Gilardi Family Farm

CARBON FARM PLAN

2017

Prepared by the Marin Carbon Project

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INTRODUCTION

In response to the rapid pace of global climate change, the Marin Carbon Project (MCP) is working to engage agricultural producers as ecosystem stewards to provide on-farm ecological benefits, improve agricultural productivity, enhance agroecosystem resilience, and mitigate global climate change through a planning and implementation process known as "Carbon Farming." MCP's goal is to develop a county-wide agricultural carbon sequestration program, with producer outreach and technical and economic support, to both help Marin County meet, or exceed, its greenhouse gas (GHG) reduction goals under the Marin County Climate Action Plan (CAP) and serve as a model for other regions in California, the western US, and the nation.

Largely taken for granted, carbon has been absent from discussion of elements essential to agriculture and the management of working lands; yet carbon is the basis for all agricultural production. Carbon enters the farm system from the atmosphere through the process of plant photosynthesis, which uses the energy of sunlight to capture carbon dioxide (CO_2) from the air and combine it with water and nutrients from the soil to produce the products of agriculture. In addition to food, fiber, fuel and flora, photosynthates (sugars) produced by the crop are moved to the soil: directly as exudates from plant roots; indirectly through plant roots to beneficial soil mycorrhizal fungi; via the sloughing of plant parts such as leaves and roots, and through deposition on the soil surface of aboveground plant parts and the bodies and manures of animals.

In addition to its transformation from CO_2 into the sugars, cellulose and lignin of the harvestable crop, carbon can also be beneficially stored long-term (decades to centuries or more) in soils and woody vegetation in a process known as terrestrial carbon sequestration. While the importance of carbon to soil health and fertility has long been understood, its significance has begun to be increasingly recognized in recent years. Today, managing for increased soil organic matter (SOM), which is about 50% carbon, is the core of the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) healthy soils program and the California Department of Food and Agriculture's 2015 Healthy Soils Initiative.

While Carbon Farm Planning includes identifying opportunities to decrease the production of GHG on farm whenever possible, Carbon Farming involves implementing on-farm practices that increase the rate of photosynthetically-driven transfer of CO_2 from the atmosphere to plant productivity and/or SOM. Enhancing working land carbon, whether in plants or soils, results in beneficial changes in a wide array of system attributes, including; soil water holding capacity and hydrological function, biodiversity, soil fertility, and resilience to drought and flood, along with increasing agricultural productivity. Increasing carbon capture on working lands also helps to slow rising levels of carbon dioxide and other GHG in the atmosphere, currently contributing to climate destabilization and unpredictability through global warming.

CARBON FARMING

Technically, ***all*** farming is "carbon farming," because all agricultural production depends on plant photosynthesis to move CO2 out of the atmosphere and into the plant, where it is transformed into agricultural products, whether 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 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 woody or herbaceous vegetation such as windbreaks, vegetated filter strips, or riparian systems, forests and woodlands.

While all farming is completely dependent upon atmospheric CO2 in order to produce its products, 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 working farm or 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, particularly from working land soils, 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 or Farm, including soil organic matter (SOM), perennial plant roots and standing woody biomass, carbon farming results in a direct reduction in the amount of CO2 in the atmosphere, while supporting crop production and farm resilience to environmental stress, including flood and drought.

On-farm carbon in all its form 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 plant to synthesize carbohydrates from atmospheric CO2 and water and nutrients from the soil. 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****).***

CFP is based upon the USDA NRCS Conservation Planning process, ***but uses carbon and carbon capture as the organizing principle around which the Farm or Farm 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 agricultural productivity.

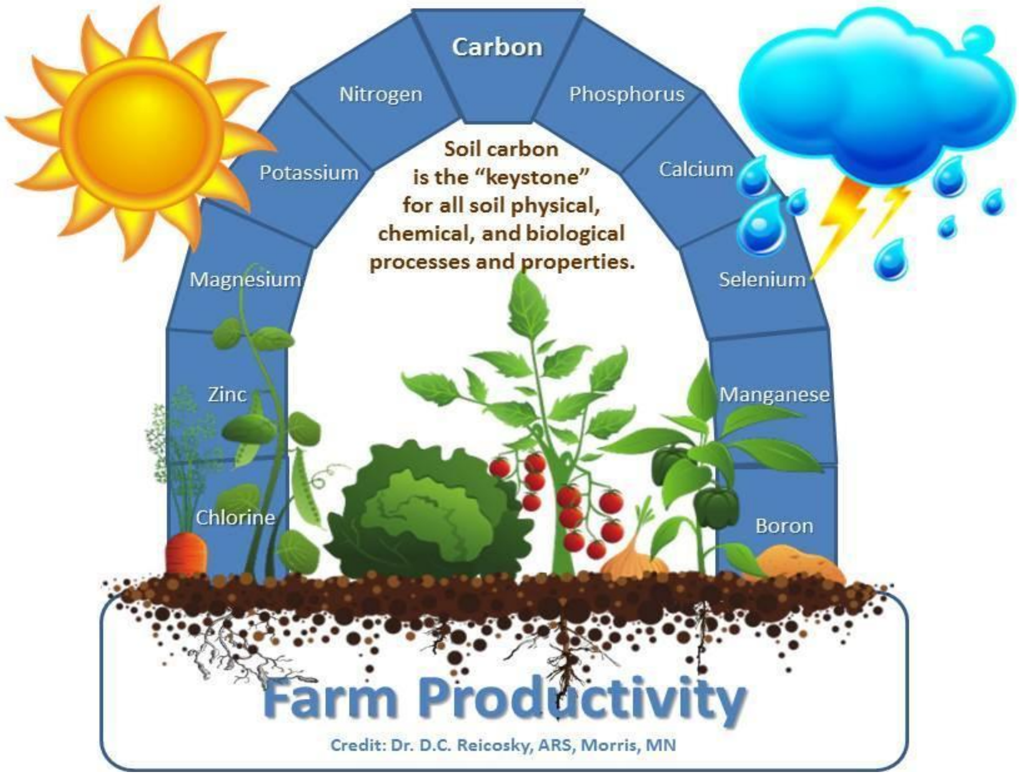

Figure 1. Carbon as the Keystone element to Working Land Productivity and Resilience

THE CARBON FARM PLANNING PROCESS

Increasing on-farm carbon capture as biomass and, most importantly, soil carbon, is the resource concern of overriding importance for the CFP process. Like NRCS Conservation Planning, CFP begins with an overall inventory of natural resource conditions on the farm or Farm, but with a focus on identification of opportunities for reduction of GHG emissions and enhanced carbon capture and storage by both plants and soils. Building this list of opportunities is a brainstorming process; it should be as extensive as possible, including everything the farmer and planners can think of that could potentially reduce emissions and capture and sequester carbon on the farm. While actions proposed in the Plan should reflect the inherent limits of the farm ecosystem, financial considerations should not limit this initial brainstorming process, as one goal of the CFP process is to identify potential funding, above and beyond existing resources, to realize implementation of the Plan.

During this process, a map, or maps, of the Farm is/are developed, showing existing Farm infrastructure and natural resource conditions. These maps can be used to locate potential carbon capture practices on the Farm and to envision how the Farm may be expected to look years down the road, following plan implementation. Next, the carbon benefits of each practice, as potentially applied at the farm scale, are quantified using the on-line USDA GHG model, COMET-Farm **cometfarm.nrel.colostate.edu**), COMET-Planner I and II, (**comet-planner.com**), or similar tools and data sources, to estimate tons of carbon dioxide equivalent (CO2e) that would be 1) avoided or 2) removed from the atmosphere and sequestered on farm by implementing each practice. A list of potential practices and their on-farm and climate mitigation benefits is then developed.

Finally, practices are prioritized based on needs and goals of the farm or Farm, choosing high carbon-benefit practices, NRCS conservation standard practices (CPS), wherever possible. Economic considerations may be used to filter the comprehensive list of options, and funding mechanisms are identified, including; cap and trade, CEQA, or other GHG mitigation offset credits, USDA-NRCS and other state and federal programs, and private funding. Projects are implemented as funding, technical assistance and farm scheduling allow. Over time, the CFP is evaluated, updated, and altered as needed to meet changing farm objectives and implementation opportunities, using the fully implemented plan scenario as a goal or point of reference. Where plan implementation is linked to carbon markets or other ecosystem service markets, periodic Plan evaluation may be tied to those verification or monitoring schedules.

Additional information about Carbon Farming can be found on line at: www.marincarbonproject.org and www.carboncycle.org.

GILARDI FAMILY FARM

In the winter of 2016, Gilardi Family Farm sought assistance from the Marin Resource Conservation District (Marin RCD) to develop a CFP. As a participant in the Carbon Farm Planning Program, the Farm has agreed to an ongoing partnership with the Marin Carbon Project through the Carbon Farm Planning Process and beyond, focusing on the potential to implement a CFP for the 80-acre Farm.

BACKGROUND

Gilardi Family Farm consists of just over 80 acres, located in Northeastern Marin County, California. The climate on the Farm is typical of the region, with rainfall occurring between October and May. The average annual precipitation is 26.58 inches. Summers are dry, moderated by frequent marine fog. The average annual temperature is 39 to 57 degrees F. The frost-free period averages 300 days.

WILDLIFE

Major wildlife species in the area include white tail deer, coyote, American badger, bobcat, jackrabbit, cottontail, and quail. Fish in San Antonio Creek include steelhead trout, shiners, and suckers. Migratory species include bald eagle, golden eagle, red-winged blackbird, Canada goose, mallard, Great blue heron, common Egret and many other resident bird species. There is some historical evidence suggesting Beaver (*Castor Canadensis*) occupied San Antonio Creek prior to Euroamerican settlement (Lundquist and Dolman 2016).

HYDROLOGY

The San Antonio Creek watershed encompasses 36.5 square miles, constituting approximately 24% of the Petaluma River watershed (Figure 2, Marin County Watershed Program website: http://www.marinwatersheds.org/san_antonio_creek.html). The largest sub-watershed of the Petaluma River, it extends from Antonio Mountain and Chileno Valley in the northwest to Petaluma Marsh and the Petaluma River to the southeast.

Historical changes to the watershed included the draining of a shallow lake at the headwaters of the creek for agricultural uses sometime between 1860 and 1885. This has probably increased the magnitude and frequency of peak flows while lowering the water table in the Chileno Valley. This is likely to have accelerated erosion and bank incision, leading to a lowering of the water table throughout the San Antonio Creek watershed because most of the tributaries are deeply entrenched (Collins 2000). The creek, which forms a portion of the border between Sonoma and Marin Counties, today flows only seasonally, yet historically was a perennial stream, at least in its lower reaches, and perhaps for much of its length. Historical accounts indicate that San Antonio Creek hosted a significant steelhead fishery.

The tidal channel of San Antonio Creek was diverted from its natural slough through the much smaller and shorter Schultz Slough around 1930, if not much earlier, by the Northwestern Pacific Railroad grade (track of today's "Smart Train"), significantly reducing access to the watershed by salmonid species, though sightings of fish were common until the mid-1950s (Collins, 2000). This change has also flattened the gradient of the stream and contributed to aggradation in its lower reaches. The extent of maximum tidal influence has moved nearly a mile downstream in the historic period (Collins, 2000).

Relative to pre-European settlement conditions, sediment production in the watershed has greatly increased, the base flow of the creek has been greatly reduced, and peak flows have also increased (San Francisco Estuary Institute). San Antonio Creek has been identified as 'impaired' (EPA 303d listing), with sediment the major impairment affecting stream capacity within the creek and adjacent tidal areas (SSCRCD 2008) (http://sonomarcd.org/documents/San-Antonio-Creek-Plan.pdf). Water quality data collected by the California Department of Fish and Game (CDFG) indicates high levels of ammonia and conductivity (an indicator of animal waste and a measure of salts in freshwater, respectively). CDFG (now CDFW)) has reported in the past that ammonia levels are high year-round (Collins, 2000). Summer water measurements typically include temperatures ranging from 22 to 26 degrees Celsius – much higher than is optimal for steelhead (SSRCD 2008). Restoring riparian vegetation is the key to lowering San Antonio Creek's water temperature and reducing toxic levels of ammonia. Historically, streamside vegetation was probably a continuous, dense forest of large riparian trees. Today the riparian corridor has thinned out in many areas, exhibiting sparse and open canopy cover and some areas converted to annual grassland with no woody canopy.

Although not currently identified as 'impaired' for nutrients, San Antonio Creek has been identified as exceeding wet season water quality objectives for nutrients, including nitrogen and phosphorus (Table 1). This suggests the value of nutrient management planning in conjunction with implementation of the Gilardi Family Farm Carbon Plan.

Table 1. Wet Season Nutrient Concentrations, San Antonio Creek, 1999-2001
Samples that exceed water quality objectives (in parentheses of column headers) are indicated by bold text. (Source: SFRWQCB 2010).

Station Number	Location	Temperature (22°C)	Nitrate as N (0.16 mg/L)	Nitrite as N (mg/L)	N, Total Kjeldahl (mg/L)	Total N (0.5 mg/L)	Ortho - Phosphate as P (mg/L)	Total P (0.03 mg/L)
PET010	San Antonio Creek	9.7	1.71	0.054	1.32	2.31	0.51	0.612

BEAVER, WATER AND CARBON

One significant factor in the drying of the West (Taylor 2015) has been the virtual eradication of the region's native hydrological engineer—the beaver. Loss of the beaver from most of its former habitat in the Western US is associated with initiation of an "epicycle of erosion" (Leopold 1976) throughout the region, as beaver dams decayed and washed away, wet beaver meadows were incised and subjected to drying and soil loss, and as watersheds responded to the resulting changes in hydrology with flashier flood events, increased erosion and less water retention (Smith 1940).

Today, beaver are increasingly recognized as a "keystone species;" ecosystem engineers that play a critical role in watershed dynamics where they are present, including benefiting fish populations. Beaver ponds can replenish aquifers, allowing groundwater to recharge streams and meadows in dry summers, and providing perennial pools for over-summering trout smolt. Fish abundance and size have been found to increase when beaver are present (Rosell et al 2005, Pollock et al 2003, Collen and Gibson 2001).

In the context of carbon farm planning, beaver can have a significant positive impact on soil carbon within their zone of influence, both through enhanced production associated with increased soil water adjacent to beaver impoundments and through increased allocation of woody biomass to the soil at the beaver-constructed wetland interface (Rosell et all 2005). While beaver probably did occur historically in San Antonio Creek watershed, immediate opportunities for enhancing beaver habitat on Gilardi Family Farm are limited to establishing beaver forage species, such as willow, alder and cottonwood, within the Farm riparian areas.

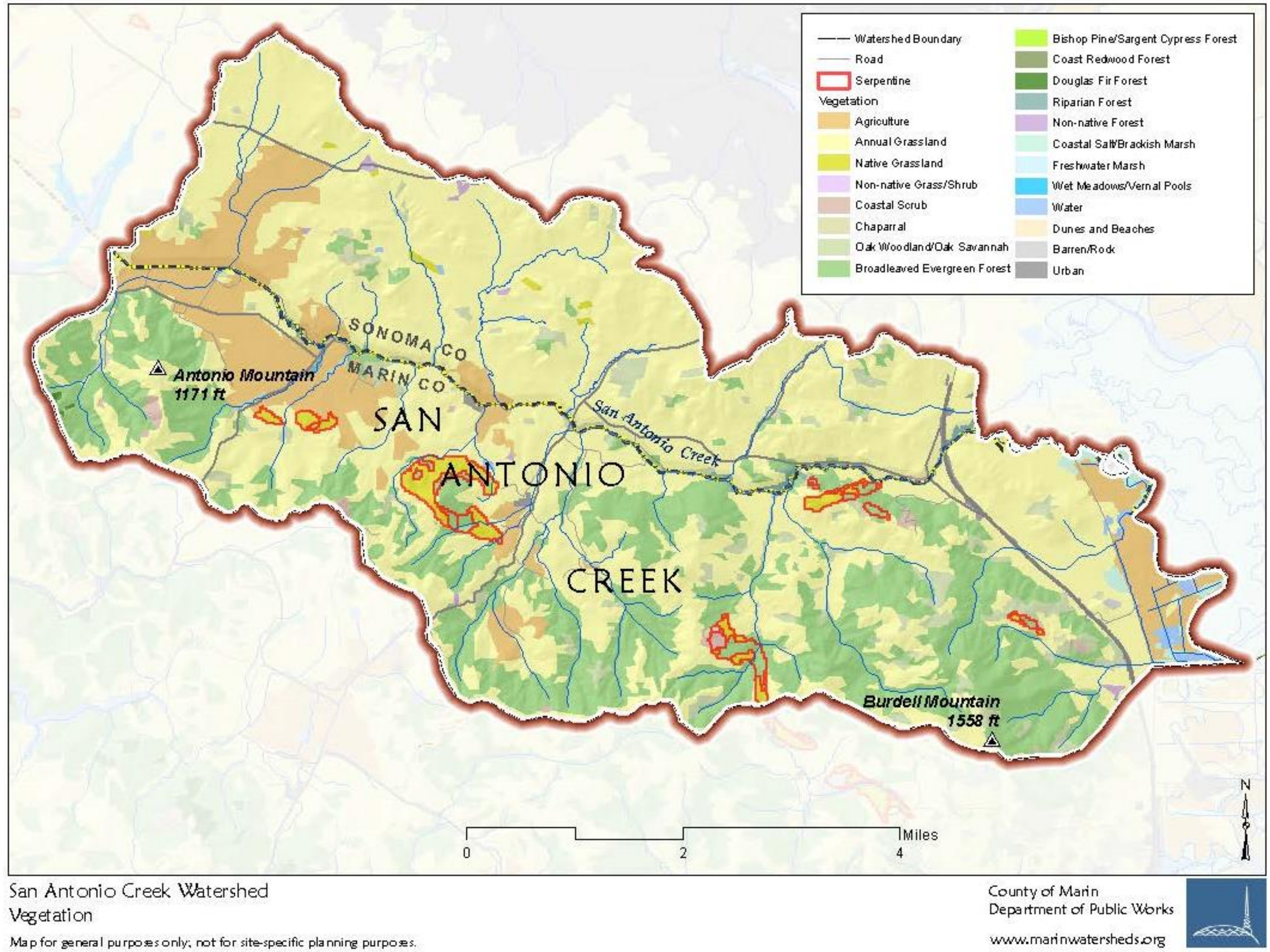

Figure 2. San Antonio Creek Watershed Map that displays the watershed boundary and a mosaic of the vegetation distribution.

HISTORY OF GILARDI FAMILY FARM

Archaeological evidence suggests occupation of the Gilardi Family Farm landscape, on at least a seasonal basis, for approximately 8,000 years (http://www.olompali.org/About-TOP.html). The Ranch itself was founded in the late 1800s. Don Gilardi provided the following information:

The Gilardi farm has been in the family since 1932; today it is a 4th generation family farm/ranch. The farm operated primarily as a dairy for approximately 50 years. Upon closure of the dairy, the family began leasing portions of the property for grazing beef through 1998-2007. In 2000, Redhill Farms was established and began utilizing the land for raising sheep, transitioning to a Certified Organic Pasture-based, Year Round Sheep Operation in 2001.

Until 2005, Redhill Farms raised 150-600 Dorset, Suffix, and Friesen sheep. The sheep were sheared in June, with the wool sent to Yolo Wool Mill, Woodland CA, and returned as yarn, batting, and roving. Sheep were also used for targeted grazing to provide fire protection, grass management and fertilization.

In 2005, Redhill Farms entered into the chicken business, eventually phasing out all the sheep and becoming primarily a chicken ranch, producing organic, pasture-raised eggs, until In 2012 the Redhill Farms label was sold and Gilardi Family Farm was established.

CURRENT LAND USE

Gilardi Family Farms currently raises some 5,500 birds, on 80 acres. Eggs are USDA-certified organic, and pasture-raised, and sold to Bay Area independent grocers under the brand 'Petaluma Pastures.' In addition to the Farm's free-range egg production enterprise, it is also home to a small herd of Jersey cows. Un-irrigated pastures, grazed by both cows and chickens, make up nearly 75% of the Farm.

GILARDI FAMILY FARM GOALS & OBJECTIVES

Through the development of this CFP, the landowner identified Farm goals and objectives. Through implementation of the grazing plan and associated conservation practices, many of the goals and objectives will be reached. A monitoring plan has been developed to track progress toward meeting the goals and objectives. The monitoring plan is described later in the document.

The following is a list of goals and objectives:

- Keep the Farm within the Family.
- Continue learning and improving land management practices.
- Integrate trees into the pasture system for shade and forage.
- Increase biodiversity on the Farm, including plant and animal diversity
- Enhance the existing compost operation.
- Maintain or improve carbon sequestration by:
    - Increasing plant growth (roots and shoots)
    - Increase living ground cover and structural diversity consistent with the potential of the

climate and site.

- Increase the livestock carrying capacity of the Farm by:
  - Improving grazing management to increase pasture health and production.
  - Optimizing rest and recovery times between grazing cycles.
  - Improving soil health & water holding capacity to increase photosynthesis.

In addition, the Farm has an aspirational goal of increasing livestock numbers significantly.

Specifically:

- Increase chicken population to approximately 20,000 over the next five years.
- Increase cow population to approximately 60 over the next five years.
- These goals represent a near four-fold increase in chicken numbers and a 10-fold increase in cow numbers and should be carefully evaluated.[1]

Finally, there is a desire to make improvements to the lower barn to meet the needs of a modern, efficient egg processing facility (powered by solar and utilizing reclaimed water).

RESOURCE CONCERNS

1. The CFP, by definition, recognizes the potential to increase on-farm carbon stocks as the principal resource concern. The plan, therefore, is constructed around potentials for increased carbon capture or conservation. To that end, other resource concerns that in some way limit carbon capture on the Farm are also identified.

2. Riparian- riparian systems on the Farm include: San Antonio Creek, which meanders west to east along the northern boundary of the Farm and the unnamed tributary to San Antonio Creek that runs south to north along the western boundary. Both San Antonio Creek and the unnamed tributary are incised, probably due to historical farming practices, stream channelization and road construction within the San Antonio watershed (see hydrology discussion above). This in turn suggests historical dewatering of the meadow systems along San Antonio Creek, including the fields and meadows of Gilardi Family Farm (see: Riparian Forest Buffer, CPS 342).

3. Water use efficiency. Limited water holding capacity of the upland and floodplain soils, and channelization of the creeks combine to limit the distribution and retention of annual rainfall in the Farm soils. Increasing Farm system carbon, as both SOM and above and below ground vegetation, including tree cover, can be expected to help hold water in the Farm soils and slow the movement of water out of the Farm system, leading to greater conservation and utilization of seasonal rainfall. Increasing system water holding capacity is expected to become increasingly important as predicted climate conditions continue to warm and dry, and as rainfall comes in fewer, but increasingly intense, storm events. Increasing soil water holding capacity by increasing SOM, as outlined throughout this plan, can lead to increased water use efficiency and in turn, increased

[1] See forage assessment section for discussion regarding estimated livestock carrying capacity of the farm.

overall Farm productivity. At the same time, there is a need for additional water development on the Farm to improve livestock distribution and pasture management (see Rain Water Harvesting (CPS 436), Development, CPS 516 & 614)

4. Forage harvest efficiency/livestock distribution; excessive bare soil; insufficient soil cover – Intensification of pasture management can improve livestock distribution, leading to increased forage harvest efficiency and, increased overall production, including increases in soil organic carbon and water holding capacity over time. Bare soil represents potential for soil quality degradation and a missed opportunity for carbon capture and soil sequestration due to a lack of plant photosynthesis on bare sites. (See: Prescribed grazing (CPS 528); Feed management (CPS 592); Residue and Tillage Management (CPS 329, 344 & 345).

5. Lack of structural diversity; excessive wind impacts. The Farm sits in the lee of a line of coastal hills, including Red Hill, from which the Farm previously took its name. This provides some protection from prevailing coastal winds, but the Farm receives enough wind to suggest windbreaks could help increase forage production as well as serving as a useful carbon sink, wildlife habitat and insectary. Windbreaks are known to provide production benefits by reducing stress on both crops and livestock. (See: Silvopasture,Tree/Shrub Establishment/Shelterbelts, Windbreaks, CPS 381, 612 & 380).

6. Waste Management. The Farm currently passively composts its on-farm organic waste materials, including chicken mortalities, unmarketable eggs, spoiled feed, etc. Improving the compost operation would increase the soil fertility and carbon benefits of this practice. A lack of equipment (loader tractor, compost spreader) limits the ability of the Farm to place compost where and when and at what rate it is needed for best effect. (See Compost Facility, CPS 484)

SOILS AND ECOLOGICAL SITES

Implementation of conservation practices within the Carbon Farm framework is based upon the grouping of land management activities by ecological site. An ecological site is an area of land with distinct geophysical characteristics, determined by slope, soil type, and aspect. Because a farm tends to consist of a mosaic of ecological sites that re-occur across the farm landscape, it can be described using just a few ecological site categories. Similar ecological sites can be expected to respond similarly to the same management, and to support similar types of vegetation and ecosystem processes, including carbon sequestration potential, assuming similar management history and similar management into the future.

Ecological site delineation helps identify those sites most likely to yield significant carbon benefits given specific practices, and those for which specific practices may not be particularly productive. For example, increasing soil organic carbon (SOC) with compost applications may be a very productive strategy on upland sites with low SOC, but may be of little value on organic matter-rich meadow soils.

Ecological sites on Gilardi Family Farm have been delineated by soil type and slope classes. Table 2 shows four distinct soil mapping units, with two constituting over 96% of the Farm soils: 105, Blucher-Cole complex, 2 to 5 percent slopes and 162, Saurin-Bonnydoon complex, 15 to 30 percent slopes. Two of these four soil types (Soil Map Units: 105 and 162) make up the majority of the Farm's acreage; therefore, at least two distinct ecological sites at a scale of relevance for livestock production (Table 3). No formal Ecological Site descriptions for Marin County have been developed, but the NRCS soil report provides a 'first cut' view of ecological sites on the Farm (Appendix B, NRCS Soil Report). Given the lack of formal ecological site designations for Marin County by USDA NRCS, traditional Range Site designations are still in use. Note that these are extremely broad designations, and do not capture the variability actually seen on the landscape. Slope class alone provides a further level of detail for planning purposes, as illustrated Figure 3. Figure 3 separates upland from lowland sites and riparian areas from non-riparian, providing a good framework for understanding how topographical variability influences both soils and forage production on the Farm, as well as site suitability with respect to potential implementation of carbon farm practices.

SOIL DATA SOURCES

Maps: NRCS Websoilsurvey; Marin RCD

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

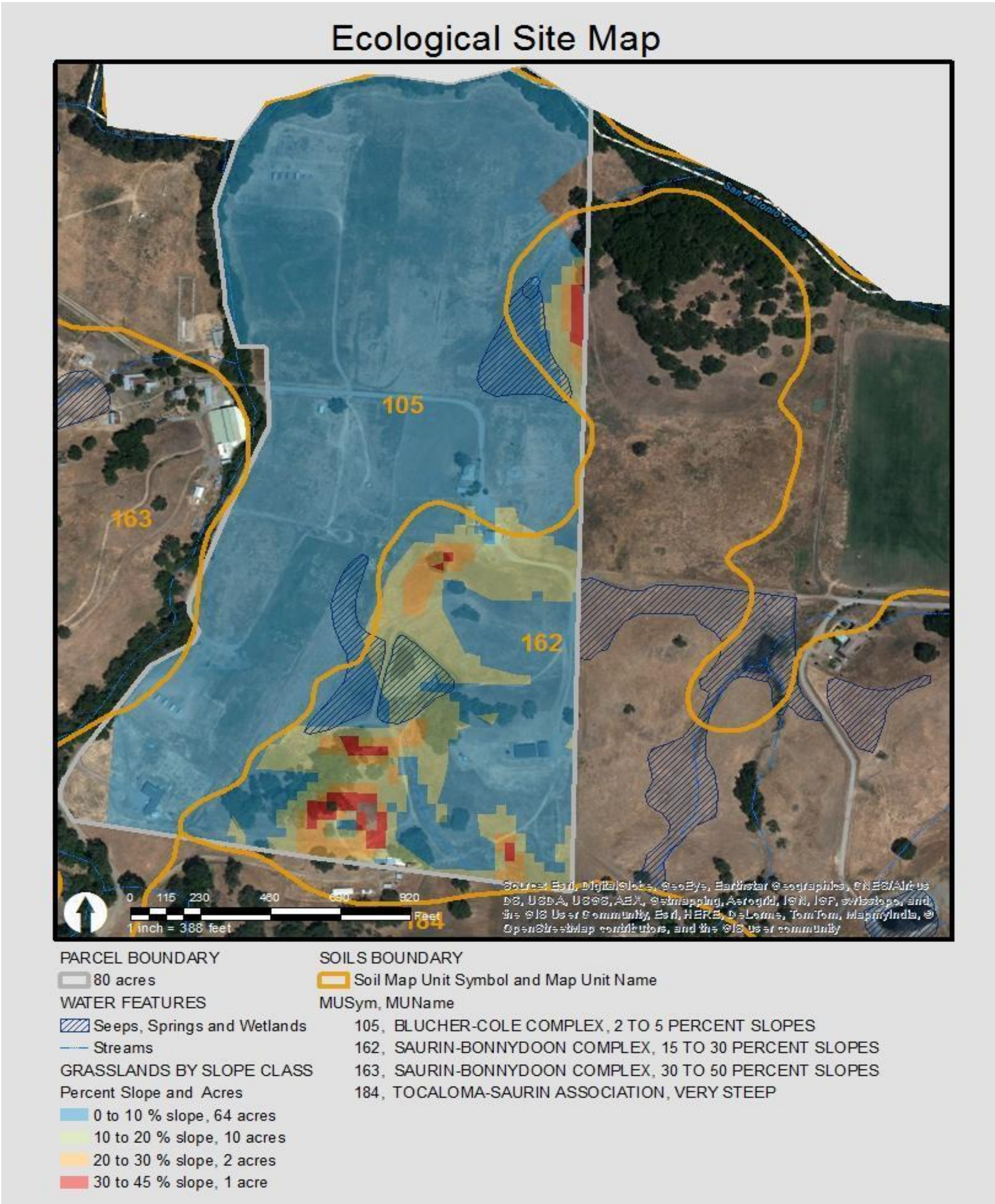

Figure 3. Using Soils and Slope to Indicate of Ecological Sites, Gilardi Family Farm (see appendix B, NRCS Soil Report)

Table 2. Gilardi Family Farm Soils: Acres and Percent Area. (NRCS WebsoilSurvey)

Map Unit Symbol	Map Unit Name	Acres	Percent Acres
105	Blucher-Cole Complex, 2 to 5 percent slopes	52.2	64.7 %
162	Saurin-Bonnydoon complex, 15 to 30% slopes	26.6	32.9 %
163	Saurin-Bonnydoon complex, 30 to 50 percent slopes	1.8	2.3 %
184	Tocoloma-Saurin association, very steep	0.1	0.1%
Totals for Soil Survey Area for Gilardi Family Farms		**80.7**	**100.0%**

Table 3. Principal Ecological Sites, Gilardi Family Farm

Map Unit Symbol	Map Unit Name	Component name (Percent)	Ecological Site	Acres on Farm
105	Blucher-Cole Complex, 2 - 5% slopes	Blucher (40%)	R015XC025CA- CLAYEY BOTTOMLAND	52.2
		Cole (30%)	R015XC025CA- CLAYEY BOTTOMLAND	
		Clear Lake (10%)		
		Cortina (10%)		
		Unnamed, slopes less than 2 percent (10%)		
162	Saurin-Bonnydoon complex, 15 - 30% slopes	Saurin (40%)	R015XC034CA- LOAMY	26.6
		Bonnydoon (30%)	R015XC037CA- SHALLOW GRAVELLY LOAMY	
		Los Osos (8%)		
		Tocaloma (8%)		
		Unnamed, dark surface (8%)		

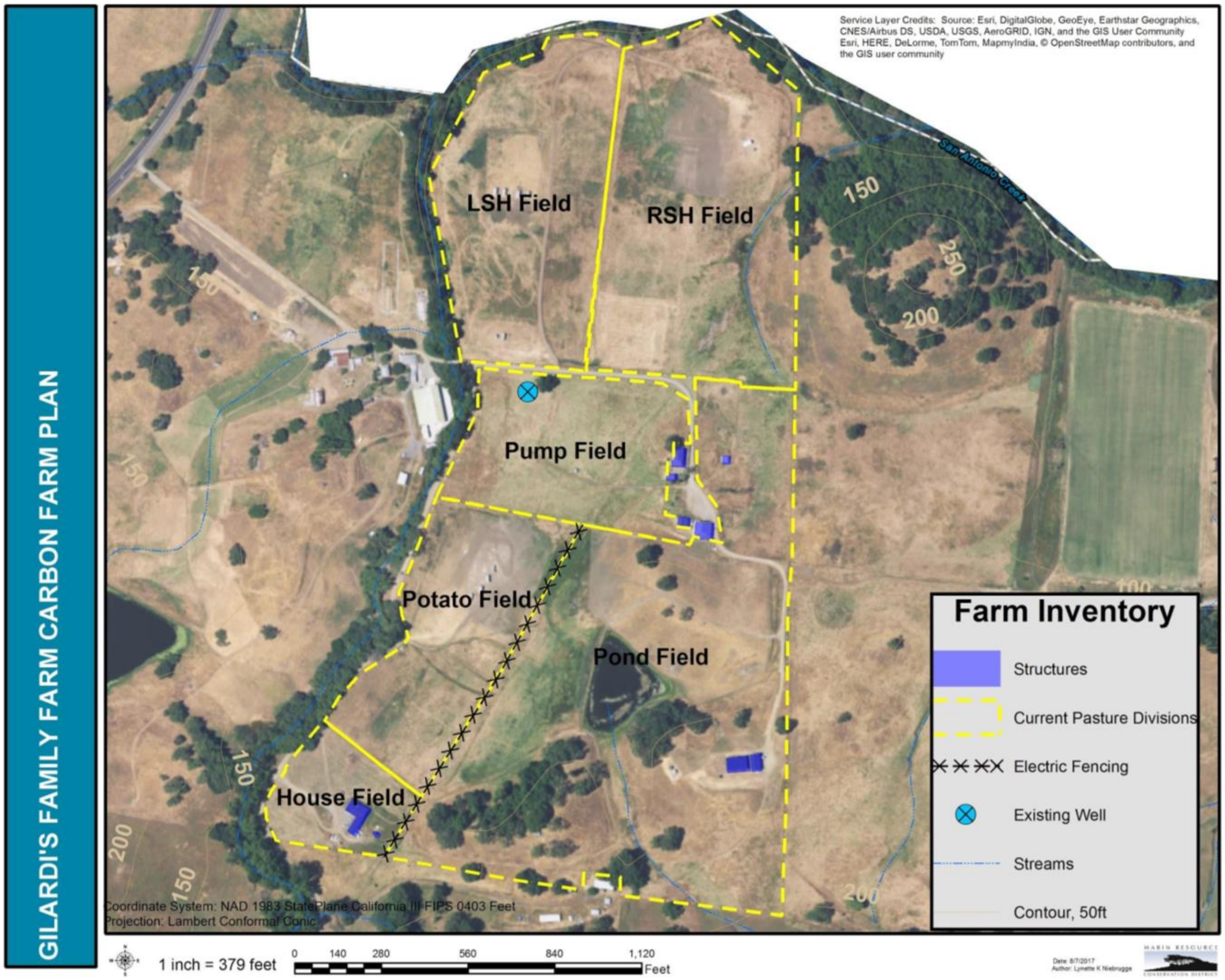

Figure 4. Gilardi Family Farm (2016), Farm Inventory displaying pasture divisions and structures.

GRAZING

GOALS & OBJECTIVES

Grazing goals and objectives for Gilardi Family Farm include maximization of forage production, increases in soil carbon and soil water holding capacity, protection of soil and water quality, improved pasture nutritional profile and increased length of grazing season.

GRAZING & CARBON

The Carbon Farm grazing plan combines estimated overall Farm livestock carrying capacity with ecological site potentials and limitations to manage for optimum carbon capture - as forage production and soil carbon - within site-specific management constraints. In general, increasing forage production from permanent pastures on farm will tend to result in an increase in soil carbon, assuming good or excellent pasture management and no net removal of carbon and nutrients in conserved forages (hay, silage, etc.) or livestock products. Practices that reduce or repair soil erosion, reduce area of bare soil and time soil is bare, reduce trailing, and provide grazed vegetation sufficient rest for adequate regrowth between grazing periods, will tend to result in both more overall forage production and more carbon sequestered in vegetation and soils over time (Derner and Schuman 2007, Conant et al 2001, Voisin 1961). (See Figure **4** for permanent pastures)

Recommended grazing management strategies within this plan, therefore, include: increasing pasture divisions to allow shorter grazing periods and longer pasture recovery periods and increase livestock harvest efficiency; compost applications, and nutrient management. Intensification of pasture management generally requires additional fencing, whether permanent or temporary, such as is already in place or planned on the Farm, along with additional troughs and supply lines to provide water to each pasture.

RESIDUAL DRY MATTER

Residual dry matter (RDM) (Bartolome et al 2006) is the herbaceous plant material -living and dead- left standing or on the ground at the end of the grazing year (typically measured in October, or just before the start of the water year). RDM measurement is commonly used to assess the year's grazing use on annual rangeland, whether moderate, heavy or light. The recommended standards are based on the observation that the amount of RDM remaining in the fall interacts with site conditions and weather –particularly timing and quantity of rainfall- to influence rangeland vegetation species composition and forage production in the coming year. This is particularly true of California annual grasslands, but the principle has relevance for perennial pastures as well.

While leaving appropriate amounts of RDM can appear to represent lost grazing opportunity in any given year, consistently low levels of RDM over time can be expected to result in gradual loss of SOM and soil carbon, soil water holding capacity and rangeland productivity. This is likely to be increasingly the case under warming and drying conditions associated with ongoing global warming. RDM can be viewed as the annual amount of above-ground carbon needed to sustain the rangeland resource into the future. Insufficient soil cover, whether live or dead material, can result in a downward spiral of declining system carbon, and declining rangeland condition. In this sense, RDM can be understood as an investment in the long-term productive capacity of the land, albeit at the "cost" of current season's total grazing capacity.

With warmer and drier average conditions experienced over the past few years, and anticipated in the future, it may be necessary to consider both historic norms and dry year precipitation when setting RDM targets on the Farm. Recommended RDM values are based on an assumed management goal of maintaining system dynamics at equilibrium ('sustained yield'). Because increasing soil carbon is an explicit goal of this plan, exceeding recommended RDM values may be necessary to enable a gradual increase in soil carbon. Alternatively, additions of carbon to the rangeland system, such as compost applications, or supplemental feeding of imported forages on pasture, can be used to drive system change in the direction of increased carbon capture and storage. It is also possible, if challenging, to increase soil carbon while maintaining RDM levels constant through focused pasture management to increase allocation of plant photosynthate to below-ground carbon pools.

Table 4. Recommended RDM values*

Woody cover (%)	Annual Hardwood Rangeland RDM (lb/acre) x percent slope			
	0–10	10–20	20–40	>40
0–25	500	600	700	800
25–50	400	500	600	700
Woody cover (%)	**Coastal Prairie RDM x percent slope (lb/acre)**			
	0–10	**10–20**	**20–40**	**>40**
0–25	1,200	1,500	1,800	2,100
25–50	800	1,000	1,200	1,400

Note: Metric conversion: 1 lb/acre = 1.12 kg/ha. **Source:* Bartolome et al, 2006.

RDM recommendations are based upon a percentage of total annual above-ground production (Table **4**). Thus, while total recommended RDM may decline from wetter to drier (ie, more to less productive) rangeland types, RDM, *as a percentage of total production*, should actually *increase* on less productive annual rangelands. The long-term implications of reduced RDM should be considered when adjusting RDM targets downward, as reducing RDM *as a percentage of total annual production* will tend to drive a downward spiral of soil degradation, reduced water-holding capacity and reduced rangeland productivity over time.

This speaks to the need to manage livestock forage utilization in relation to forage availability, including the need for destocking under low production conditions, in order to insure RDM targets are met. It also speaks to the potential to "bank" soil carbon—and future forage production—by increasing RDM in favorable years and using concentrated herd impacts to facilitate the transfer of that accumulated "surplus" above-ground biomass to the soil carbon pool via manuring and trampling. If followed by sufficient rest to allow adequate regrowth prior to the next grazing period and/or plant establishment in the following season, forage production, and overall carbon capture, can *gradually increase* over time. See further discussion below under Prescribed Grazing.

PRESCRIBED GRAZING

Prescribed grazing practices are designed to improve livestock production by improving grassland condition and productivity. *This will tend to lead to increases in soil carbon stocks over time.* This process generally involves planning both pasture grazing periods and rest periods to meet long-term management objectives, as pasture conditions and infrastructure allow. Successful grazing prescriptions often involve reducing paddock size while increasing paddock numbers to increase livestock grazing efficiency and increase the length of *rest* between grazing periods on each paddock. Decreasing the number of herds by combining herds where possible, can also facilitate this process, again by increasing the number of paddocks that are rested from livestock use at any one time, and thus increasing the period of rest between grazing periods.

Changing the length of grazing periods and rest periods with season and pasture phenology (stage of plant growth) is a key strategy to optimize forage production and utilization. As rapid forage growth begins in spring, grazing periods (time animals stay in each paddock) can be shortened. This accelerates the rotation, which leads in turn to fewer days of rest between grazing periods. Rest periods during the rapid growth period can be as short as three or four weeks, while grazing periods can be shortened to a few hours to three days or so, depending upon rate of forage growth, which is a function of soil moisture and soil temperature, and number of days of rest, which again depends on number and size of paddocks and number of herds.

Ideally, grazing livestock is moved rapidly enough to prevent grazing of plant regrowth within the same grazing period, which allows more rapid plant recovery from grazing impact and, ultimately, more total forage production and carbon assimilation. This approach also tends to favor perennial grasses, if adequate time for carbohydrate storage and plant regrowth is allowed between grazing periods. Rapid early season rotation may allow complete deferment of grazing for some paddocks, which may not all need to be included in the rotation at this time of year. This in turn enables "banking" of forage for later in the year, whether as standing forage in the field, or as conserved forage (hay, haylage, silage, swathed forage).

As forage growth begins to slow in late spring or summer, rotations should also slow, and the time animals remain within a given paddock can increase, assuming forage availability. Rest periods necessarily increase accordingly, so that by summer, periods of rest may be 90-120 days or more, assuming sufficient forage is available. Forage quality will generally decline, and supplemental feeding of conserved forages during this period is typically necessary. All else being equal, it is better, with respect to long-term pasture productivity, to hold animals longer than ideal on a given pasture (assuming adequate forage or supplemental feed) –and thus lengthen the rotation- than to bring them back to a pasture before it has achieved adequate regrowth (Voisin 1961). This phase of the rotation provides opportunities for transfer of fertility and carbon around the Farm, from areas of surplus to areas of deficit, in the form of conserved forage.

Water developments and fencing are essential to achieve intensification of pasture management, as outlined below.

GRAZING MANAGEMENT PLAN, GILARDI FAMILY FARM

The Farm principally supports pastured chickens on the relatively flat meadow soils (

Figure 5). A few Jersey cows and their calves are grazed on the upland pastures, and could be integrated into the chicken pastures in the future. Poultry could also be grazed on upland pastures with some infrastructure improvement.

Figure 5. Photo of RSH field and pasture chickens grazing, April 2016.

LIVESTOCK HISTORY

An animal unit (AU) is typically defined as a 1,000-pound cow with her calf, or the equivalent. An animal unit month (AUM) is a measure of forage, and represents the amount of forage required to support one animal unit for one month. Assuming laying hens and broilers weigh four pounds, numbers can be expressed in common animal units by multiplying bird numbers by 0.004,[2]

eg, (5000 chickens) x (.004) = 20 AU.

The Farm currently feeds an average of 5,000 birds (20 AU) year-round, yielding roughly 4500 eggs per day or 135,000 eggs/month, with an aspirational goal of housing 15-20,000 laying hens (60-80 AU), producing 12,000-18,000 eggs per day.

Currently four Jersey cows with calves (4 AU) graze the upland pastures. Eventually the Farm would like to increase cow numbers and follow the cows through the pasture rotation with the chickens, as chickens are currently unable to keep up with seasonal grass growth. This may be a function of leaving the chickens too long in one spot, resulting in taking pastures to bare soil. Moving the birds when a target forage height is achieved (eg. 2"), rather than taken pastures to bare soil, would tend to accelerate the rotation and result in more uniform utilization of available forage. This in turn could result in improved production by insuring birds are receiving sufficient forage from pasture, while also allowing more rapid recovery of pastures between grazing periods. It could also lead to a need for less purchased feed, if a greater percentage of forage can be obtained from pasture.

Total AUs: *20 (5000 chickens) + 4 (cows) = 24 AU.*

Carrying Capacity Calculations

Forage Production – RDM Requirement = Available forage

Available forage/Acre x Net Acres (Gross acres minus accessibility & distance to water) = AUM's

AUM's divided by the number of months on the land = Carrying Capacity.

Stocking Rate is the actual Animal numbers on a given land area for a given amount of time.

FORAGE INVENTORY

The Farm is currently divided into several main fields of varying size, with additional temporary divisions using electric using electric net fencing as needed to define grazing paddocks.

[2]University of Illinois Cooperative Extension Service.
http://web.extension.illinois.edu/ezregs/ezregs.cfm?section=viewregs_byq&QuestionID=196&searchTerm=&ProfileID=1

Table 5 **shows soil type, total acres, average year forage production per acre, recommended RDM and total average year available forage in AUM. The Farm is currently feeding 15 tons of purchased grain/month, with about 20% of total chicken feed (4 AUY) coming from the pastures on an annual basis. This renders the current forage demand from the Farm pastures roughly eight animal unit years (AUY). This is consistent with "favorable year" NRCS Range Site production production values (**

Table **5**).

Values presented in Table 5 assume no supplemental feeding, no pasture improvements, no intensification of management and no regrowth of forage after peak production. Other factors may increase carrying capacity, including:

- Intensive grazing management may allow additional plant growth and increase carrying capacity.
- Production of hay, or haylage and swathing of fields at peak production can capture more production at a nutritionally optimum period and increase overall carrying capacity, as well as a reducing carbon losses from oxidation of forage that would otherwise have been allowed to continue to senesce and return much of its embodied carbon to the atmosphere through photo-degradation and decay.
- Perennial forage species have a greater potential for regrowth after grazing, which can add to total forage produced per acre.

Table 5. Estimated annual "normal year" and Favorable forage production with recommended RDM and estimated total available AUM at Gilardi Family Farm, based on unimproved conditions.

Soil Map Unit	Acres	Normal Year Production lbs/acre*	RDM lbs/acre	Available Forage lbs	AUM**	AUY***
105	51.9	1750	1200	28545	31.72	2.64
162	28.7	2146	1200	27150.2	30.17	2.51
163	2.9	2146	1200	2743.4	3.05	0.25

184	0.2	2237	1500	147.4	0.16	0.01
TOTAL	**83.7**			**58586**	**65.10**	**5.42**

Soil Map Unit	Acres	Favorable Year Production	RDM	Available Forage lbs	AUM	AUY
105	51.9	2100	1200	46,710	51.90	4.33
162	28.7	2576	1200	39,491.2	43.88	3.66
163	2.9	2576	1200	3,990.4	4.43	0.37
184	0.2	2684	1500	236.8	0.26	0.02
TOTAL	**83.7**			**90,428.4**	**100.48**	**8.37**

*Data derived from Range Site values, Web Soil Survey, USDA; all acreage approximate.
**One AUM (animal unit month) is the amount of forage needed to support a 1,000 lb cow and her calf for one month; here it is assumed to be 900 lbs of dry forage
***One AUY is the amount of forage needed to support one AU for one year.

FORAGE/ ANIMAL BALANCE

The forage/animal balance describes the relationship between the forage available and the livestock demand for forage. The numbers will vary from year to year based on total precipitation, distribution of rainfall, livestock numbers and seasonal temperatures, among other factors. NRCS production values used to estimate poor, normal and favorable year forage are based on rangeland conditions when no inputs are used to enhance production.

Current annual forage demand is estimated to be 288 AUM (24 AU x 12 months = 288 AUM), or roughly 259,200 pounds of pasture-based forage per year. The NRCS favorable year production value of 100 AUM is estimated to meet about 35% of current forage demand, while average year production would meet roughly 23% of forage demand.

If animal numbers were to be increased to meet the Farm's stated maximum aspirational goal of 20,000 chickens and 60 mother cows, AUs would increase to 140 and annual forage demand would increase to (900 x 140 x 12 =) 1,512,000 pounds, or 1,680 AUM. By intensifying pasture management, increasing forage quality, decreasing bare ground and increasing the structural and forage diversity of the Farm pastures through agroforestry practices, it should be possible to increase overall forage production and/or forage harvest efficiency significantly. How much forage production can be further increased remains to be seen, but under the currently estimated favorable forage production scenario, less than 6% of the estimated future forage demand could be met from on-farm forage under such a scenario, while estimated average year production would meet less than 4% of estimated demand.

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OFF- FARM INPUTS

As animal units increase beyond the point where forage demand can be met by on-site forage production, feed and forage imports to the farm also necessarily increase. This in turn creates the potential for nutrients to accumulate on farm to levels of excess, presenting additional management challenges. As poultry numbers increase over 5,000 birds, for example, a Comprehensive Nutrient Management Plan (CNMP) would be required by USDA-NRCS under typical farm bill assistance programs, such as the Environmental Quality Incentive Program (EQIP). From a Carbon Farming perspective, increasing on-farm inputs presents a number of challenges. Properly managed off-farm inputs can lead to rapid on-farm increases in soil carbon, soil fertility and farm production. However, depending on the farming conditions from which those input are derived, they may actually represent a net carbon loss to the atmosphere.

To claim net carbon benefits resulting from input-supported farming practices, an evaluation of the farm system(s) that produced those inputs is needed (Delonge et al, 2013). In addition, as nutrient imports increase, such as nitrogen in feed grain protein, the potential for excess nutrients to accumulate in the farm system also increases. This in turn can lead to increased risk to soils and both surface and groundwater quality, such as increased risk of nitrous oxide (N20) emissions from the farm's soils and waste streams. Because N2O, for example, is a GHG almost 300 times more powerful than CO2, even small increases in N20 emissions can represent significant reductions in the net benefits of carbon farm practices. Therefore, as off farm inputs increase, it can become increasingly difficult to evaluate the net GHG benefits of implementing carbon farm practices at the farm scale, and increasingly likely that GHG benefits of carbon farming may be reduced due to increased emissions, whether on or off farm.

While recognizing there are economies of scale below which farm production may not be economically viable, it is also important to recognize that there are "ecologies of scale," above or below which farm ecosystem function may not be sustainable. Decisions to scale up production at Gilardi Family Farms would ideally be evaluated with such considerations in mind.

GRAZING STRATEGY

Gilardi Family Farms is fundamentally a grass-based, grazing operation. In order to meet Farm objectives and address resource concerns, the Farm grazing strategy involves rotations among paddocks with the recommended goal of at least 28 days rest between grazing cycles during the rapid growth season (variable, but typically March-May). This should allow adequate time for plants to regrow to their pre-grazing height prior to being re-grazed[3] and allow carbohydrate storage and carbon sequestration in plant roots, crowns, and soils. At the same time, period of stay, that is, the length of time animals remain on any one paddock, should not be so long that vegetation is removed completely. While recognizing the value of bare soil for poultry dusting purposes, taking forage to bare ground prolongs recovery time, reduces overall carbon capture, exposes soil to erosion and leads to a gradual degradation of the forage resource.

INFRASTRUCTURE NEEDED TO INCREASE FORAGE PRODUCTION, IMPLEMENT GRAZING STRATEGY AND INCREASE CARBON CAPTURE:

- Interseed improved forage species in pasture fields, particularly perennial grasses, legumes and forbs, as needed.
    - *Example perennial pasture mix: orchard grass; strawberry clover; birdsfoot trefoil; meadow barley[4].*
- Consider summer pasture-cropping trials with no-till spring-sown annuals in standing pasture vegetation, following chicken pass.
    - *Example: wheat; triticale.*
- Provide diatomaceous earth in chicken houses for dusting to replace need for bare soil in chicken pastures. Preventing bare soil may increase pasture production by up to 50% by replacing the current, "half bare, half grass" management approach. This will also allow for smaller grazing paddocks, which will increase paddock number and length of rest between grazing periods, while also increasing the utilization of available pasture area.
- Water development, including new well installation and/or spring development to facilitate pasture rotations and forage utilization. Improved vegetation cover in pastures will improve rainfall infiltration and groundwater recharge.

EQUIPMENT NEEDED:

Swather
Baler
Compost spreader
Tractor/loader (for bailer, spreader and compost operations).

FUTURE INFRASTRUCTURE NEEDS:

Dairy cow loafing/composting barn
Milk barn
Composting facility

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[3] 28 days rest should be adequate on pasture during the rapid-growing season, but rest periods will need to be longer as regrowth begins in spring and slows in the fall and winter. Ultimately, increasing pasture numbers by increasing pasture divisions will enable increased rest periods in each pasture.

[4] Meadow barley (*Hordeum brachyantherum) is a native perennial grass. Seed is quite expensive, and seeding is therefore not recommended. However, this grass probably formed a natural component of the site's vegetation at one point, and may show up on its own if grazing practices allow its reestablishment.*

CARBON BENEFITS OF GRAZING LAND PRACTICES

Prescribed Grazing (CPS 528). Implement prescribed grazing program on all 80 acres of pasture. *Sequester an additional 14 Mg CO2e per year.*

Range Planting (CPS 550). No-till interseeding of forage species in 58 acres of bottomland pasture. *Sequester an additional 29 Mg CO2e/yr.*

Total annual carbon benefits: 34 Mg CO2e/yr.

AGROFORESTRY SYSTEMS AT GILARDI FAMILY FARM

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 include:

- ***Silvopasture/ Tree & Shrub Planting or Systems*** combine trees with forage and livestock production on the same field. The trees are managed for wood, fruit, nuts or other products while at the same time provide shade and shelter for livestock. **Agro-silvopastures** combine crops, trees and livestock.
- ***Forest farming*** is the cultivation of high-value non-timber crops (food, medicinal, and crafts) under the protection of a forest canopy that has been managed to provide a favorable crop environment.
- ***Windbreaks and Shelterbelts*** are rows of trees and shrubs that reduce wind speed. They improve crop yields, reduce soil erosion, improve water-efficiency, protect livestock and conserve energy.
- ***Alley cropping systems*** include widely-spaced rows of high-value trees that create alleyways for crops. This system benefits trees and crops and provides annual and long term cash flow.
- ***Riparian forest buffers or Riparian Systems*** are streamside plantings of trees, shrubs and grasses that reduce water pollution and bank erosion, protect aquatic environments, and enhance wildlife habitat.

Special applications are plantings used to solve unique problems. Examples include a short rotation woody crop to generate biomass for composting, and plantings to stabilize streambanks or gullies.

Useful agroforestry practices for Gilardi Family Farm include: Silvopastures, Windbreaks, Shelterbelts and Riparian Forest Buffers, discussed below (**Figure 6**). Integrating trees and woody shrubs into the Gilardi Family Farm system could provide a number of benefits to grazing livestock, as described below, as well as increasing carbon capture. There are numerous opportunities for windbreaks, shelterbelts and silvopasture on the Farm. The carbon benefits of these agroforestry practices are quantified in Table **7**.

Figure 6. Photo displaying a variety of common Agroforestry Practices (Schoeneberger et al 2012)

SILVOPASTURE/ TREE & SHRUB ESTABLISHMENT

Silvopastures involve the integration of woody species, particularly trees, into grazed pastures, or the integration of grazing livestock into existing forest, woodland or savanna systems. Agrosilvopasture systems include annual crops as an element of the silvopasture system. Trees can provide near and long-term economic returns, shade, wildlife habitat and other benefits, while livestock and forages generate an annual income from the same land area. Correctly managed, the combined production from a silvopasture can be greater than traditional forestry and forage-livestock systems. Intensive livestock management may be required, particularly during tree establishment or during sensitive growth periods of the woody species (http://nac.unl.edu/practices/silvopasture.htm).

Table 6. Reducing On-Farm Climate Risk through Agroforestry
This table lists climate change risks and how implementing certain agroforestry practices can increase the farm's resilience to those changes. Information is from the USDA National Agroforestry Center. (http://nac.unl.edu/documents/workingtrees/infosheets/WTInfoSheet-ClimateAdaptation.pdf).

Risk	Adaptation	Agroforestry Practice
Intense rainfall events	Slow water runoff to reduce flooding, soil erosion, and water pollution	Riparian forest buffers; alley cropping
Increased temperatures	Reduce heat stress on animals by providing shade	Silvopasture
Increased frequency and intensity of drought	Reduce evapotranspiration by reducing windspeed; trap for soil moisture improvement.	Windbreaks
Increased storm intensity (wind & precipitation)	Protect crops, livestock and pasture from wind	Windbreaks; alley cropping
Changes in length of growing season due to temperature and precipitation	Protect crops and livestock by creating microclimates	Windbreaks; alley cropping; forest farming
Winter storms and cold temperature extremes	Reduce cold stress on animals by providing shelter	Silvopasture; windbreaks
Increased insect and disease problems	Control pests by providing habitat for beneficial insects	Windbreaks; riparian forest buffers; alley cropping
Increased possibility of crop failure due to other risks	Reduce total crop loss by increasing crop diversity	All agroforestry practices

Agroforestry, Silvopasture, for organic egg production, displayed below are a series of free- range poultry production integrated into fruit and nut tree plantations, located in New Zealand (Figure **7**).

Figure 7. The image displays an image of a Walnut silvopasture utilized by free-range poultry production.
Photo source: https://www.agforward.eu/index.php/en/agroforestry-for-poultry-systems-in-the-netherlands.html

Figure 8. Chicken Agroforestry, photo displays a plantation of young fruit trees approximately six months after planting and the integration of a free range poultry operation. Note the trees are staked and all stems are protected.
Photo source: https://www.agforward.eu/index.php/en/agroforestry-for-poultry-systems-in-the-netherlands.html

Figure 9. Chicken Agroforestry displays the chicken utilization as well as the spacing and density of the fruit plantation established six months prior.
Photo source: https://www.agforward.eu/index.php/en/agroforestry-for-poultry-systems-in-the-netherlands.html

Figure 10. Chicken Agroforestry, photo displaying the staking of the juvenile trees and chicken utilization.
https://www.agforward.eu/index.php/en/agroforestry-for-poultry-systems-in-the-netherlands.html

Trees in pastures provide shade and evaporative cooling, reduce radiant heat loss at night, and reduce wind speed. This allows animals to spare energy for growth, particularly under hot, windy or very cold conditions. Increased weight gain, milk yield, and conception rates have been reported for cattle and sheep grazing pastures with trees in warm environments. Forage nutritional value, digestibility, and botanical composition can be improved in silvopasture systems. Trees can be a direct source of livestock forage, including foliage, twigs and fruits (http://nac.unl.edu/practices/silvopasture.htm).

According to the University of Missouri Center for Agroforestry:

> "Shade has been shown to improve animal performance, with primary emphasis placed upon heat stress amelioration. McDaniel and Roark (1956) conducted a shade experiment with Angus (black hair coat) and Hereford (red and white hair coat) cows comparing artificial or natural shade to open pastures. The natural shade consisted of abundant, savannah-type tree spacing, and scanty shade, clusters of trees in the grazed pasture, treatments. Cows of both hair coat colors gained more than cows without shade, as did their calves. During the daylight hours from 6am to 7pm, the cows on the abundant shade treatment spent the most time grazing, with grazing time decreasing concomitantly with decreasing shade. McIlvan and Shoop (1971) measured improved gains in yearling Hereford steers on rangeland given access to shade. Of particular interest in their findings was that shade could be used to create more uniform, or less spot grazing by cattle. Shade was noted to be nearly as effective as water placement or supplemental feeding location to promote uniform grazing within a pasture. Silvopastoral practices could be extrapolated to encourage more uniform grazing and waste nutrient deposits within a pasture compared to open pasture or range. The natural shade areas, particularly the abundant shade treatment, resulted in superior weight gain of cattle compared to the artificial shade treatment.
>
> Properly positioned trees and shrubs or natural forest stands can provide much needed protection for pastures, feedlots and calving areas. Reducing wind speed lowers animal stress, improves animal health and increases feeding efficiency of livestock. Adequate wind protection has been found to reduce the direct effects of cold by more than half (Webster 1970). Similar findings have been reported for swine and dairy animals (Hintz 1983)." (Garrett et al, n.d.).
>
> Agroforestry-poultry systems have been widely reported; see images 6a-6d, above.

SILVOPASTURE AT GILARDI FAMILY FARM

Integrating trees into pastures at Gilardi Family Farm could provide a number of benefits to grazing livestock, as described above, as well as increasing carbon capture on those pastures. The Farm offers significant potential for silvopasture, oak woodland and orchard establishment over most of the fields, including the planting of Oaks and other selected native trees, fruit and nut trees in a widely spaced planting to achieve a 40% canopy cover at maturity. Table **7** shows the silvopasture potential at Gilardi Family Farms: the numbers of acres that could be planted and how much carbon the silvopasture could capture over one year, 20 years and 80 years. The overall agroforestry systems potential is outlined in Table **7**.

Table 7. Estimated CO2e Potential, Initial Silvopastures Gilardi Family Farms.

Agroforestry System Type	Field #	Acres	1 yr CO2e	Mg CO2e @ 20 years	Mg CO2e @ 80 years
Orchard, Fruit & Nut	Pond Field, Pump Field, RSH Field & House Field	7	130	2600	10400
Oak Woodland	RSH Field & Pond Fields	25.97	35	700	2800
Silvopasture	LSH Field, RSH Field, Pump Field, & Pond Field	43.29	58	1160	4640
TOTAL		**76.26**	**223**	**4460**	**17,840**
Mg = megagrams, one metric ton, or 2,200 lbs					

HEDGEROWS, WINDBREAKS & SHELTERBELTS

Hedgerows, windbreaks and shelterbelts are, “single or multiple rows of trees or shrubs planted in linear configurations” (NRCS). 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, increase biodiversity, increase production, and act as shaded fuel breaks to limit the spread of wildfire. In addition, shelterbelts and hedgerows can be configured to capture or distribute surface runoff to optimize moisture, sediment and nutrient retention (Figure **11**, see *Windbreaks for Livestock Operations:* http://nfs.unl.edu/documents/windbreaklivestock.pdf).

Windbreaks are hedgerows or shelterbelts that are planted approximately perpendicular to the prevailing winds and structured to dissipate or deflect wind energy over or away from the area downwind of the windbreak. Well-designed windbreaks also offer protection upwind of the windbreak by creating a high-pressure zone that helps lift the wind ahead of the windbreak itself.

WINDBREAKS & SHELTERBELTS AT GILARDI FAMILY FARM

- **Low, Medium,Tall multi-row windbreak/shelterbelt**
  - 780.82 linear feet extending north to south along the east boundary of the RSH Field and Pond Pasture of the property.
  - 820.51 linear feet extending west to east along the north border of the Pump Pasture.
  - 2,046.00 linear feet extending north to south along the main driveway and west boundary of the Pump, Potato, LSH and House Fields. Note, there will need to be a 25 foot buffer from road when installed.
  - Possible addition : 784.29 linear feet extending east to west and north to south located in the southeast corner of the Pond Field

  Total Length: 4,431.62 (+) linear feet x 40 feet

- **Low, Medium two-row windbreak/shelterbelt**
  - The 10 prescribed shelterbelts will act as division between fields to support rotational grazing. The shelterbelts to be installed in fields LSH, RSH, Pump and Potato field.

  Total Length: 9268.295' x 20'

- **Medium Shelterbelt**
  - 388.81 linear feet dividing the Potato and House field

  Total Length; 388.81' x 20'

For visual location identification, see Agroforestry Systems Practice Map, Appendix A and Planting list and definitions, Appendix C.

Figure 11. Windbreaks and Shelterbelts (USDA NRCS).

Quantifying Hedgerow, Windbreak and Shelterbelt Carbon Capture

The Colorado State Ecosystem Carbon team (CSU 2013) estimates mean plant biomass carbon accumulation rates for Marin County windbreaks to be approximately 1 Mg C/ha/yr (1.49 metric tons of CO2e per acre per year), until reaching maturity (approximately 34 yrs for low windbreaks, 57 yrs for medium windbreaks, 80 yrs for tall windbreaks). Sequestration values can be maintained indefinitely through periodic windbreak renovation and maintenance (CPS 650). As neither growth models nor regional measurements from comparable agroforestry systems were available, in order to derive sequestration values, CSU used area-based data from analogous native systems and applied them to the assumed areas these agroforestry systems represent. It is important to emphasize that the biomass accrual data provided for the windbreaks above (table 9) are subject to interpretation, as no actual measurements are available. The biomass stocks and accrual rates developed for windbreaks on a per 100m basis are sensitive to the width assigned to each windbreak row (length x width = area, Figure **12**, Table **8**). Thus COMET-Planner reports agroforestry benefits in metric tons per acre, rather than per linear foot (Table **9**).

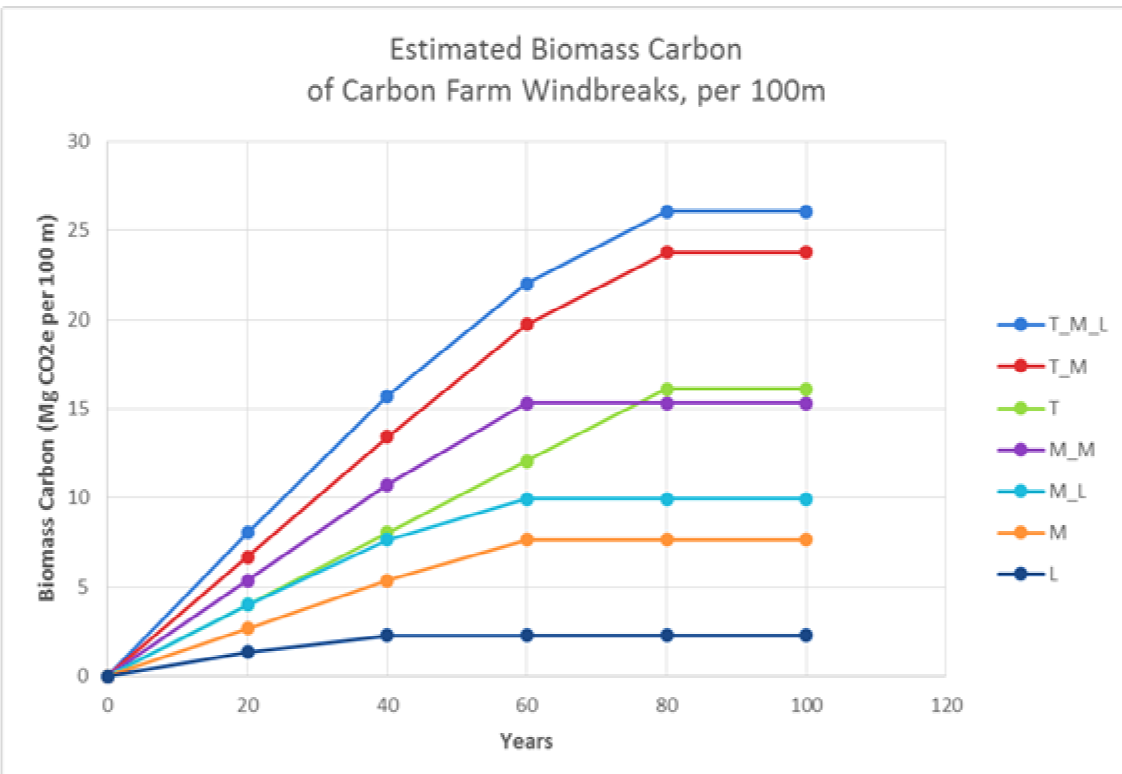

Figure 12. Estimated biomass carbon accumulation over time for Marin Carbon Project, Windbreaks/Shelterbelts.

The graph shows carbon biomass accumulating in windbreaks over time. Windbreaks come in various sizes and are included on the graph as an abbreviation: L = low windbreak, M = medium windbreak, T = tall windbreak, M_L = two-row windbreak (one row medium, one row low), etc. Values are for plant carbon above and below- ground only and do not include soil carbon (CSU, 2013).

Table 8. Estimated biomass carbon stocks (CO2e) over time for Marin Carbon Project Windbreaks/ Shelterbelts. Values include above and below-ground plant carbon stocks per 100 meters, expressed as CO2e, but do not include soil carbon increases resulting from woody species detritus, root exudates or the role of structural features such as trees or hedgerows as biological magnets for wildlife and the associated additions of nutrients and biomass resulting from increased wildlife presence on these sites .

Years since establishment:	20	40	60	80
System	**Biomass Carbon Stock ($Mg\ CO_2e$/100 meters)**			
Low (1 row) + Medium (1 row) + Tall (1 row) Windbreak	8.0	15.7	22	26.4
Medium (1 row) + Tall (1 row) Windbreak	6.7	13.4	19.7	23.8
Tall Windbreak	4.0	8.0	12.1	16.1
Medium (1 row) + Medium (1 row) Windbreak	5.4	10.7	15.3	15.3
Low (1 row) + Medium (1 row) Windbreak	4.0	7.7	10	10
Medium Windbreak	2.7	5.4	7.7	7.7
Low Windbreak	1.3	2.3	2.3	2.3

Table 9. Estimated Agroforestry CO2e Potential, Gilardi Family Farm Windbreaks, Hedgerows, Shelterbelts. See figure for field numbers and explanation of Agroforestry System Type;

Windbreak/ Shelterbelt Type	Linear Feet	Width	Acres*	CO2e @ 1.49* Mg/acre/ year	Mg‡ CO2e @ 20 years	Mg CO2e @ 80 years
Low (1 row)+ Medium (1 row) + Tall (1 row) Windbreak/ Shelterbelt	4431.62	40	4.07	6.06	121.29	485.14
Low (1 row)+ Medium (1 row) Windbreak/ Shelterbelt	9,268.24	20	4.25	6.33	126.65	506.6
Medium Windbreak/ Shelterbelt	388.81	20	0.18	0.27	5.30	21.22
TOTAL	**14,088.67**		**8.5**	**12.66**	**253.24**	**1012.96****

‡Mg = megagrams = one metric ton = 2,200 lbs

* COMET-Planner estimates used for Agroforestry system types while Marin-specific analysis by CSU (2013) used for Shelterbelts.

** For 80-year values, 4 is multiplied by the 20 year value. The justification for that is that Table **9** only includes biomass carbon; no soil C.

RIPARIAN SYSTEMS

Stream restoration projects typically focus on streambank stabilization, in-stream grade control structures and vegetation establishment. As structural practices and planted shrubs and trees mature over multiple decades, atmospheric carbon is sequestered in both the soil and vegetation within the riparian area (Lewis et al 2015). Consistent with the relatively high productivity of riparian systems, carbon capture in the soils and woody vegetation of these systems is typically several times greater than in the woodland, grassland or cropland of associated upland areas (Lewis et al 2015, Leonard et al 1997).

Gilardi Family Farm Riparian Forest Buffer

Approximately 2127' of the south bank of San Antonio Creek is contiguous with the northern and western boundary of Gilardi Family Farm, as determined via Google Earth (see figure, Carbon Farm Plan, Gilardi Family Farm). Of this, virtually all is well forested, although approximately 300 feet of both the north and south bank are unstable due to vertical cut banks associated with historical stream incision (see hydrology discussion, above). There is potential to expand the riparian forest buffer along the south side of this entire reach of San Antonio Creek. This would be effectively a "one-sided" riparian forest buffer; a double, staggered row width of 40' is assumed. Similar potential exists along approximately 100' of the well-vegetation ephemeral stream flowing north-south along the western edge of the property.

In addition, there is potential for enhancement of three grassed waterways on the Farm, totaling 1,296' in length and approximately 20 feet in width.

- Plant trees and shrubs as a riparian forest buffer along 2127' of the Farm boundary along San Antonio Creek and along 100' of the west boundary ephemeral stream Tree species could include: Poplar, Willow, Box Elder, Black Locust, Black Walnut, Alder, Live Oak, Valley Oak, etc. Shrub species could include hazelnut, elderberry, currant, gooseberry, redtwig dogwood, etc. (see appendix C, species list).
- Plant two grassed waterways and a vegetated swale totaling 1,296' in length and approximately 20 feet in width.
- Fence riparian forest buffer and grassed waterways as needed with temporary fencing to allow plant establishment.
- Provide temporary drip irrigation system for woody plant establishment (2-3 years).

Quantifying Riparian Forest Buffer Carbon Capture Potential at Gilardi Family Farm

COMET-Planner was used to quantify the carbon sequestered over time from Riparian Forest Buffers and Grassed Waterways at Gilardi Family Farm. The proposed 2,227 feet of riparian forest buffer would occupy approximately 2.0 acres of the Farm and accrue an estimated 4.5 metric tons of CO2e annually, 88 metric tons over 20 years and 195 metric tons at 45 years. Extrapolating out 80 years, an estimated 350 metric tons of CO2e would be sequestered by these projects at maturity (

Table 10**).**

Table 10. Riparian Carbon Capture Potential, Gilardi Family Farm

Riparian System Types	Length (feet)	Width (feet)	Acres	Riparian Forest Buffer (COMET-Planner Riparian Restoration)			Maturity
				Annual	20 years	45 years	80 years
Grassed Waterway	1,296	20	0.6	0.60	12.00	27	48
San Antonio & West Creek	2,227	40	2.04	2.04	40.8	91.8	163.2
TOTAL	**3,523**		**2.64**	**2.64**	**52.8**	**118.8**	**211.2**

1 Mg = one megagram = 1000 kilograms (kg) = one metric tonne = 2,200 pounds
Metric Tons (Mg*) CO2e per Year

COMPOST APPLICATIONS AT GILARDI FAMILY FARM

RANGELAND COMPOST

Research conducted on northern California rangelands by the Silver Lab at the University of California, Berkeley has shown significant, ongoing increases in forage production, soil carbon, and soil water holding capacity over multiple years in response to a single ½" compost application on grazed sites in both coastal and foothill rangelands (Ryals and Silver 2013). Forage production increased by approximately 40% and 70%, respectively, and soil water holding capacity increased by nearly 25%, while soil carbon increased by about 0.4 metric tons (1.49 Mg CO_2e) per acre per year. These changes have persisted across six years of data collection, and ecosystem models suggest this increase will continue for at least 20-30 years in response to the single compost application in year one, reflected in improved forage production and improved soil water holding capacity. Compost application therefore, is recognized as an effective means of increasing carbon capture, through increased net primary production, on grazed rangelands, particularly where low SOM is a limiting factor.

Importantly, compost applications enable increasing soil carbon stocks above what could otherwise be achieved through management of vegetation and soils on a given site. Improved management alone, such as application of a carbon-focused grazing program, increased use of cover crops, implementation of a no-till program, etc., can all lead to soil carbon increases. 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. 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 can thus be a powerful tool for soil carbon increase, but is not always a realistic option, particularly where target fields are far from sources of compost. On-farm compost production is one option that allows for increasing conservation of on-farm carbon and its addition to origin-farm soils at relatively low cost. Bootstrapping of soil carbon in this manner can be an effective and relatively inexpensive soil carbon enhancement strategy.

Soils unsuitable for compost applications generally include those already high in organic matter and those on slopes too steep to access safely with spreading equipment. Also excluded from consideration for compost application is land not currently being actively managed for agricultural production or restoration, land within 30' of a surface water body, and special status soils, such as serpentine or Histosols.

Based on USDA soil survey data, all of Gilardi Family Farm has a baseline organic matter content of below 3%, and is thus 3%, and is thus potentially suited for compost application (

Table **11**), SOM). Not all sites would be accessible for compost application, however, and selected sites should be sampled and evaluated for baseline SOM content prior to compost application to insure a high probability of soil health and crop production benefits from the practice.

Table 11. Soil Organic Matter, Gilardi Family Farm (websoilsurvey data)

Map Unit Symbol	Map Unit Name	Organic Matter Rating (Percent)	Area Acres	Area Percent
105	Blucher-Cole Complex, 2 - 5 % slopes	2.83	52.2	64.7
162	Saurin-Bonnydoon complex, 15 - 30% slopes	2.00	26.6	32.9
163	Saurin-Bonnydoon complex, 30 - 50 % slopes	2.00	1.8	2.3
184	Tocoloma-Saurin association, very steep	1.50	0.1	0.1

For this analysis, and pending soil sampling to confirm baseline SOM content, it was assumed up to 80 acres of Gilardi Family Farm pasture would receive compost over a period of several years (Appendix A). The Farm is currently accumulating an average of 40 cubic yards per month of organic material for composting on site. Assuming volume reduction of 50% through composting, approximately 240 cubic yards of finished compost is available for pasture application on farm annually. The Farm can therefore treat about seven acres of permanent pasture per year (Table **12**) at the rate of ¼" of compost (about 34 cubic yards) per acre. At this rate of compost production and use, all suitable acreage on the Farm can be treated about every twelve years. Data developed through ecosystem models suggest the ¼" application rate would be as effective in increasing grazed grassland productivity as the ½" application rate employed in Marin Carbon Project research (Ryals and Silver 2013, Ryals et al 2015). As shown in table 13, (predicted cumulative CO2e from compost applications on grasslands), using the ¼" application rate results in more CO2e being sequestered in less time than the ½" rate, as more acreage can be treated each year, resulting in overall greater carbon capture over fewer years.

Note that yearly values in table 13 represent the amount of CO2e sequestered *in that year only for all acres treated up to that point in time*. Cumulative CO2e, on the other hand, represents *all* CO2e sequestered by *all treated acreage for all years up to the current year*. Thus year four includes all eligible acreage, all CO2e for all acreage that year, *and* all CO2e for all acres treated *in every previous year.* This ongoing cumulative increase in soil sequestration of atmospheric CO2 in response to a single compost application is expected to continue for up to 30 years following the original application (Ryals et al 2015).

Table 12. Predicted Cumulative CO_2e Sequestration from Compost Application on Grazed Grassland, Gilardi Family Farm (assumes 240 cubic yards on-farm compost available each year).

Year	Cumulative Acres 1/4" Rate	Metric Tons CO2e/yr 1/4" Rate	Cumulative CO2e
1	7	10.43	10.43
2	14	20.86	31.29
3	21	31.29	62.58
4	28	41.72	104.3
5	35	52.15	156.45
6	42	62.58	219.03
7	49	73.01	292.04
8	56	83.44	375.48
9	63	93.87	469.35
10	70	104.3	573.65
11	77	114.73	688.38
12	84	125.16	813.54
13	91	135.59	938.7
14	98	146.02	1063.86
15	105	156.45	1189.02
16	112	166.88	1314.18
17	119	177.31	1439.34
18	126	187.74	1564.5
19	133	198.17	1689.66
20	140	208.6	1,814.82

Table **12** estimates of carbon sequestration increases in Gilardi Family Farm rangeland soils in response to compost application were based on increased photosynthetic capture of CO2 from enhanced forage growth alone (Ryals and Silver 2013). Not included was any CO2e resulting from avoided emissions of methane or nitrous oxide associated with diversion of manure, chicken litter, or other organic wastes to aerobic composting (Delonge et al 2013), nor was the carbon contained in the compost itself included in this analysis. Overall, this suggests CO2 sequestration values presented in table 13 are conservative.

CROPLAND COMPOST

Approximately 52 acres of the 80 acres of the Farm soils are classified as Blucher-Cole complex, a soil of statewide importance. Though currently managed for permanent pasture, it should be considered cropland, based on soil type and potential land use. This is particularly true if agroforestry and related practices recommended in this plan are implemented. Compost use on cropland is a widely accepted agronomic practice that enables the partial or complete elimination of synthetic fertilizer use and results in improvement in a wide range of soil and water quality factors, as well as the reduction or mitigation of GHG emissions from cropland. Soil aggregation and aggregate stability, fertility, water holding capacity, aeration, organic matter and resilience in the face of drought and flood are all improved by compost applications to cropland. Carbon sequestration effects of compost applications to cropland are highly variable because cropland management is itself highly variable, including variation among tillage practices, crop species, cover crops, irrigation, and post-harvest grazing practices, among other factors.

Because of the high potential for the Blucher-Cole soils to store carbon, in addition to the potential for increased photosynthetic capture of CO2 from enhanced crop growth in response to compost application, potential increases in cropland soil carbon in response to compost application were also evaluated *based on the carbon content of the added compost.*

CROPLAND COMPOST CARBON SEQUESTRATION POTENTIAL

For the current analysis, a goal of 5% SOM for Gilardi Family Farm 'croplands' –defined as of its 52 acres of Blucher-Cole complex soils on slopes of 2 - 5% - was assumed, based on the NRCS Soil Health program, which suggests 5% SOM as an indicator of soil health.

USDA-NRCS soil data (
Table **11**) shows a SOM level on Gilardi Family Farm cropland soils of 2.83%. SOM is roughly 50% carbon. As noted above, NRCS has suggested 5% SOM as an indicator of a healthy agricultural soil. Table **13** shows potential additional carbon sequestered, in the plow layer (top 6.7") only, of 52 acres of cropland soils of Gilardi Family Farm if all 52 acres were elevated to 5% SOM, from USDA-NRCS baseline SOM levels, assumed, for this analysis, to be 2.83%. Increasing the target depth of SOM increase in the Farm cropland soils would further increase overall carbon sequestration achieved in these soils.

Again, these values are based on carbon added to the soil as compost (compost is assumed to be 50% organic matter and thus 25% carbon), and do not reflect carbon gained from increased production, as was the case for compost applied to rangelands (Table **12**). This assessment assumes 5% SOM is achieved using only compost additions. As noted throughout this Plan, compost is only one of many strategies, although a particularly powerful one, for achieving soil carbon increases.

Compost application rate on cropland should be based on an agronomic assessment of the soil's need for organic matter, which is both a soil and crop-specific evaluation process. As an alternative to using a SOM goal to drive compost application rates, the nitrogen (N), phosphorus (P) or potassium (K) content of the compost can be used to define or limit the desired application rate, based upon crop demand for those nutrients and which nutrient is likely to be of water or soil quality concern if applied in excess. However, it is important to note that organic forms of nutrients are not as readily available, nor as likely to be lost to ground or surface waters, as are synthetic forms. As a rough rule of thumb, about 10% of compost nutrient content can be expected to become available each year following its application. For example, at 2% N, a ton of compost will contain 40 pounds of nitrogen in organic form, but only about four pounds of that will be available in any given year. This underscores the importance of viewing compost as a soil amendment that improves overall soil quality and water holding capacity, and as a source of energy (carbon) to support soil ecosystem processes, rather than as a fertilizer in the conventional sense. Nevertheless, compost can have a notable beneficial impact on soil fertility and crop productivity.

Importantly for Gilardi Family Farm, given the high levels of production desired and high external inputs of nutrients as chicken feed, achieving high levels of soil carbon will be critical to buffering the effects of high nutrient inputs. Development of a Comprehensive Nutrient Management Plan is recommended as the Farm increases livestock numbers above current levels.

Estimated Nitrogen Release (ENR)

ENR is sometimes, but not always, reported in agronomic soil analyses. ENR is a calculated estimate of how much N will be released through the growing season from SOM as it decomposes. As SOM levels increase, ENR also tends to increase. The rate at which compost decomposes and releases plant available nutrients depends on many factors, but soil type, moisture, temperature and management practices all influence the process.

Compost applications to cropland (as compared with pastures or rangeland) are typically less than about 1" per acre per crop cycle (140 cubic yards or about 70 tons/acre), though rates as low as three tons per acre per year are common in Central Valley almond orchards, for example. Where water quality considerations are paramount, this quantity should be modified as needed, depending upon which nutrient is most likely to be over-applied, given increasing volumes of compost per acre, particularly where multiple cropping cycles per year result in multiple or larger applications of compost annually. In general, mature compost, as defined by CalRecycle[5], presents negligible water quality risk when applied at agronomic rates to cropland or rangeland with appropriate buffers adjacent to surface waters.

[5] Compost is the end result of controlled biological decomposition of organic material to a stable, humus-like product that has many environmental benefits: http://www.calrecycle.ca.gov/organics/compostmulch/CompostIs.htm

ON FARM COMPOSTING

Gilardi Family Farm has a strong interest in developing an on-farm compost operation, using primarily a blend of Gilardi Family Farm organic waste materials and imported horse bedding as both a carbon source and a bulking agent. Currently, some 480 cubic yards of feedstock accumulates each year. Assuming annual production of 240 cubic yards of compost, SOM increases to 5% on 52 acres of cropland, as shown in table 14, could be achieved in approximately ten years. A compost yard for on-farm composting of approximately 500 cubic yards of feedstock each year is currently located on about one quarter acre northeast of the barn on Blucher-Cole soils. An alternative site, which may offer improved wet season access, is located south of the barn, on the better-drained Saurin-Bonnydoon soils.

Table 13. Carbon Sequestration (Mg CO2e) Potential At 5% SOM, Cropland (Blucher-Cole Complex) Soils of Gilardi Family Farm based on NRCS soil data; see appendix B. 1 Mg = 1 metric ton = 1.1 short tons

Fields	Cropland Acres	Baseline SOM% (NRCS)	Gap to 5%	Additional Mg C/acre at 5% OM	Total Additional Mg CO2e at 5% OM	Mg compost/acre needed for 5% SOM	Total Mg Compost needed for 5% SOM
Cropland	52	2.83	2.17	9.86	2,099.36	39.45	2,288.13

*Assumptions:
1% SOM = 0.5% SOC = 10 short tons = 9.09 metric tons (Mg) SOM per acre.
Compost = 50% OM, or 25% C;
1" compost = 70 short tons/acre x 0.25 = 17.5 x 3.67/1.1 = 58.39 Mg CO2e/acre.
Approximately one half of compost C is assumed lost annually under tillage.

Application of 39.45 short tons (35.8 metric tons) of compost to each acre of cropland would represent soil sequestration of approximately 36 metric tons (Mg) of CO2e per acre, or over 2,099 Mg CO2e across all 52 acres, and bring all 52 acres up to 5% SOM, assuming no carbon losses from these soils (Table **13**). The rate at which this could be achieved is dependent upon rates of compost production and implementation of other carbon-beneficial practices on cropland at Gilardi Family 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. Under a no-till rangeland scenario, as outlined for rangeland compost, above, this level of SOM increase could be achieved with compost additions alone, during the 2nd eight-year cycle of compost applications across the 52 cropland acres (Table **13**).

CARBON BENEFICIAL PRACTICES AT GILARDI FAMILY FARM

Table **14** summarizes the farm-specific prescription and the estimated impacts of implementing carbon beneficial practices in this CFP.

Table 14. Gilardi Family Farm Potential Carbon Beneficial Practices and Estimated Effects

PRACTICE	FARM – SPECIFIC PRESCRIPTION	CO2e SEQUESTERED	CO-BENEFITS	REFERENCE
Compost application on grazed grassland (NRCS interim practice standard in development)	Application of 1/4" of compost to 7 acres of permanent pasture each year up to 80 acres. Increase soil organic carbon, water and nutrient holding capacity	At a rate of 1.49 Mg CO2e per acre per year, sequester 10.43 Mg on 7 new acres each year, and 688 Mg on 80 acres over 11 years, and 1,814 Mg over 20 years.	Improved water holding capacity, soil quality and fertility, net primary productivity and forage production	Ryals and Silver 2013, DeLonge et al, 2014; Ryals et al 2015.
Compost application on Cropland (CPS 590)	Application of compost to 52 acres of cropland to reach 5% SOM. Increase soil organic carbon, water and nutrient holding capacity and crop production	At 5% organic matter on all 52 crop acres, sequester a total of 2,099 Mg CO2e. Total sequestered and duration dependent upon farming practices	Improved water holding capacity, soil quality and fertility, and crop production	Ryals and Silver 2013, DeLonge et al, 2014; Lal, 2015.
Agroforestry: Windbreaks, Hedgerows, Shelterbelts, (CPS 380 & 422)	Plant 14,087.81 (8.50 acres) of windbreaks, shelterbelts, and hedgerows throughout the Farm.	Sequester 12.66 Mg CO2e annually, 253.24 Mg at 20 years and 1,012.96 Mg at 80 years.	improve microclimate stabilize soils, improve water quality, habitat diversity, increase forage	CSU-Marin analysis, 2013.
Silvopasture (CPS 381)	40% Valley Oak canopy on 69.00 acres of lowland pasture area	93.00 Mg CO2e annual, 1860.00 Mg at 20 years; 7440.00 over 80 years.	Improved biodiversity, livestock comfort, habitat, water infiltration	COMET-Planner
Tree & shrub establishment (CPS 612)	7 acres of mixed orchard plantings.	130.00 Mg CO2e/yr; 2600.00 Mg over 20 years.	Income diversity; biodiversity,	COMET-Planner

Riparian forest buffer (CPS 391)	Plant 2,227', totaling 2.04 acres along boundary fence line parallel to San Antonio Creek and unnamed tributary to San Antonio Creek.	Sequester 2.04 Mg CO2e/ per year; 40.80 Mg CO2e at 20 years, 91.80 Mg CO2e at 45 years, and 163.20 Mg CO2e at maturity at 80 years.	Stabilize soils and stream banks, improve soil moisture and wildlife habitat structural and species diversity; sediment reduction; improved soil and biomass carbon capture from vegetation establishment, improved water quality.	COMET-Planner
Grassed Waterway (CPS 412)	1,296 linear feet of on 0.60 acres	Estimated capture of 0.60 Mg CO2e/yr and 12.00 Mg over 20 years; 27.00 Mg over 45 years and 48.00 Mg over 80 years.	Improved pasture production and water quality.	COMET-Planner
Prescribed Grazing (CPS 528)	Grazing management	Estimated enhanced CO2e-capture of 14 Mg per year, 280 Mg over 20 years	Enhanced pasture productivity, improved water holding capacity, climatic resilience and species diversity	COMET-Planner
Range Planting (CPS 550)	No-till interseeding of forage species in bottomland pastures (58 ac)	Estimated enhanced CO2e-capture of 29 Mg CO2e per year, 580 Mg over 20 years	Enhanced pasture productivity and climatic resilience	COMET-Planner
No Tillage (CPS 329)	No or strip tillage on 44 acres; from annual to strip tillage as needed	capture 6 Mg CO2e per year;120 Mg tonnes CO2e over 20 years	Increased Soil Organic Matter and soil water holding capacity. Increased resilience to heavy rainfall.	COMET-Planner
Rainwater Harvesting (CPS 636) Water Development (CPS 516, 614)	Install gutters, tanks, pipelines and wildlife-friendly water troughs for plant establishment, livestock distribution and wildlife use	Soil and biomass carbon capture from woody vegetation establishment and pasture improvement	Improved wildlife habitat, improved pasture management capacity	Supporting practice

Fencing or Access Control (328/ 472)	Temporary electric or permanent fence protection for tree and shrub cover establishment for windbreak, shelterbelt and riparian plantings	Increase soil and biomass carbon capture on protected sites	Stabilize soils, improve water capture, water quality and habitat structural and species diversity	Supporting practice

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 17 shows estimated additional water storage capacity associated with soil carbon increases on Gilardi Family Farm resulting from implementation of the CFP.

Total estimated additional soil water storage capacity associated with soil carbon increases on Gilardi Family Farm resulting from implementation of the CFP is estimated to be 38.41-acre feet by year 20. This is a significant quantity of additional water storage capacity, representing an average increase of over 5 inches of water holding capacity per acre for the Farm. This analysis is assumed to be conservative, yet reveals the potential significance of even small increases in soil carbon for overall Farm dynamics. In addition, there is some additional water catchment potential on farm through diversion of roof runoff from the Farm buildings to the water storage pond if the pond should fail to fill in dry years, and/or to future water storage tanks.

A preliminary analysis of roof runoff capture potential reveals the following potential. Runoff potential reflects Petaluma average annual rainfall of 26.58", derived from:
http://www.usclimatedata.com/climate/petaluma/california/united-states/usca0854ADD

Table 15. Roof Rainfall Catchment Potential, Gilardi Family Farm

The numbers are based on the assumption that annual rainfall is 26.58 inches per year; all roof areas are estimates based on Google Earth imagery. Water Volume is expressed in Acre Feet (1 AF = 325,851 gallons).

Structure	Roof Area (ft^2)	Volume In acre feet @ 26.58 inch/year
Don's House	4,347	0.22
Don's Pump House	238	0.01
Main Barn	3,760	0.19
Joyce's House	2,161	0.11
Hill House	3,052	0.16
Hill House Garage	1,535	0.08
Pullet House	462	0.02
Joyce's Shed	562	0.03
Barn Shed	1,267	0.06
Chicken Houses		
TOTAL	**17,384**	**0.88***

As shown in Table 15, total average year roof runoff catchment potential is estimated to be 0.88 acre feet, or 286,748 gallons. If all or most of this water could be stored, it would provide a significant source of water for establishment of agroforestry plantings recommended in this plan. These in turn would increase water holding capacity in the farm's soils, as outlined in
Table **16**. Chicken house roof runoff was not included in this analysis.

Table 16. Estimated Additional Annual Soil Water Holding Capacity (WHC) Gilardi Family Farm with Carbon Farm Plan Implementation, Year 20

PRACTICE	DESCRIPTION	20 YEAR SOM INCREASE (Mg)	SOIL WHC INCREASE BY YEAR 20 (AF)
Compost application on Rangeland (NRCS conservation practice standard (CPS) in development)	One time application of 1/4" of compost to 80 acres of permanent pasture approximately every 12 years.	*988.60	*9.06
Compost application on Cropland (CPS 590)	Application of compost to 52 acres of cropland to reach 5% SOM	*1,144.00	*10.49
Agroforestry (CPS 380) Windbreaks, Hedgerows, Shelterbelts; Silvopasture and Tree Shrub Establishment	84 + acres of agroforestry practices	**1,378.00	12.63
Prescribed Grazing (CPS 528)	Grazing management to favor perennials and improve production on 80 acres	152.00	1.40
Riparian Forest Buffer (CPS 391)	2.04 acres	**11.00	0.03
Grassed Waterway (CPS 412)	0.6 acres	12.00	0.03
Range Planting (CPS 550)	No-till interseeding of forage species on 80 acres	580.00	5.32
TOTAL		**4,265.6**	**38.96**

* 'rangeland' C gains from increased photosynthetic capture only; 'cropland' gains from direct compost additions of C

** assumes below ground C = ½ total C.

SUMMARY

Table 17 summarizes the overall potential for terrestrial carbon sequestration on Gilardi Family Farm through implementation of the suite of conservation practices identified through the Carbon Farm Planning Process, as outlined above.

Table 17. Estimated CO2e Reduction/Sequestration Potential, Gilardi Family Farm

Practice	Average Annual CO2e Sequestration (Mg)	20 yr CO2e Sequestration (Mg)	80 yr CO2e Sequestration (Mg)
Grazed Grassland Compost (CPS 590)	10.43	1,814.00	7,256.00
Cropland Compost (CPS 590)	102.25*	2,099.00	2,099.00**
Agroforestry: Windbreaks, Hedgerows, Shelterbelts (CPS 380) Silvopasture and Tree Shrub Establishment (CPS 612)	235.66	4,713.24	18,860.00
Riparian Forest Buffer (CPS 391)	2.04	40.80	163.20
Grassed Waterway & Vegetated Swale (CPS 412)	0.60	12.00	48.00
Prescribed Grazing (CPS 528)	14	280	1,120
No Tillage (CPS 329)	6	120	480
Range Planting (CPS 550)	29	580	2320
Totals	**297.73**	**9659.04**	**30,247.20**

** assumes SOM on 58 acres of cropland is held at 5% with periodic compost applications.
* assumes 240 yards of compost is applied to cropland each year for 20 years, remainder applied to pasture. Some combination of these two compost uses is assumed each year.

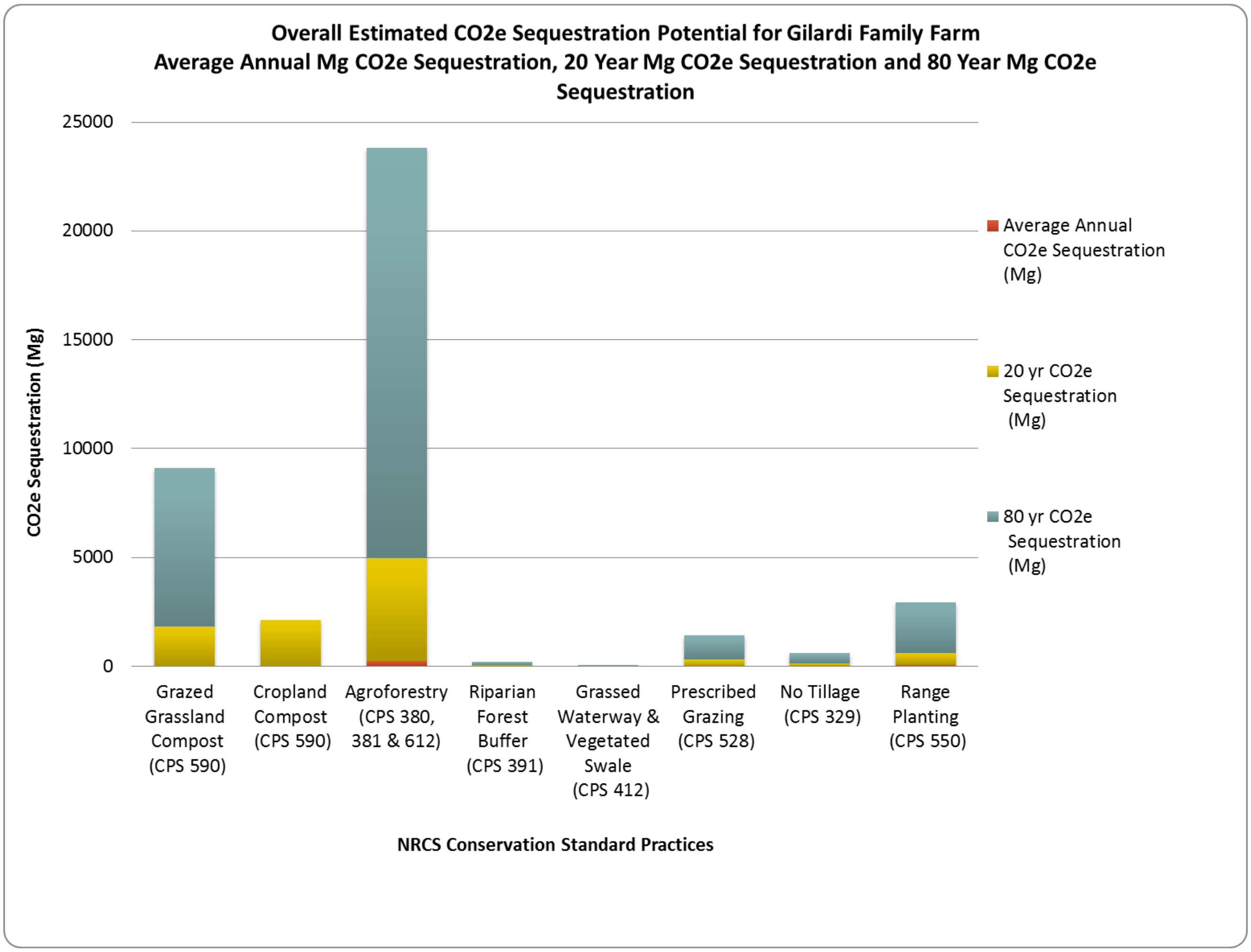

Figure 13. Overall estimated CO2e reduction potential at Gilardi Family Farms, average annual, 20 year and 80 year CO2e sequestration Mg. An associated values for terrestrial carbon sequestration through implementation of the suite of conservation practices are identified in Table 18, as outlined above.

DISCUSSION

Average annual CO_2e reduction values in Table 18 and Figure 1 are for illustrative purposes only. Actual sequestration of CO_2 in response to management interventions and conservation practices is not expected to be linear over time, and is expected to vary annually. Length of time during which practices will sequester carbon also varies among practices. For examples, see tables above for variable ages of maturity for different practices. Terrestrial carbon sequestration resulting from each practice tends to increase cumulatively to maturity and then tends to decline, though remaining net positive relative to baseline conditions for many years. This underscores the value of periodic renovation of windbreaks and shelterbelts, periodic reapplication of compost, and long-term maintenance of all carbon beneficial practices to maintain high levels of carbon accumulation in the farm system.

Values presented in table 18 are best understood as gross CO_2e sequestered through implementation of the various on-farm practices at the spatial and temporal scales outlined in table 12 and the CFP as a whole. GHG emissions associated with these practices are generally accounted for in the models used (COMET-Farm, COMET-Planner, etc.). Exact emissions –and sequestration- achieved from practice implementation at Gilardi Family Farm cannot be determined precisely, however sequestration values presented here are based on conservative estimates and are likely to be exceeded in real world application.

In some cases, rates of accumulation of CO_2e may fall below emission rates, resulting in temporary net increases of GHG. For example, initial GHG costs of compost production or riparian plantings may exceed first year sequestration rates. Net sequestration associated with a single compost application to grazed grassland may also decline over time. Models suggest soil nitrous oxide, (N_2O) emissions may gradually overtake reductions in CO_2 associated with this practice, some three decades after initial compost application (Ryals et al 2015). This suggests reapplication of compost sometime before the third decade after initial application may be warranted for sustained GHG reduction benefits from this practice.

As with positive feedbacks to pasture productivity associated with compost applications, total additional water storage capacity associated with soil carbon increases on Gilardi Family Farm resulting from implementation of the Farm Carbon Plan, estimated at over 38 acre feet (table 17), can be expected to provide further feedback to higher productivity and increased carbon capture potential over both the near and long term.

CONCLUSION

Gilardi Family Farm offers significant opportunity for enhanced capture of atmospheric carbon consistent with increased agricultural productivity, water quality and quantity enhancement, and wildlife habitat improvement. The Farm also presents unique challenges, and opportunities, associated with pastured poultry production. The potential to pioneer new approaches to pasture-based egg production in Marin County through a comprehensive carbon farming framework offers unique challenges and an opportunities.

Over the long term, the combined suite of agroforestry practices offer the greatest potential for carbon capture on the Farm (18,660.85 metric tons over 80 years). Application of compost to grazed grassland also results in significant CO2 capture (7,256 metric tons CO2e over 80 years), due to the ongoing, cumulative effects of this practice. In addition, the Farm croplands could hold significantly greater quantities of carbon (at least 2,099 metric tons of CO2e, and possibly twice that amount) as SOM, with attendant benefits for water holding capacity and productivity. Compost offers a particularly direct and rapid -though certainly not the only- means to that end.

The Farm riparian areas offer modest potential in the form of both soil carbon and increased tree, shrub and herbaceous perennial cover, accumulating an estimated 162 metric tons of CO2e over 80 years while providing wildlife habitat, and improved water quality. The full import of this opportunity is best understood in the context of overall San Antonio Creek watershed enhancement efforts being undertaken with various regional partners (see hydrology section, above). GHG benefits from other agroforestry practices, including silvopasture, shelterbelts and windbreaks reach 820.85 metric tons at maturity, while also offering significant benefits in the form of wildlife habitat and microclimate amelioration for livestock yards and pastures.

Beyond agroforestry benefits, pasture and rangeland practices on the Farm also offer significant carbon capture potential. Prescribed grazing alone presents the potential to capture 1,120 metric tons of CO2e over 80 years, to which can be added the long-term benefits of Range Planting (2,320 metric tons over 80 years).

Overall, the carbon-beneficial practices identified for potential implementation on the Farm, including compost applications, also offer significantly enhanced soil water infiltration rates and soil water holding capacity, along with improved water quality, and increased pasture, rangeland and cropland productivity, while simultaneously improving aquatic and terrestrial habitat.

By stacking multiple practices, including those outlined here and others that may be identified going forward, the greatest potential for capture and sequestration of carbon in soils and biomass at Gilardi Family Farm can be realized. Some 38 acre-feet of additional soil water holding capacity on the Farm is one of many significant co-benefits expected to result from increasing soil carbon on the Farm.

Overall, if fully implemented, this plan has the capacity, by year 20, to capture 9659.04 Mg CO2e, offsetting one year’s emissions from 2,030 passenger vehicles, or one year’s energy use by 1,015 homes, or 1,081,468 gallons of gasoline.[6]

MONITORING AND RECORD KEEPING

Practice monitoring (plant survival, pasture management, RDM monitoring, compost applications, etc.) should be carried out in coordination with project managers from the NRCS or others involved in project implementation or monitoring, such as the Marin RCD or Point Blue Conservation Sciences, in conjunction with its Rangeland Monitoring Program:

http://www.pointblue.org/our-science-and-services/conservation-science/working-lands/rangeland-monitoring-network/

Soil carbon and other ecosystem services should be monitored in accordance with market or voluntary protocol requirements (if applicable). Baseline data and records of implementation activities, including locations, spatial extent of project(s), dates of implementation, etc. should all be included in plan implementation documentation. The Farm production records can also serve as an indication of the direction of overall agroecosystem productivity, predicted to increase over time in conjunction with adoption of the carbon farm framework. Overall Gilardi Family well-being may also be a variable of interest to monitor over the CFP implementation period.

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 realistic and conservative, based upon the best available information at the time of this plan's completion (June, 2017).

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[6] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

SHORT TERM ACTION PLAN and TIMELINE

Because the scope of the CFP is extensive, practices are likely to be implemented over time, based upon GHG and co-benefits, available funds, and Farm priorities. Table 18 provides a framework for prioritizing and recording CFP practices at they are implemented.

Table 18. Gilardi Family Farm Carbon Beneficial Practices Implementation

CONSERVATION PRACTICES	LOCATION & EXTENT	CO2e BENEFIT	ASSOCIATED BENEFITS							DATE	Funding Source
NRCS Conservation Practice Standard & Associated Number	Identify Location (see CFP Map) & Monitoring Photo Points	Calculated Using: COMET-Farm, COMET-Planner, or Local Data	Soil Health	Water Quality	Water Quantity	Wildlife Enhancement	Plant Community	Air Quality	Producer Economics	Planned, Implemented, Completed &/or Maintained	
Carbon Farm Plan	Entire Farm, 80 acres		x	x	x	x	x	x	x	Completed, 2017	Marin RCD
Range Planting	All pasture fields, 58 acres	29 Mg/ year CO2, COMET-Planner	x	x	x		x		x	Fall, 2017	
Riparian Forest Buffer	Between Pastures & San Antonio Creek, 2227 linear feet	COMET- Planner	x	x	x	x	x	x		2017/2018	
Windbreak/ Shelterbelt	TBD	COMET- Planner	x	x	x	x	x	x	x	2018	
Roof Rainwater Harvest		N/A			x				x	2018	

SOIL CARBON MONITORING

Table 19. Soil Monitoring Table

SAMPLE LABEL **(number & depth of sample)**	**DATE SAMPLE TAKEN** **(m/d/y)**	**PHOTO POINT** **(identify on map)**	**SOIL ORGANIC CARBON CONTENT** **(data from lab)**	**NOTES**
SMR#1, *0-10cm*	*2/8/2016*	*GPS LOCATION*	*0.36 mg/kg* *% SOC*	*Soil Characteristics*
Name of laboratory used to process samples:			*Describe or Sampling Location and Lab Methodology used*	

To document monitoring of soil carbon/agroforestry practices and track changes over time.

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APPENDIX A: MAPS

APPENDIX B: WEB SOIL SURVEY

APPENDIX C: AGROFORESTRY SPECIES FOR GILARDI FAMILY FARM

Please note this list is not comprehensive.

TREES

Shore Pine (*Pinus contorta*)Native that to grows to 40 feet.

Green Ash (*Fraxinus dipetala*) – Fragrant yellow flowers, deciduous, height to 23 feet, 15 feet wide; medium density, moderately drought tolerant, moderate growth rate.

White Ash (*Fraxinus Americana*) – Timber, tool handles.

Yellow Poplar (*Liriodendron tulipifera L.*) – Lumber.

Black Locust (*Robinia pseudoacacia*) – The wood of black locust is strong, hard, and extremely durable, it is extensively utilized for fence posts, mine timbers, and landscaping ties. This tree also serves as a good erosion control plant on critical and highly disturbed areas, due to its ease of establishment, rapid early growth and spread, and soil building abilities. It provides excellent wildlife cover when planted in spoil areas, excellent bee forage and firewood. Nitrogen fixer; some livestock forage value. PREFERRED

Incense Cedar (*Calocedrus decurrens*) (California Incense-cedar; syn. *Libocedrus decurrens Torr.*) – A native species of conifer. It grows at altitudes of 50 to 2900 meters. It is a large tree, typically reaching heights of 120 to 200 feet and a trunk diameter of up to 9 feet, with a broad conic crown of spreading bFarmes. If given deep, infrequent watering when young it will develop drought tolerance. Tolerates a wide variety of rainfall levels, soil types over most of California. Sun, Part Shade. Prefers deep woodland soil with high organic content.

Redwood (*Sequoia sempervirens).*
Black Walnut (*Juglans hindsii)*
English/Carpathian Walnut (*Juglans regia/)*
Coast Live Oak (*Quercus agrifolia)*
Black Oak (*Quercus Kellogii)*
White Oak (*Quercus garryana)*
Valley Oak (*Quercus lobata)*
Russian Mulberry (*Morus alba tartarica)*
Black Mulberry (*Morus nigra)*
Almond (*Prunus dulcis)* - Edible nut.

SHRUBS

Saskatoon Serviceberry (*Amelanchier alnifolia*) – A beautiful shrub that grows primarily in northern California and the Sierra mountains. It tends to grow in well drained open places and hillsides at elevations from 200 to 8500 feet. Saskatoon Serviceberry grows in an upright form to a height of 15 to 35 feet. It usually has a rounded shrubby form, though it can sometimes grow more upright especially in shadier areas. The serviceberry fruit tastes a lot like blueberries. It is an important food source for birds and animals, was an important food source for northwestern Native Americans and is still grown commercially for human consumption. Great for attracting birds and other small animals. It's fairly easy to grow as long as it is in a spot with excellent drainage, though it prefers loam or sandy loam. In its natural range, it prefers full sun, and is fast growing and long lived—reaching 6 feet in 3 to 6 years and lasting about 60 years.

Beaked Hazelnut (*Corylus cornuta*) – Deciduous shrub or small tree. In California it is found primarily in the central and northern parts of the state where it grows in dry woodlands and forest edges of the Coast Ranges and Sierra Foothills. It can reach 12 to 25 feet tall. The spherical nuts, which are surrounded by a hard shell, are edible.

Redbud (*Cercis occidentalis*) – Deciduous small tree to 15 feet, plant 10 to 15 feet apart, multi-trunk, very showy; N fixer.

Blue Elderberry (*Sambucus nigra* ssp. *caerulea*) – Native deciduous shrub or small tree, to as tall as 30 feet. Purple berries are one of the most important source of food for birds in California. Blue Elderberry is tough, easy to grow, and can grow from a 1 gallon container to a 15-foot tree in 3 years if happy. It can handle permanently moist soil near stream sides or seeps, and once established, it also grows well in fairly dry soils; in drier conditions it will normally go deciduous or semi-deciduous in the summer and fall and green up in the early winter. It likes part shade or sun, and will tolerate full shade. Streambanks, slope bottoms, canyons, slightly moister places throughout the state. It occurs in conjunction with a variety of vegetation types including chaparral, sage scrub, grassland, and wetland-riparian.

Siberian Pea Shrub (*Caragana arborscens)* - recommended as a nitrogen-fixing windbreak that produces edible seed, fiber and dye. It is often used as a single row field shelterbelt for borders, screen plantings, or flowering hedges. During World War II, Siberian peasants reportedly carried their chicken flocks through the winter by feeding them Caragana arborscens seeds. The seeds serve as valuable food for wildlife. It also provides cover for upland game.

Lemonade berry *(Rhus integrifolia)* - Windbreak, edible seed.

Pacific wax myrtle *(Myrica (Morella) californica)* - Windbreak, N-fixer, edible seed.

Currant *(Ribes spp.)* - various, wild and domestic; edible fruit.

RIPARIAN SPECIES

Oregon Ash (*Fraxinus latifolia*) – Native, to 82 feet, width 30 feet, fast growth, winter deciduous. Excellent multi-use hardwood.

Big Leaf Maple (*Acer macrophyllum*) – Deciduous tree to 100 feet tall, more commonly 50-60 feet. Trunk up to 3 feet in diameter. Native, deciduous, Very fast growing. Sap used for syrup.

Box Elder (*Acer negundo*) – Deciduous, to 66 feet, 40 feet wide, fast growth. Tolerates cold to -15° F, moderately drought tolerant.

Black Hawthorn (*Crataegus douglasii*) – A native thorny compact, erect bushy shrub. Thorns along the bFarmes are one to two centimeters long. The fruit is a very dark purple pome up to about a centimeter across. The fruits were a food source for Native American peoples. Streamsides, meadows, grassy places. Sun, Part Shade. Prefers deep, moist, fine-textured soil.

Vine Maple (*Acer circinatum*) – Native, large shrub to 15-25 feet, occasionally a small to medium-sized tree, exceptionally to 60 feet. Typically grows as understory below much taller trees, but can sometimes be found in open ground, and occurs at altitudes from sea level up to 5000 feet. Cold and drought tolerant.

Big Leaf Maple (*Acer marcophyllum)* - Native.

Creek Dogwood (*Cornus sericea*) – Native shrub, formerly known as *Cornus stolonifera*. Moderately fast growing and moderately long-lived. It grows in a semi-upright form to a height of up to 15 feet, noted for its red bark, especially on new growth. Moist places, at elevations from 0 to 9000 feet. Requires moist soil and partial shade.

Oregon Alder (*Alnus oregona*) – Native tree or shrub, fast growing and moderately long-lived. Upright to a height of 20 feet. Nitrogen fixer; possible forage species.

Northern California Black Walnut (*Juglans hindsii*) – Native, large tree to 60 feet, with a single erect trunk commonly without bFarmes for 10 to 40 feet. Specimens commonly reach 5 to 6 feet in diameter near the base. The nut has a smooth, brown, thick shell containing a small edible nutmeat. It is commercially important as a rootstock for English walnut orchards all over the world, both on its own and as a parent to the *J. hindsii* x *J. regia* hybrid, commonly called "Paradox." The wood of *Juglans hindsii*, sometimes called Claro walnut, is used for furniture making and gunstocks because of its good working properties and beautiful grain patterns.

Black Cottonwood (*Populus trichocarpa*) – Native, fast growing and moderately long-lived. Upright to 100 feet. Alluvial bottomlands and streamsides, from 0 to 9000 feet. Tough and easy to grow as long as it is in sun, near a water sources and has very good drainage. Black Cottonwood is a great choice to help build a natural irrigation system—its long shallow roots will reach out to the water source and pull underground water molecules through the soil. It needs moist soil until mature, and then becomes moderately drought tolerant. Possible forage species.

Fremont Cottonwood (*Populus fremontii*) – Native tree from 36 to 120 feet, trunk up to 6 feet diameter; an important plant for birds and butterflies. Requires moist soil and plenty of sun, but tough and easy to grow. When properly situated and with access to plenty of water, they can grow 10 to 20 feet in a year and reach up to 100 feet in height and 35 feet in canopy width. Best to plant these trees by creeks, in seeps, or in areas with plenty of natural water. Tolerates occasional flooding. Almost always found in riparian or other wetland habitats such as alluvial bottomlands, streamsides and seeps, up to 6,500 feet. Sun and sandy or clay soil as long as there is sufficient water. Tolerates Saline Soil. Tolerates cold to 5° F

Agroforestry Definitions

Table A1. Example Low Windbreak

Species	% Composition	spacing feet	#/100'	width single line	width double line
First line				6'	10'
Baccharis pilularis	100%	3	17	6'	10'
Second line					
Corylus cornuta californica	20%	3	3	3	6
Heteromeles arbutifolia	15%	3	3	3	6
Holodiscus discolor	10%	3	2	2	4
Lonicera involucrata	5%	3	1	1	2
Rhamnus californica	15%	3	3	3	3
Ribes sanguineum	10%	3	2	2	4
Rubus spp.	5%	3	1	1	2
Sambucus nigra cerulea	10%	3	2	2	4
Vaccinium ovatum	10%	3	2	2	4
TOTAL per 100'	200%		33	17	35

Table A2. Example Medium Windbreak

Species	System %	Row %	spacing feet	#/100'	width single line	width double line
Front line						
Myrica californica	35	75%	6	13	6'	12'
Ceanothus thyrsiflorus	10	25%	6	4		
Single line count				**17**		
Second Line						
Acer circinatum	5	10	6	2		
Amelanchier alnifolia	5	10	6	2		
Corylus cornuta californica	5	10	6	2		
Crataegus douglasii/C. suksdorfii	5	10	6	2		
Garrya elliptica	5	10	6	2		
Heteromeles arbutifolia	5	10	6	2		
Prunus lyonii or Prunus ilicifolia	5	5	6	1		
Rhamnus californica	5	10	6	2		
Sambucus nigra cerulea	5	10	6	1		
Sambucus racemosa	5	5	6	1		
Vaccinium ovatum	5	10	6	2		
Total Count, double line				**50**		

Table A3. Example Tall Windbreak

Species	%	spacing feet	#/100'	width single line	width double line
First line optional					
Cupressus macrocarpa	100	6	17	8'	16'
single line count			17		
Acer negundo	20	12	2		
Populus fremontii (forage) (moist sites)	tbd	12			
Populus lombardii (forage) (moist sites)	tbd	6			
Pseudotsuga menzesii	40	6	7		
Quercus agrifolia	40	6	7		
Salix spp. (forage) (moist sites)	tbd	6			
Umbellularia californica	tbd	6			
Double line count			49		

APPENDIX D: SPECIAL-STATUS SPECIES POTENTIALLY OCCURRING WITHIN THE SAN ANTONIO CREEK WATERSHED (SSRCD 2008)

Federally Listed Species: Endangered (E) and Threatened (T)

Mammals

Salt-Marsh Harvest Mouse, Reithrodontomys raviventris (E)

Birds

California Clapper Rail, Rallus longirostris obsoletus (E)
Western Snowy Plover, Charadrius alexandrinus nivosus (T)

Amphibians

California red-legged frog, Rana aurora draytonii (T)

Fish

Steelhead - Central California Coast ESU, Oncorhynchus mykiss irideus (T)

Plants

Sonoma Spineflower, Chorizanthe valida [E]
Soft Bird's-Beak, Cordylanthus mollis ssp. mollis (E)
Yellow Larkspur, Delphinium luteum [E]
Marin Western Flax, Hesperolinon congestum [T]
Contra Costa Goldfields, Lasthenia conjugens [E]
Showy Indian Clover, Trifolium amoenum (E)

State Listed Species: Endangered (E), Threatened (T), and Rare (R)

Mammals

Salt-Marsh Harvest Mouse, Reithrodontomys raviventris (E)

Birds

California Black Rail, Laterallus jamaicensis coturniculus (T)
California Clapper Rail, Rallus longirostris obsoletus (E)

Plants

Sonoma Spineflower, Chorizanthe valida [E]
Soft Bird's-Beak, Cordylanthus mollis ssp. mollis (R)
Yellow larkspur, Delphinium luteum [R]
Marin Western Flax, Hesperolinon congestum [T]

California Special Concern Species

Mammals

Pallid Bat, Antrozous pallidus
Townsend's Big-Eared Bat, Corynorhinus townsenddii
American Badger, Taxidea taxus

Birds

Burrowing Owl, Athene cunicularia
Saltmarsh Common Yellowthroat, Geothlypis trichas sinuosa
San Pablo Song Sparrow, Melospiza melodia samuelis

Reptiles

Western Pond Turtle, Actinemys marmorata
Northwestern Pond Turtle, Actinemys marmorata marmorata

Amphibians

California red-legged frog, Rana aurora draytonii
Foothill Yellow-Legged Frog, Rana boylii

Fish

Sacramento Splittail, Pogonichthys macrolepidotus

APPENDIX E: GLOSSARY OF TERMS