Wool Ranch 1 Carbon Farm Plan

Photo by Paige Green

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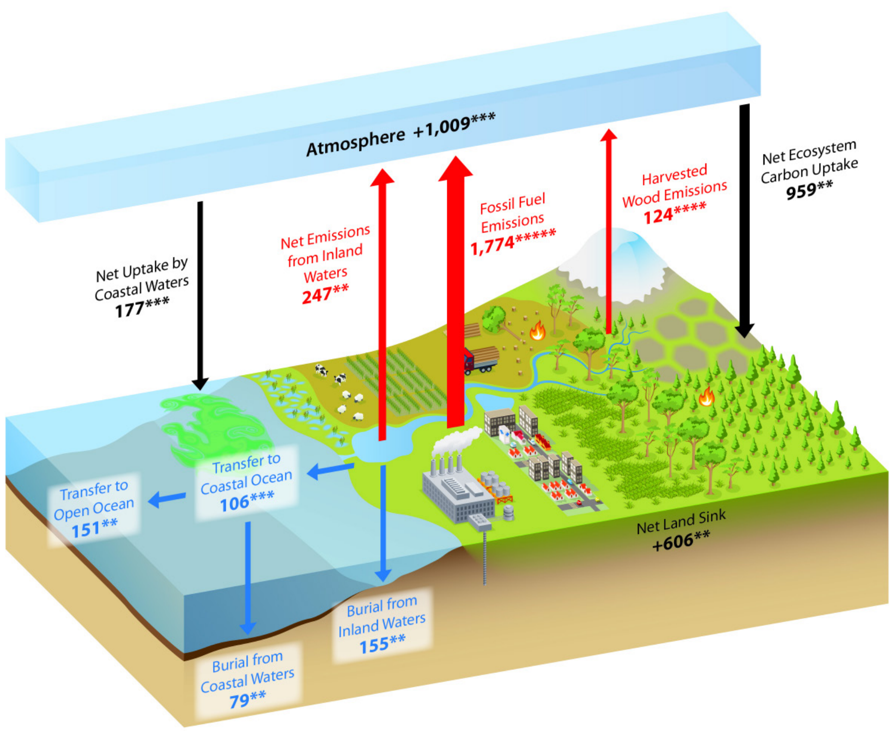
Introduction

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: food, fiber, fuel and flora. Furthermore, photosynthates (sugars) produced by the plant are moved to the soil directly as exudates from plant roots and from the soil surface through litter from plant parts such as leaves and stems. These feed soil mycorrhiza, thus adding additional carbon to the soil. Another pathway for added soil carbon is through manure from animals.

Figure 1. The Carbon Cycle, as modeled by the US Carbon Cycle Science Program



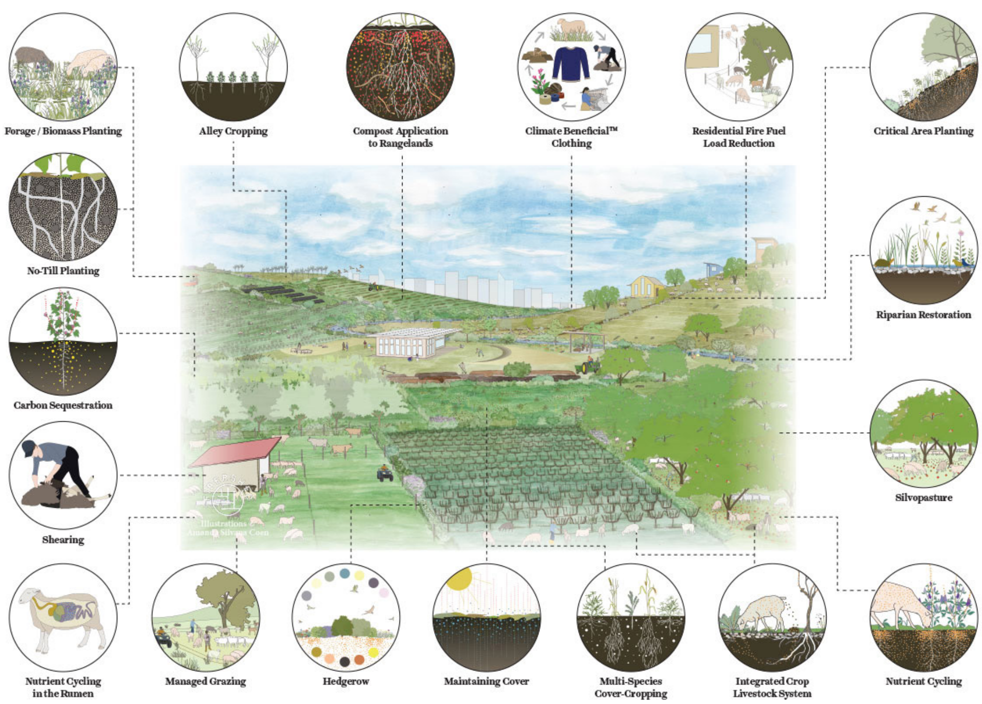
In addition to its transformation from CO_2 into the sugars, cellulose and lignin of the harvestable crop, carbon can also be beneficially stored long-term (decades to centuries or more) in soils and woody vegetation in a process known as terrestrial carbon sequestration. While the importance of carbon 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) Soil Health program and the California Department of Food and Agriculture's Healthy Soils Program.

Carbon Farm Planning is the process of identifying opportunities to decrease the production of greenhouse gasses on-farm and increase the photosynthetically driven transfer of atmospheric CO2 to stored carbohydrates in soils and above and below ground biomass. 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, soil hydrological function, biodiversity, soil fertility, agricultural productivity, as well as, resilience to drought and flood. Increasing carbon capture on working lands also helps slow rising levels of CO2 and other greenhouse gasses 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 the photosynthetic process of moving CO2 out of the atmosphere and into the plant where it is transformed into agricultural products, whether food, flora, fuel or fiber. Atmospheric carbon entering the farm can end up in several locations: the harvested portion of the crop; the standing crop carbon stocks (grassland vegetation, vines and orchards, etc.); the soil as root exudates; the soil organic matter from “waste” materials (compost or manure); or as other permanent woody or herbaceous vegetation (windbreaks, vegetated filter strips, forests

Figure 2. Carbon farming practices, courtesy of Fibershed



and woodlands). While all farming is completely dependent upon carbon, the various farming practices, and the different farm systems, can lead to variable amounts of on-farm carbon capture and storage. The carbon farm planning process differs from other approaches to land use planning by focusing on increasing the capacity of the working farm or ranch to capture carbon and to store it beneficially in the crop, in the standing carbon stocks, and/or in the soil.

While agricultural practices often lead to a gradual loss of carbon from the farm system, particularly from working land soils, carbon farm planning 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 ranch, carbon farming can result in a direct reduction in the amount of CO_2 in the atmosphere, while supporting crop production and farm resilience to environmental stress, including flood and drought.

On-farm carbon in all its forms (soil organic matter, 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 CO_2 and water and nutrients from the soil. The carbon in plants and soil organic matter can thus be understood as converted solar energy that enhances on-farm processes. Farming is still viable in low soil organic matter operations, as evidenced by current conventional, but there are long-term concerns about sustainability and viability of farms as soil organic matter drops. Increased soil organic matter increases soil water holding capacity and nutrient capture, which further enhances plants, and their outputs. With that understanding, carbon farm planning places carbon at the center of the planning process, looking at on-farm resource issues through solutions that also increase carbon sequestration.

The Carbon Farm Planning Process

Carbon farm planning is based upon the USDA NRCS Conservation Planning process. The USDA NRCS Conservation Planning process is a natural resource problem solving and management activity that integrates economic, social, and ecological considerations to meet private and public needs on a farm or ranch. The end goal aims to improve natural resource management, minimize conflict, and address problems and opportunities. Carbon farm planning utilizes that same framework, but incorporates an additional lens of carbon sequestration as another natural resource issue. 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.

Similar to NRCS Conservation Planning, carbon farm planning begins with an overall inventory of natural resource conditions on the farm or ranch, but carbon farm planning focuses on identifying opportunities for reduction of greenhouse gas emissions and enhanced carbon capture and storage by both plants and soils. Building this list of opportunities is a brainstorming process that aims to be as extensive as possible, including everything the farmer and planners can think of to potentially reduce emissions, capture and sequester on the farm, while also balancing food and farm production. While actions proposed in the carbon farm planning should reflect the inherent limits of the farm ecosystem, financial considerations should not limit this initial brainstorming process, as one goal of the carbon farm planning process is to identify potential funding, above and beyond existing resources, to realize implementation of the carbon farm planning. Soil erosion or water quality issues, for example, are addressed in the plans by recognizing the carbon capture opportunities associated with addressing these resource concerns. It is the premise of the carbon farm planning process that these resource concerns arise due to a failure to recognize the central role of carbon in the farm or ranch system, and that by addressing system carbon capture potential, virtually all other resource concerns will be addressed.

During this process, a map or maps of the farm are developed to show existing farm infrastructure and natural resource conditions. These maps are 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 online USDA greenhouse gas model, COMET-Farm (cometfarm.nrel.colostate.edu), COMET-Planner, (comet-planner.com), the CDFA Designed COMET-Planner (http://comet-planner-cdfahsp.com) or similar tools and data sources, in order to estimate metric tons of carbon dioxide equivalent (CO2e) that would be 1) avoided, or 2) removed from the atmosphere and sequestered on farm by implementing the identified conservation practices. A site-specific list of potential practices and their on-farm and climate mitigation benefits is then developed.

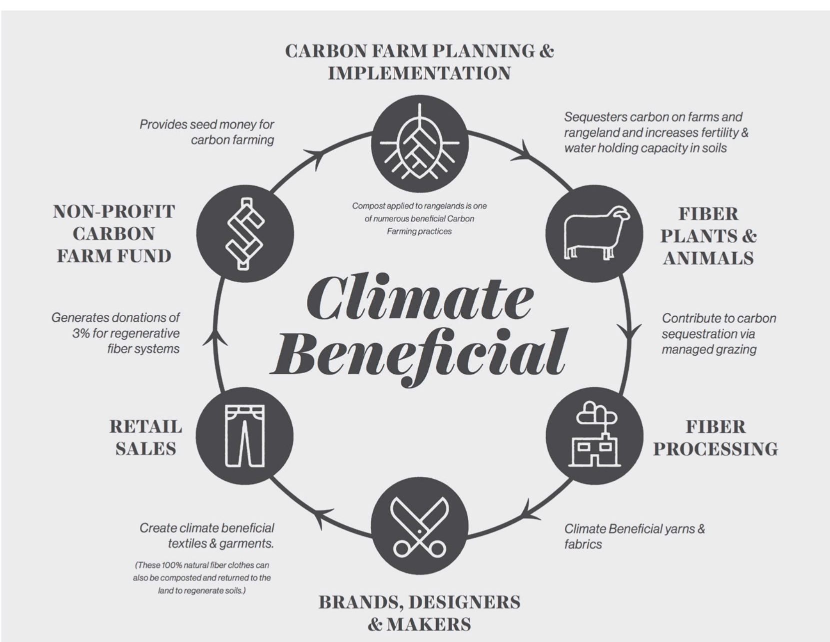
Economic considerations may be used to filter the comprehensive list of practices, and funding mechanisms are identified, including: cap and trade, CEQA mitigation, or other greenhouse gas mitigation offset credits, USDA-NRCS and/or other state and federal programs, and private funds. Practices are implemented as funding, technical assistance and farm scheduling allow. Over time, the carbon farm planning is evaluated, updated, and altered as needed to meet changing farm objectives and implementation opportunities. The fully implemented plan scenario is the ultimate 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 is online at: www.marincarbonproject.org and www.carboncycle.org.

Wool Ranch

In Summer of 2021, Fibershed approached the Wool Ranch to gauge interest in writing and funding a carbon farm plan, connecting to two other carbon farm plans nearby, completely enrolling the entirety of the Hills in the Fibershed Climate Beneficial Wool program, which would significantly improve the "wool pool" for the area. Fibershed then put the plan in motion, working with the Carbon Cycle Institute (CCI) to find a carbon farm plan writer in the area. The Carbon Cycle Institute approached C.C. RCD with the local RCD's approval, to write the carbon farm plan with CCI, Fibershed, and the Wool Ranch. As a participant in the Carbon Farm program, the Ranch has agreed to an ongoing partnership with Fibershed through the carbon farm assessment, planning and implementation phases. The project will include monitoring and adaptive management to meet landowner and CFP goals from the implementation phase and beyond.

Wool Ranch is part of the Fibershed producer community and through participation in the Fibershed Carbon Farm Cohort program, Wool Ranch is working to better understand the carbon cycle and to manage their ranch with a focus on increasing the landscape's capacity to draw down atmospheric carbon and store it in the soil. As part of Fibershed's work to encourage markets that support Climate Beneficial land management and to communicate this concept to consumers and citizens, Fibershed, together with the Carbon Cycle Institute, has developed a Climate Beneficial verification process for products derived from carbon-farmed lands. For more information about this program see Figure 3 and Appendix A: Climate Beneficial Fiber: Verified by Fibershed.

Figure 3. Climate Beneficial Fiber, verified by Fibershed



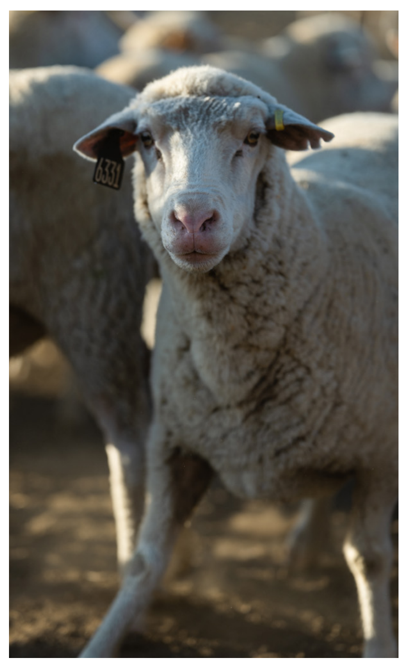
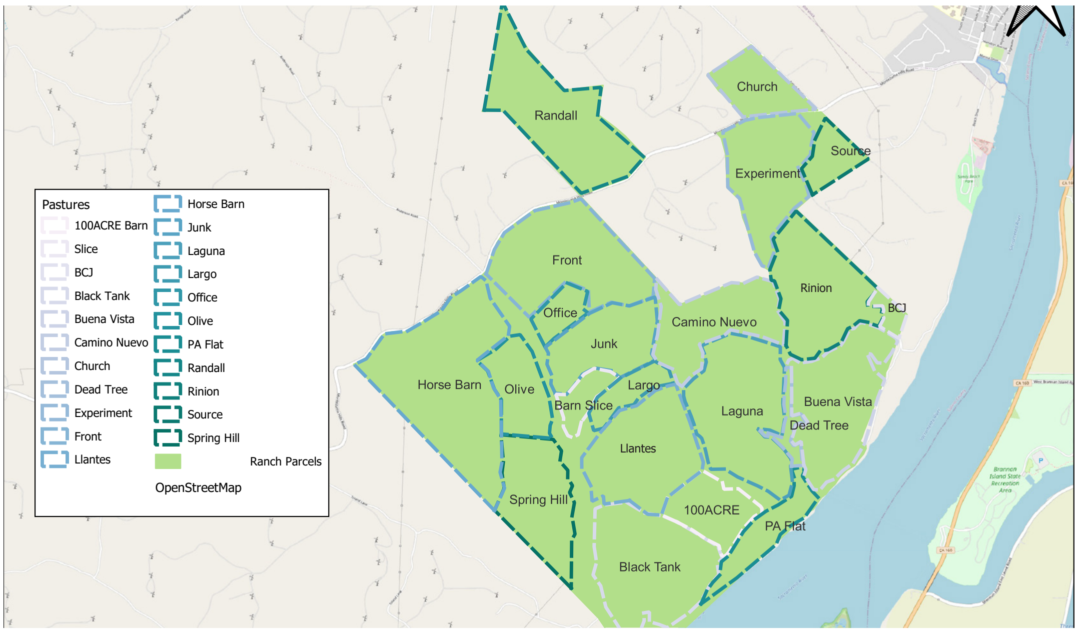


Photo by Paige Green

Wool Ranch Location

The Wool Ranch is located in California. This portion of the Ranch contains all infrastructure, including the Ranch headquarters. Two non-contiguous parcels are located on the northwest side of Hills Rd., totaling ~369-acres.

Map 1. Location Map of the Wool Ranch with approximate pasture boundaries



The ranch is surrounded by private agricultural property and primarily southeast facing, with topography consisting of gently rolling, open grasslands. The Ranch contains three sub-watersheds and seasonal streams that empty into the S. River and create long valleys that run northwest to southeast. The Ranch also varies in elevation, from 10-feet above sea level at the S. River to 185-feet on the hilltops near Hills Road.

History of Ranch

The Wool Ranch property, including 2,000-acres, was originally leased in 1896 by Wool's grandfather and later purchased in 1917. In 1999, the Wool's purchased the adjacent ~1700-acre property bringing the total owned acres to over 3,700-acres (Koopmann Rangeland Consulting, 2021). The Wools continue to farm grain, alfalfa, and wine grapes, and market pasture-raised sheep from their herd of over ~1,800 ewes.

The Wool Family has a tremendous history in sustainable livestock production and farming. The Wools continue many of the practices her grandfather started and are progressive with regard to resource management and protecting soil and water quality.

Existing Environmental Conditions

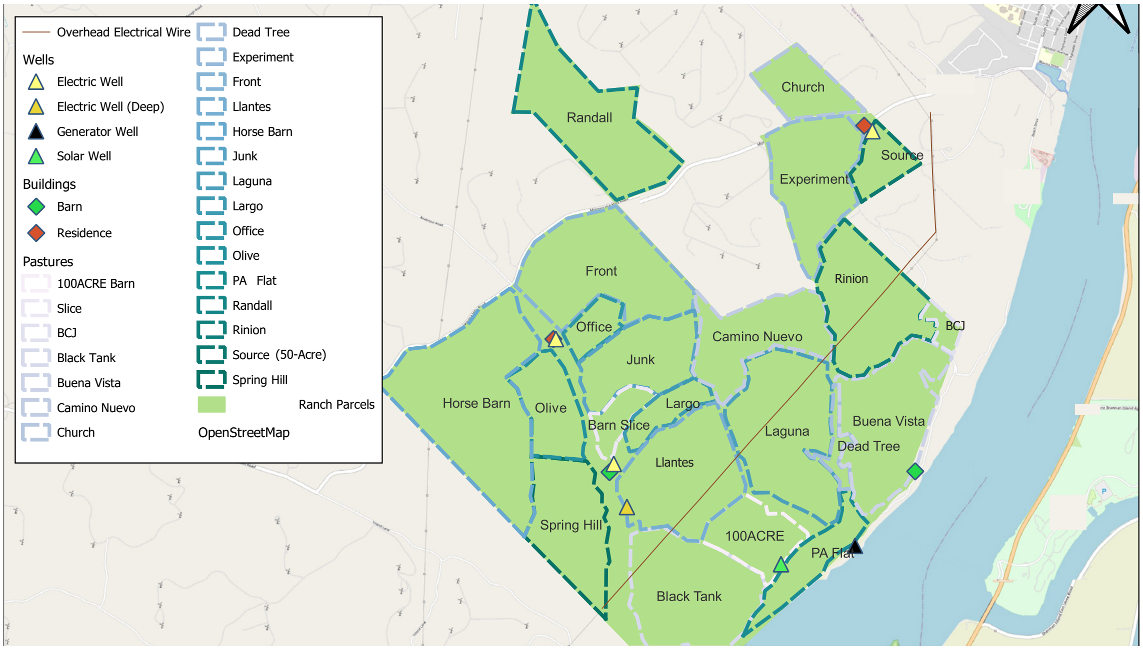
Wool Ranch is located within a landscape that has a Mediterranean climate, with most rainfall occurring from October through April, followed by a warm dry summer. The Wool Ranch is located in the interior of California adjacent to the S. River at the edge of the S.J.-S. River Delta. The annual precipitation varies from 10 to 35 inches, but more closely averages around 17 inches annually, with an average annual temperature of 57 to 62 degrees Fahrenheit. The freeze-free period averages 270 days. The elevation ranges from 10 feet at the southeastern portion of the property adjacent to the S. River, and crests just over 185 feet in the northwest corner of the ranch.

Map 2. Wool Ranch Streamlines (blue) and pasture boundaries (pink)

The landscape within the property boundary consists of rolling hills covered mostly in a variety of grasslands and ribbons of riparian forest along seasonal streams. The Wool Ranch rests in the lower reaches of the Lower S. River watershed, specifically the T.S.-S. River Watershe, and is home to a large array of wildlife. The Wool Ranch is split by five seasonal streams that flow into three tributary systems before ultimately ending in the S. River.

The ranch has seven wells, five electric, one portable gas/diesel powered, and one solar that provides water for livestock, domestic, and irrigation uses across the property. These wells provide all water on the property, with no developed stock ponds.

Map 3. Wool Ranch Pastures, Wells, and Buildings



Vegetation

The Ranch is dominated by grassland vegetation and the steeper hillsides are covered in California Bay Laurel, Coast Live Oak and a small amount of coastal scrub. While the riparian areas contain some arroyo willow, there is a mix of mature Bay Laurel (*Umbellularia californica*) and Coast Live Oak (*Quercus agrifolia*) and scattered California buckeye (*Aesculus californica*). The herbaceous vegetation on the ranch consists primarily of non-native annual grasses, which include, but are not limited to Soft brome (*Bromus hordeaceus*), Italian ryegrass (*Lolium multiflorum*), Wild oat (*Avena fatua*), Mediterranean barley (*Hordeum murinum*), Silver hairgrass (*Aira caryophyllea*), and Foxtail fescue (*Vulpia myuros*). The plant community also consists of forbs and legumes, including Redstem filaree (*Erodium cicutarium*) Burclover (*Medicago polymorpha*), Narrowleaf plantain (*Plantago lanceolata*), and various clovers (*Trifolium spp.*) Although the perennial plant populations are not as predominant as the annuals, they do include natives such as California Oatgrass (*Danthonia californica*), Purple needlegrass (*Nasella pulchra*), and Blue wild rye (*Elymus glaucus*). There is a small component of the vegetation that is comprised of non-desirable invasive species, which include Woolly distaff thistle (*Carthamus lanatus*), Purple star thistle (*Centaurea calcitrapa*), and Yellow star thistle (*Centaurea solstitialis*).

Current Land Use

Wool Ranch was originally founded in 1896 by D. Wool, J.Wool's grandfather, after immigrating from Scotland to Canada, then settling in Rio Vista in 1892. J. Wool is a third generation rancher after her grandfather; her father managed the ranch from 1934 to 1999.

Wool Ranch has always practiced a rotational system of grazing and grain production across the 3,800-acre property. The land is rotated in three-year cycles where in year one, a field will serve as a volunteer pasture, is disked and fallowed in the second year, then planted in grain the third year, after which the cycle begins again. In 2008, 51-acres of vines were planted to begin growing grapes for wine. Wool Ranch also grows alfalfa on approximately 81-acres next to the S. River at the bottom of the property, and 45-acres of barley, pea, and vetch in the flat lands above the vineyard.

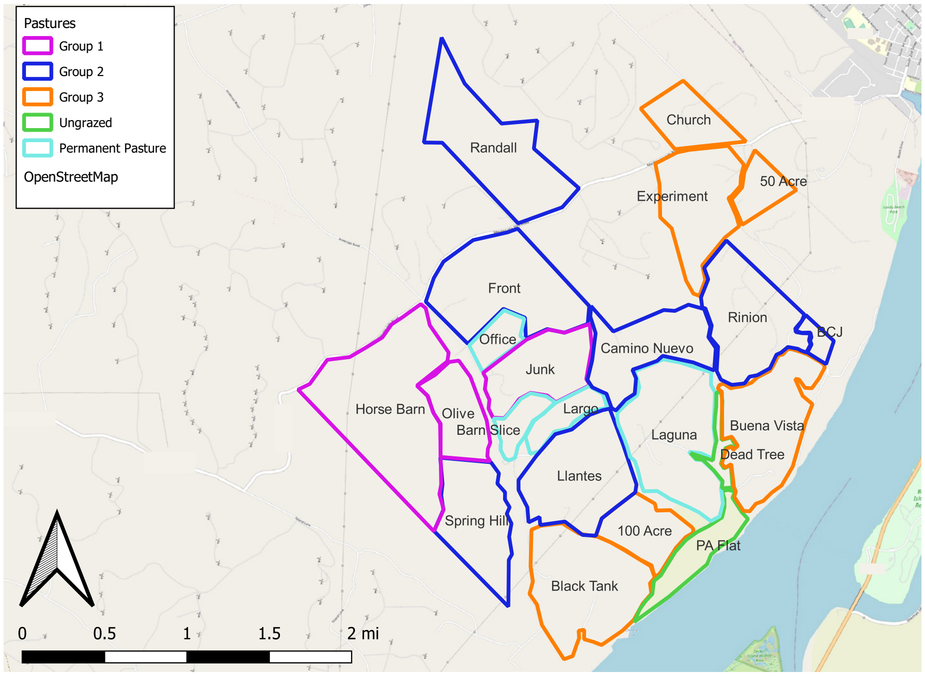
The entirety of the property is zoned by S. County as an A-160 Exclusive Agricultural Zoning District, the largest agricultural zoning district in S. County (S. County, 2022). The Zoning Code allows for most agricultural uses allowed by right, including grazing or pastured livestock. The surrounding area matches this zoning designation.

The Wool Ranch resembles most other neighboring properties and ranches with the exception that there are no commercial wind turbines on the property Neighbors nearby have negotiated with wind energy companies for the construction of these wind turbines, and as a result face additional restrictions to vegetation, vegetation height, and the planting of trees to avoid offering bird perch or nesting opportunities in an effort to limit bird strikes by wind turbines. Because there are no commercial wind turbines, none of these restrictions are in effect on Wool Ranch.

Table 1. Wool Ranch pasture groups and reported acreage

Cycle Group 1	Reported Acreage	Cycle Group 2	Reported Acreage	Cycle Group 3	Reported Acreage	Permanent Pasture	Reported Acreage
Horse Barn	400	Spring Hill	182	Black Tank	262	Barn Slice	35
Olive	104	Front	283	100 Acre	100	Largo	50
Junk	209	Randall	277	Buena Vista	180	Office	45
		Llantes	180	Experiment	156	Laguna	267
		Camino Nuevo	180	Church	90		
		BCJ	30	Source (50-acre)	50		
		Rinion	207				
Total	**713**		**1339**		**838**		**397**

Map 4. Wool Ranch Pasture Rotation Groupings



Most of the Wool Ranch is open-space and grazed pasture land/rotational grain production. Within the property however, there are a number of ranch improvements, including barns for storage of equipment, office space, and residences, barns for livestock, wells to pull water for livestock use, and transmission wires that cut across the property that supply electricity from the Oroville Dam north of S..

The ranch is also cross cut with roads, graded, but unpaved or graveled, that provide access to the tops of pastures and hills. An estimate through Google Earth estimates approximately 16-miles of roads cut across the property that also help to create pasture divisions for rotational grazing.

The Wool Ranch currently includes 20-pastures, ranging in size from 100-300-acres that are grazed, left fallow, and planted with grains in a three year cycle. Two additional pastures (PA Flat and Dead Tree) are not grazed with PA Flat regularly planted in alfalfa. Based on aerial imagery, and later confirmed with the producer, the following pastures are included within each cycle.

Wool Ranch Goals and Objectives

Through the development of this Carbon Farm Plan, the landowner identified ranch goals and objectives. Through implementation of this carbon farm plan and associated conservation practices, and the grazing management plan developed by Koopmann Rangeland Consultants, many of the goals and objectives should be met at varying time frames. A short term action plan and timeline template, found on page 94, has been developed to allow the landowner to develop a plan and track progress toward meeting the ranch goals and objectives.

The following is a list of the goals and objectives:

1. Continue the Wool Ranch legacy by utilizing cutting edge agriculture practices and technology to ensure economic success
2. Follow environmentally sensitive management practice to promote sustainable organic agriculture
    - Reducing tillage across the entire ranch
    - Converting land to permanent pasture
    - Integrating trees and shrubs into the landscape
3. Maintain or increase agricultural productivity and carbon sequestration by:
    - Better utilizing pastures and increasing plant growth and vigor
    - Improve soil health and water holding capacity to improve plant growth and climate change resilience
    - Improve forage quality and production on hillslopes with topographic access constraints for equipment

Ranch Resource Concerns

For the purpose of this plan, the principal resource concern to be addressed on the ranch is carbon sequestration. Additional resource concerns were also identified through the planning process that may have a secondary cause and effect relationship with carbon capture potential. These may include, but are not limited to soil erosion, available livestock water, livestock distribution, and degraded plant condition. All resource concerns link to soil, water, animals, plants, air, and/or humans. It is the responsibility of the planner to identify and prioritize those resource concerns identified on farm, and identify planned practices that will address the resource concerns, ideally by linking those concerns to carbon sequestration opportunities.

These practices may be structural, vegetative, or management. This inventory and evaluation process takes place through site visits, discussions with the landowner, and field assessments.

Another important resource concern to keep in mind is the economics of the ranch, and the cost-benefit ratio of the planned practice. Beyond field assessments, any planned practice must be economically viable, as well as sustainable, and address landowner's goals and objectives.

Soil

Soil Erosion: S. River

- While soil erosion is of concern across the entirety of Wool Ranch, significant soil erosion was observed, and later confirmed through aerial imagery, along the portion of the ranch directly adjacent to the S. River, resulting in retreat of the alfalfa field in-land and loss of farmable acreage at the edge of the river. (see: Riparian Restoration (CPS 395), Riparian Forest Buffer (CPS 391), Riparian Herbaceous Cover (CPS 390), Critical Area Planting (CPS 342)

Soil Health: Soil Organic Matter and Carbon

- Broadly speaking, the Wool Ranch seeks to improve soil health on the ranch, creating a sustainable agricultural operation that balances current needs with future needs, ensuring a healthy and viable ranch now and in the future. (see: Cover Crop (CPS 340), Mulching (CPS 484), Compost Application (CPS 363), Silvopasture (CPS 381), Hedgerow Installation (CPS 422), and Windbreak Establishment (CPS 380))

Soil Erosion: Wind

- While site visiting, planners observed what historically may have been a series of windbreaks that are in need of repair, pointing to wind erosion as a threat on the ranch, particularly in the valleys of the ranch. (see: Windbreak Installation (CPS 380) and Hedgerow Installation (CPS 422))

Animals

Predation

- While talking with land managers during the site visit, they expressed interest in planting hedges and trees for a variety of benefits, but expressed concerns that it could lead to creation of habitat for coyotes that would prey on the lambs or ewes. (see Prescribed Grazing (CPS 528))

Air

Air Quality: Carbon Sequestration

- Landowner is seeking to improve carbon capture and sequestration on the ranch. (see Table 25 for full list of management practices and carbon sequestration estimates)

Human

Economic and Social Conditions

- Limited funds to implement vegetative and structural improvements to meets goals and objectives (see: Table 29 for currently known or available funding opportunity list at end of plan)
- Initial practice installation may increase costs and management in the short term

Plants

Invasive Weed Pressure

- Grazing management plan identified the need to manage invasive weeds to avoid being inundated with non-productive forage for livestock (See: Prescribed Grazing (CPS 528))

Photo by Paige Green

Photo courtesy of CCI

Photos displaying examples of on ranch Soil and Plant Resource Concerns where there are opportunities for increasing productivity and carbon sequestration by improving soil health and water holding capacity to improve plant growth and climate change resilience; improving forage quality production; reduce wind impact to pastures resulting in decreased soil moisture and vegetative growing season. Bottom left: Photo displays soil stream bank erosion along S. River resulting in retreat of the alfalfa field inland and loss of farmable acreage. Bottom right: Dr. J. Creque and K. Nicols observing pasture forage composition.

Pasture and Range Definitions, and Ecological Sites

Pastureland description differs from rangeland as it primarily produces vegetation that has been planted to provide preferred forage for grazing livestock. It can also have been manipulated by mowing, cropping, haying, tilling, or by having a soil amendment applied. Rangelands are considered to not have a history of physical manipulation, and can be associated with a historic climax plant community. Rangeland plant communities have adapted specifically to climatic, biotic, and abiotic factors, which make them unique to site-specific settings. These unique areas are also known as ecological sites and are very helpful to understand in the planning process as the soils and vegetation of similar ecological sites respond to similar input, management and/or disturbance. Each ranch can have few to many ecological sites which can dictate the response to implementation of planned practices, and the landscape's ability to sustain productivity over time. For example, the specific soil, slope and aspect of a site can help determine what species of tree, shrub or grass will thrive. This, in turn, would also affect the degree of potential carbon sequestration due to survival rate or growth potential. To classify these historic climax plant communities, Ecological Site Descriptions (ESDs) have been developed by the USDA-NRCS. The development of these ESDs with NRCS are still in process for some areas of California and are not available for use in S. County as of yet. For the Wool Ranch, visual assessment of the landscape and delineation of potential ecological sites, based on soil, slope and aspect criteria, were used for planning purposes.

Implementation of conservation practices within the Carbon Farm framework is based upon the grouping of land management activities first by soil type and then further subdivided into ecological sites. An ecological site is a unit of land with specific physical characteristics that differs from other land in its ability to produce a distinctive kind and amount of vegetation. An ecological site is defined by its geophysical characteristics, including: soil, slope class, aspect and climate. A landscape is made up of a patchwork of ecological sites, so that a single pasture may contain several ecological sites. Different ecological sites can be expected to respond differently to similar management, underscoring the challenges associated with managing diverse ecological sites within a single pasture or management unit.

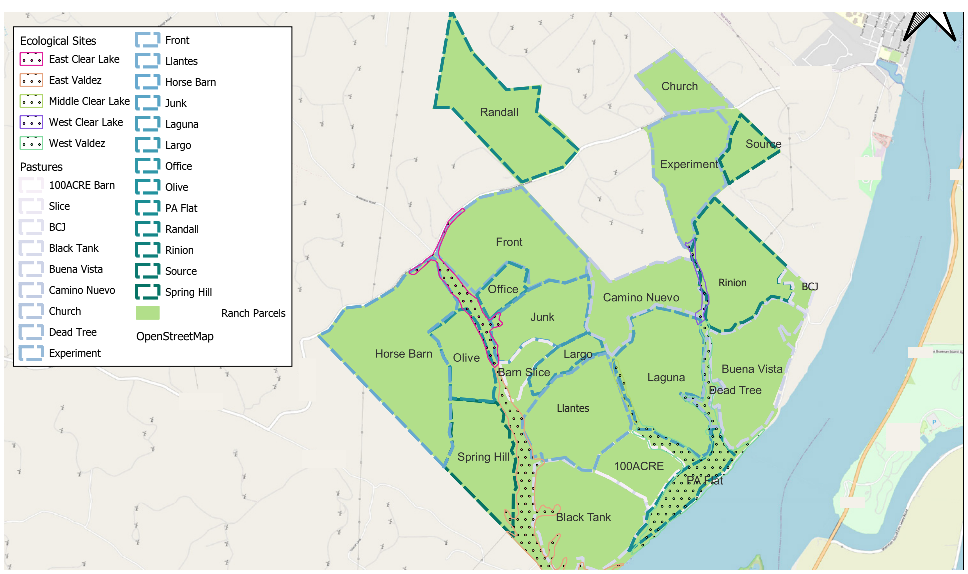
Photo by Paige Green

Each farm or ranch can typically be described using just a few ecological site descriptions, which commonly reoccur across the landscape. Similar ecological sites can be expected to respond similarly to management. Each ecological site supports similar ecosystem processes, including carbon sequestration potential, assuming similar vegetation, management history, and future management. Ecological site delineation helps identify 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 with compost applications may be a very productive strategy on shallow soil on a south-facing slope of 30%, but of limited value on an organic matter-rich meadow site. Knowing the ecological site will help determine which plant species will be suitable for a specific site or restoration project, i.e., some sites will support trees and brush while others will only support herbaceous vegetation. Trees, such as willow or valley oaks, might thrive on one site while failing to survive on another. Each ecological site has its own annual forage production values. These values help determine the carrying capacity of the land and are used in the development of the Grazing Plan.

Speaking broadly, the Wool Ranch is fairly uniform rolling pasture land with few ecological sites. The property and surrounding area have been intensively grazed for over 100+ years, and as a result are fairly uniform pasture land made up of native and non-native grasses and forbs, with trees planted intentionally for a variety of goals including for windbreaks, for restoration, and for aesthetic purposes near residences and/or farm infrastructure.

While site visiting in February 2022, planners identified three potential ecological sites that could potentially support a different array of plant and management activities, mostly along

Map 5. Wool Ranch Ecological Sites



riparian corridors: (1) at the entrance to the property (between the Front, Horse Barn, Olive, Office, and Junk pastures) (2) from the barns and lambing paddocks down to the vineyard (between the Barn Slice, Spring Hill, Largo, Llantes, and Black Tank pastures, (3) the drainages that feed into the alfalfa field. Further examination into these potential ecological sites through soil maps and Google Earth revealed that these areas were largely driven by different dominant soil types (the Clear Lake and Valdez series.). Planners broke these sites along dominant soil series into the five ecological sites above in Map 6.

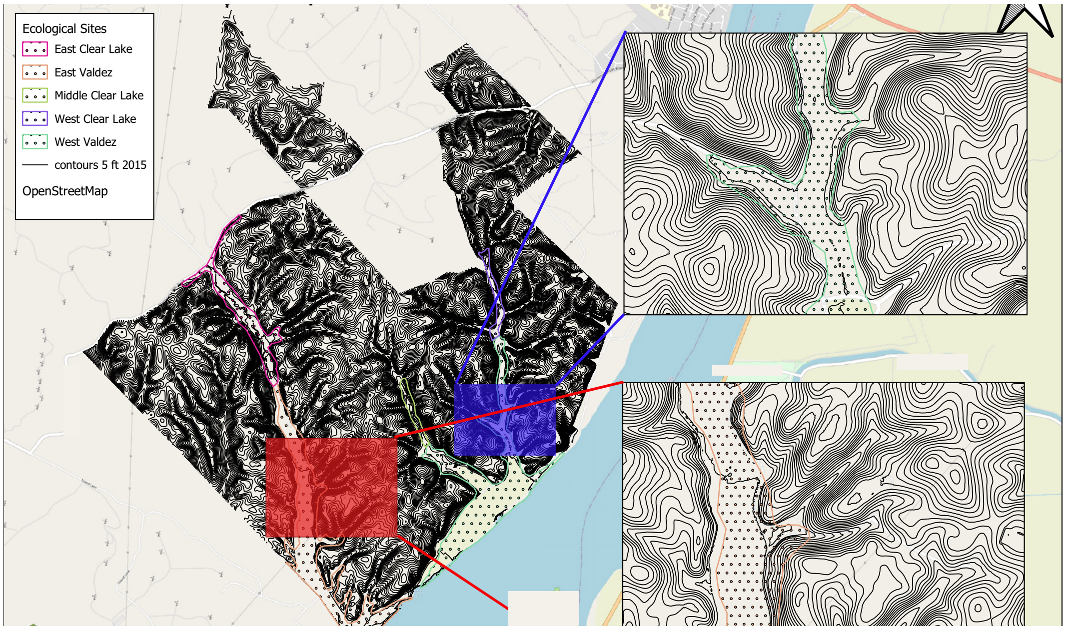
The Clear Lake Ecological Sites mostly encompass the higher end of drainages to the S. River. The Valdez Ecological Sites encompass the lower end of drainages and are where active row crop and vineyard agriculture are currently happening. Aside from these pockets, the rest of the property is broadly one soil type and almost exclusively grazed pasture land.

For planning purposes then, planners have determined five ecological sites driven by soil: East Valdez, West Valdez, East Clear Lake, Middle Clear Lake, and West Clear Lake, as seen in Map 6. Ecological sites can also be driven by other factors such as slope direction (north vs. south, east vs. west). A Google Earth approximation of terrain can be seen in Map 7 and Map 8, and shows that there are a number of smaller, ecological sites when considering slope direction.

In general, slopes exhibit differences in vegetation and plant community when comparing south facing slopes to north facing slopes and east facing slopes to west facing slopes. In the northern hemisphere, south facing slopes receive more direct sunlight than north facing

Map 6. Wool Ranch with 5-Foot Contours

Map 7. Wool Ranch Slope Direction Detail



slopes, typically resulting in faster growing plant communities. Ungrazed, these slopes would be expected to follow a typical vegetation succession from smaller grasses, to shrubs, and eventually wood plants, and trees. North facing slopes would undergo this process as well, but typically at a slower rate. Eastern facing slopes get more sunlight in the early morning, typically during cooler parts of the day and higher relative humidity. Western facing slopes on the other hand receive more sun in the late afternoon, and are typically warmer than east facing slopes. While we haven't mapped or analyzed these in the context of this document, these larger assumptions can help inform management practice success or failure and should be considered in the design phase. Map 8 shows two examples of areas on the ranch that have multiple slope directions, facing north, south, east and west. Given the diverse geographic terrain and slope direction across the ranch, we expect a number of smaller ecological sites that vegetation may behave differently in.

Soils of Wool Ranch

There are seven soil series types across the Wool Ranch based on soil surveys completed by the USDA NRCS, collected from the online Web Soil Survey with available parcel data used as the Area of Interest. Our discussion in the previous chapter mentions two, the Clear Lake Series and the Valdez series given their locations relative to identified ecological sites. Full details of each soil series and locations can be seen in Appendix B: Wool Ranch Web Soil Survey report. What follows below is a summary of that report and how it could influence the carbon farm plan.

Table 2. USDA WebSoilSurvey Soil series acres and percent of total within Wool Ranch

Soil Series Unit Name	Soil Series Unit Symbol	Acres within Wool Ranch	Percent of Wool Ranch
Antioch-San Ysidro complex, 2 to 9 percent slopes	AoC	59.4	1.6%
Clear Lake clay, 0 to 2 percent slops, MLRA 17	CeA	77.3	2.1%
Diablo-Ayar clays, 2 to 9 percent slopes	DaC	127.1	3.4%
Diablo-Ayar clays, 9 to 30 percent slopes, eroded	DaE2	3217.5	85.4%
Rincon clay loam,m 0 to 2 percent slope	RoA	1.5	0.0%
Tujunga fine sand	Tu	2.5	0.1%
Valdez silt loam, drained, 0 to 2 percent slopes, MLRA 16	Va	279.8	7.4%
Water	W	2.1	0.1%
		3767.2	100%

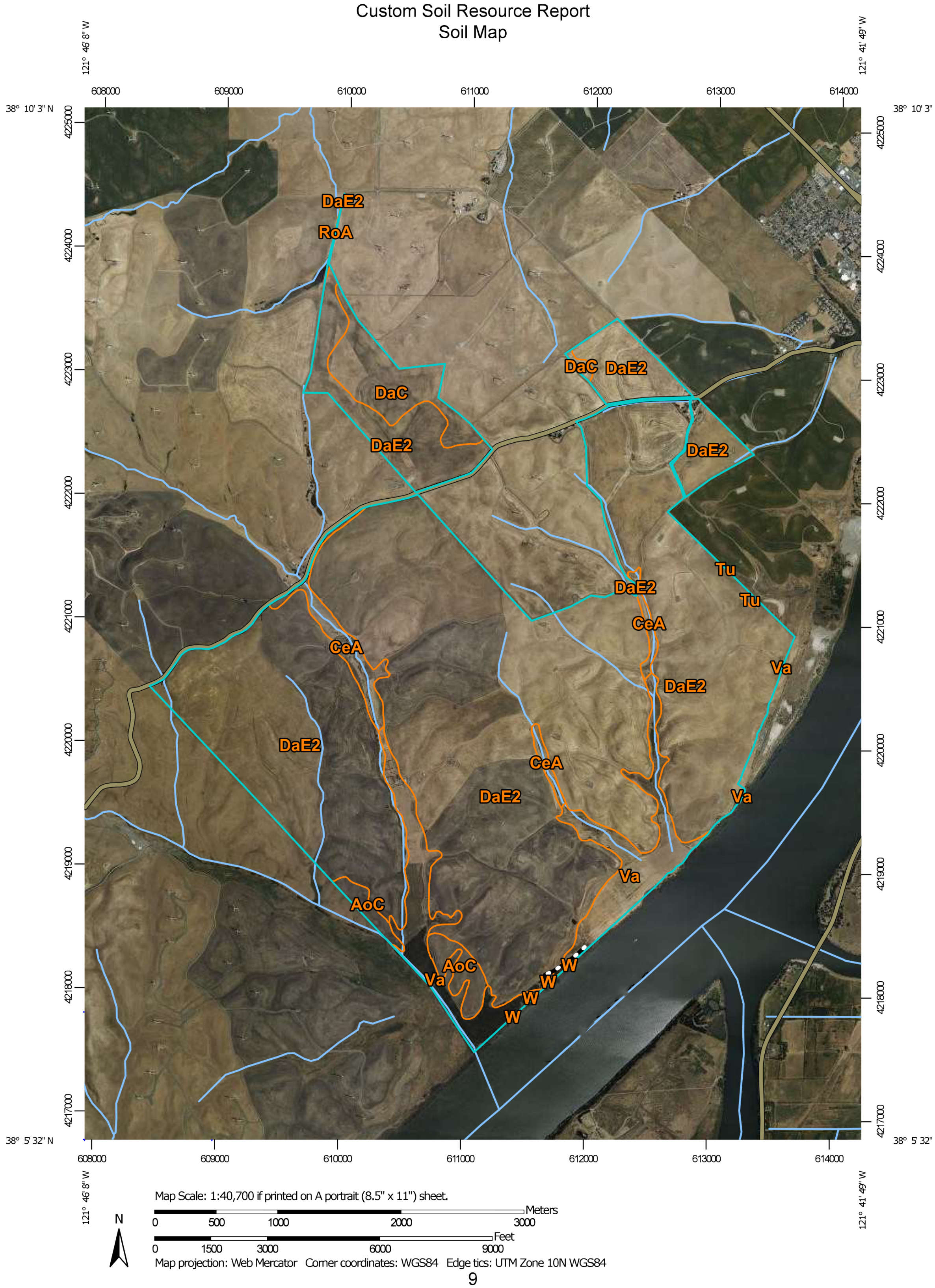
Antioch-San Ysidro Complex

The San Ysidro series consists of very deep, moderately well drained soils that formed in alluvium from sedimentary rocks. San Ysidro soils are on fan remnants and stream terraces and have slopes of 0 to 9 percent. The mean annual precipitation is about 20 inches and the mean annual air temperature is about 59 degrees F (USDA NRCS, 2022). This soil type is observed on the southern portions of the Wool Ranch adjacent to the vineyards, but accounts for very little of the total acreage. This soil series is also classified with a low organic matter content around 1.5% in the first 50 cm and less than 0.5% from 50 to 150 cm (California Soil Resource Lab, 2022). This complex is highly productive in terms of forage and the primary land use is for grazing pasture, dryland farming, and shallow row crop cultivation. Where uncultivated, the normal vegetation type consists of annual grasses and forbs. Permeability is very slow with slow to medium runoff resulting in a very low risk for erosion. These soils can be grazed year-round with minimal impacts from soil compaction or erosion by livestock (Koopmann Rangeland Consulting, 2021).

Clear Lake clay

The Clear Lake series consists of very deep, poorly drained soils that formed in fine textured

Map 8. Wool Ranch Soil Map; blue outlines represent the parcel boundaries and orange lines represent the soils.



alluvium derived from mixed rock sources. Clear Lake soils are in flood basins, flood plains and in swales of drainageways. Slopes are 0 to 5 percent. The mean annual precipitation is about 20 inches and the mean annual air temperature is about 60 degrees F (USDA NRCS, 2022). This soil type is mostly observed at the bottom of valleys on the Wool Ranch along the calving paddocks and the valley that drains into the alfalfa fields. This soil series is also classified with low organic matter content at 1.4% in the first 30 cm, dropping to 0.7% from 50 cm to 115 cm, and then at 0.2% below 115 cm (California Soil Resource Lab, 2022). Where uncultivated, typical vegetation consists mainly of annual grasses and forbs used for livestock grazing. Primary soil use is for farming of row crops, dryland grains, and irrigated pasture/alfalfa. Permeability is very slow however based on slope erosion risk is very low. Grazing on these soils should be delayed until soil has drained sufficiently and is firm enough to withstand the risk of soil compaction from heavy livestock use (Koopmann Rangeland Consulting, 2021).

Diablo Ayar clays

The Diablo series is a member of the fine, smectitic, thermic family of Aridic Haploxererts. Typically, Diablo soils have dark gray, neutral and mildly alkaline, silty clay upper A horizons, gray and olive gray, calcareous, silty clay lower A horizons, and light olive gray, silty clay AC and C horizons that rest on shale (USDA NRCS, 2022). The Diablo-Ayar soil series dominates the Wool Ranch, accounting for over 3200 of the 3700-acres across the ranch. This soil series is found most everywhere that isn't a riparian valley, and is further classified depending on the slope with most of the series occurring on slopes between 9 and 30%. This series has some of the highest organic matter content on the ranch at 2.5% down to a depth of approximately 60 cm, and 0.8% below 60 cm (California Soil Resource Lab, 2022). These highly productive soils support annual grasses and forbs primarily used for livestock grazing and for dryland grain production in some areas. These soils are well drained with slow to medium runoff and slow permeability with a low erosion risk, particularly on slight to moderate slopes. These soils can be grazed year-round with minimal impacts from soil compaction or erosion by livestock (Koopmann Rangeland Consulting, 2021).

Rincon clay loam

The Rincon series consists of deep, well drained soils that formed in alluvium from sedimentary rocks. Rincon soils are on old alluvial fans and both stream and marine terraces, and have slopes of 0 to 30 percent. The mean annual precipitation is about 16 inches and the mean annual air temperature is about 60 degrees F (USDA NRCS, 2022). The Rincon series is very limited on Wool Ranch and is found on the northernmost extent of the ranch. This series is characterized by organic matter content of about 2% in the first 50 cm, increased to 3.0% from 50 to 110 cm, and then drops to trace organic matter content below 110 cm (California Soil Resource Lab, 2022).

Tujunga fine sand

The Tujunga series consists of very deep, somewhat excessively drained soils that formed in alluvium from granitic sources. Tujunga soils are on alluvial fans and floodplains, including urban areas. Slopes range from 0 to 12 percent. The mean annual precipitation is about 18” and the mean annual temperature is about 64 degrees F (USDA NRCS, 2022). Tujunga series is very limited across the Wool, found on the eastern extents and along the base of the property adjacent to the S. River. The Tujunga series has low organic matter content at 0.7% in the first 30 cm, and 0.1% below 30 cm (California Soil Resource Lab, 2022). Where not cultivated, typical vegetation consists of shrubs with a mix of annual grasses and forbs used for grazing. These soils are conducive to citrus and grape production in many areas. Tujunga soils are excessively drained with negligible to low runoff and high saturated hydraulic conductivity. These soils can be grazed year-round with minimal impacts from soil compaction or erosion by livestock (Koopmann Rangeland Consulting, 2021).

Valdez Series

The Valdez series consists of very deep, poorly drained soils that formed in recent alluvial material from mixed rock sources. Valdez soils are near rivers, sloughs and old stream channels in river deltas and floodplains and have slopes of 0 to 2 percent. The mean annual precipitation is about 17 inches, and the mean annual air temperature is about 60 degrees F (USDA NRCS, 2022). The Valdez silt loam series is largely found in the Alfalfa fields of the Wool Ranch along the S. River and is classified by a soil organic matter percentage of 1.2% in the first 40 cm and then drops to 0.6% below 40 cm (California Soil Resource Lab, 2022). These soils are generally irrigated and used for intensive row and field crops, alfalfa production or used for wildlife habitat where not actively irrigated [4]. Valdez silt loam is poorly drained with moderate permeability and very slow runoff, posing little erosion risk though soil compaction can be a concern. Grazing on these soils should be delayed until soil has drained sufficiently and is firm enough to withstand the risk of soil compaction from heavy livestock use (Koopmann Rangeland Consulting, 2021).

Photos by Paige Green

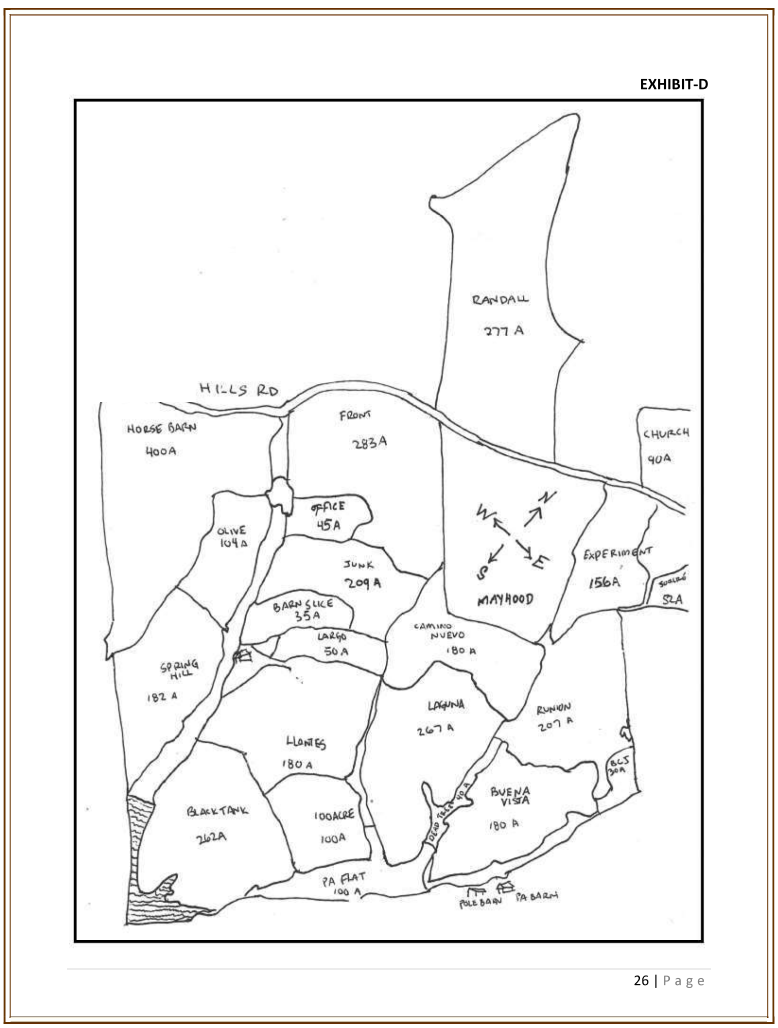
Photos displaying Diablo Ayar on-farm soils series

Grazing Protocols

Grazing and Carbon

The CFP grazing plan combines overall ranch 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 farms 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.). Practices that reduce or repair soil erosion, reduce areas of bare soil, 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 & Schuman, 2007; Conant, Paustian, & Elliott, 2001; Voisin, 1961).

Map 9. Hand drawn pasture map provided by Wool Ranch to Koopman Rangeland Associates



Prescribed Grazing

The practice of prescribed grazing is the management of vegetation through control of grazing or browsing, with the intention to achieve specific goals and objectives. This can be applied to all grazing and browsing landscapes, rangeland or pastureland, and can be with any class of livestock, depending on their plant community preference. The prescribed grazing plan includes clear goals and objectives, resource inventory, forage inventory, forage-animal balance, grazing plan, contingency plan, and monitoring plan. These components of the plan are all important for success in achieving goals and objectives. To meet identified landscape objectives, the livestock rotation is based on the rate of plant growth, available forage and forage demand. The intensity, frequency, timing and duration of grazing, and/or browsing, is determined to meet desired plant community and other management objectives while keeping in mind the nutritional needs of the animal. Supporting infrastructure, such as fence and water developments, also need to be planned to meet grazing regime needs. Typically, pastures or fields are divided, and stocking rates are set to meet vegetation management goals. With prescribed grazing, stocking rates may be increased or decreased from previous numbers and can be coupled with short duration grazing periods, and longer rest periods. It is important to not set rotations based on calendar dates, but on current conditions, and this is particularly important in times of drought. Increased pasture rest periods between grazing cycles allows for improved vegetation productivity, and in turn, improved carbon sequestration potential.

To optimize forage production and utilization, grazing periods should be planned around seasonal forage growth. Keeping in mind soil moisture and temperature, grazing and rest periods can be shortened or lengthened to allow adequate plant regrowth. The number of animals may or may not change during the course of a season, which has further impacts on days of rest that will vary throughout the grazing season. Typical rest periods can vary from 21 days to a full year deferment, depending on conditions. Annual and perennial plant communities will respond differently to prescribed grazing, with the latter being optimal due to regrowth potential. Perennial grasses have larger and deeper rooting systems and have the potential to store more carbon above and below ground.

Residual Dry Matter

Residual Dry Matter (RDM), is the old herbaceous plant material left standing, or on the ground, at the start of a new growing season (Bartolome, Frost, & McDougald, 2006). This is generally in September or October. Over time, there have been varying definitions of RDM, and whether it included standing vegetation or not, and whether or not to include summer annuals and non-palatable species. The goal of RDM is to provide adequate soil protection from winter rainfall and wind events, which reduces runoff and erosion potential. It also has an important role in improving water infiltration rates, seed germination, nutrient cycling, and soil stability and structure. In turn, adequate RDM levels can support and improve plant species composition, as well as forage availability.

RDM measurement can be used to assess annual grazing pressure/use on annual rangelands, with pounds per acre thresholds depending on slope and hardwood canopy cover. Mixed annual and perennial grasslands can be measured with the same protocol, with coastal prairie having a higher RDM threshold due to perennial species dominance. Leaving adequate forage at the end of the growing season should to be looked at as a safety net for future growing seasons. Not only does RDM protect the soil, it increases organic matter and soil carbon, improves soil water holding capacity, and influences future species composition and forage production. To meet RDM goals, it is often necessary to plan infrastructure to support the grazing regime. For the Wool Ranch, this includes cross fencing and water development to assist with desired livestock distribution.

Table 3. Recommended minimum RDM values as shown in UCCE Publication 8092 - Guidelines for Residual Dry Matter on Coastal and Foothill Rangelands in California

Woody Cover (%)	Annual Hardwood Rangeland RDM for percent slope (lb/ac)			
	0–10%	10-20%	20–40%	>40%
0–25	500	600	700	800
25–50	400	500	600	700
50–75	200	300	400	500

Woody Cover (%)	Dry Annual Rangeland RDM for percent slope (lb/ac)			
	0–10%	10-20%	20–40%	>40%
0–25	300	400	500	600
25–50	400	500	600	700
50–75	200	300	400	500

Woody Cover (%)	Coastal Prairie RDM for percent slope (lb/ac)			
	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
50–75	400	500	600	700

From (Bartolome, Frost, & McDougald, 2006)

Grazing Management Plan

In December 2021, Clayton Koopmann of Koopmann Rangeland Consulting created a Grazing Management Plan for the Wool Ranch. This grazing plan "contains a description of the types of crops, number and kind of livestock, and seasons and areas of use, provisions for minimizing erosion and the transport of pollutants or sediment into creeks, and other material aspects of the agricultural uses and practices in sufficient detail to allow landowners to make an informed judgment and adaptive management decisions to ensure the level of agriculture on the Ranch is consistent with their long term goals and objectives" (Koopmann Rangeland Consulting, 2021). For the purposes of this carbon farm plan, we assume that the Grazing Management Plan recommendations will be followed, implemented, monitored, and adaptively managed as necessary. Below is a short summary of the management recommendations and best management practices as recommended by Koopmann Rangeland Consulting. The full Grazing Management Plan is also available for viewing in Appendix C: Wool Ranch Grazing Management Plan.

Photo by Paige Green

Vegetation Prescriptions

Leaving prescribed levels of residual dry matter (RDM) on the ground surface will provide a grassland seed crop for the following season, minimize the risk of soil erosion and sedimentation, protect water quality and reduce the presence of noxious vegetation. To protect soil stability, minimize the risk of sedimentation into local streams, and the spread of noxious vegetation, all grazed pastures on the Ranch should meet the following RDM performance standards per average slope at the conclusion of the grazing season:

- 0-30% Slopes – An average minimum of two to three inches of standing forage – approximately f 800-1,000 pounds RDM per acre per Natural Resources Conservation Service (NRCS) and University of California Cooperative Extension (UCCE) definition.

Greater than 30% Slopes – An average minimum of three to four inches of standing forage – approximately 1,000-1,200 pounds RDM per acre per NRCS and UCCE definition. Note that these are conservation RDM values.

While the NRCS/UCCE RDM standards should be applied to permanent pasture where feasible, fields that are farmed for grain and also grazed may be grazed to shorter stubble heights as sheep graze standing stubble and glean fallen grain after harvest. Additionally, the Wool's use timed grazing to control invasive plants which reduces herbicide use but may require forage to be grazed to levels lower than recommended by NRCS/UCCE. At no time should there be significant areas of bare soil void of vegetation cover in any of the grazed pastures (excludes cultivated fields, but the same recommendation can be applied there in years in which tillage is not deployed. Soil should be covered and vegetated to the maximum extent feasible. Reduced or no-till management practices help to ensure this. This is particularly critical on steep slopes or areas adjacent to riparian corridors.

Grazing Season

A moderate year-round rotational grazing regime is best suited for the Wool Ranch. The Ranch is currently divided into twenty-two large pastures (>30 acres) with an average size of 163- acres, plus over a dozen smaller pastures (Map 10). This pasture configuration works well in implementing a rotational grazing system which has been in place for many years. The three-year pasture rotation includes 1-year dryland farmed, 1-year grazed, and 1-year

Table 4. Estimated carrying capacity for Wool Ranch based on calculated available forage production

		Estimated Forage Production in Animal Unit Months (AUM)*		
Soil Map Unit	**Approximate Grazeable Acres**	**Unfavorable Year**	**Normal Year**	**Favorable Year**
AoC	39.9	30.3	40.4	48.5
CeA	73.0	103.3	137.7	165.2
DaC	121.8	172.4	229.9	275.9
DaE2	3129.5	4426.0	5901.3	7081.6
Tu	2.9	0.9	1.2	1.4
Va	99.1	0	0	0
Va**	90	1800	1800	1800
Total AUM	3558.3	6532.9	8110.3	9372.6
Carrying capacity (AUYs, includes alfalfa)	(AUM /12 months)	544	676	781
Total AUM minus irrigated alfalfa	3,468.3	4732.9	6310.3	7572.6
Carrying capacity (AUYs, withoutalfalfa)	(AUM /months)	394	525	631
Annual Carrying capacity (Sheep)*		1576 - 1970	2100 - 2625	2524 - 3155

From Grazing Management Plan, Koopman 2021
*4 sheep are assumed to be equivalent to 1.0 AU (Koopman 2021). This is conservative; 5 sheep per AU is more typical.
** Indicates carrying capacity on irrigated alfalfa pastures during winter months (Koopman 2021).

Table 5. Actual Stocking Rate and Estimated Annual Carrying Capacity based upon Current Rotation (~1,000 Acres Grazed/yr), (plus 90 acres of irrigated alfalfa)

Acres Grazed Annually	Actual Stocking Rate (Ewes, approximate)	Unfavorable Year estimated Carrying Capacity (AUY)	Normal Year estimated Carrying Capacity (AUY)	Favorable Year estimated Carrying Capacity (AUY)
28% of 3,468.3 acres	1800	28% of 4732.9/12 = 110.4	28% of 6310.3/12 = 147.2	28% of 7572.6/12 = 176.7
Irrigated alfalfa		1800/12 = 150	150	150
1000 + alfalfa	1800 @ 4/AU	1042 ewes	1189 ewes	1307 ewes
1000 + alfalfa	1800 @ 5/AU	1302 ewes	1486 ewes	1635 ewes
Additional on-farm Supplemental Feed, 45 acres of (barley/pea/vetch)	6 tons/acre x 45 acres = 270 tons = about 700 AUM/12 = 60 AUY x 4 = 300 ewes	1542 ewes @ 4/AU = 386	1706 ewes @ 4/AU = 427	1875 ewes @ 4/AU = 469
Additional on-farm Supplemental Feed, 45 acres of (barley/pea/vetch)	6 tons/acre x 45 acres = 270 tons = about 700 AUM/12 = 60 AUY x 5 = 300 ewes	1602 ewes @ 5/AU = 320	1786 ewes @ 5/AU = 357	1935 ewes @ 5/AU = 387

fallow. Rotational grazing allows the landowner greater flexibility in managing livestock to achieve desired RDM and stubble height standards and enhance ecological values on the Ranch. While the current pasture configuration is effective, temporary cross fencing to create additional pastures may further enhance future management efforts, particularly when using targeted/timed grazing for specific vegetation management goals. In a rotational grazing regime, standing forage levels should determine pasture rotation schedule, assuming other management goals are met.

Table 6. Estimated Annual Forage/Demand Ratio*

AU Equivalents	Actual Stocking Rate (AUY)	Unfavorable Year estimated Forage/ Demand	Normal Year estimated Carrying Capacity (AUY)	Favorable Year estimated Carrying Capacity (AUY)
4 ewes/AU	450	386/450 = 0.85	427/450 =0.95	469/450 = 1.04
5 ewes/AU	360	320/360 =0.88	364/360 = 0.99	387
				/360 = 1.08

*Assumes only 1,000 of 3,500 acres grazed annually, relatively high RDM values, 4 or 5 sheep/AU, annual production of irrigated alfalfa @ 1800 AUM (Koopman 2021) and 333 AUYo on-farm additional supplemental forage annually.

The Wool Ranch is currently stocked year-round with over 1,800 ewes (450 AU) (Koopman 2021), consistent with the estimated Unfavorable Year carrying capacity. However, only a portion of the ranch is actually grazed each year, in conjunction with the 3-year rotation. According to Koopman (2021): *"The Ranch is divided into multiple pastures which are managed on a three-year rotation; year-1 is farmed, year-2 is grazed, and year-3 is fallow. In total, the Wool's dryland farm approximately 1,000-acres of grain annually, graze sheep on 1,000 acres, and leave 1,000 acres fallow."*

Actual Normal Year carrying capacity is thus estimated to be roughly 225 AUY. Actual carrying capacity, based on current sheep numbers (1800) and an AU equivalency of 4 (conservative per Koopman 2021) or 5 (standard) sheep per AU, is between 450 and 360 AUY, respectively.

This analysis suggests that, given assumptions outlined above, forage demand exceeds available forage in poor forage production years. If correct, this suggests the need to provide off site supplemental feed. However, a discussion with the producer indicates adequate on site forage is produced each year, suggesting actual production on grasslands exceeds NRCS estimates, and also suggesting an AU equivalence of 5 sheep, rather than 4, is appropriate. Addressing any forage deficit is clearly important from the point of view of both Ranch economic viability and carbon dynamics.

Soils

On steeper, more erosion-prone slopes and riparian corridors susceptible to soil compaction, grazing should be delayed until soil is firm enough to withstand grazing pressure without impacting soil stability. Livestock grazing should be managed to protect the soil from erosion as loss of the surface layer can severely decrease forage productivity. The risk of erosion can be reduced by maintaining adequate plant cover and allowing sufficient residual dry matter (RDM) to remain on the soil surface at the conclusion of the grazing season. In addition to protecting soil stability, leaving prescribed levels of RDM on the soil surface will enhance permeability and water retention which will promote soil organic matter resulting in healthier soils which better sequester greenhouse gasses. Note that fully 85% of the ranch soils are currently classified as "eroded," suggesting significant potential for both soil carbon, and overall soil quality improvement.

Water Supply

Livestock generally prefer the cleaner, cooler water in troughs over that from seasonal streams. Developing alternative water sources reduces dependence by livestock on stream channels, minimizes potential impacts to riparian vegetation and stream bank stability, and reduces congregating and loafing near riparian corridors. Livestock water is well developed and available in troughs on the Ranch. Continue to monitor water infrastructure and complete maintenance and repairs as necessary. It is recommended that wildlife escape ramps be installed in all water troughs on the Ranch.

Supplemental Feed

Proper placement of livestock watering facilities and supplemental feed/mineral stations promotes good livestock distribution. Supplemental feed (mineral tubs, salt blocks, etc.) should be placed on uplands and ridge tops away from water sources and riparian features. Supplemental forage (hay) that is fed in pastures should be thoroughly inspected prior to feeding to ensure it does not contain invasive vegetation that may spread seed into pastures. Supplemental feeding should not be used to extend the grazing season beyond the point at which the prescribed RDM levels are reached in the pastures, although this strategy can be used to target undesirable species for heavier livestock impact, and/or to build soil organic matter on poorer cropland or rangeland sites.

Ranch Infrastructure

The landowner should continue to maintain existing ranch infrastructure in good condition and make repairs or improvements as necessary. Maintaining quality, functional infrastructure, including fencing and corrals, increases the ease of livestock handling and effectiveness of rotating livestock between pastures as well as protecting livestock from predation. Maintaining safe facilities provides a low-stress atmosphere for livestock and minimizes risk of injury.

Herd Health

Maintaining a healthy, productive livestock herd is fundamental to profitability and sustainability. Continue to implement the comprehensive and efficient vaccine and deworming program currently in place. Continue to provide mineral and protein supplements strategically as needed to support herd health and production. Consider conducting a forage analysis to better determine specific mineral deficiencies that may determine if a more efficient mineral supplement package could further enhance herd health and productivity.

Ranch Roads

Ranch roads provide access for the grazing operation, infrastructure/ranch maintenance, and emergency response. The landowner should continue to maintain ranch roads in good condition. Routine maintenance including cleaning ditches and culverts, particularly prior to storm events, is important. Maintaining road grades, water diversions, and water bars during winter months to minimize water flow on road surfaces is important for reducing potential soil erosion and road damage. Mowing vegetation on road surfaces is recommended to provide a safe driving environment. Mowing or grazing, as opposed to grading, is recommended to leave vegetation cover on the road surface which helps hold soil in place to reduce the risk of erosion. Additionally, mowing roads will not create a soil disturbance that can lead to increased or spread of invasive plant species. Consider restricting driving on ranch roads to UTV/ATV use during wet winter months to minimize damage and impacts from vehicle traffic.

Drought Preparedness

Agricultural production has historically provided a significant source of income for the Ranch and continues to be an important factor in maintaining its sustainability. Drought conditions can severely hinder the operational capacity and productivity of a ranch and can threaten long-term sustainability. Planning ahead to respond to drought can alleviate some of the potential impacts such as reduced forage, reduced water, herd health, mineral deficiencies, and overall lack of production when drought occurs. The following management practices can help alleviate the impacts of drought:

- Maintain a clean, reliable water source for livestock and maintain an increased water storage capacity. The Ranch currently has a good water supply system in place. Consider adding additional water storage tanks, strategically located to support pasture management;

- Lower stocking rates to slightly below the recommended carrying capacity for the forage production year to provide a surplus of forage to carry livestock through the fall until new, green forage is available. If drought conditions persist, lower stocking rates further to extend the grazing season and avoid overuse of available forage;

- Implement a grass banking system when feasible. Save forage in a designated pasture by minimizing or eliminating grazing pressure during the late spring and summer. If available forage is depleted in grazed pastures, forage will be available in the grass bank pasture;

- Store supplemental forage, such as hay, that can be fed to livestock to supplement pasture forage during a drought;

- Provide livestock with mineral/protein supplements to increase forage utilization, herd health, and overall productivity.

Invasive Plant Control

Available forage production on the Wool Ranch is minimally impacted by non-palatable invasive plant species, most likely the result of diligent efforts to control invasive vegetation by the landowner. Invasive plants can decrease forage productivity, impact herd health, impact habitat value, and create significant fiscal impacts to the landowner. Implementing an integrated approach to monitoring for and controlling pest plants is critical to the success of maintaining forage production and quality in grazed pastures. To prevent an increase in the current extent of invasive vegetation and avoid the introduction of new invasive species, the landowner should manage the Ranch with the minimum goal of containing any weed infestation to its current extent, reducing invasive weed populations as feasible, and preventing the introduction of new invasive species.

- Primary means of control will be mechanical and biological strategies including mowing, hand digging individual plants, grazing and the application of herbicides. The following recommended practices are designed to reduce the presence of noxious vegetation, protect soil and water quality, and promote forage production.

- Adjust the stocking rate, as necessary, in order to maintain a minimum of two-three inches of beneficial vegetation cover at all times.

- Mowing can be an effective tool to manage noxious thistles, provided it is well timed and used on plants with a high branching pattern. Mowing at early growth stages results in increased light penetration and rapid regrowth of the weed. If plants branch from near the base, regrowth will occur from recovering branches. Repeated mowing of plants too early in their life cycles (rosette or bolting stages) or when branches are below the mowing height will not prevent seed production, as flowers will develop below the mower cutting height. Plants with a high branching pattern are easier to control, as recovery will be greatly reduced. Even plants with this growth pattern must be mowed in the late spiny or early flowering stage to be successful. An additional mowing may be necessary in some cases. Be sure to mow well before thistles are in full flower to prevent seed spread.

- Prioritize invasive plant control where the likelihood of seed spread is high, such as roadsides, cattle trails and loafing areas.

- Prioritize treatment of small infestations to maximize efficiency. Small patches are easily removed and do not become large overwhelming patches if treatment is timely and persistent over time.

- Carefully monitor areas where outside feed is brought in for new invasive species and remove new weeds before they become established.

- Do not import outside soil or fill material. It is often contaminated with invasive species.

- Be aware of seed transport on ranch equipment and clean vehicles/equipment as needed. Avoid driving through invasive plants as seeds are easily transported throughout the Ranch by ATVs, tractors, and other vehicles.

- Contact the S.County Department of Agriculture for technical assistance to help with integrated pest management practices.

Implement an integrated approach described above to identifying and treating noxious invasive plants on the Ranch that are impacting forage production and grassland health including but not limited to bronco grass, yellow starthistle, purple starthistle, perennial pepperweed, white horehound, milk thistle, bull thistle, spiny cocklebur, datura, and artichoke thistle.

Carbon Benefits of Grazing Land Practices

Multiple practices are described below, displaying the carbon benefits of each practice. These practices are either broadly applied across the entire ranch (ex: Prescribed Grazing, Reduced or Minimum Tillage) or are not currently recommended, but could be implemented in the future if needed (Forage and Biomass Planting).

Prescribed Grazing (CPS 528) will be implemented exclusively on the grazed lands of the ranch. The other practices, which are restorative in nature, will be implemented at site-specific locations where additional carbon storage potential exists.

Forage and Biomass Planting (CPS 512) while not explicitly recommended by Koopman Rangeland Consulting is another practice that is typically recommended in range and pasture systems to re-invigorate pasture lands and provide adequate forage for livestock. Should Wool Ranch opt for this practice in the future, we'd expect additional sequestration benefits that can be calculated.

Reduced or Minimum Tillage (CPS 345) or No-Tillage (CPS 329) are typically reserved for cropland scenarios, but can be implemented in rangeland scenarios like Wool Ranch where, the ranch is tilled occasionally in the dryland farming->grazed->fallow three year rotation. Reduced Tillage and No-Tillage management practices aim to reduce or eliminate the tillage of agricultural land as necessary to leave soil undisturbed, allowing the soil to retain and sequester more carbon over time. Wool Ranch currently practices "No-Tillage" on approximately 397-acres of permanent pasture and "Reduced Tillage" on the remaining acreage. Transitioning from "Reduced Tillage" to "No-Tillage" will bring numerous carbon sequestration and soil health benefits. Our calculation below shows current expected annual sequestration values based on planners understanding of the pasture rotation of 397-acres of permanent pasture (no till) and 3161-acres of pasture in the cycle (reduced till) On a per-acre basis, switching acreages out of the rotation and into permanent pasture results in approximately 0.07 Mg CO2e sequestered annually. Note that these values are estimates and are generally used to classify management practices that move from "intensive tillage" to reduced till or no-till. With no strict definitions of intensiveness of tillage, actual sequestration values may be lower than estimated here. Further discussions with farm managers, owners, NRCS staff, and RCD staff is needed to determine the potential for converting pastures into permanent pasture, but with tremendous carbon sequestration and soil health benefits.

Nutrient Management (CPS 590)
In general, the application of mineral N-fertilizers, regardless of type, leads to elevated N2O emissions in the field (Spiegel et al 2015), as well as GHG emissions associated with their production (Foucherot and Bellassen 2011). N20 has a global warming potential approximately 273 times that of CO2, so even small decreases in on-farm N2O emissions can contribute significantly to overall farm GHG emission reductions.

As part of the pasture rotation at Wool Ranch, grains are planted once every three years on roughly 1/3 of the acreage or 800-1200-acres annually by a neighbor farmer (avg/yr = 963 acres). This farmer manages the grains, and applies UAN-32 (Urea Ammonium Nitrate 32-0-0) at a rate of 100 lbs/acre, or 9 gallons of UN-32/acre (1 gallon weighs 11.02 pounds, with 32% of that weight being nitrogen.) resulting in approximately 33 lbs of nitrogen applied/acre. This leads the planners to believe that approximately a total usage of 96,300 lbs N/yr, or 48.1 tonnes N annually.

Under the Nutrient Management conservation practice (CPS 590) in COMET-Planner farmers reduce synthetic nitrogen use by approximately 15%, by substituting compost for synthetic N. In this case, a 15% reduction in synthetic N use implies moving from applying an average of 48.1 tons N per year to 40.9 tons per year. Overall, substituting compost for synthetic N has been found to result in negligible production decreases and relative decreases in GHG emissions, supporting the use of compost as a best management practice from a GHG perspective (Spiegel et al 2015).

To achieve a reduction in synthetic fertilizer use, there are a number of viable pathways including: straight reduction, use of compost to provide additional nitrogen, and use of cover crops (legumes) to fix nitrogen in soils, among others. Adding a legume cover crop combined with managed grazing in lieu of the fallow year in the three year rotation has the potential to result in increases in both SOC and SON in the treated fields (Munier et al., 2006) Planners recommend contacting the local USDA NRCS office to further investigate and develop a nutrient management plan to reduce synthetic N use in the grain fields at Wool Ranch.

Ongoing Experimental Research

The Wool Ranch also hosts ongoing research plots from local and nearby universities and colleges. Dr. Charlie Brummer, Director of and Professor at the Center for Plant Breeding within the Department of Plant Sciences at the University of California, Davis, is currently leading a study at the Wool Ranch that aims to identify specific varieties of alfalfa that can survive with low to no inputs. Dr. Brummer and colleagues have over 40 varieties of Alfalfa planted at Wool Ranch within the Front and Office pastures to test the viability of these varieties with the goal of reducing fertilizer inputs. While results are still being collected and analyzed, this research should result in identification of alfalfa cultivars that should provide significant climate benefit with reduced nutrient input.

Photo by Paige Green

Photo of ranch manager standing in demonstration pasture, October 2022.

Grazing Management Discussion

The grazing management plan recommends an annual stocking rate, depending on unfavorable or favorable year production, ranging anywhere from 544 to 781 animal units (2176-3905 sheep depending on animal unit equivalents used (4 or 5 sheep/AU)) across 3558-acres. However, later conversations with land managers at Wool Ranch estimate their current year-round stockingrate to be ~1800 ewes. Further investigation into pasture rotations revealed that in any given year, sheep graze 1100, 1235, or 1736-acres (see Table 1. Wool Ranch Pasture Cycles). Based on these figures, the grazing management plan stocking rate should be adjusted. See Tables 5 and 6 and associated discussion for details.
There is a clear opportunity to examine the entire ranching system at Wool Ranch for enhanced carbon sequestration and improved overall production and resilience in the face of climate change. While planners offer ideas and recommendations, further discussion is needed among the land managers, the farm owners, and other experts in the field, including staff from the USDA NRCS, the University of California Cooperative Extension, and the Carbon Cycle Institute.

As currently understood by planners, the Wool Ranch employs a rotation of planting wheat and/or barley on a pasture in November, harvesting that field for grain in June the following year, grazing the pasture with sheep until April the following year, then discing the pasture

Table 7. Wool Ranch Potential Grazing Management Practices and annual carbon sequestration estimates

Management Practice	Acreage	Mg CO2e Sequestered/yr *	Mg CO2e Sequestered/yr/acre
Prescribed Grazing**	3558.3	640.49	
No Tillage	397	63.52	0.16
Reduced Tillage	3161	284	0.09
Nutrient Management	2890	57.8	
Total		**1,045.81**	

*CO2e estimate calculated using CDFA Comet Planner
**Although the above values for Prescribed Grazing (CPS 528) are not reflected in the current CDFA COMET-Planner results, planners used an emission reduction coefficient of 0.18 Mg/acre from Swan et. all (Swan, 2015) that is likely more consistent with sequestration estimates on the ground.

and leaving it fallow until a new grain planting in November, beginning the cycle again. Through conversations with land managers, planners learned that equipment is used to plant the grains in November, harvest the grains in June, disc the grazed pastures in April, and then plant again in November. Figure 4 illustrates this rotation.

Broadly speaking, the current pasture rotation of dryland-farmed, grazed, and fallowed is likely leading to eroded soils, declining soil health, and as a result, declining carbon sequestration. The combination of sheep movement, field discing, planting, nutrient application, harvest, and fallow is leading to slow erosion throughout the ranch. It's possible that a different rotation could stop, and even reverse this cycle in the long-term, leading to long-term ranch health and viability. Further discussion and research are needed to determine economic and environmental viability of switching to a different rotation, and planners look forward to discussing this along with other experts and land managers at Wool Ranch. For this plan however, planners have met and discussed some options that could result in greater carbon sequestration, and by association, reduced erosion and other natural resource benefits.

Soil carbon loss is likely occurring most during tillage and bare fallow phases of the rotation. From a carbon sequestration perspective, these management actions break up the soil, releasing stored carbon, and facilitating the movement of soil off site through both wind and water erosion, while also missing an opportunity to capture additional carbon and nitrogen through a cover crop -and additional grazing opportunities- in the fallow year. Land managers at Wool Ranch are aware of this, as expressed by a stated goal to improve soil on the ranch and move towards more permanent pasture. An important first step towards a new rotation will be reducing impacts to soil by minimally tilling, or eliminating the management practice entirely. Direct seeding of annual forage legumes into pasture following the grazing year could allow additional biological nitrogen fixation, and an additional grazing cycle prior to grain seeding in year 3 of the rotation, potentially eliminating, or significantly reducing the need for synthetic nitrogen inputs, increasing soil carbon and enabling an additional season of forage harvesting by sheep.

One potential opportunity is “pasture cropping, a technique where annual crops are sown into perennial grassland that is either entering dormancy or that has been prepared by

Figure 4. Wool Ranch Grain Year/Grazed Year/Fallow Year Rotation

	Year 1								Year 2									Year 3		
	Nov	Dec	Jan	Mar	May	Jun	Jul	Sep	Nov	Dec	Feb	Mar	Apr	May	Jul	Sep	Oct	Nov	Dec	Jan
Grain Year	Plant				Harvest													Plant		
Grazed Year												Disced								
Fallow Year																				

grazing to take away the competitive advantage of the perennial grasses in the pasture” (Smith, 2015). Through pasture cropping, the grain planting would occur directly into the residual vegetation using a no-till drill seeder, during the dormant season, prior to fall rains. This would follow a season of grazing of the legume cover crop, instead of a bare fallow, as described above.

Removing the fallow year and replacing it with another year of grazing would likely require additional forage to be planted in the pasture after the first grazing cycle. Using the same no-till drill seeder, a cover crop could be planted that would grow to become additional forage for the sheep, while providing conditions for direct seeding of grain into residual grazed vegetation prior to the onset of the next rainy season: hence “pasture cropping”. Landowners could also elect to select a mix of species that includes legumes that would fix nitrogen in the soil prior to the grain rotation, reducing the need for nitrogen inputs on the ranch and leading to both greater carbon sequestration by the growing cover crop, and reduced nitrous oxide emissions. Nitrous oxide is a greenhouse gas with roughly 275 times the global warming potential of carbon dioxide.

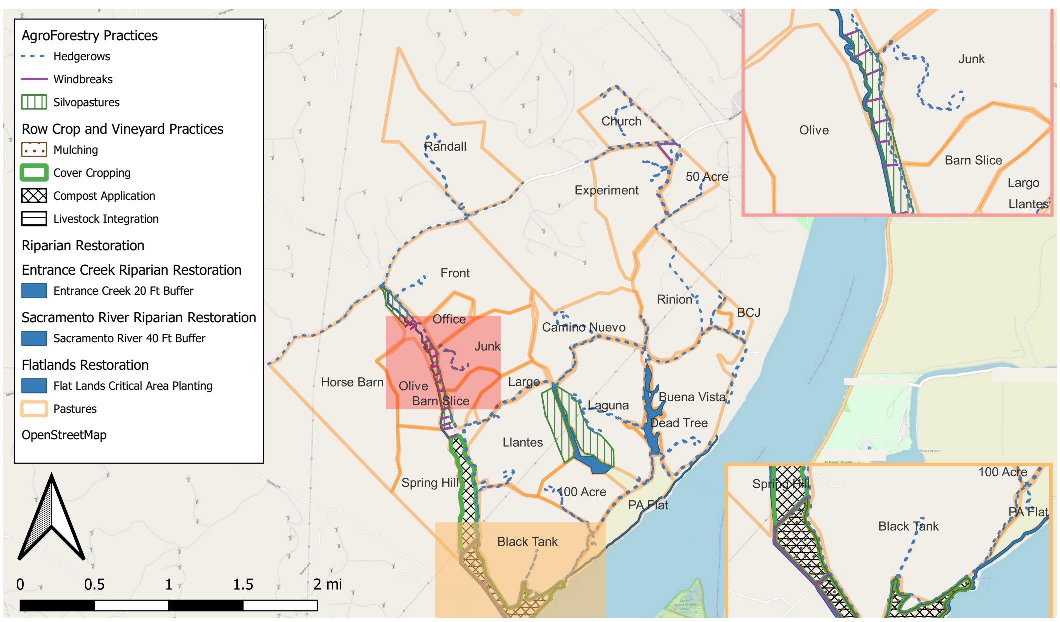
While hypothetical, a grain year>grazed volunteer (or seeded) pasture>grazed cover crop pasture rotation should yield significant carbon sequestration benefits. Incorporating a cover crop instead of a fallow field would sequester an estimated additional 220 Mg of CO2 equivalent annually over an average of 1100-acres. Completely removing tillage from the equation on 1100-acres annually would result in an additional 261 Mg of CO2 equivalent sequestered annually. Planting a leguminous cover crop mix would fix anywhere from 70-150 lbs./acre total nitrogen from the atmosphere (dependent on the species selection, soils, climate, and other factors) (Curell, 2015), which could reduce synthetic nitrogen requirements across the ranch, resulting in fewer emissions of nitrous oxide leaving the soil. All told, this new management rotation could result in around 500 Mg CO2 equivalent being sequestered or emissions avoided annually, and around 10,000 Mg CO2 equivalent over 20 years.

While largely speculative, these numbers warrant further discussion in conversation with the landowners, the land manager, and other relevant experts from UC Cooperative Extension, the local RCD, CCI, and the USDA NRCS. There is tremendous potential for enhanced carbon sequestration by tweaking the Wool Ranch pasture rotation.

Figure 5. Wool Ranch Grain Year/Grazed Year/Grazed Year 2 New Rotation

	Year 1								Year 2									Year 3		
	Nov	Dec	Jan	Mar	May	Jun	Jul	Sep	Nov	Dec	Feb	Mar	Apr	May	Jul	Sep	Oct	Nov	Dec	Jan
Grain Year	Plant				Harvest													Plant		
Grazed Year									Cover Crop											
Grazed Year 2																				

Map 10. The Wool Ranch and all recommended Carbon Farm Practices



Agroforestry Systems at Wool Ranch

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; and reduce cold and heat stress on animals by providing shade and shelter. Agroforestry can also slow water runoff to reduce flooding; reduce soil erosion and water pollution while increasing water infiltration; reduce crop evapotranspiration by reducing wind speed for soil moisture conservation; and provide multiple products: forage, fruit, nuts, timber and fence posts. In short, agroforestry can help increase a farm's climate resiliency.

Agroforestry practices considered in this carbon farm plan include:

- Silvopasture/Tree & Shrub Plantings combine trees with forage and livestock production on the same field. The trees are managed for biodiversity, wood, fruit and/or nut production while at the same time provide shade and shelter for livestock and wildlife.

- Windbreaks are single or multiple rows of trees and shrubs that are planted perpendicular to prevailing winds to reduce wind speed. They improve crop yields, reduce soil erosion, improve water-efficiency, protect crops and livestock and conserve energy.

- Hedgerows and Shelterbelts are rows or blocks of trees and/or shrubs that provide microclimate improvement and support on-farm structural and biological diversity. They improve crop yields, reduce soil erosion, improve water-efficiency, protect crops and livestock and conserve energy.

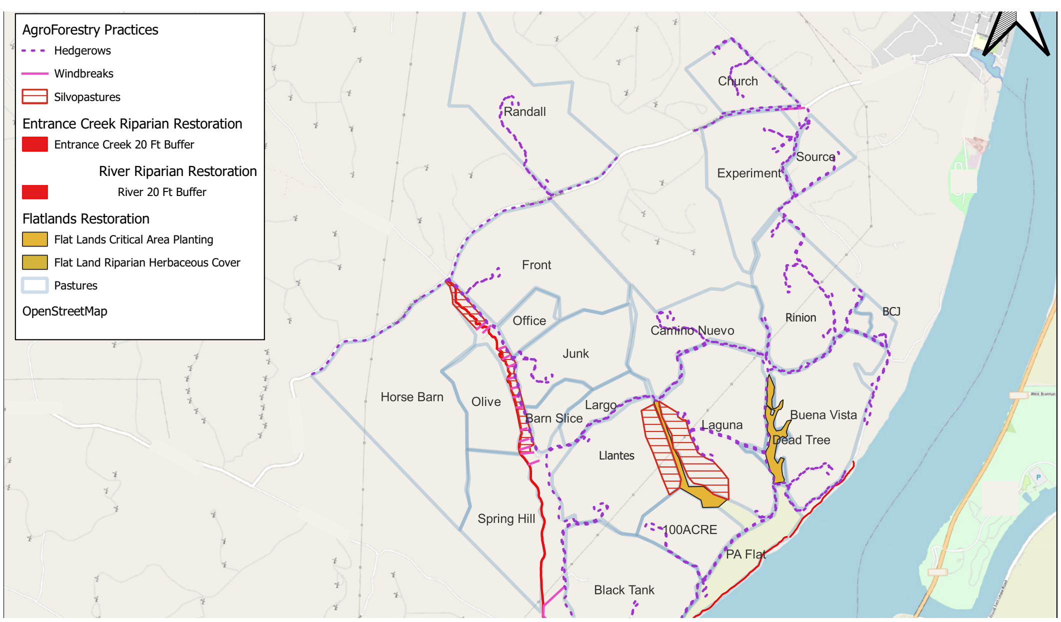
- Riparian Forest Buffers are streamside plantings of trees, shrubs and grasses that reduce water pollution and bank erosion, protect aquatic environments, and enhance wildlife habitat.

Silvopasture/Tree & Shrub Establishment

Silvopasture systems are defined by the integration of woody species, particularly trees, into grazed pastures. Trees can provide long-term economic returns, shade and other benefits, while livestock and forages generate an annual income from the same pasture. Silvopasture systems have three management components: trees, forages, and livestock. Correctly managed, the combined production from a silvopasture can be greater than traditional forestry and forage-livestock systems. Intensive livestock management is required, particularly in the early years during tree establishment (Klopfenstein, et al., 1997).

Trees in pastures provide evaporative cooling, reduce radiant heat loss at night, and reduce wind speed. These improved conditions allow animals to spare energy for growth, particularly under hot conditions. Increased weight gain, milk yield, and conception rates have been reported for cattle and sheep grazing pastures with trees in warm environments. Forage nutritive value, digestibility, and botanical composition can be improved in silvopasture systems. In the winter, trees can provide protection from cold and reduce wind velocity (Klopfenstein, et al., 1997).

Map 11. All recommended agroforestry practices at Wool Ranch



Silvopastures at Wool Ranch

Under a silvopasture scenario, trees can be planted for either production (fruit, nuts, etc.) or for other environmental benefits (increased carbon sequestration, habitat, shade etc.) dependent on landowner preference and species selected. Map 12 below shows four potential silvopasture locations discussed by planners in February 2022; at the Entrance pasture, the Lambing Pasture, Llantes Pasture, and the Laguna pastures. These locations were selected based on field observations during the February 2022 site visit. Given that most of the ranch is dryland farmed except for the alfalfa fields and vineyards, water likely poses the most significant natural resource challenge for any silvopasture planting success aside from grazing animals. Further, the farm manager expressed concerns over woody plantings potentially creating habitat for predators to hide in and predate on lambs and sheep.

When designing silvopasture systems, the NRCS recommends establishing and maintaining a forested condition that is at least 10% cover of single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity (see attached NRCS Conservation Practice Standard 381 - Silvopasture.) Given land manager concerns for predators, we recommend implementing a silvopasture scenario close to that 10% cover. Higher density plantings could lead to more carbon sequestration, but could pose challenges in management of farm equipment between trees. Additionally, while ecological history of the Hills is currently unknown, its likely fair to assume that the Hills largely resembled that of their neighboring range foothills in C.C. County that are primarily blue oak savanna’s with lower density of trees as compared to other silvopasture operations. While 10% cover may seem low, it’s likely consistent with the ecological history of the surrounding area. However, with warming conditions and intensification of solar radiation attendant to climate change, the Ranch may want to consider the value of a higher percentage of canopy cover, depending on initial experience with silvopasture implementation.

The Entrance Field, a suggested location for a silvopasture.

The Laguna Field, a potential silvopasture location.

Photos by Paige Green

Table 8. Reducing On-Farm Climate Risk through Agroforestry*

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

* Information is from the USDA National Agroforestry Center.

Species selection of trees is ultimately dependent on landowner goals for the property. Silvopastures do not have 'strict' definitions requiring landowners to choose only native species, as many landowners have found financial success in operating specialty crop silvopasture systems (fruit and nuts mixed with sheep). However, given that most of the ranch is dryland farmed, drought resistant native species will likely lead to greater success than a more commercially viable fruit or nut silvopasture system. Table 9 below shows the NRCS eVegGuide native tree recommendations using Wool Ranch as the location under NRCS Conservation Practice Standard 612 Tree/Shrub Establishment (planners were unable to use CPS 381 Silvopasture in the eVegGuide, but Tree/Shrub Establishment is a suitable analog for the practice). A full plant list is available in Appendix D: NRCS eVegGuide Version 5 - Tree/ Shrub Establishment Plant List.

During the site visit, planners also learned from the land managers that Wool Ranch has already been experimenting with tree planting at the northernmost edge of the Laguna Field by trialing California Valley Oak (Quercus lobata). The five observed trees have succeeded and appeared healthy at the February 2022 site visit, indicating that silvopasture can be a viable practice at the Wool Ranch.

Using the California Valley Oak as a starting point, planners have calculated approximate densities in order to hit the 10% cover recommendations put forth by the NRCS. Data for this calculation came from [CalScape, a product of the California Native Plant Society](). Percent cover is a calculation of the area of the crown of the tree at maturity divided by the area of the pasture. California Valley Oak at maturity tends to range anywhere from 12 to 30 meters tall (39 to 98 feet) and with a crown of approximately 15 meters (50 feet) in diameter. The area of the tree canopy then is 1963 sq ft (25 ft2 X 3.14), so one tree covers approximately 0.04 of an acre (1-acre = 43,560 sqft). These calculations work out to approximately three trees per acre at maturity. Depending on how this practice is implemented however, seeding/planting rates will need to be higher to ensure management practice success. If growing from acorns, typical restoration practices call for planting three acorns per hole in the ground. Further, if planting established trees that have been grown out in a nursery, planners still recommend a higher planting rate of at least three trees for every mature tree desired.

Hedgerows, Windbreaks, and Shelterbelts

NRCS defines hedgerows, windbreaks and shelterbelts as, "single or multiple rows of trees or shrubs planted in linear configurations." These plantings have numerous benefits including: increased carbon storage in biomass and soils, reduced soil erosion and loss of soil moisture from wind, protection of pastures and crops from wind related damage, improved microclimate for plant growth, shelter for livestock, and enhanced wildlife habitat. In addition, windbreaks and shelterbelts also provide noise and visual screens, improve

Table 9. NRCS eVegGuide Native Tree Recommendations for Wool Ranch using CPS 612 Tree/Shrub Establishment

Common Name	Scientific Name	Ease of Planting and Maintenance
White fir	Abies concolor	easy
California buckeye	Aesculus californica	easy
Oregon ash	Fraxinus latifolia	easy
California Foothill pine (aka Gray pine	Pinus sabiniana	easy
California sycamore	Platanus racemosa	easy
Chokecherry	Prunus virginiana	easy
California live oak	Quercus agrifolia ssp. agrifolia	easy
Scrub oak	Quercus berberidifolia	easy
Blue oak	Quercus douglasii	easy
Valley oak or California white oak	Quercus lobata	easy
Interior live oak	Quercus wislizeni	easy
Red willow	Salix laevigata	easy
Arroyo willow	Salix lasiolepis	easy
Box elder	Acer negundo	moderately easy

Fremont cottonwood	Populus fremontii ssp. fremontii	moderately easy
Bitter cherry	Prunus emarginata	moderately easy
Canyon live oak	Quercus chrysolepis	moderately easy
Sandbar willow	Salix exigua	moderately easy
White alder	Alnus rhombifolia	slightly difficult
California black walnut	Juglans hindsii	slightly difficult
Black cottonwood	Populus balsamifera ssp. trichocarpa	slightly difficult
Western chokecherry	Prunus virginiana var. demissa	slightly difficult
Goodding's willow	Salix gooddingii	slightly difficult

irrigation efficiency, increase biodiversity, increase production, and act as shaded fuel breaks to limit the spread of wildfire (Nebraska Forest Service, 2022). Shelterbelts and hedgerows can be configured to capture or distribute surface runoff to optimize moisture, sediment and nutrient retention. Windbreaks, specifically, are planted approximately perpendicular to the prevailing winds and structured to dissipate or deflect wind energy away from the area "behind," or downwind of, the windbreak.

Hedgerows, Windbreaks, and Shelterbelts at Wool Ranch

Hedgerows

There are several opportunities at Wool Ranch for hedgerow establishment which can increase carbon capture through increased woody species cover, increased soil carbon and decreased wind speed, resulting in water savings and enhanced net primary productivity in wind protected areas.

There is tremendous potential for hedgerow installation within the Wool Ranch along interior and exterior ranch roads. Additional hedgerows could be considered or planned along pasture boundaries, but given the complexities of maintaining those hedgerows, and that

Table 10. Planned silvopasture acreages, recommended tree cover, and Mg CO2e Sequestered

NRCS Recommends 10% Tree Cover (25 trees/acre)				
Pasture	Acres	NRCS Recommended Percent Tree Cover Acres	Approximate # of Trees to hit 10% Cover	Estimated Mg CO2e Sequestered*
Entrance	11.9	1.19	30	7.89
Lambing	17	1.7	43	11.21
Laguna	42.9	4.29	108	28.33
Llantes	29.9	2.99	75	19.75
Total	**101.7**	**10.17**	**256**	**67.18**

*CO2e estimate calculated using CDFA Comet Planner

Map 12. Silvopasture potential locations at Wool Ranch

these pasture boundaries may change in the future, planners focused entirely on hedgerows along existing ranch roads. The above map shows hedgerows which have been broken down by proximity to pasture or roads within Wool Ranch for ease of planning and implementation.

For the purposes of this plan, all hedgerows are assumed to be one row of plants approximately eight-feet wide at maturity. Plant selection will determine the actual width of the hedgerow, and in some instances available space may allow for two rows of plants. More than likely though, hedgerows will be located on either side of a ranch road between a fenced in pasture area, and as such consist of one row of plants.

Any number of species of trees, shrubs, and forbs can be used to build a hedgerow. Ultimately species selection is driven by landowner goals and preference, compatibility with the farming system, and compatibility with the natural environment. For that last reason, planners recommend using native plant species from the surrounding area that can succeed in similar weather and climate conditions. Regarding compatibility within the farming system, most, if not all hedgerow locations are recommended to be installed outside of pastures, between ranch roads and pasture fencing or boundary fencing along Hills Road. Still, the farming operation should be considered, and plants that can be poisonous to sheep should be avoided or planted in areas where sheep can't graze.

In conversations with the land manager and owner, a primary concern around hedgerows was the creation of favorable habitat for predatory animals, namely coyotes. Multi-species hedgerows should alleviate this concern, breaking up larger shrubby plants that could hide coyotes and dens with smaller forbs or larger trees could reduce this potential. Further, proper maintenance of shrubby plants should prevent creating coyote and predator habitat on the ranch.

A cursory search into the NRCS eVegGuide for compatible hedgerow species at Wool Ranch yielded 69 individual species that could be planted. The full list of species is included in Appendix E. Table 12 shows a small number of native, potential species that are classified as “easy” to care for. Further, planners recommend planting perennial, long-lived woody species that offer benefits that justify planting and maintenance over time. Annuals, while great and can certainly still be included, are harder to manage and may fade from the site over time.

EXAMPLE: Hills Road Front Pasture Hedgerow

Hedgerow, 4101 linear feet, six to eight foot width of hedgerow parallel with Hills Road and Front Pasture, 0.75-acres

- Sample planting; single line where space is limited. Plant on 4’ off Front Pasture fence between road and fence (further verification is needed, but Google Street view suggests that this is allowed in this area, as evidenced by shrubby plants growing between road and fence along Hills Road. Plant 1 shrub every 6 to 10 feet and seed between with species mix below

- Planting will enhance visual esthetic, reduce sedimentation, and provide pollinator and bird species habitat while capturing carbon, both above and below ground.

- Examples Species and Quantities, but not limited to:

Windbreaks

Repairing Existing Windbreaks

Within the Wool Ranch, planners observed existing windbreaks along the lambing areas near the property headquarters. With that in mind, we have quantified those windbreaks as a baseline practice scenario as it currently exists and propose new windbreaks and repair of the existing windbreaks (i.e. filling in with appropriate tree and/or shrub species). The nearest Wind Rose station is at Travis Air Force Base and suggests a wind direction primarily from the southwest. However, nearby wind turbines typically face from west-northwest to true north. On a more local level, the wind can be observed moving from southerly to northerly through the valleys of the Wool Ranch, hence the need for the existing windbreaks along the ranch headquarters and lambing areas.

The windbreaks pictured in the below map were largely drawn along existing fence lines and are spaced anywhere from 100 to 650-ft. apart. In general, windbreaks provide great protection at lengths 6-8 times their height , fair protection at lengths 10 times their height, and minimal, if any protection at lengths 15-20 times their heights (Kuhns, 2012). A windbreak height of 30 feet should provide noticeable benefits 300 feet downwind. An additional windbreak could be planted between Repair D and Repair E; this would allow the

Map 13. Hedgerows within and around Wool Ranch

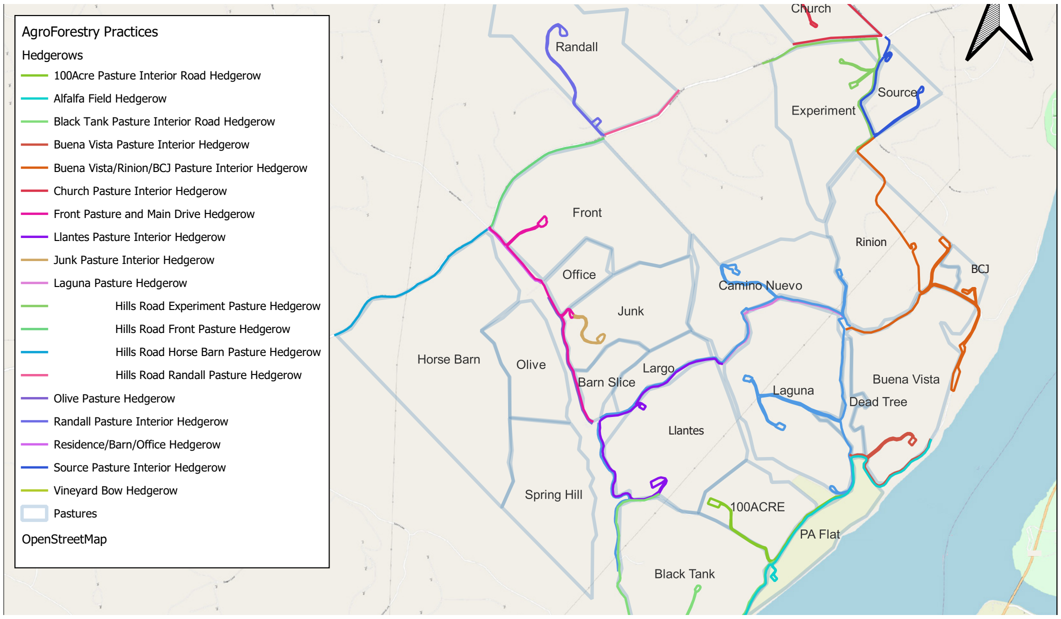


Table 11. Wool Ranch Potential Hedgerows and Length in Feet

Name	Length (ft)	Name	Length (ft)
Hills Road Front PastureHedgerow	4101	Buena Vista Pasture Interior Hedgerow	6790
Hills Road Horse Barn Pasture Hedgerow	5122	Buena Vista/Runion/BCS Pasture Interior Hedgerow	20746
Hills Road Experiment Pasture Hedgerow	10160	Source Pasture Interior Hedgerow	7900
Hills Road Randall Pasture Hedgerow	2377	Largo/Camino Nuevo Pasture Interior Hedgerow	16545
Residence/Barn/Office Hedgerow	1994	Front Pasture and Main Drive Hedgerow	9958
100Acre Pasture Interior Road Hedgerow	8250	Junk Pasture Interior Hedgerow	3448
Laguna Pasture Interior Hedgerow	14566	Llantes Pasture Interior Hedgerow	9900
Olive Pasture Hedgerow	3579	Black Tank Pasture Interior Road Hedgerow	13330
Laguna Pasture Hedgerow	4497	Randall Pasture Interior Hedgerow	8413
Spring Hill Pasture Hedgerow	4725	Church Pasture Interior Hedgerow	10934
Vineyard Bow Hedgerow	758	Alfalfa Field Hedgerow	9813
		Total	**177,906**

landowners to split this field into 2 fields. Planners weren't able to site verify the species, but based on the area and photos from the field trip, we know that these planted tree species are Pine trees (Pinus spp.) potentially California foothill pine or Gray pine (Pinus sabiniana), planted in single rows. Continuing the existing windbreaks by planting additional trees, should provide sufficient wind protection for Repair A, B, C, D, and F windbreaks. An additional windbreak between D and E would provide great protection, but would require splitting the lambing pasture into two pastures.

Note that Pine trees as they grow tend to lose lower branches, leading to a potential for the windbreak to fail, allowing wind to pass under the tree. While they are useful while young, at maturity the windbreak effectiveness is diminished. See Photo 1 above for an example of this gap in the lower 4-6 feet of the tree. As the tree grows taller, this gap will grow larger.

In addition to repairing the existing windbreaks, there is potential for new windbreaks in the lambing and ranch headquarters areas. These windbreaks are roughly drawn at 300-600 foot intervals and along existing fence lines. Note that the ranch headquarters are located between New Windbreak G and New Windbreak F. Given the relative distance of ~300 feet between rows, single row plantings of trees along each windbreak should provide sufficient protection for the lambing fields. Windbreak design is described below in general.

Planners also recommend installing windbreaks along the western and northern-western areas of the vineyards to protect the vines. This results in a windbreak stretching along the western edge of the vineyard and two perpendicular windbreaks at the north end and middle of the vineyard. Given the vineyards' relative narrow width and the surrounding hills, the eastern vineyard likely does not suffer as much wind damage as the western parts of the vineyard. A single row windbreak would provide good protection of the grapes, but given the distance of over 1000 ft between the North Vineyard Windbreak and the Middle Vineyard Windbreak, a double row of trees could be considered for the North Vineyard Windbreak. The Western Vineyard Windbreak is likely sufficient as a single row.

Finally, there is one additional windbreak that could provide benefit to the residence and other ranch infrastructure located on the northeast corner of the property at the intersection of Hills Road. and E. Road. The Residence Windbreak would fill in gaps between trees along the northern and western edge of the residence, providing great wind protection for the residence and equipment storage areas. For this windbreak, a single row of trees is likely sufficient.

Table 12. Potential Perennial Hedgerow Species classified as "easy" to grow by the NRCS eVegGuide

Common Name	Scientific Name	Growth Cycle	Plant Type	Bloom Period	Spacing Ft
False indigobush	Amorpha fruticosa	Perennial	Legume	Feb-Apr	4
Western columbine	Aquilegia formosa	Perennial	Forb	Mar-May	4
Kinnikinnick	Arctostaphylos uva-ursi	Perennial	Shrub	Mar-Jun	3
Fourwing saltbush	Atriplex canescens	Perennial	Shrub	May-Jun	6
Pacific reedgrass	Calamagrostis nutkaensis	Perennial	Grass	Mar-Jun	
San Diego sedge	Carex spissa	Perennial	Grass		4
Blue wildrye	Elymus glaucus	Perennial	Grass	May-Jul	2
California poppy	Eschscholzia californica	Annual / Perennial	Forb	Apr-Jul	
California fescue	Festuca californica	Perennial	Grass	Feb-Apr	
Idaho fescue	Festuca idahoensis ssp. idahoensis	Perennial	Grass	Jun-Jul	
Great Valley gumweed	Grindelia camporum	Perennial	Forb	Apr-Oct	
Coastal gumweed	Grindelia stricta	Perennial	Forb	May-Oct	4
California melic	Melica californica	Perennial	Grass	Jun-Aug	
blue eyed grass	Sisyrinchium bellum	Perennial	Forb	Mar-May	2

As discussed previously, most if not all of the windbreaks should provide sufficient protection for the respective field downwind of the windbreak with a single row of trees, with the exception of the North Vineyard Windbreak which may benefit from taller plantings if wind damage is a concern on the vineyard. Ultimately when designing a windbreak, planners attempt to provide as much coverage as possible and reduce gaps between trees, while allowing a permeability of 40% to avoid creating turbulence downwind of the windbreak.

For carbon farm planning purposes, we have sketched these windbreaks largely based on the idea of a) repairing existing windbreaks, and b) building new windbreaks along appropriate fence lines/pasture boundaries. While these methods are sufficient for deriving an expected annual carbon sequestration estimate, windbreaks will need to be designed for the specific circumstances they're needed for. Tree height may vary across the various windbreaks depending on the length of windbreak needed (smaller pastures may only require a 30 ft. tree while larger gaps may require taller trees). Planners recommend working with the local RCD and NRCS staff to design and implement specific windbreak designs for needs at each potential windbreak.

Table 13. Potential hedgerow species and quantities need for Hills Road Front Pasture Hedgerow*

Type	Species Name	Quantity
Forb	Asclepias speciosa (showy milkweed) (4 ft spacing)	1025 plugs
Forb	Eschscholzia californica (California poppy) (7.4 lbs/acre)	1.38 lbs seed
Forb	Lupinus nanus (Sky Lupine) (48.4 lbs/acre)	9 lbs seed
Grass	Elymus glaucus (Blue wildrye) (16.2 lbs/acre)	3 lbs seed
Grass	Stipa pulchra (purple needlegrass) (19.8 lbs/acre)	3.71 lbs seed
Shrub	Artemisia californica (California sagebrush) (6 ft spacing)	157 plants
Shrub	Frangula californica (California coffeeberry) (10 ft spacing)	157 plants
Shrub	Atriplex polycarpa (Cattle saltbush) (6 ft spacing)	157 plants
Shrub	Atriplex canescens (Fourwing saltbush) (6 ft spacing)	157 plants

*Further consultation with USDA NRCS and the local RCD is needed for viability of the hedgerow at the selected location. Assumed numbers are based on species, spacing requirements, and recommended broadcast seed pounds required, evenly split across the 0.75-acre hedgerow (assume that each forb and grass is included at 25% of total mix, actual mix will vary depending on goals, seed availability, cost, etc.).

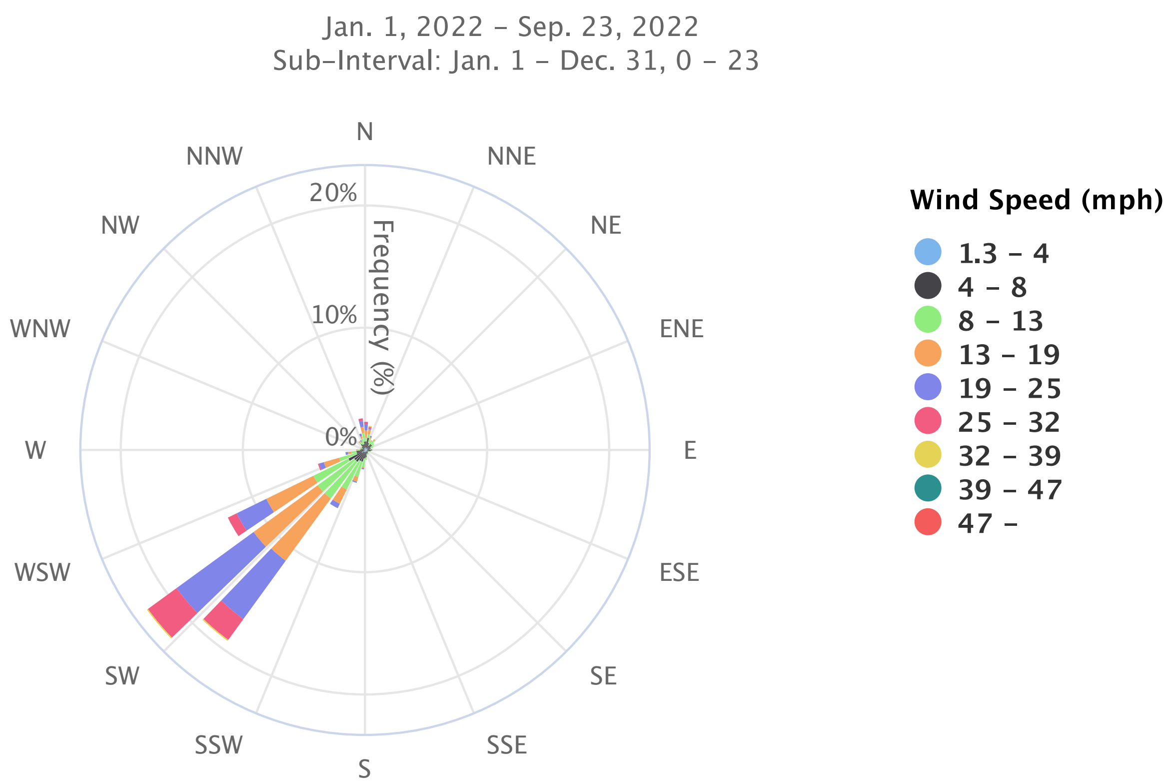
Table 14. Potential hedgerow species and quantities need for Hills Road Front Pasture Hedgerow*

Hedgerow (CPS 422) and Location	Linear (Feet) and Miles	Mg CO2E Sequestered*
Vineyard Bow Hedgerow	758	1.14
Spring Hill Pasture Hedgerow	4725	7.12
Source Pasture Interior Hedgerow	7900	11.9
Residence/Barn/Office Hedgerow	1994	3
Randall Pasture Interior Hedgerow	8413	12.67
Olive Pasture Hedgerow	3579	5.39
Hills Road Randall Pasture Hedgerow	2377	3.58
Hills Road Horse Barn Pasture Hedgerow	5122	7.71
Hills Road Front PastureHedgerow	4101	6.18
Hills Road Experiment Pasture Hedgerow	10160	15.3
Largo/Camino Nuevo Pasture Interior Hedgerow	16545	24.92
Laguna Pasture Interior Hedgerow	14566	21.94
Laguna Pasture Hedgerow	4497	6.77
Junk Pasture Interior Hedgerow	3448	5.19
Llantes Pasture Interior Hedgerow	9900	14.91
Front Pasture and Main Drive Hedgerow	9958	15
Church Pasture Interior Hedgerow	10934	16.47
Buena Vista/Runion/BCS Pasture Interior Hedgerow	20746	31.24
Buena Vista Pasture Interior Hedgerow	6790	10.23
Black Tank Pasture Interior Road Hedgerow	13330	20.07
Alfalfa Field Hedgerow	9813	14.78
100Acre Pasture Interior Road Hedgerow	8250	12.42
Total	**177,906 ft, 33.69 miles**	**267.93**

*CO2e estimate calculated using [CDFA Comet Planner]

Speaking generally now about windbreak design, the NRCS eVegGuide recommends over 51 trees (see Appendix F for full list) that are well suited for the location and climate. Table 19 below details native species that could suitable work across the landscape. Each windbreak will be designed a little differently (i.e. vineyard wind break may not need wind protection in Winter after grapes are harvested, can opt for a deciduous tree instead of an evergreen, etc.). Below, we provide an example windbreak to repair existing windbreaks in the lambing area of the ranch. While we've selected California sycamore, for this example, the landowner may prefer to plant windbreaks that provide pollinator habitat, fix nitrogen in the soil, or meet any other ranch goals. In general, planners recommend approaching windbreak design with a diversified palette and goals, as that should lead to carbon sequestration, but also other natural resource benefits.

Figure 6. Wind Rose, courtesy of [Midwestern Regional Climate Center.]



EXAMPLE: New Windbreak H

Windbreak, 341 linear feet, parallel with pasture fence in lambing area

- Sample planting; single line, Plant on 4’ off pasture fence between road and fence Plant 1 California sycamore (*Platanus racemosa*) tree every 10 feet

- Planting will enhance visual esthetic, reduce sedimentation, and provide pollinator and bird species habitat while capturing carbon, both above and below ground.

- Maintenance: A denser planting is recommended here (spacing every 10 feet), but at maturity, *P. racemosa* have a diameter of approximately 50 feet. Pruning, and or removal of trees may be needed as trees grow in age and begin to overlap.

Map 14. Windbreaks in need of repair or replacement with corresponding windbreak length in feet

Riparian Systems Restoration

Within the Wool Ranch, there are five seasonal streams, all unnamed, that drain into the S. River. Most of these streams are functionally seasonal drainages, suggesting soils and seasonal hydrology consistent with riparian systems (See Map 3 on page 12. One of them, discussed below, has potential for Riparian Restoration and is included as a climate smart agricultural practice.

This central riparian corridor begins at the property entrance and headquarters, flows through the main barn and ranch infrastructure area, through the lambing areas, around the edge of the grain field, and meets up with another tributary before running alongside

Table 15. Wool Ranch Potential Windbreaks in need of repair and extension

Assuming renovation of existing, 1-row windbreak with 10 ft spacing			
Windbreak Name	**Windbreak Length (feet)**	**Estimated Existing % Cover on Windbreak**	**MG CO2E***
A	341	50%	0.26
B	284	50%	0.21
C	261	25%	0.29
D	157	75%	0.06
E	168	25%	0.19
F	287	10%	0.39

*Ran through CDFA COMET-Planner then multiplied by (100-Estimated Existing % Cover on Windbreak) to determine approximate sequestration from repair.

the vineyard and draining into the S. River. These six reaches are split largely by roads and assumed culverts that continue the drainage, but could feasibly be treated in segments depending on available funding, time, and energy. (Planners recommend connecting with the USDA NRCS to determine if these culverts are appropriately sized for the drainage given potential increasing intensity of precipitation events (i.e., atmospheric rivers, etc.). For quantification purposes, the Riparian Restoration Practice will include Riparian Forest Buffer for the overstory cover, Riparian Herbaceous Cover for more herbaceous species, and Critical Area Planting to retain soil and reduce erosion. The length of each stream

Map 15. Proposed New Windbreaks in lambing area

Table 16. New Windbreaks to be created at Wool Ranch

Windbreak Name	Length (feet)	Mg CO2e Sequestered*
New A	137	0.21
New B	198	0.30
New C	214	0.32
New D	209	0.31
New E	231	0.35
New F	181	0.27
New G	274	0.41
New H	341	0.51
Total	**1785**	**2.68**

*CO2e estimate calculated using CDFA Comet Planner

segment is multiplied by an 20 foot buffer centered on the creek (10 ft on either side) to arrive at an approximate acreage which is typical of riparian restorations. Speaking broadly, the "Entrance" and "House and Barn" portions of the main creek or ditch lack significant vegetation and are thinner sections or creek. The "Lambing Area" and "Barn" portion of the creek widens to, at some points, an estimated 20 ft. width from bank to bank before

Map 16. New Windbreaks along Vineyard

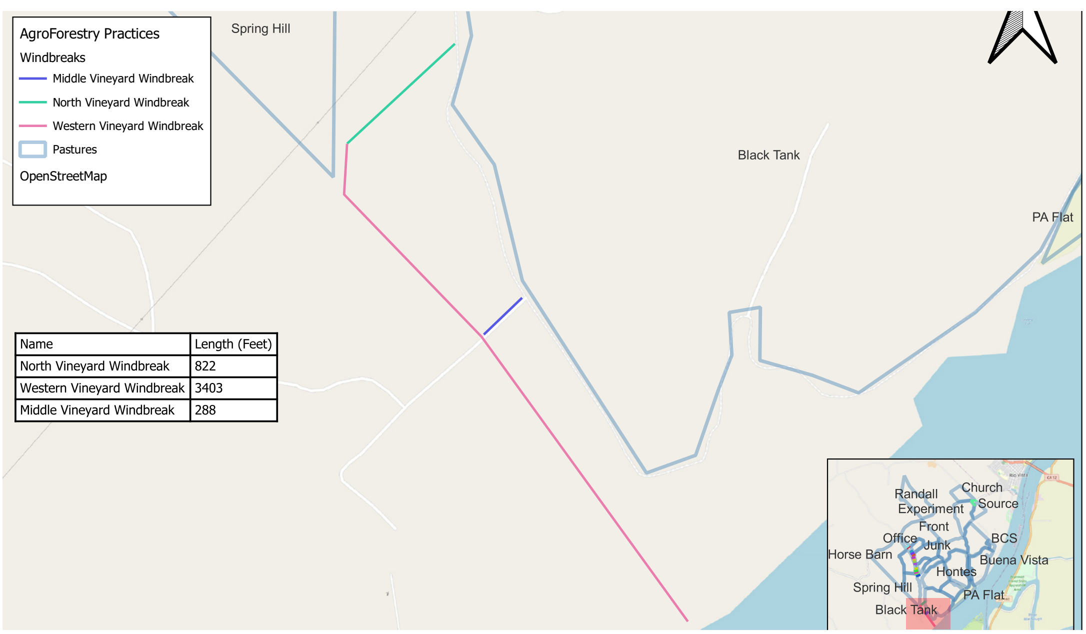


Table 17. Wool Ranch Potential New Windbreaks around vineyard

Windbreak name	Length	Mg CO2e Sequestered*
Western Vineyard Windbreak	3403	5.12
Northwest Vineyard Windbreak	822	1.24
Middle Vineyard Windbreak	288	0.43
Total	**4513**	**6.79**

*CO2e estimate calculated using CDFA Comet Planner

narrowing again at the "Grain Field" and "Vineyard". As with windbreak design, each reach of creek restoration design will need to be examined and thought through. For planning purposes, we apply a 10 foot buffer on either side of the stream center line to approximate a carbon sequestration estimate. In some parts of the creek, the buffer may be smaller, and in others larger. On the whole though, the management practice should aim to provide a 10 ft. stream buffer minimum from the bank or creek center line. For planning purposes, we assume a 20 ft. buffer, but implementation lengths may exceed that.

Map 17. Residence Windbreak

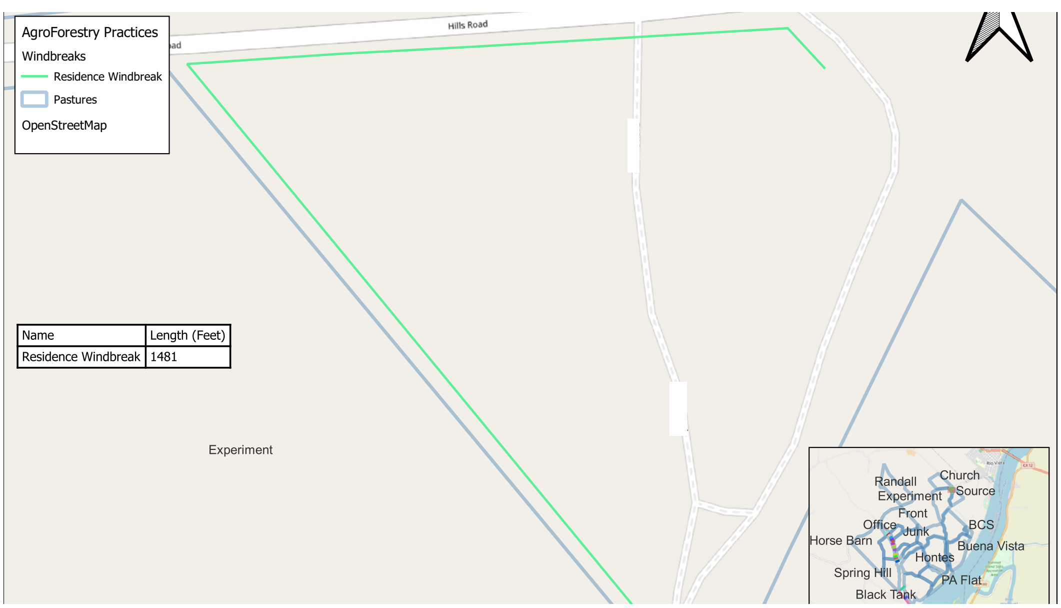


Table 18. Wool Ranch Potential Windbreaks around residence in need of renovation

Windbreak Name	Length (feet)	Estimated % Cover Existing Already	Mg CO2e Sequestered*
Residence Windbreak	1481	50%	1.12

*Ran through CDFA COMET-Planner then multiplied by (100-Estimated Existing % Cover on Windbreak) to determine approximate sequestration from repair.

S. River Erosion control

After the site visit in February 2022, planners examined historical aerial imagery to determine approximate acreage lost as a result of erosion by the S. River. In total, approximately 1/3 to ½ of an acre has been lost as the S. River erodes the alfalfa field from 2002 to 2021. Historically, sheep were herded southeast across what was a wet meadow to grazing on high ground on the island to the east, west of what was the main channel of the S. River. The deep water channel that is now slowly consuming the alfalfa field was constructed in the early 20th century, indicating significant historical loss of soil and associated organic matter from what was undoubtedly a carbon rich organic soil prior to channel construction (J. Wool, personal communication). The alfalfa field has slowly retreated inland and taken over previous roads or fallow areas. The lines in the below map show approximate shoreline positions in June 2002 (Red), and June 2021 (Blue) according to Google Earth aerial imagery.

This erosion can potentially be slowed and future erosion prevented through the creation of a Riparian Forest Buffer (CPS 391), Riparian Herbaceous Cover (CPS 390), and Critical Area Planting (CPS 342).

The Wool Ranch shoreline along the S. River is just over 2 miles long. The proposed riparian forest buffer drawn here, broken up by existing roads or other infrastructure, is approximately 40 feet wide. While typical Riparian Restoration scenarios focus on a 20 ft buffer, given the extreme erosion witnessed, a 40 ft buffer, or potentially even larger, is likely needed to prevent further erosion. Whatever level of buffer is selected, 40 ft is likely the minimum needed to protect the alfalfa field. Further project descriptions and plans will need to be made and discussed with the landowner and ranch manager, but this provides a starting place for our carbon sequestration estimates by calculating acreages.

Lowlands Riparian Restoration

Additional potential for riparian restoration was observed in the two drainages and lowlands that drain into the alfalfa fields. These areas aren't regularly grazed as they are between defined pastures and could be potential areas for more riparian restoration. Functionally, these acreages are more drainage than riparian corridor, but the usual practices of Riparian Herbaceous Buffer (CPS 390), and Critical Area Planting (CPS 342) apply. Since the area is more of a flat drainage, Tree/Shrub Establishment (CPS 612) is likely a better fit.
Species recommendations for all four practices (Riparian Herbaceous Cover (CPS 390),

Table 19. NRCS eVegGuide Native Tree Recommendations for Wool Ranch using CPS 380 Windbreak/ Shelterbelt Establishment

Common Name	Scientific Name	Ease Rating
Incense cedar	*Calocedrus decurrens*	easy
California sycamore	*Platanus racemosa*	easy
Red willow	*Salix laevigata*	easy
Port Orford cedar	*Chamaecyparis lawsoniana*	moderately easy
Sargent's cypress	*Hesperocyparis sargentii*	moderately easy
Fremont cottonwood	*Populus fremontii ssp. fremontii*	moderately easy
Douglas-fir or Douglas fir	*Pseudotsuga menziesii var. menziesii*	moderately easy
Sugarberry (hackberry)	*Celtis laevigata*	slightly difficult
Tecate (Forbes) cypress	*Hesperocyparis forbesii*	slightly difficult
MacNab Cypress	*Hesperocyparis macnabiana*	slightly difficult
Monterey cypress	*Hesperocyparis macrocarpa*	slightly difficult
Cuyamaca cypress	*Hesperocyparis stephensonii*	slightly difficult
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	slightly difficult
Goodding's willow	*Salix gooddingii*	slightly difficult

Riparian Forest Buffer (CPS 391), Tree/Shrub Establishment (CPS 612) and Critical Area Planting (CPS 342)) are included within the appendix (Appendix D, G, H, I) but contain a number of potential native plants that are well suited at Wool Ranch. The riparian corridor is characterized mostly by some small shrubs at the start of the creek where it enters Wool Property, mostly vacant any vegetation in the middle reaches below the lambing barn adjacent to the Spring Hill Pasture, and then mixed with some trees along the vineyards edge. As recommended previously, the highest success will come from species already thriving on site, assuming these are native and desired species. Below is an example for one reach of creek from above that appears to have little to any existing vegetation. Before implementing this management practice, planners recommend talking to the local RCD or NRCS staff to develop specific implementation plans for each stretch of creek. Vegetation can change stream flow and function, and lead to constricted future flows, creating future hazards. Careful design and implementation is needed in consultation with the local RCD and NRCS staff.

Map 18. Riparian Restoration at Wool Ranch

EXAMPLE: Grain Field Riparian Restoration

Riparian Forest Buffer

- 4294 feet long, 20 feet wide, 1.97 Acres, between Barley, Pea, Vetch Field and Spring Hill Pasture
- Sample Planting:
  - 1 row on both sides of stream, offset (to make a zig-zag pattern)
  - Species: Arroyo Willow (*Salix lasiolepis*), Red Willow (*Salix laevigata*), Sandbar Willow (Salix exigua), Fremont Cottonwood (*Populus fremontii spp. fremontiiI*), White Alder (*Alnus rhombifolia*)
  - 15 ft. Spacing between trees on same side of stream, 10 feet between trees on opposite side of stream
- Planting should provide overstory cover for creek/stream, wildlife habitat for birds and pollinators, capturing atmospheric carbon and increasing above and below ground biomass.

Note: Willows can be bushy while young and may create predator habitat. Adequate spacing should reduce this, but could be a factor in species selection

Riparian Herbaceous Cover, 4294 feet long, 20 feet wide, 1.97 Acres

- 4294 feet long, 20 feet wide, 1.97 Acres, between Barley, Pea, Vetch Field and Spring Hill Pasture
- Sample Planting:
  - Between trees in Riparian Forest Buffer, forbs and grasses
  - Species: Generally select shade tolerant species that can grow up underneath the selected tree species

        - Common Yarrow (*Achillea millefolium*), Great Valley gumweed (*Grindelia camporum*), Western Goldenrod (*Euthamia occidentalis*), Yellow monkey flower (*Erythranthe guttatus*), Santa Barbara sedge (*Carex barbarae*), Creeping wildrye (*Elymus triticoides*)
    - 2 ft. plant spacing between trees on both sides of streams, seeding of native or desirable grasses
- Planting should provide herbaceous cover for creek/streambank, and pollinator habitat, capturing atmospheric carbon and increasing above and below ground biomass, and reducing erosion into stream

Note: Herbaceous cover is a difficult practice to establish even in ideal site conditions. Planners recommend focusing on woody plants if at all possible, or letting resident grasses continue to function.

Critical Area Planting, 4294 feet long, 20 feet wide, 1.97 Acres

- 4294 feet long, 20 feet wide, 1.97 Acres, between Barley, Pea, Vetch Field and Spring Hill Pasture

Table 20. Riparian Systems restoration, name of section and length and annual MgCO2e sequestration potential

Riparian System at Wool Ranch	Name of Section within Riparian System	Area (acres, length x 20 ft buffer for Main Creek, 40 ft buffer for S. River)	MgCO2E/yr Sequestered Critical Area Planting	MgCO2E/yr Sequestered Riparian Herbaceous Cover	MgCO2E/yr Sequestered Riparian Forest Buffer	MgCO2E/yr Sequestered Tree and Shrub Establishment
Main Creek (Ditch)	Entrance	1.97	2.07	0.53	4.57	-
	House and Barns	0.72	0.75	0.19	1.66	-
	Lambing Area	3.72	3.90	1.01	8.63	-
	Barn	0.42	0.44	0.11	0.97	-
	Grain Field	4.06	4.26	1.10	9.42	-
	Vineyard	3.47	3.65	0.94	8.06	-
S. River	Vineyard	4.77	5.00	1.29	8.44	-
	Alfalfa South	3.22	3.38	0.87	5.69	-
	Alfalfa North	2.33	2.45	0.63	4.12	-
	North	0.76	0.80	0.21	1.34	-
Flatlands Restoration	Laguna/100Acre	19.55	20.53	5.30	-	369.36
	Dead Tree	16.17	16.98	4.38	-	305.45
	Total	**61.15**	**64.21**	**16.56**	**52.89**	**674.81**
					Grand Total	**808.47**

*CO2e estimate calculated using CDFA Comet Planner

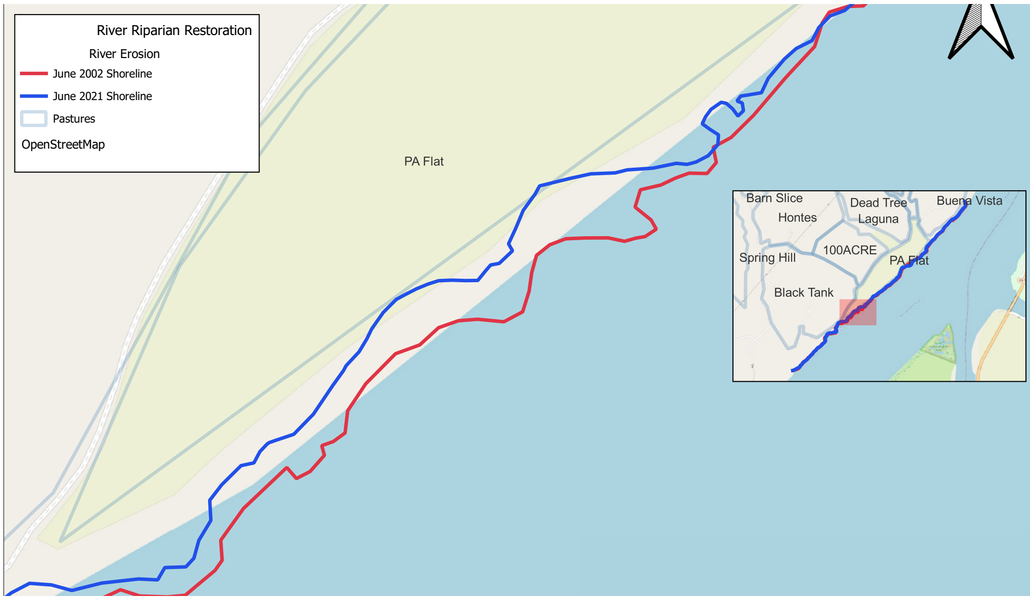
Photo courtesy of CCRCD

Main creek riparian area taken from barn.

- Sample Planting:
    - Between trees in Riparian Forest Buffer, shrubs (in addition to other forbs and grasses)
    - Species: Generally select shade tolerant species that can grow up underneath the selected tree species
        - California wildrose (*Rosa californica*), California blackberry (*Rubus ursinus*), Mule-fat (*Baccharis salicifolia*), Saltbush species (*Atriplex spp.*), other shrubs

Note: shrubby species may lead to increased predator habitat. Further investigation is recommended with NRCS/RCD staff to meet landowner goals and objectives.

Map 19. Historical Shoreline erosion at Wool Ranch showing June 2002 (red) and June 2021 (blue)



Map 20. Erosion of Wool Ranch by S. River, notice retreat of alfalfa field inland. Red lines are acres lost while green lines are acres gained.

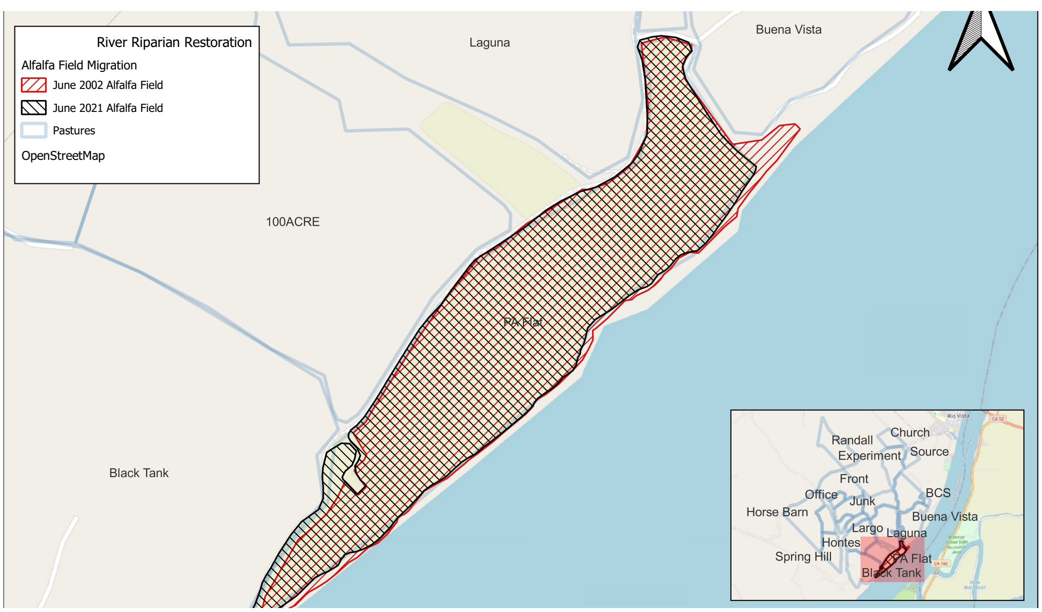


Photo courtesy of CCRCD

Observed shoreline erosion in February 2022 site visit. Rising tidal influences are likely to contribute to further undercutting and eroding of the alfalfa field.

Map 21. Riparian Restoration/S. River Buffer at Wool Ranch

Map 22. Lowlands Restoration areas

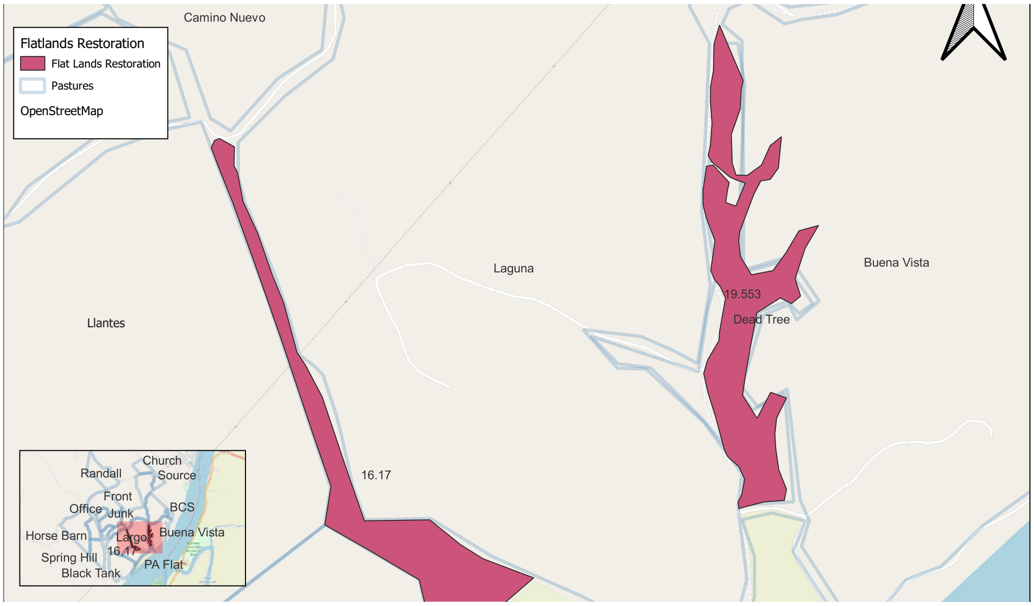


Photo courtesy of CCRCD

Lowlands area between Laguna and 100 Acre pasture facing Laguna Pasture, 16,2-acres.

Compost Application

Research conducted on northern California rangelands by the Silver Lab at the University of California at 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 grassland sites in both coastal and foothill rangelands (Ryals & 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 ten years of data collection, and ecosystem models suggest this improvement will continue for at least 20-30 years in response to the single compost application in year one, reflected in improved forage quality and quantity, and improved soil water holding capacity. Compost application, therefore, is recognized as an effective means of increasing carbon capture, through increased forage 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 increase. 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 off site sources of carbon, such as compost, can elevate soil carbon levels and, in some cases, enable increased carbon capture above that of equilibrium conditions (Ryals & Silver, 2013). Compost can thus be a powerful tool for soil carbon increase, but is not always a realistic option. This is especially the case where target fields are far from sources of compost. However, 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.

GIS Slope Analysis

Pending soil analysis results confirming soil nutrient deficiencies on pastures with slopes less than 15%, an estimated 3602 acres of Wool Ranch could potentially be suited for compost application (Map 10), based on reported NRCS soil survey data showing baseline soil organic matter below 5%.

To determine suitable areas for Compost Application to rangelands of the Wool Ranch, a GIS analysis was performed using publicly available GIS data from the S. County government Parcel Viewer. The Parcel Map is assumed to be accurate as it was provided directly from the S. County GIS Service. The 5-foot contour layer from the UC Berkeley Geodata library was derived from a 2008 digital elevation model created by the S. County government. Based on a cursory search of available data, this appears to be the most recent and high-resolution contour data available, despite being nearly 15-years old. Further, the geography of the

Wool Ranch hasn't changed substantially since then to warrant further searching or data collection.

The 5-ft contour layer was then clipped to the extent of the Wool Ranch parcels and a digital elevation model was created from the clipped contour layer. Using the new DEM, planners ran the Slope Raster Terrain Analysis tool in QGIS to convert the DEM layer into a similar layer that instead of showing contours on a 5-foot basis created a slope layer to show slopes across the property. The Slope Raster layer was then converted back into a vector polygon layer from which we could further determine eligible and ineligible compost application areas.

Compost application on rangelands and pasture systems is an ongoing research endeavor by many parties across California and recommendations could change with new information in the future. For now, we are going to assume that the only way to fund this practice is through the California Department of Food and Agriculture's Healthy Soils Incentives Program which provides a framework for where compost could be applied. Within rangeland settings, the Healthy Soils Incentives Program dictates two areas of ineligibility: 1) compost cannot be applied on peaty, high organic matter content soils (SOM>20%), commonly found in the S.-S.J. River Delta and 2) compost cannot be applied on slopes greater than 15%. A quick examination of the NRCS Web Soil Survey and the UC Davis Soil Web maps as well as the CDFA Healthy Soils Incentives Program RePlan tool shows that all of the soils within the Wool Ranch are eligible for compost application as they typically range from 1-4% organic matter, far under the threshold of 20% Organic Matter (CDFA, 2021). Our analysis described previously accounts for the second criteria, that compost is only applied to areas with slopes less than 15% (Gravuer, 2016).

Based on those criteria then, we identified potential locations for compost application within the Wool Ranch. Of the 3766 acres throughout the ranch, only 220-acres were determined ineligible, mostly located along the sides of valleys.

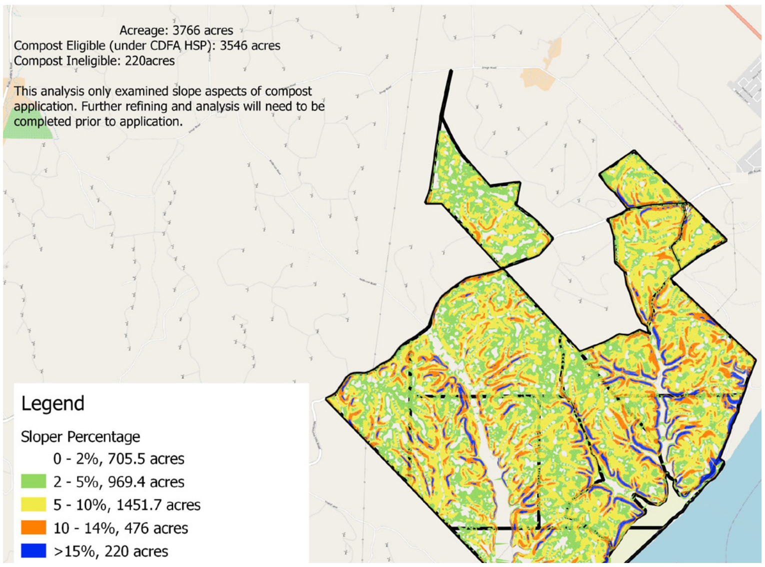
Based on these maps, there is potential for compost application on 3,600 acres of the Wool Ranch. Applying compost on the lowest slopes (0-5%) would result in 1724-acres alone, nearly half of the Wool Ranch. For the most part, these areas are confined to the lower lying areas of the vineyard and alfalfa fields as well as the tops of hills, the lambing quarters, and the ranch

Table 21. Wool Ranch Slope Classifications and acreages based on GIS analysis

Slope Percentage	Acreage within Slope Percentage
0-2%	705.5
2-5%	969.4
5-10%	1451.7
10-14%	476
>15%	220
Total	**3822.6**

headquarters. Further determinations will need to be made by a NRCS Conservation Planner or RCD Technical Assistance Provider in conversation with the ranch manager and owner to determine at which stage of the three-year rotation compost is likely to be most beneficial, application rates, and where best to apply compost, but there is significant potential within the Wool Ranch.

Map 23. Wool Ranch GIS Analysis for Compost Application Suitability



Estimated Nitrogen Release (ENR)

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

Compost applications to cropland (as compared with pastures or rangeland) are typically less than 1" per acre per crop cycle (140 cubic yards or about 70 tons/acre), though rates as low as 3 tons per acre per year are common in almond orchards, for example. This quantity should be modified as needed, depending upon which nutrient, including SOM, is most likely to be limiting, or 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, presents a negligible water quality risk when applied at agronomic rates to cropland or rangeland with appropriate buffers adjacent to surface waters (CalRecycle, 2022). Buffers of at least 30 feet are recommended.

Compost Application at Wool Ranch

The Wool Ranch currently produces compost on-farm, combining sheep manure with remaining hay or other ranch vegetation and estimates creating "1 dump trailer full" annually (Personal Communication with ranch manager). Planners estimate 1 dump trailer full to equal approximately 15 cubic yards of compost, enough to cover approximately 0.44-acres at a ¼" thickness. Assuming 1.0 metric tonnes of CO2e sequestered per acre following a ¼" compost application to untilled, grazed rangeland (Ryals and Silver 2013; Silver et al 2018), Table 22 below calculates the benefits of applying ONLY FARM PRODUCED COMPOST on 0.44 new acres annually over 20 years. While small, the cumulative impact results in 92 metric tons of CO2e sequestered after 20 years of implementation across only 8.8-acres.

Thinking more broadly, if Wool Ranch were to purchase compost or acquire through various state and federal sources approximately 6000 cubic yards of compost/year, that would be enough to cover approximately 180-acres annually. If Wool Ranch were able to sustain 180-acres per year over 20 years to fully cover the available acreage, the cumulative CO2e sequestered would be on the order of approximately 37,800 metric tons of CO2e sequestered. While 600 cubic yards of compost is a lot, recent advances in state and federal policy are

Table 22. On Farm Compost Production Carbon Sequestration Estimate

On Farm Produced (est. 15 cubic yards or 1 truck load)			
Year	Cumulative Acres 1/4" Rate	Metric Tons CO2e/yr*	Cumulative CO2e
1	0.4	0.4	0.4
2	0.9	0.9	1.3
3	1.3	1.3	2.6
4	1.8	1.8	4.4
5	2.2	2.2	6.6
6	2.6	2.6	9.2
7	3.1	3.1	12.3
8	3.5	3.5	15.8
9	4.0	4.0	19.8
10	4.4	4.4	24.2
11	4.8	4.8	29.0
12	5.3	5.3	34.3
13	5.7	5.7	40.0
14	6.2	6.2	46.2
15	6.6	6.6	52.8
16	7.0	7.0	59.8
17	7.5	7.5	67.3

18	7.9	7.9	75.2
19	8.4	8.4	83.6
20	8.8	8.8	92.4

*Calculated using Ryals and Silver 2013 data.

working to shift organic materials out of landfills into composting systems to reduce fugitive methane emissions and provide climate benefit. Under California Senate Bill 1383 as a recent example, municipalities will be required to procure 0.08 tons of compost per person residing within city limits. For the city nearby (population est. 119,000), that amounts to 9520 tons of compost procured, or roughly 19,000 cubic yards. How the compost is utilized is ultimately up to the cities to determine, but there may be opportunities for some of this compost to wind up at Wool Ranch. Planners recommend connecting with local RCD staff to determine the latest developments and take advantage of available programs.

Table 23. Compost application evenly spread over 20 years (~180-acres/yr)

Purchased Compost on 120-acres/yr			
Year	Cumulative Acres 1/4" Rate	Metric Tons CO2e/yr*	Cumulative CO2e
1	180	180	180
2	360	360	540
3	540	540	1080
4	720	720	1800
5	900	900	2700
6	1080	1080	3780
7	1260	1260	5040
8	1440	1440	6480
9	1620	1620	8100
10	1800	1800	9900
11	1980	1980	11880
12	2160	2160	14040
13	2340	2340	16380
14	2520	2520	18900
15	2700	2700	21600
16	2880	2880	24480
17	3060	3060	27540
18	3240	3240	30780
19	3420	3420	34200
20	3600	3600	37800

*Calculated using Ryals and Silver methodology.

Hay Field and Vineyard System

The Wool Ranch also practices row crop agriculture both in the vineyard, and in the hay and alfalfa fields. The Hay Field is located just above the vineyard on approximately 45-acres that is planted in pea, vetch, and barley. These crops are used as supplemental feed for the sheep operation. Additionally, Wool Ranch also includes a 81-acre alfalfa field in the PA Flat pasture. This field is irrigated and annually grows alfalfa, and is occasionally grazed in winter if needed.

The vineyard system at Wool Ranch was planted in 2008 and produces wine grapes that are managed by P. Vineyards. The vineyard appears to be healthy and reportedly produces good grapes. While not the entire focus of the field day, planners observed some natural resource management practices being implemented on the vineyard. Barn owl boxes appeared throughout the vineyard as a means to reduce rodent populations in the vineyard. Likewise, vegetation is allowed to grow between the vineyard rows, but is mowed periodically, acting as a volunteer cover crop. While functionally similar, this does not meet NRCS Standard and Specifications to meet the "Cover Cropping" practice.

Photos courtesy of CCI

Mulching, Cover Cropping, Vineyard Compost Application

Within the vineyard, there is potential to apply compost, cover crops, and mulch as appropriate between the rows of vines for improved soil health.

Based on current vineyard acreage, we estimate the following acreages for the above practices.

Map 24. Wool Ranch Vineyard and Hay Field

The vineyard alone occupies the Valdez soil series described previously, with an organic matter percentage of 1.2% in the first 40 cm and 0.6 below 40 cm (California Soil Resource Lab, 2022). Assuming a healthy soil organic matter (SOM) content of 5%, there is significant potential for increase in carbon in the vineyard soils. Increasing SOM from 1.2% to 5% in the

Table 24.Wool Ranch Row Crop Management Practices and Mg CO2e Sequestered Estimate

Management Practice	Acreage	Mg CO2e Sequestered/yr *
Mulching (Vineyard)	20.36	7
Cover Crops Vineyard)	20.36	33
Cover Crops(Hay Field)	45.4	18
Cover Crops (Alfalfa Field)	81	32
Compost Application (Hay Field	45.4	206
Compost Application (Vineyard)	50.9	231.00
Compost Application (Alfalfa field)	81	368
Total		**895**

*CO2e estimate calculated using CDFA Comet Planner

plow layer alone (top 17cm) represents an increase of 3.8%. This is roughly 38 tons of SOM, or 19 tons of organic carbon per acre. This represents approximately 63.4 metric tons of CO2e per acre. Over the 50.9 acre vineyard, this would represent some 3,227 metric tons of CO2e moved from the atmosphere to the soil via compost, mulch and cover crops. Improved soil health should lead to improved plant and vineyard health. Further, improved soil water holding capacity should increase resilience to drought and increasing rainfall intensity as well as decrease reliance on irrigation water from the S. River, which is predicted to increase in salinity and potentially threaten the vineyard system. Planners recommend working with P. Vineyards, or any future vineyard managers, to implement these management practices and increase the sustainability of the vineyard long-term.

Cover Cropping & Mulching

Cover cropping is a popular practice amongst vineyards all over California. Each vineyard system requires special attention to design a cover cropping system that works for each vineyard's unique soils, microclimates, grape varieties, and management practices. The UC Cooperative Extension has put together a guide exploring a number of different questions and scenarios for cover cropping systems in "Cover Cropping in Vineyards: An Introduction to Vineyard Cover Crop Management". This handbook details seeding mixes, planting questions, management practice concerns and other discussion topics vineyard managers should consider and be aware of when utilizing cover crops. Species mixes will vary depending on landowner goals (i.e. nitrogen-fixing legumes vs. pollinator habitat, etc.) but could reasonably include a number of different grasses (ryegrass, wheat, triticale), legumes (clover, purple vetch, bell (fava) bean), and forbs (brassicas, phacelias, other flowering plants). Please contact your local NRCS or RCD office for further discussion about cover crops and suitable species for the Wool Ranch.

Mulching is another popular practice in vineyards for water management (increasing surface water holding capacity), erosion and dust management, and for building/protecting soil health. Wood chip mulching can provide excellent weed protection, keeping vineyard rows clear for ease of management on site.

Mulching and cover cropping can be practices at odds with each other. For this purpose, planners recommend a rotation between the rows as follows. The vineyards at Wool Ranch are spaced at approximately 10-feet, assuming a one-foot buffer on either side of the vines themselves, this leaves approximately 8-feet of workable space. While site visiting, planners observed that every other row of the vineyard had been mowed, likely resulting in something close to a cover crop. Building off this practice, planners recommend applying mulch every other row and cover crop on the other rows, resulting in approximately half of the field receiving mulch and half of the field receiving a cover crop. Over time, managers may switch and plant a cover crop on the mulch rows and mulch the cover crop rows. Rather than do it annually, planners recommend mulching one row to a minimum of 3-inches, but closer to 6-inches (OMMS, 2002). At 6-inches, the mulch should last at least two years, potentially longer.

Cover cropping could also be practiced on the 45-acre pea, vetch, and barley field as well as the alfalfa field for additional nutrient storage and carbon sequestration. Mulching could theoretically also be applied but given that there aren't "rows" typical of a vegetable system, mulching as a practice would be difficult to implement and could potentially hinder growth of desired crops.

Compost Application

Compost Application in vineyards, alfalfa, and barley, pea, and vetch fields is another excellent way to boost soil health and reduce use of fertilizers. Compost can be purchased from a certified facility or created on site and applied as needed. Planners recommend meeting with NRCS or RCD staff to further discuss this practice and determine application rates and quantities.

Prescribed Grazing

Planners did not include an estimate here for the potential sequestration value of prescribed grazing within the vineyard system as it is included in the larger, prescribed grazing analysis for the entire ranch. Still, there is potential to incorporate the sheep, or other livestock, in the management of the cover crop and vegetation between the vineyard rows. Incorporation of livestock into vineyard systems is a popular management practice and research topic, with research results emerging in the near future as vineyard managers look to manage their vines more sustainably with less reliance on pesticides and herbicides.

As with most grazing, timing is everything, and there are considerations to be made to protect the vines and their fruits. Planners recommend connecting with UC Cooperative Extension Specialists and Resource Conservation District staff to fully develop a livestock incorporation plan before deploying any livestock in the vineyard.

Photo by Paige Green

The following practice list includes carbon beneficial practices and extents identified as appropriate for Wool Ranch (NRCS conservation practice numbers appear in parentheses).

Table 25. Wool Ranch carbon beneficial practice opportunities

NRCS Conservation Practice	Description	Annual CO2e-Sequestered (tonnes)	CO2-Benefits	Reference
Cover Crop (340)	Application of permanent, legume mix cover crop to 20.36 acres of vineyard floor, and 45-acres of Hay Field annually	51	Increase soil organic carbon, Improved soil water and nutrient holding capacity	HSP Comet Planner - Vineyard
Mulching (484)	Application of mulch (natural material or wood chips) to 20.36 acres of vineyard floor annually	7		
Compost Application (363)	Application of compost C/N > 11 to 50.9 acres of vineyard floors @ 8 tons/acre and 45.4 acres of hay field and 100 acres of alfalfa field annually	805		HSP Comet Planner - Vineyard
Compost Application (363)	Application of 1/4" of compost to approximately ~180 acres annually	180		Ryals et. al
Prescribed Grazing (528)	Grazing management of 3558-acres of Wool Ranch for enhanced forage production	640	Enhanced rangeland and pasture productivity, climatic resilience and species diversity.	HSP Comet Planner – Grazing Lands
Silvopasture (381)	Incorporation of trees for food or shade into rangeland or pasture settings on 102-acres	67	Provide shade for livestock and wildlife, sequester carbon, improve microclimate stabilize soils, improve water quality, and habitat diversity, reduce water loss.	HSP Comet Planner – Grazing Lands
Hedgerow (422)	Establishment of 177,906 feet of hedgerow along existing ranch roads and pasture borders.	268		HSP Comet Planner – Grazing Lands
Windbreak (380)	Establishment or renovation of 9277 feet of windbreaks across Wool Ranch.	12		HSP Comet Planner – Grazing Lands

Critical Area Planting (342)	Planting of native grasses and shrubs on approximately 61.15 acres along main creek (ditch), S. River, and Laguna/100 Acre and Dead Tree Pastures	64	Stabilize soils and stream banks and channels, water capture soil moisture and organic matter, wildlife habitat structural and species diversity.	Comet Planner
Riparian Forest Buffer (391)	Planting of trees and shrubs on approximately 25.4 acres along S. River and other riparian channels to reduce erosion of degraded riparian areas.	53		HSP Comet Planner – Grazing Lands
Riparian Herbaceous Cover (390)	Planting of herbaceous cover on approximately 25.4 acres along S. River and other riparian channels to reduce erosion of degraded riparian areas.	17		HSP Comet Planner – Grazing Lands
Tree and Shrub Establishment (612)	Planting of trees in the riparian flatlands on 35.72-acres	675		HSP Comet Planner - Crop Lands
Residue and Tillage Management - No Till	Continuation of no-till on 397-acres of permanent pasture.	64	Reduced soil disturbance, enhanced soil health	HSP Comet Planner - Crop Lands
Residue and Tillage Management - Reduced Till	Continuation of reduced tillage on 3161-acres of grazed Wool Ranch parcels (Note, transitioning to permanent pasture (no till) will result in further sequestration.	284		HSP Comet Planner - Crop Lands

Supporting Conservation Practices

The following list of practices includes supplemental and supporting practices that may be useful in combination with previously listed practices, but don't directly sequester carbon. However, their incorporation with the above-mentioned practices will lead to better management practice success, and therefore greater sequestration.

Table 26. Wool Ranch Supporting Conservation Practices

NRCS Conservation Practice	Description		
Fence (382)	Temporary electric or permanent fence for pasture management, protection for tree and shrub cover establishment, as well as windbreak and shelterbelt plantings.	Increase soil and biomass carbon capture on protected sites	Stabilize soils, improve water capture, water quality and habitat structural and species diversity.
Bioengineering/ Grade Stabilization Structure (410) Streambank Protection (580)	Install Grade Stabilization Structure, and or willow walls at locations along creek where large scale active erosion is occurring.	Supporting practice to arrest erosion followed up planting through Critical Area Planting or Riparian Herbaceous Cover	Improve water quality, reduce erosion, stabilize soil, increase vegetative cover and soil organic matter
Water Development (Livestock Pipeline-516, Watering Facility-614, Pumping Plant-533)	Install tanks, pipeline 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.
Herbaceous Weed Control (315)	Improve native species diversity throughout ranch with mechanical, grazing and hand tool control of invasive thistle populations.	Supporting practice.	Improved wildlife habitat, improved livestock forage, stabilize soils, improve carbon and water capture by vegetation and soils.

Photo by Paige Green

Soil, Water and Carbon

The USDA NRCS suggests that a 1% increase in SOM results in an increase in soil water holding capacity (WHC) of approximately 1 acre inch, or 27,152 gallons of increased soil water storage capacity per acre. A 1% increase in soil organic matter represents roughly 20,000 pounds (10 short tons) of organic matter, or 5 short tons of organic carbon. Table 27 shows estimated additional water storage capacity associated with soil carbon increases on Wool Ranch resulting from implementation of the Wool Ranch CFP.

Total estimated additional water storage capacity associated with soil carbon increases on Wool Ranch resulting from implementation of the CFP over 20-years is estimated to be 437-acre feet (~140,000,000+ gallons). This analysis is assumed conservative yet reveals the potential significance of even small increases in soil carbon storage for overall Farm dynamics.

Table 27. Carbon beneficial practices and 20-year soil water holding capacity increases associated with increases in soil organic carbon

NRCS Conservation Practice	Description	20 Year CO2e Sequestered Estimate	20 Year SOC Increase (Mg)	20 Year WHC Increase (AF)
Cover Crop (340)	Application of permanent, legume mix cover crop to vineyard floors	1020	278	5.1
Mulching (484)	Application of mulch (natural material or wood chips) to vineyard floors.	140	38	1.7
Compost Application (363)	Application of 1/4" of compost to approximately 175 acres annually	16100	4387	80
Compost Application (363)	Application of 1/4" of compost to approximately 180 new acres every year for 20 years	37800	10300	188.8
Prescribed Grazing (528)	Grazing management of 3558-acres of Wool Ranch for enhanced forage production	12810	3490	63.99

Silvopasture (381)	Incorporation of trees for food or shade into rangeland or pasture settings.	1344	366	3.36
Hedgerow (422)	Establishment of 177,906 feet of hedgerow along existing ranch roads and pasture borders.	5359	1460	13.4
Windbreak (380)	Establishment of 9,277 feet of windbreaks across Wool Ranch.	240	65	0.6
Critical Area Planting (342)	Planting of native grasses and shrubs on approximately 61.15 along S. River to reduce erosion of degraded riparian areas.	1284	350	3.21
Riparian Forest Buffer (391)	Planting of trees and shrubs on approximately 25.4 acres along S. River and other riparian channels to reduce erosion of degraded riparian areas.	1058	288	2.64
Riparian Herbaceous Cover (390)	Planting of herbaceous cover on approximately 25.4 acres along S. River and other riparian channels to reduce erosion of degraded riparian areas.	331	90	0.33
Tree and Shrub Establishment (612)	Planting of trees in the riparian flatlands on 35.72-acres	13496	3677	33.71
Residue and Tillage Management No Till (329)	Continuation of no-till on 397-acres of permanent pasture.	1270	346	6.34
Residue and Tillage Management Reduced Till (CPS 345)	Continuation of reduced tillage on 3161-acres of grazed Wool Ranch parcels (Note, transitioning to permanent pasture (no till) will result in further sequestration.	5680	1548	28.37
Nutrient Management (590)	15% Reduction of Nitrogen Application to Non-Irrigated Crop or Grain Fields	1160	316	5.69
	Total	**99092**	**27001**	**437**

Discussion

Average annual CO2e reduction values for Wool Ranch is summarized by Table 25. Actual sequestration of CO2 in response to management interventions and conservation practices are not expected to be linear over time, and are expected to vary annually. Length of time during which practices will sequester carbon also varies among individual 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 28 are best understood as gross CO2e sequestered through the implementation of the various on-farm practices at the spatial and temporal scales on the Carbon Farm Plan as a whole. GHG emissions associated with these practices are generally accounted for in the models used (COMET-Planner, etc.). Exact emissions—and

Table 28. Carbon sequestration estimations for Wool Ranch annually, and at 20 years

NRCS Conservation Practice	Annual CO2e- Sequestered (tonnes)	20-Year CO2e- Sequestered (tonnes)
Cover Crop (340)	51	1020
Mulching (484)	7	140
Vineyard and Hay Field Compost Application (336)	805	16100
Rangeland Compost Application (336)	180	37800
Prescribed Grazing (528)	640	12810
Silvopasture (381)	67	1344
Hedgerow (422)	268	5359
Windbreak (380)	12	240
Critical Area Planting (342)	64	1284
Riparian Forest Buffer (391)	53	1058
Riparian Herbaceous Cover (391)	17	331
Tree and Shrub Establishment (612)	675	13496
Residue and Tillage Management, No Till (329)	64	1270
Residue and Tillage Management, Reduced Tillage (345)	284	5680
Nutrient Management (590)	58	1160
	3,245	**99,092**

sequestration—achieved from practice implementation at Wool Ranch 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 restoration may exceed first year sequestration rates. Net sequestration associated with a single compost application to grazed grassland may also decline over time. Models suggest soil nitrous oxide (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.

Improved soil hydrologic status, improved porosity, improved micronutrient status and other soil quality enhancements typically resulting from compost amendment are not currently accounted for in the model. The ecosystem carbon team at Colorado State University Natural Resource Ecology Laboratory is in the process of updating the model to account for these important soil qualities, shown by MCP research to be subject to positive influence by compost applications (Ryals and Silver 2013). Meanwhile, models will tend to undervalue the combined benefits of carbon sequestering practices.

As with positive feedback to pasture productivity associated with compost applications, the total additional water storage capacity is expected to increase when soil carbon increases. If Wool Ranch implemented its Carbon Farm Plan, the farm's water storage capacity is estimated to increase by 437 acre-feet over 20 years (Table 27), which would be expected to provide further feedback to higher productivity and increased carbon capture potential over both the near and long term.

Conclusion

There is significant potential for additional GHG reduction and terrestrial carbon capture at Wool Ranch. Through implementation of the conservation practices described above, an estimated 86,962 Mg CO_2e could be sequestered in soils, as well as, above and below ground biomass over 20 years. There is also potential for additional on-farm carbon capture over this period through the reapplication of compost on grazed pastures at 20-year intervals, through the renovation of windbreaks or other agroforestry systems at maturity and through the implementation of other carbon-beneficial practices not currently included in this CFP.

Most of the carbon sequestration potential is due to compost application. The suitability analysis suggests that approximately 3600-acres are eligible for compost application under the CDFA Healthy Soils Program as 3600 out of the 3800-acres are on slopes less than 15%. Applying compost on 180-acres annually to arrive at 3,600-acres total application after 20 years before starting again is estimated to sequester approximately 37,800 Mg of CO_2e.

Aside from compost application, there is also significant potential for riparian restoration (and carbon sequestration) across the ranch, both within the ranch on streams and along the S. River. When combined, Riparian Herbaceous Cover, Riparian Forest Buffers, and Critical Area Planting, and Tree/Shrub Establishment (in the Flatlands) combine to an estimated 16,169 Mg of CO_2e sequestered over 20 years, mostly as a result of the Tree/Shrub Establishment in the Flatlands Restoration areas. All of these practices assume a minimum 20 ft buffer on one or both sides of the stream/river, and 40 ft buffer from the S. River. Further riparian enhancement (i.e. a larger buffer) will increase sequestration.

If Wool Ranch fully implemented this Carbon Farm Plan, we estimate that it would sequester an additional 99,092 metric tonnes of carbon dioxide over 20 years, the equivalent of 21,351 gasoline-powered passenger vehicles driven for one year, or over 245,000,000 miles driven by an average gasoline powered passenger vehicle (USEPA, 2022).

Funding the Carbon Farm Plan

All of the management practices recommended are, at a minimum, eligible for partial funding through financial assistance programs run through various levels of local, state, and federal governments. In Table 29, CCRCD staff have compiled known programs that could lead to partial or full implementation funding. This list is not exhaustive, and additional funding sources may come to light. CCRCD staff recommends connecting with them or the local RCD to determine the latest status of any of these funding programs or new programs to come.

Table 29. Currently Known or Available Funding for Climate-Smart Agriculture

Funding or Implementation Source	Description
CDFA Healthy Soils Incentives Program (HSP)	Under the CDFA Healthy Soils Incentives Program, farmers can apply through CCRCD for partial cost-share funding to implement climate-smart agriculture practices for three years. In 2021, this program received $67.5 million from the California Budget and received $90 million+ in applications and will likely be funded again.
CDFA Healthy Soils Demonstration Program	Under the CDFA Healthy Soils Demonstration Program, RCDs or other research groups can apply for funding to demonstrate climate-smart agriculture with partner farms and/or research new practices. In 2021, this program received 12 applications for $2 million and funded 7 projects for $1.1 million. This program will likely be funded again, but CCRCD staff recommend pursuing the Incentives Program.
CDFA Pollinator Habitat Program	Under CDFA, the Pollinator Habitat Program aims to provided financial assistance funding to farms and ranches throughout California for the implementation of agricultural management practices that increase pollinator habitat like hedgerow installation, cover cropping, and windbreaks. In 2022, this program had $15 million available for funding, and will likely be funded again.
USDA NRCS Environmental Quality Incentives Program (EQIP)	Under the 2018 Farm Bill, the USDA NRCS is authorized to provide cost-share contracts to farms to conserve natural resources and address ongoing resource concerns. This program will very likely continue on in perpetuity through the federal government.
Xerces Society Hedgerow Kits	The Xerces Society is a non-profit organization with the goal of conserving invertebrates and their habitats. Through the California Monarch and Pollinator Habitat Kits, farms can apply for free hedgerow kits (cover approximately 450 linear ft) to implement on their farm. CCRCD staff can assist in applications, and potentially in installation depending on available funding.
Project Apis M. Seeds for Bees	Project Apis m. is a non-profit that funds and directs honey bee research to enhance health and vitality while improving crop production. Through the Seeds for Bees program, Project Apis m. provides free cover crop seed to interested farmers to promote pollinator forage. CCRCD staff can assist in applications to this program.
Zero Foodprint/ Restore CA	Zero Foodprint is a non-profit organization mobilizing the food world around agricultural climate solutions and runs the Restore CA program, a program that provides cost-share funding to farms interested in implementing carbon farm plans and climate-smart agricultural practices. In Summer 2022, Zero Foodprint intends to grant $200,000 to farms throughout California.

Monitoring and Record Keeping

Practice monitoring (plant survival, pasture management implementation, compost applications, etc.) should be carried out in coordination with annual inspections by land managers and/or project managers from the local RCD or other organizations involved in project implementation. 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, extent of project(s), dates of implementation, etc. should all be included in plan implementation documentation.

This plan should be viewed as a living document. It should evolve as practices are implemented and new information and new tools become available. Additional carbon-beneficial practices may be considered for inclusion in the plan in the future. GHG values presented here as associated with specific practices are considered to be both conservative and based upon the best available information at the time of this plan's preparation (September 2022).

Photo by Paige Green

Short Term Action Plan and Timeline

Because the scope of the Carbon Farm Plan is extensive, practices are likely to be implemented over time, based upon GHG and co-benefits, available funds, and ranch priorities. Table 30 provides a framework for prioritizing and recording Carbon Farm Plan practices as they are implemented.

Table 30. Carbon Farming Practice Implementation

Practice ID (Location shown on map)	NRCS Practice Standard	Date Implemented/ Maintained	CO2e Reduction/ Sequestration Potential Estimate	Details/Notes	Potential Funding Source

Soil Carbon Monitoring

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

Table 31. Soil Monitoring Log

Label on Map	Date Sample Taken (Y/N)	Photo Taken (Y/N)	Soil Organic Carbon Content (Lab Data)	Soil Organic Matter (SOM)	NPK (Lbs/ AF)	pH	Notes

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Appendices

Available upon request

Appendix A: Climate Beneficial Fiber: Verified by Fibershed

Appendix B: Wool Ranch WebSoilSurvey Report

Appendix C: Wool Ranch Grazing Management Plan

Appendix D: NRCS eVegGuide Version 5 - Tree/Shrub Establishment Plant List

Appendix E: NRCS eVegGuide Version 5 - Hedgerow Installation Plant List

Appendix F: NRCS eVegGuide Version 5 - Windbreak Establishment

Appendix G: NRCS eVegGuide Version 5 - Riparian Herbaceous Cover

Appendix H: NRCS eVegGuide Version 5 - Riparian Forest Buffer

Appendix I: NRCS eVegGuide Version 5 - Critical Area Planting

Appendix J: Wool Ranch Carbon Farm Practice Maps

Appendix K: Selected NRCS Conservation Practice Standards (links)