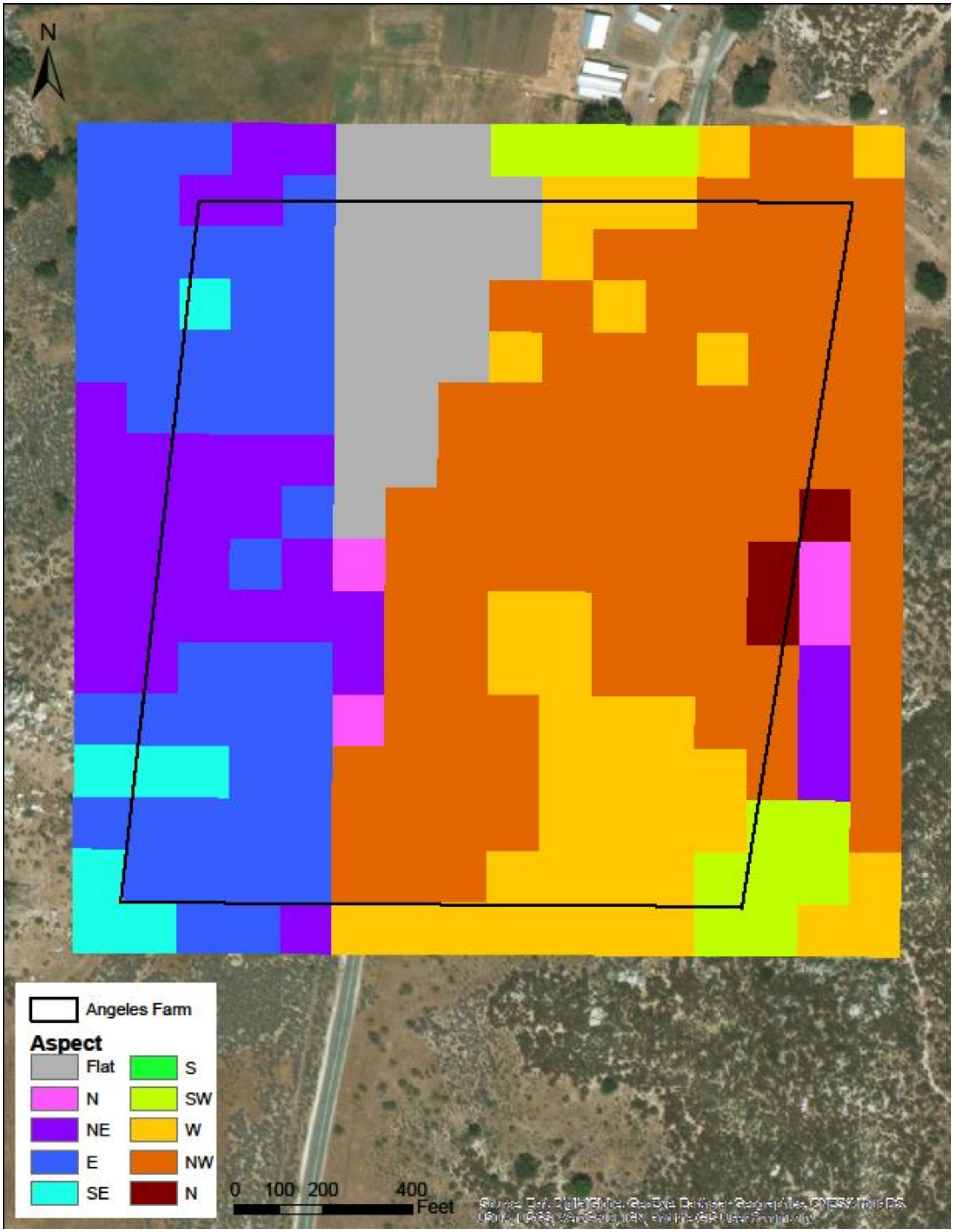

Figure 3, ***aspect – cardinal direction of slope***

Ecological sites

Ecological sites are areas determined by distinct geophysical characteristics, such as soil type, slope, and the orientation of the slope (aspect). Similar ecological sites are assumed to react similarly to the same management practice. Large farms may have a mosaic of different and reoccurring ecological sites. Grouping similar ecological sites thus gives an overview in the planning process. The farmed area of this property is small compared to the national average, but compared to the majority of farms in San Diego it is a representative size. The small size makes the planning process less complex. The farmed area is 18 acres, fairly flat and contains two different soil types. This area will be treated as one single ecological site though the different soil types will react slightly different to the different practices.

Soil description

Belinda Xu describes the western part of the field as having “better soil”, meaning that plants grow better in this area than the soil towards the road to the east. The soil in the eastern part of the field is described as more sandy. From a geochemical point of view, this description would imply that the soil in the western part of the field has properties like soil texture, soil structure and organic matter content that is more beneficial to plant growth.

On the farmed area, there are no signs of erosion. The land is covered from March to December and is mostly flat. This season, snow peas for chicken feed were planted early February where corn and peanuts will be planted in May.

In the map below, the dark area extending from the Loamy alluvial land soil type might be a result of the grassy area from previous management shown in Figure 1A. Table 1 lists the four soil types that are present on the farm.

Table 1*, soil type, slope range, symbol, acres and percent of area*

Soil type	Percent slope	Symbol	Acres	Percent of area
La Posta loamy course sand	5 – 30	LaE2	2.2	5.5
Loamy alluvial land	0 - 5	Lu	7.3	18.4
Mottsville loamy coarse sand	2 - 9	MvC	20.1	50.3
Tollhouse rocky course sand loamy	30 - 65	ToG	10.3	25.8

The two soil types, Loamy alluvial land and Mottsville loamy course sand, are mostly flat, the actual slope is not measures. Only an area of 18 acres is farmed containing the Loamy alluvial land (Lu) and Mottsville loamy coarse sand (Mvc) soil types.

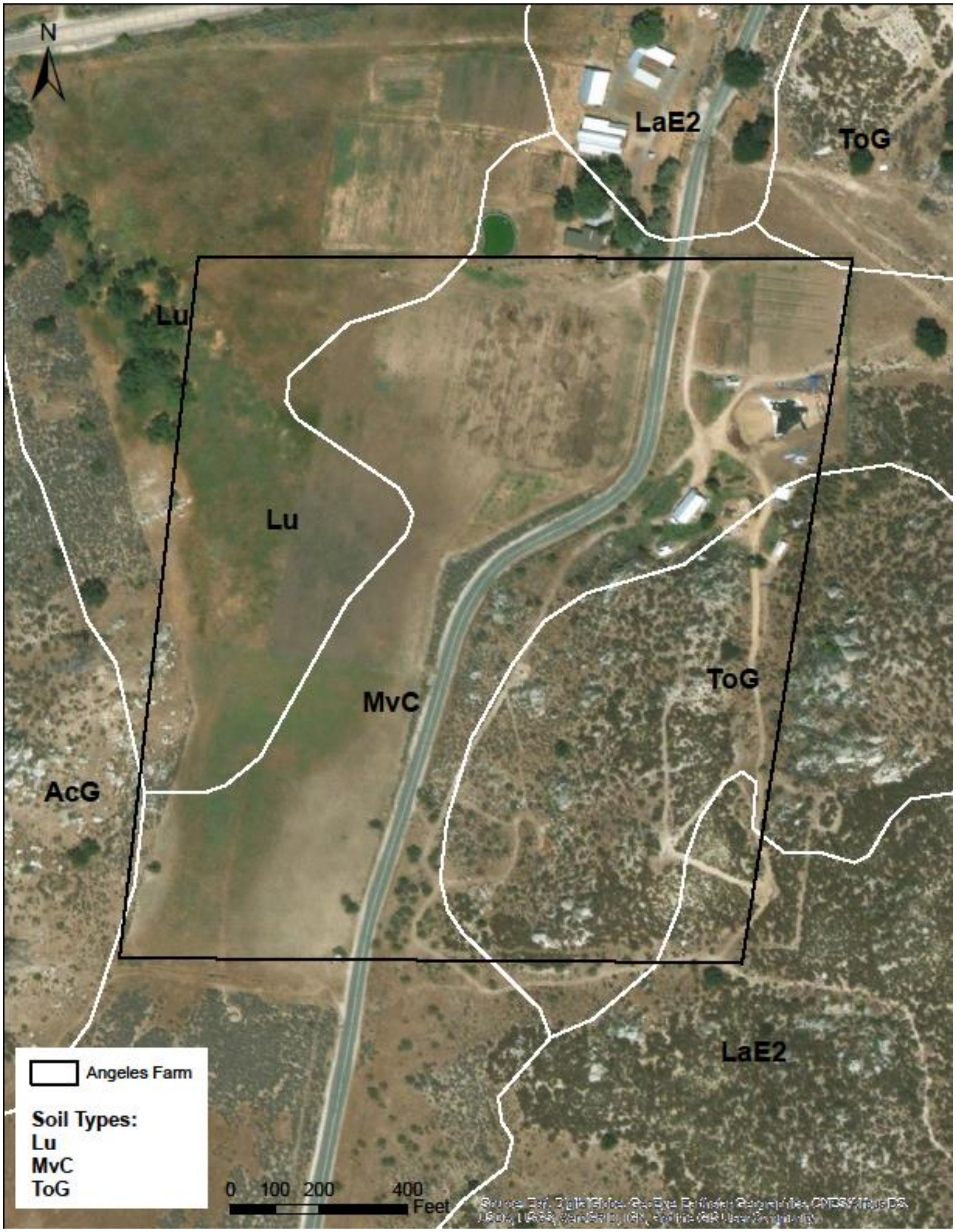

Figure 4, ***soil types of Angels Farm***

La Posta loamy course sand. A small area in the very southeast corner of the property contains this soil type. The La Posta series exist in mountainous upland and are somewhat excessively drained due to loamy coarse sand. The color of the A horizon ranges from grayish-brown to very dark grayish brown. The vegetation consists of chamise, ceanothus, sumac, scrub oak, red shank, and annual grasses. Fertility is low and permeability is rapid. Erosion risk is moderate with moderate rill and gully erosion. La Posta soils are used for watershed, wild life habitat and to a smaller degree for range. The water availability is 2 – 3 inches and rooting depth is 25 – 32 inches.

The soil types Kitchen Creek and Tollhouse often occur in the same mapping area. The latter is the case here (Bowman, 1973).

Loamy alluvial land (Lu). About a third of the farmed area contains this soil type; it is situated in the northwestern part of the property. This soil type was earlier referred to as "better soil" by the landowners. This land type occurs in mountainous areas and has slopes of 0 to 5 percent. The soil material is neutral to medium acid. According to soil samples taken on the property, the pH is neutral.

This soil type consists of very deep, dark brown to black silt loam and sandy loam. These areas were formerly wet meadows that were drained by head cutting of gullies. The water table was lowered by gullies that formed drainage ditches. Now the land is seldom saturated except in winter when there is a risk of overflow. Most of the water-tolerant vegetation has disappeared. The acreage is used mainly for pasture and range.

Fertility is medium to high. Because of a soil texture with small particle size, the permeability is moderate. The soil is described not to drain well. The rooting depth is 60 inches with available moisture from 6 – 9 inches. In many places the underlying material is stratified with lenses of silt loam to fine sand (Bowman, 1973).

This soil type is classified as prime agricultural land if irrigated and drained. In this case it is irrigated, but the field is not drained by ditches (USDA NRCS, 2018).

Mottsville loamy coarse sand. About two thirds of the farmed land contains this soil type. This series consists of excessively drained loamy coarse sand and is very deep. The sandy sediments have in some places formed from transported granitic rock. The vegetation is mainly California live oak, sage bushes, buckwheat, and annual grasses. It is mainly used for range (Bowman, 1973). This area corresponds to what the landowners describe as "more sandy soil".

The upper layer (0 – 17 cm) has a dark grayish color to very dark brown. Very fine roots and fine pores are situated in this layer. The percentage of fine gravel increases from 10 % to 20 %. The rooting depth is more than 60 inches, but very few coarser roots occur at that depth. The soil is slightly acidic. According to soil samples taken on the property, the pH is neutral (USDA NRCS, 2018).

It is often mapped together with Calpine, Bull Trail soils and La Posta soils. The latter is the case here. Native plants to this soil type are sagebrush, antelope bitterbrush, Anderson's peachbrush, and needlegrasses.

The available water holding capacity is 4 – 5 inches and the permeability is very rapid. Runoff is slow to moderate and the erosion risk is slight to moderate. There are no observations of erosion on the farmed area (Bowman, 1973).

This soil is categorized as farmland of statewide importance (USDA NRCS, 2018)

Tollhouse rocky course sand loamy (ToG). This soils type is found in mountainous areas and consists of excessively drained and shallow soil with coarse sandy loam. Due to the steepness the soil is only 5 – 20 inches deep. Rocky outcrop covers 10 % of the area and large boulders cover 20 – 25 % of the area. The surface layer is dark grayish brown, neutral to slightly acidic. The vegetation consists mainly of shrub oak, chamise, ceanothus, elm brush and annual grasses. These soils are often wild life habitat, recreational areas, watershed and to a limited degree used for range (Bowman, 1973).

Table 2, ***showing soil type, soil organic matter (SOM) and water content***

Key	Soil type	Percentage of area (%)	SOM (%)	Water Content (%)
LaE2	La Posta loamy course sand	5.5	1.71	7.6
Lu	Loamy alluvial land	18.4	2.0	15.7
MvC	Mottsville loamy coarse sand	50.3	1.18	6.5
ToG	Tollhouse rocky course sand loamy	25.8	1.5	7.8

Reference: NRCS, 2018b

Table 3, ***Soil testing report***

Soil type	SOM (%)	Cation Exchange Capacity
Loamy alluvial land	2.0	16.8
Mottsville loamy coarse sand	1.4	6.9

Reference: presented by Belinda Xu, 2018

The highest soil organic matter (SOM) is found in the Loamy Alluvial land series. The Mottsville loamy coarse sand has the lowest SOM content of the four soils. Soil test taken by Xu shows that where the Loamy alluvial land series is situated, the soil has a SOM content of 2.1 % and where the Mottsville loamy coarse sand is situated, the SOM is 1.4 %, which corresponds with numbers from Web Soil Survey (Table 2). Cation Exchange Capacities are 16.8 and 6.9, respectively. Phosphorus levels are very high in both Lu and MvC, Potassium is low in Lu, but high in MvC. There is no data on nitrogen levels. The pH is 7.1 in both soils.

The assumption that a higher SOM content gives a higher water holding capacity seems to be confirmed in this case. The Loamy alluvial land series has the highest water content and the Mottsville loamy coarse sand has the lowest water content. Higher water holding capacity is also likely due to the smaller particle size of the loam and clay. A contributing factor to a higher SOM in the Loamy alluvial land series may be the fact that in previous years there was permanent grass for grazing in the area. Permanent grass is one of the most efficient measures to increase SOM.

Pests and pollinators

Rabbits, ground squirrels and gophers represent the pest problem on the farm. During the planting season of 2017, rabbits ate all the peanuts.

As the farm has organic certification, no pesticides are used on the property. Ladybugs and frogs are used as biological pest control. Native bees (i.e. not from a known bee hive) and other pollinators are observed despite the winds. Insect pests have not been a problem; it is believed that the cold winter weather creates a low pest pressure.

Water

The primary well is placed on the north side of the property and pumps 160 gallons/min. The second well is located on the west side of the property and pumps 15 gallons/min. The smaller well is powered by the wind turbines.

The quality of the irrigation water is good according to the laboratory test that has been performed. The nitrate levels a slightly high, but beneficial for plant growth. This should be taken into consideration when fertilizing to avoid over-fertilization.

According to the Web Soil Survey, there is a clear difference between the two soil types when it comes to possibilities and limitations for irrigation. The MvC series has low SOM, a coarse soil texture and very limited potential for irrigation due to low water-holding capacity and seepage, while the Lu series is not limited.

Belinda Xu reports that 10,000 gallons of water was used on the hottest day of 2017. 10,000 gallons equals 0.37 acre-inches. Evapotranspiration on hottest day is estimated to 0.31 acre-inches (Anderson, 2018). Leaching of nutrients with irrigation water could potentially be problematic when watering rates are high and water-holding capacity is low.

Frost has been a problem for the water pipes, making them burst. Rodents have also punctured water pipes.

Ecology

Wildfire has not been a problem. The neighbor farm burnt recently, so defensible space is potentially needed.

The oak trees on the property are described as quite large and healthy. There is a rich wildlife in the area containing foxes, mountain lions, deer, rabbits, birds of prey and coyotes.

Current management

Angels Farm is selling their produce to four preschools, one of which Dr. Xu is employed.

Produce

A wide variety of vegetables are grown on 3 acres during the whole growing season (from March to December). This season snow peas were planted early in February to precede the corn and the peanuts. In the summer corn and peanuts are grown to source their own feed for the chicken operation.

Seeds and fertilizer are certified organic. Organic fertilizer from a certified CA organic group is used.

Animals

Approximately 1000 chickens (broilers and egg layers) are being kept on 1 acre of land in 4 structures. A slaughter facility is permitted on the property because they have fewer than 5000. Currently the manure, feathers and other slaughter waste is not composted but stored in an uncovered long term stockpiling. Fish were recently added to the pond.

Goals

Angels Farm is looking to increase water efficiency and to provide the main well pump with wind power or solar. The main goal is not to increase revenue from the production; both owners have off-farm income and are not dependent on income from the farm. A more efficient and profitable production is desirable, however. If the farm becomes more profitable and can produce more produce, they would like to lower the prices and provide fresh and healthy food for more children.

Angels Farm would like to (1) expand the farm enterprise by adding an element of agro-tourism and education. The owners are interested in teaching children about the cycle of nutrients and the way food can be produced in a non-industrial way. Adding goats and peacocks as an expansion of the agro tourism is also of interest. (2) Climate awareness such as carbon farming and other environmental issues is also a focus of the farming operation. As a beautifying aspect, the owners would like to (3) expand the rose garden at the base of the slope, on the east side of the road. The area on the hill (with soil type Tollhouse rocky sandy loam) is not of interest to develop for production. The area will continue to be a home for the local wildlife and an area of recreation.

In order to accommodate more people visiting the farm, the septic tank would need to be expanded. There is also a need for frost protection for the irrigation system. The irrigation is also subject to damage from rodents.

The owners would also like to (5) produce fruit, but have not had success with fruit trees in the past. This might have been because of the wind or the cold, or a combination of the two. About 200 orange trees died in 2016/17. Peaches and apples have also been attempted, but without success.

Potential carbon beneficial practices

The overall function of carbon beneficial practices is the fact that they have the potential to sequester carbon in the soil and therefore decrease the atmospheric levels of CO_2. From a planning perspective it is important to consider the co-benefits of carbon farming practices to give the farmer a more thorough understanding of how they can benefit the overall farm and production.

Listed in Table 4 are practices that are considered contributing to lowering the greenhouse gas (GHG) emissions, followed by a short description and how it affects the soil-, water-, plant-, biota-, and air resources. Not all practices affect all resources, and are left blank. Some measures will have a trade-off effect, for example cover crops may compete for moisture and will require watering for establishment, but will increase soil organic matter with its subsequent positive effects.

The main function of many of these practices is to decrease erosion, but since the farmed land is close to being completely flat, that is not the focus here. Wind erosion can be a problem, and all practices that increase soil cover; soil organic matter and soil structure will decrease this risk.

Table 4, C*o-benefits of carbon beneficial practices. The number in parenthesis in the first column corresponds to the code used by NRCS to identify a conservation practice.*

Practice (NRCS code)	Description	Benefits				
		Soil	Water	Plant	Biota	Air
Compost facility (317)	The facility will treat manure and slaughter waste into stable material		The nutrients are slowly released and are less susceptible to losses from runoff or leaching			Composting will increase CO_2 emissions but will reduce methane and N_2O emissions. Reduce odor.
Mulching (484)	Apply plant material to land surface	Reduce erosion from water and wind, adds organic matter	Increase soil moisture	Mulching material may improve growing conditions and may suppress undesired species	Increase biological activity, and cover, space and forage production for wildlife	Plant uptake reduce atmospheric CO_2 from the soil
Nutrient management (590)	Composted material with varying C:N ratio is applied on land surface	Increase organic matter, root biomass, improve soil structure	Increase water holding capacity	Increase plant production	Increase biological activity	Plant uptake reduce atmospheric CO_2
Nutrient management (590)	Replacing synthetic N fertilizer with composted chicken manure	Increase organic matter, soil structure	Excess nutrients are less soluble, decreased risk of leaching	Slow release of nutrients, more difficult to time nutrient management		Decreased CO_2 emission from manufacturing and transportation

Conservation cover (327)	Establish and maintain permanent vegetation cover	Increase soil cover, organic matter, root biomass, buffer salts, improve soil structure	Increased water usage by permanent vegetation. Increased infiltration	Increase plant cover slow noxious plant growth	Increased quality and quantity of vegetation provides more food for wildlife	Plant uptake reduce atmospheric CO_2
Cover crop (340)	Establish seasonal plant cover between main crops	Increase soil cover, organic matter, root biomass, buffer salts, improve soil structure	Cover crop may compete with main crop moisture. Increased water usage for establishing cover crop; increase water holding capacity over time	Can contribute to subsequent crop health and productivity, slow noxious plant growth	Increased quality and quantity of vegetation provides more food for wildlife	Plant uptake reduce atmospheric CO_2
Conservation crop rotation (328)	Decrease fallow frequency by growing crops in a planned sequence	Increase soil cover, organic matter, root biomass, and improve soil structure. Decrease wind erosion	Increased water usage by permanent vegetation. Increased water uptake and longer growing season reduce risk of nutrient leaching	Increased plant growth and vigor, can reduce pests and weeds by interrupting life cycle	Increase biological activity, and cover, space and forage production for wildlife and beneficial insects	Plant uptake reduce atmospheric CO_2
Firebreak 394	Adding a permanent or temporary strip of	Bare soil can increase wind erosion				Minimum reduction in particulate

	bare or vegetated land to retard fire					matter and CO_2 emissions due to decreased fire incidences
Hedgerow (422)	Establish a dense linear design of herbaceous and woody plants	Permanent vegetation increase organic matter	Shade and slower wind speed may decrease evaporation	May increase numbers of pollinators depending on species chosen	May protect crops from animal pests	Reduce atmospheric CO_2, store C in plants and soils
Residue and Tillage, no till (329)	Limiting soil disturbance to those necessary to place nutrients, condition residue and plant crops	Less oxidation of organic matter	No-till increases infiltration and decreases evaporation resulting in more available water.	Conserving moisture and improving soil conditions contribute to enhanced plant productivity and health	Crop residue provides some food for wildlife	Reduced use of machinery reduces CO_2 emissions and increases soil carbon storage

Reference: Richards and Caires (2017); NRCS (2018a)

There are other conservation practices that would be beneficial to the production, and I encourage the owners of Angels Farm to visit the NRCS website and look through the list of measures and explore the possibilities to learn about practices that potentially could benefit the farm and production. Some examples are listed below:

Water harvesting, to utilize rainwater (636)
Irrigation System Micro, for water efficiency (443)
Irrigation water system, for water efficiency and frost protection (449)
High tunnel System, to avoid wind (325)
Fencing, to limit animal pests (382)
Recreational area improvement, to facilitate ideas of agro tourism (562)
See reference list for URL.

Calculations of carbon sequestration

Table 5 shows all practices applicable to Angels Farm that relate to carbon farming. The online tool COMET–planner, which was used to make these calculations, dictates the combination of practices, and the way the practices are listed. Positive values indicate carbon sequestration and GHG emission reduction and negative values indicate loss of carbon or increased emission. All numbers have the same unit: CO_2 equivalents, to be able to compare different GHGs such as methane and nitrous oxide that have a higher global warming potential than CO_2.

All practices (except hedgerows) are applied to the total area of farmable land on the property, which is set to 18 acres. In a more detailed plan, some practices could be combined on different areas for practicality. This level of detail is not possible to achieve in the current plan. This table also serves as an overview for the landowner to see the effect of different practices, combination of practices and how it effects GHG emissions. Firebreaks are not listed as a carbon beneficial practice in COMET–farm, and will not be discussed further in this report. However there are practices to protect against fire that are more carbon beneficial than others as bare ground would be a source of carbon emission. Shaded fuel break (i.e. avoiding buildup of flammable biomass) can be implemented to capture additional carbon while also minimizing fine fuels as a risk factor for fueling wildfires.

The C:N ratio of compost is a measure of the content of carbon to nitrogen. Compost material with more brown or woody material will have a higher C:N ratio (more carbon) than a compost material with more easily degradable material.

Hedgerows are applied almost around the entire farmed area, except in the northeastern corner to not decrease the effect of the windmills. The hedgerow is 3405 feet long and 15 feet broad according to NRCS conservation practice standard. This gives 1.17 acres of hedgerow. Calculation of hedgerow acreage is done differently within the California Department of Food and Agriculture (CDFA) Healthy Soils Incentives Program. 3405 feet of hedgerows is calculated to result in 0.63 acres. This report follows NRCS conservation practice standards.

Table 5, ***potential carbon sequestration each year calculated by COMET–planner. All practices except hedgerows are applied on the total farmable area (18 acres). Hedgerows are applied on 1.17 acres. Negative values represent emission, and positive numbers represent sequestration***

NRCS conservation Practice	Carbon dioxide	Nitrous oxide (CO_2 E)	Total CO_2 – Equivalent
	Metric tons per year per area applied		
Conservation crop rotation (328) Decrease fallow frequency or add perennial crops to rotation	5	0	5
Cover crop (340) to irrigated crop land			
Legume	9	-4	5
Non-legume	5	-0.7	5
Mulching (484) – add mulch to cropland*	4	0	4
Nutrient management (590) Replace synthetic N fertilizer with:			
Chicken broiler manure on irrigated cropland	3	-0.7	2
Layer manure irrigated cropland	3	-0.7	2
Compost CN ratio 10	4	-0.6	3
Compost CN ratio 15	5	-0.4	5
Compost CN ratio 20	7	-0.3	7
Compost CN ratio 25	8	-0.1	8
Residue and tillage management (329) Reduced till to no-till on irrigated cropland	3	0.2	3
Residue and tillage management (329) Intensive till to no-till on irrigated cropland	4	0.1	4
Hedgerow (422) Replace a strip of cropland with 1 row of woody plants	10	0	10

*The CN ratio on the mulch applied in table 4 is not specified.

The practices with the highest amount of potential carbon sequestration are, hedgerow (10 tons CO_2 Equivalents per year) and replacement of synthetic fertilizer with compost with a high CN ratio (8 tons CO_2 Equivalents per year)**.** Table 6 shows the results from another online tool: Compost–planner, it only deals with compost application.

Table 6, ***potential carbon sequestration calculated by Compost – planner (2018)***

Compost application practice	Acres applied	CO_2	Nitrous oxide (tons CO_2 E)	Methane (tons CO_2E)	Total tons CO_2 Equivalent
		Metric tons per year			
Compost application to cropland C:N ratio < 11	18	41	-4	0.1	37
Compost application to cropland C:N ratio > 11	18	80	-3	0.2	77

An attempt was made to use the online tool COMET–farm (2018). Detailed data from the farm was entered and scenarios were calculated, but the results were inconclusive. The reasons for this will be discussed in the next section.

Discussion

Results from COMET–farm are not shown in this report, as they do not give any additional input to the planning process. The main reason for this is that the scenarios constructed in COMET–farm are largely inapplicable to small farming systems in California; it seems best suited to commodity-crop/annual crop-based agriculture (Creque, 2018). Although, the results did lead to the realization that the previous grass management produces long-term effects when the management is changed to annual crops. Growing corn several years in a row after perennial grass management would result in net emission of GHG until a new degraded equilibrium is reached. At this point "improved" practices like cover crops and composting would again create reduced amounts of GHG emission and increased carbon sequestration.

Results shown in table 4 and 5 are not comparable due to how the scenarios are calculated. It is not clear whether the addition of compost in Compost–planner replaces synthetic fertilizer and it only divides the compost material into two categories: C:N ratio under or over 11, whereas COMET–planner calculates the use of compost with a wider variety of C:N ratios.

In the opinion of Jeffrey Creque (2018), the Compost–planner tool is not yet reliable because the underlying modeling is still too unsophisticated. Though it is interesting to see the significant difference from applying compost with a C:N ratio under or over 11.

The COMET–planner, on the other hand, utilizes relevant and well-established practices, though the model is conservative and tends to underestimate the carbon benefit of the various practices. The tool allows calculations of the benefits of a single conservation practices, and the combination of selected practices to facilitate quantification of GHG benefits in a comprehensive analysis. The model does not take into account the accumulative GHG benefits of combining several practices in a broad whole-farm or landscape plan.

Challenges of implementation

- **Cost**: equipment, labor, cover crop seeds, hedgerow plants, watering for establishment of plants and seeds
- **Sourcing**: where to get compost in satisfactory quality
- **Know-how/advisory service**: how to choose the optimal and most suitable species for cover crops and hedgerow.
- **Practicality**: how can the compost be spread? Are there appliances to hitch a John Deer? Where can farmers find machinery for no-till seed drilling?

The practical implementation of the practices and the final choice of practices will be further discussed with the farmer.

Cost is a significant inhibitor for farmers to implement conservation practices. Labor is related to cost and is also a challenge. Sourcing of material, equipment and choice of species are issues related to available advisory service in San Diego County.

An important distinction must be made between chicken manure that has been composted or chicken manure that is applied to land untreated. Table 4 contains *untreated* chicken manure as a replacement of synthetic fertilizer. Treated (i.e. composted) manure is preferable as it reduces overall GHG emissions. If funding for composting is to come from CDFA Healthy Soils Program, it dictates that compost must come from a certified facility, thus on-farm compost cannot be utilized.

Furthermore if cover crops are already established, it voids the possibility for CDFA grant for this practice. In this case snow peas was established this January/February 2018, the question is whether this crop will be harvested at maturity or plowed down at flowering. In case it is harvested for peas it should not be defined as a cover crop. Belinda Xu reports that if the crop succeeds, the peas will be harvested for chicken feed.

Recommendations

The following recommendations are based on choosing the practices that have the highest amount of potential carbon sequestration in combination with the owner's goals and how the practices can benefits the production. A professional evaluation of the land by the authors of this report, with input from Jeffrey Creque (Carbon Cycle Institute) and Lance Anderson (Mission Resource Conservation District) has also contributed to these recommendations.

This relatively newly established farm has a lot of potential and there are several opportunities to expand the enterprise. The farm has not utilized the whole area of farmable land and there are many opportunities to increase soil fertility and water efficiency. Landscape elements also facilitate possibilities to expand the farm enterprise with elements of agro-tourism.

Figure 7 shows an overview of the recommended practices. A combination of compost application, a legume cover crop and hedgerow is chosen as three complimentary practices. The hedgerow will slow down wind speed; cover crops and compost will increase the input of organic matter and prevent wind erosion. Decreased wind speed will decrease evaporation of irrigation water and increased soil organic matter will keep the water longer in the root zone. This is especially important in the sandy soil (on the MvC soil type). An additional co-benefit of hedgerows is increased pollinators if the appropriate species are chosen.

No-till is not chosen as a practice both because it has a lower carbon sequestration potential than other measures, but also because it would require specialty equipment like a no-till seed drill. Though specialty equipment is also necessary to spread compost on a larger area, reasonably priced attachments for tractors are available.

Compost application and a high N-fixing capacity legume that is not harvested, but is incorporated at blooming can reduce or eliminate the need for synthetic fertilizer.

Compost with the highest C:N ratio is not chosen because of a slow release of nutrients compared to materials with a lower C:N ratio. The release of nutrients from compost can be difficult to time to plant requirements. A C:N ratio of 25 increases the risk of nitrogen immobilization: the mechanism of microorganisms competing with plant available nitrogen in order to break down long chains of carbon molecules in the compost (Brady & Wail, 2010).

Table 7, ***the recommended carbon beneficial farming practices***

Conservation practice	**Code**	**Applied acre**	**Sequestration for applied area, per year (tons CO_2 E)**	**Tons CO_2 E per acre per decade***
Compost application, CN 15 - 20	590	18	5 - 7	2.8 – 3.9
Hedgerow	422	1.17	10	85.5
Legume cover crop	340	18	5	2.8
Total			20 - 25	91.1 – 92.2

**CO_2 Equivalent from table 4 is divided by applied acreage and multiplied by 10*

Hedgerows are by far the measure that sequesters the most carbon per acre because the practice entails perennial woody plants. Furthermore compost should be applied annually, and will have an accumulative effect over several years (Batra, personal comment). As mentioned in the previous section, the combination of several practices will likely have an accumulated effect that is not represented in the calculations made by COMET–planner.

As such, Angels Farm has the potential to sequester 20 – 25 tons CO_2 E per year, according to calculations in COMET-planner. According to Compost-planner this number would be 92 tons CO_2 E per year. Over ten years the 18 acres of the farm has the potential to sequester 200 – 250 CO_2 E, or 91.1 – 92.2 CO_2 per acre per decade.

Additional recommendations for management changes include relocating the vegetable field from the coarse sandy soil (MvC soil type) in the eastern part of the field to the more loamy soil (Lu soil type) in the west. It is evaluated that the sandy soil has a very rapid infiltration rate that contributes to an excess need of watering. The loamy soil has a slower infiltration rate that will keep the water longer in the root zone of the plant.

Also shown in Figure 4 is the location of a composting facility. Chicken manure and slaughter waste can be composted, a great resource, and is much better utilized on the farm than going to waste. According to one method, it requires a cheap and plentiful source of wood chips or other carbon source to layer or mix in approximately equal quantities with the high nitrogen manure and slaughter waste. If moisture is maintained, compost can be produced in about 3 months if piles are turned, or 6 months if managed as static piles. To conform with National Organic program standards for composting of manure, temperatures must be maintained at or above 131˚F for at least 15 days, with a minimum of 5 turnings during this pathogen reduction phase. Daily temperature records must be kept during this period as well. If turning is not desired or not possible, a static pile process can be used. However, the finished compost should be treated as manure under the Organic Standard, and applied at least 120 days prior to harvest. Alternatively, it can be applied to non-food crops (e.g. cover crops) (Creque, 2018). If a 6 month static pile system is chosen, the process is not very labor intensive, but because the process is slow, it is necessary to expand the facility when new static piles needs to be added.

On site composting of farm waste is highly recommended from both a carbon sequestration perspective and a resource conservation perspective. This practice may be implemented on a longer timeline if funding from CDFA Healthy Soils Program is pursued because of the before mentioned restrictions (see top of page 19). The funding period for CDFA Healthy Soils Program is three years, so these three years might be a good timeline for implementing the on-farm utilization of chicken manure and slaughter waste with funding and technical assistance from NRCS (practice code 317). In this way, compost application practice can continuo after the CDFA funding period has ended using an on-farm resource.

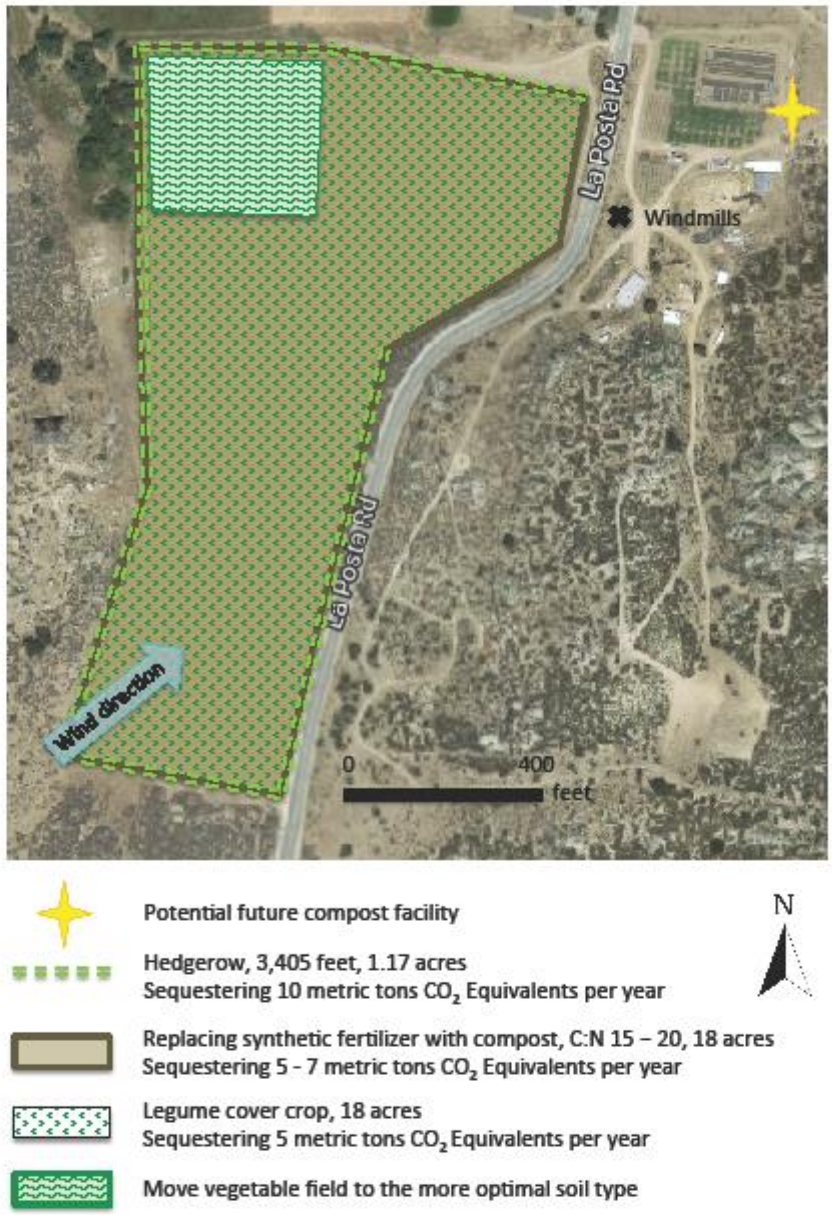

Figure 4, ***Suggested carbon farming practices and other beneficial practices***

Funding opportunities

The challenge of advisory service, sourcing material, equipment and costs all relate to the possibilities and obstacle of applying for funding.

The following are funding opportunities that may be further investigated:

- CDFA Healthy Soils Program Incentives Program: "*Provides financial incentives to California growers and ranchers to implement conservation management practices that sequester carbon, reduce atmospheric greenhouse gases (GHGs), and improve soil health*". https://www.cdfa.ca.gov/oefi/healthysoils/IncentivesProgram.html
- NRCS Environmental Quality Incentives Program (EQIP): "*Provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality conserve ground and surface water, reduce soil erosion and sedimentation or improve or create wild life habitat*". https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Future planning and recordkeeping

It is our hope that this document will be useful in many aspects of the future planning of the farming enterprise.

Recordkeeping is always a useful tool to keep track of development and results of changed practices. Because the implementation of carbon farming planning is in its infancy in San Diego County, it would also be helpful for the RCD to gather information from one of the first Carbon Farming Plan implemented in San Diego County.

Implementation of the chosen practices, operation and maintenance of selected management practices depends on available funding.

Implementation plan

Table 8, ***Carbon Beneficial Practices Implementation Record, see Figure 4***

Conservation Practices	**Co_2 E Benefit**	**Associated Co-Benefits**							**Date**	**Funding Source**
NRCS Conservation Practice Standard & Code	**Calculated Using: COMET-Planner**	Soil Health	Water Quality	Water Quantity	Wildlife Enhancement	Plant Community	Air Quality	Producer Economics	**Planned, Implemented, Completed**	
Legume cover crop (340)	5	x	x	x	x	x			Completed 2018 Established August – December 2018 depending on crop rotation	USDA
Compost application (590)	5 – 7	x	x	x	x	x			Completed August 2018 – March 2019 depending on crop rotation	USDA
Hedgerow (422)	10	x	x	x	x	x	x		Completed 2019 Beginning preparations August 2018	USDA
Composting facility (317)							x	x	Completed 2022 Planning preparations January 2020	NRCS
Change location of vegetable field				x		x		x	Completed 2019	Angels Farm

Table 8 shows the implementation plan for Angels Farm. It also suggests what the associated benefits of the measures are. The co-benefits for a variety of practices are listed in Table 4. Specific associated benefits of the selected practices are elaborated below.

Compost application:

Increased biomass input and SOM improves soil structure, it makes the soil more resilient to soil compaction and soil erosion. Improved soil structure and SOM content increases water-holding capacity, which reduces the risk of nutrients leaching into ground water. Decreased need for irrigation water would benefit the overall water quantity and availability. Wildlife benefits from increased above ground biomass and increases in the macro and microorganism diversity. Quality and quantity of plant growth also benefits from compost application. Decomposing compost delivers nutrients for growing plants and decreases the need for synthetic fertilizer. Decreased water bill would be at great economic benefit for the producer, though implementation will be an initial expense to the farmer.

Legume cover crop:

A cover crop has many of the same benefits as compost application as it increases SOM and above ground biomass. A legume cover crop also inputs nitrogen to the soil, which decreases the need synthetic fertilizer. Quality and quantity of plant growth benefits from legume cover crops. Implementation will be an initial expense to the farmer.

Hedgerow:

A hedgerow equally has many of the same benefits as compost application as it increases SOM and above ground biomass. Its main function however is to create a wind brake that decreases evaporation of soil moisture and wind erosion as a result of decreased wind speed. A hedgerow with flowering species will benefit the quality and quantity of plant growth. Air quality will be benefited by decreased dust created by wind soil erosion. Increased soil cover will also alleviate this by the above-mentioned practices. Implementation will also be an initial expense to the farmer, but it will contribute to saving water use.

Compost facility:

Composting manure and slaughter waste will decrease smell and thus improve air quality. Implementation will be an initial expense to the farmer, but will alleviate the need to buy off-farm compost and decrease the need for synthetic fertilizer.

Changing the location of the vegetable field

By moving the vegetable field to the more optimal soil type, the yield and water use efficiency will increase. This will have a positive effect on the producer economy.

Common for all these practices is that they reduce both the production of GHGs and decrease the atmospheric levels of GHGs by storing it in biomass. These practices thereby participate in climate change mitigation.

Operation and maintenance of selected management practices

Planning and implementation of the selected practices rely on the crops and farm practices already adopted by the farm.

Compost application and cover crop implementation:

Certified organic compost will be purchased and an attachment for the tractor will be acquired to spread the compost. Compost application on the corn and peanut fields will either be applied after harvest, before the cover crop is being planted, or in the spring after the cover crop is being incorporated. Establishing the cover crop in early fall will require more watering, and will require a species mix with a long growing season that will not go to seed.

In the vegetable field, the cover crop will be established in the winter after the last vegetables are harvested. The cover crop on this field will have a much shorter growing season and species will be chosen accordingly. The same principal for the compost application applies as mentioned in the previous paragraph.

Cover crops and compost application maintenance:

Compost (5 dry tons per acre) will be applied every year and a legume cover crop will be planted every year. The species mix might change according to feasibility.

Hedgerow implementation:

An assessment of weed pressure in the areas where the hedgerow will be established will be made as soon as possible. If the weed pressure is high, then appropriate measures will be taken to address this issue. The level of weed pressure and measures needed will determine when the hedgerow is to be planted. Native perennial and annual forbs, flowering bushes and trees will be chosen. There will be put in a watering system for the period needed to establish the hedgerow.

Hedgerow maintenance:

The progress of the hedgerow will be closely monitored. Weeds will be managed according to the strategy chosen. Mulch could be necessary if spraying is not an option. Dead plants will be replaced as necessary.

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