CARBON FARM PLAN

Viader Vineyard

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Viader Vineyard

Carbon Farm Plan

Contents

INTRODUCTION

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

Carbon can be beneficially stored long-term (decades to centuries or more) in soils and vegetation through biological carbon sequestration. Carbon Farming involves implementing on-farm practices that are known to improve the rate at which a given land area can support photosynthetically-driven transfer of carbon dioxide (CO_2) from the atmosphere to plant productivity and/or soil organic matter. Enhancing agroecosystem carbon, whether in plants or soil, is known to drive beneficial changes in other system attributes, including soil water holding capacity, hydrological function, soil fertility, biodiversity, ecosystem resilience and agricultural productivity.

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

SOIL

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

Soil Organic Carbon (SOC)

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

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

SOM and SOC

A primary goal within the carbon farm planning framework is to achieve the maximum carbon storage potential of the soil within the agricultural system, while maintaining desirable grape quality and yield. Achieving maximum soil health and soil carbon (organic matter) while maintaining desirable grape production should be compatible, with the assumption that over time the farmer may have to alter their management practices. For example, upon improving soil health, farmers may need to reduce irrigation and fertilizer inputs to maintain the desired vine growth and vigor.

The Cornell Soil Health Assessment suggests that optimal soil health for a fine textured soil is achieved when SOM of 4-5%, and 3-4% for a medium textured soil, is present in the plow layer (0-15 cm). Although the Cornell Soil Health Index was developed for soils from New York State, it is consistent with research conducted world-wide that suggests similar soil health standards.

Limitations to carbon sequestration

The rate of carbon sequestration in any given system will depend on the current carbon content and in the physical properties of the soil in question such as soil texture and bulk density. Figure 1 shows maximum carbon sequestration potential based on soil type.

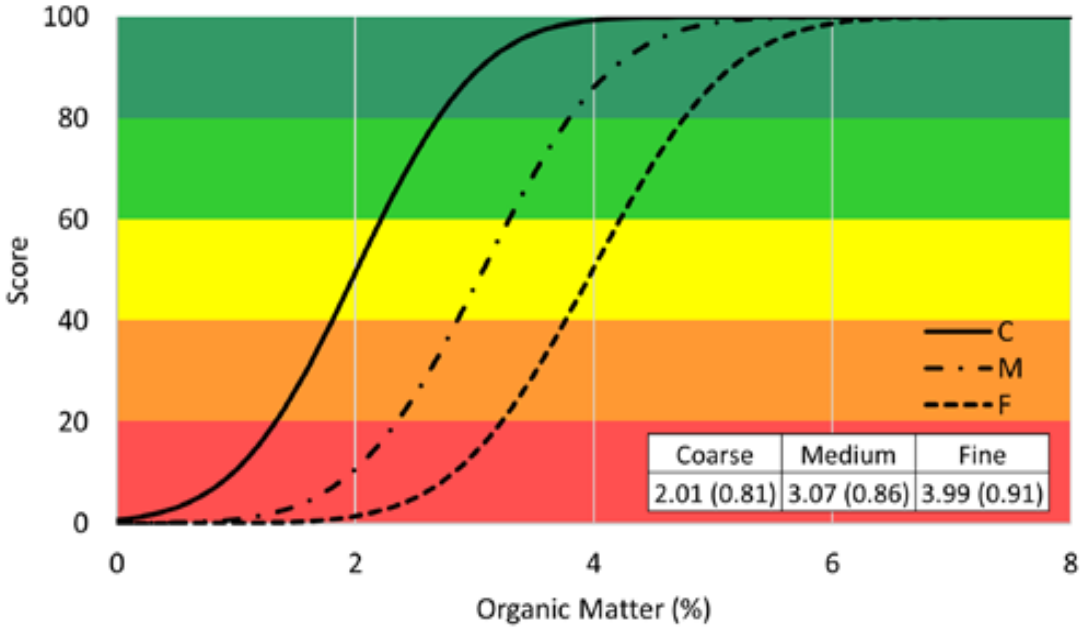
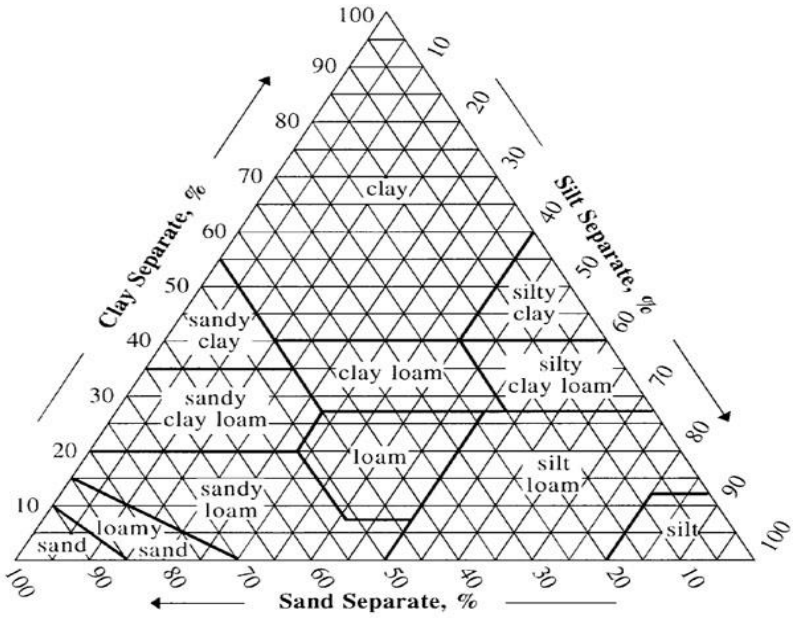


Figure 1. Soil Organic Matter (OM) scoring functions and upper value limits for Coarse (C), Medium (M) and Fine (F) textural classes. Mean and standard deviation (in parenthesis) for each class are provided. Soils with higher OM scores generally require lower inputs of nutrients and are more resilient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

Soil Texture

The ability to store soil organic matter tends to be positively correlated with higher concentrations of clay. Some studies have found that soil carbon sequestration was associated with the aggregate size that corresponds to clay soils. Clay soils have larger aggregates when compared to other soil types. These larger aggregates protect a larger amount of carbon in the soil and thus, would theatrically have a higher soil carbon content.



Bulk Density

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

Factors Affecting Bulk Density

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

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

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

Table 1. General relationship of soil bulk density to root growth based on soil texture

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

The Carbon Farm Planning Process

The Carbon Farm Planning (CFP) process differs from other approaches to agriculture by focusing on *increasing* the capacity of the farm or ranch to capture carbon and to store it beneficially as soil organic matter and/or standing carbon stocks in permanent vegetation. While most modern agriculture results in a gradual loss of carbon from the farm system, CFP works when it leads to a *net increase* in farm-system carbon. By increasing the amount of photosynthetically captured carbon held, or sequestered, in long-term carbon pools on the farm or ranch, such as soil organic matter, perennial plant roots and standing woody biomass, carbon farming results in a direct reduction in the amount of carbon dioxide in the atmosphere.
On-farm carbon in all its forms (soil organic matter, living and dead plant and animal material), represents embodied solar energy. As such, carbon provides the energy needed to drive on-farm processes, including the essential soil ecological processes that determine water and nutrient availability for the growing crop. Consequently, the CFP process views carbon as the single most important element, upon which all other on-farm processes depend. CFP is similar to Conservation Planning but uses carbon capture as the organizing principle around which the Plan is constructed. This both simplifies the planning process and connects on-farm practices directly with ecosystem processes, including climate change mitigation and increases in the farm's climate resilience, soil health and productivity.

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

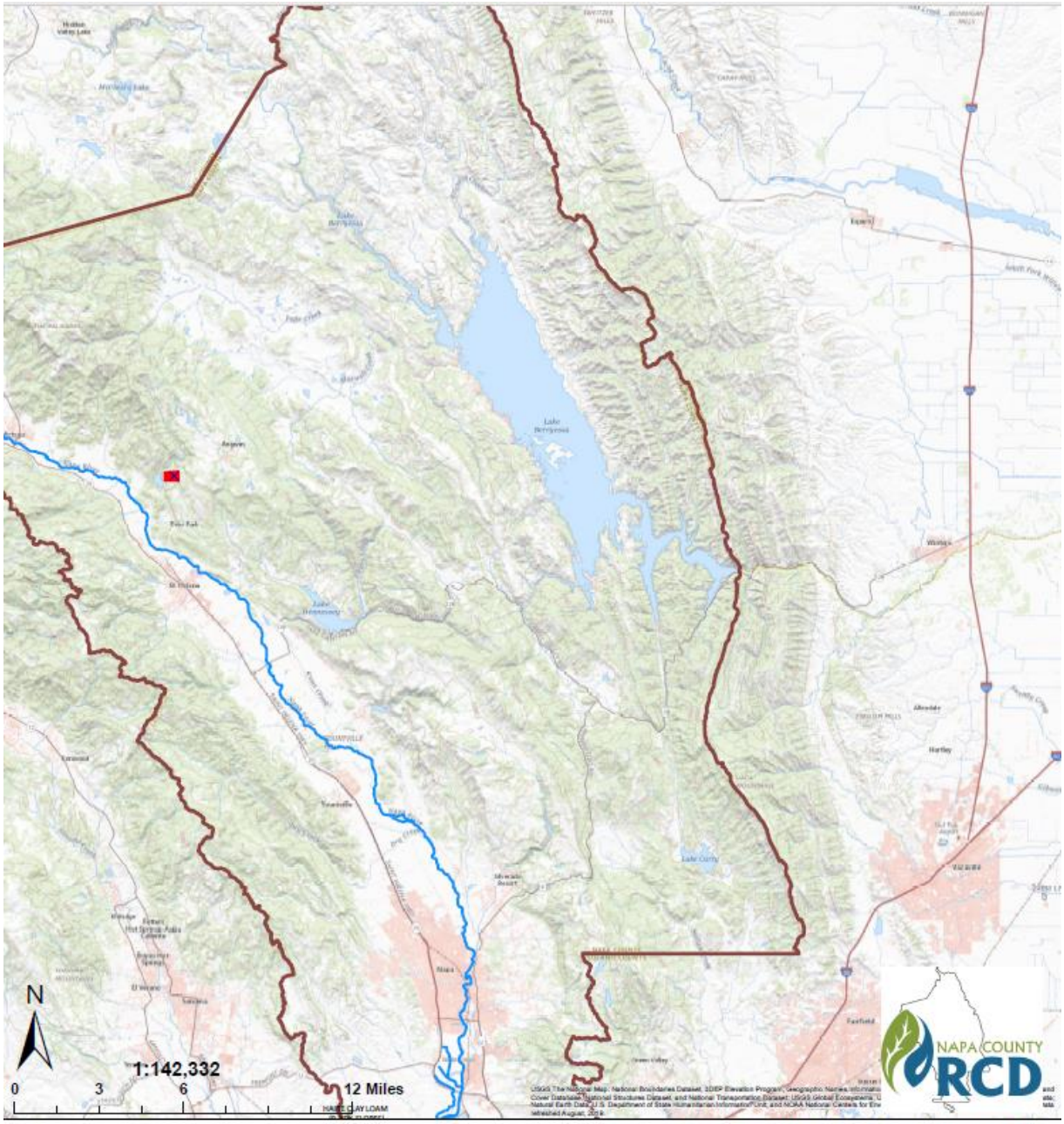
Next, needs and goals of the farm and economic considerations are used to filter the comprehensive list of options. Models, such as USDA's COMET-Farm and COMET-Planner, and empirical data sources are used to estimate tons of carbon dioxide equivalent (CO_2) that would be avoided or sequestered from the atmosphere on farm by implementing each practice.

Finally, practices are prioritized based on needs and goals of the farm and climate benefits provided. Economic considerations may be used to filter the comprehensive list of options, and funding mechanisms are identified, including; cap and trade, CEQA, or other greenhouse gas mitigation offset credits, USDA-NRCS and other state and federal programs, and private funding.

Projects are implemented as funding, technical assistance and farm scheduling allow. Over time, the CFP is evaluated, and updated as needed to meet changing farm objectives and implementation opportunities, using the fully implemented plan scenario as a point of reference.

VINEYARD BACKGROUND

Viader Vineyard is located in Howell Mountain, APNs 021420038 and 021420039. The total acreage of the property is 90.7 acres of which 27.9 are planted with Cabernet Sauvignon, Cabernet Franc, Malbec, Syrah and Petit Verdot. Built on the foundations of family, perseverance and determination, Viader (pronounced Veeya Dare) thrives today as a multigenerational, internationally-recognized boutique Napa Valley first growth estate specializing in limited production, mountain-grown Bordeaux-style blends.



Map 1. Geographic location of Viader Vineyard Parcel within the Napa River Watershed.

Vineyard Soil Types and Properties

Soil Series

The NRCS websoil survey identifies four major soil types in the vineyard, Boomer Gravelly Loam, Boomer Loam, Boomer-Forward-Felta-Complex, and Rock Outcrop (Map. 2). The properties and characteristics of these soil types will vary depending on the geomorphology and land management practices. The map provides an estimation of soil variation and the extent on the landscape. Field proofing the exact soil type is valuable, however, the evaluation of soil within the carbon farm planning framework is focused on measuring quantifiable properties through soil sampling and lab analysis. The soil map provided will be used in determining soil sampling locations.

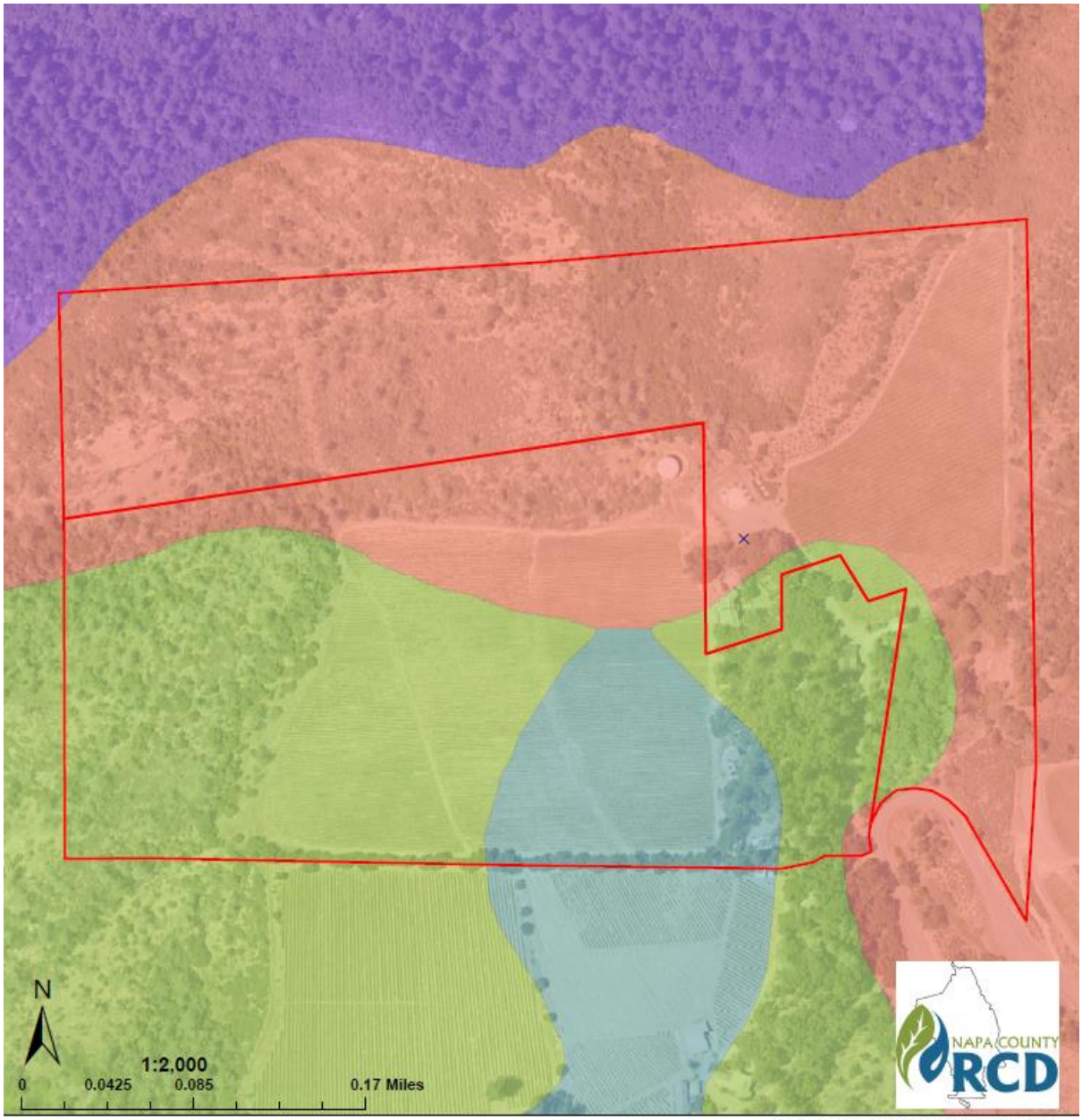
Soil Lab Analysis and Soil Pit Descriptions

Soils have not been described in the field or analyzed in lab at the time of producing this report. Soil lab analysis is an important component within the carbon farm planning process, so that baseline organic carbon levels are established, and change over time can be monitored. In addition, baseline organic carbon measurements, along with other soil lab analysis, provides essential information for prescribing soil management practices to build and store organic carbon.

Primary Sampling Protocol

Soil Sampling Depths	Soil Properties for Lab Analysis
0-10 cm	Soil Total Organic Carbon
10-20 cm	Bulk Density
20-40 cm	Soil Texture

* Landowners may be interested in analyzing more soil properties for a more thorough assessment of soil health. Such lab analysis can be conducted at the Oregon State University Analytical Lab – Soil Health Assessment Package. https://agsci.oregonstate.edu/cal/service



Viader

Legend

Viader

Soil Type

- AIKEN LOAM, 30 TO 50 PERCENT SLOPES
- BOOMER GRAVELLY LOAM, 30 TO 50 PERCENT SLOPES
- BOOMER LOAM, 2 TO 15 PERCENT SLOPES
- BOOMER-FORWARD-FELTA COMPLEX, 5 TO 30 PERCENT SLOPES
- ROCK OUTCROP-KIDD COMPLEX, 50 TO 75 PERCENT SLOPES

Maps prepared for informational purposes only. Image depicts publicly available data and needs to be considered with on-the-ground conditions and more accurate site-specific data that may exist. No liability is assumed for the accuracy of the information or data displayed.

Map Date: 10/18/19
Prepared By: NCRCD
Data Sources:
Slope - LiDAR DEM (2005)
Napa County Parcels (2015)
Napa RCD Hydrography (2015)
Napa County BDR Hydrography (2005)

Map 2. Viader Vineyard Soil Map.

CURRENT PRACTICES

The management at Viader Vineyard has done an effort to maintain natural vegetation around the vineyard. Currently, only 27.9 acres of 90.7 total acres are being farmed.

CURRENT CARBON SEQUESTRATION

Assuming a soil organic matter content of 4% at this vineyard, this soil is currently storing about 32 tonnes of CO_2 per acre. Current practices will have an impact on future CO_2 sequestration or release.

Practice	Acreage	CO_2 sequestration (tonnes/year)
No till	28	7
Permanent cover crop	28	15
Natural Habitat	62	118
Tractor usage/year	About 100 miles driven	-0.18
Total net CO_2 sequestration = 139.8 tonnes of CO_2 per year		

CARBON FARM GOALS AND OBJECTIVES

- Continue implementing a permanent cover crop to prevent erosion and foment proper bulk density and water storage and distribution
- Continue implementing no till practices to prevent erosion and loss of organic matter
- Apply compost to foment microbial health
- Establish Hedgerows/Tree/Shrubs to increase beneficiary insect populations

PLANNED CARBON BENEFICIAL PRACTICES AND ANTICIPATED OUTCOMES

1. Cover crops (CPS 340)

The implementation of permanent cover crops in vineyards has many benefits, including:

Reduce erosion from wind and water.

Maintain or increase soil health and organic matter content.

Reduce water quality degradation by utilizing excessive soil nutrients.

Suppress excessive weed pressures and break pest cycles.

Improve soil moisture use efficiency.

Minimize soil compaction.

Cover crops may be selected to provide food or habitat for natural enemies of production crop pests. Cover crops residues should be left on the soil surface to maximize allelopathic (chemical) and mulching (physical) effects. Seed a higher density cover crop stand to promote rapid canopy

closure and greater weed suppression. Increased seeding rates (1.5 to 2 times normal) can improve weed competitiveness. Cover crops may be selected that release bio fumigation compounds that inhibit soil-borne plant pests and pathogens. Species can be selected to serve as trap crops to divert pests from production crops. Select a mixture of two or more cover crop species from different plant families to achieve one or more of the following: (1) species mix with different maturity dates, (2) attract beneficial insects, (3) attract pollinators, (4) increase soil biological diversity, (5) serve as a trap crop for insect pests, or (6) provide food and cover for wildlife habitat management. Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to achieve biological nitrogen fixation.

Although monocultures of cover crops are often used in vineyards because of proven success and economic feasibility, using a single species of cover crop can lead to the buildup of insects, pathogens, or weeds associated with that species. Providing different species in a mix may enable one species to thrive in areas where another might be weak, increasing the chances for a healthy stand throughout the vineyard. Vigorous polyculture may also reduce weeds that would otherwise fill the voids and may also attract a diversity of beneficial insects that may aid in pest management.

See Appendix A and B for cover crop seed mix suggestions.

2. No Till (CPS 329)

There are countless benefits to the land, the grower and the environment from adopting a no-till system. First and foremost, reducing or eliminating tillage will save the grower money from less equipment use. Also, by leaving the soil mostly undisturbed and leaving high levels of crop residues behind, soil erosion is almost eliminated through no-till farming. The USDA's National Resources Inventory credits the 43 percent reduction in soil erosion in the United States between 1982 and 2003 to the increase in conservation tillage. The utilization of crop residues in no-till farming also drastically increases water infiltration and therefore retention (i.e. less evaporation) by the soil. This means there is less runoff of contaminated (by fertilizers, pesticides, etc.) water, as well as a reduction in the amount of watering necessary for a given crop. Some estimates suggest crop residues provide as much as 2 inches of additional water to crops in late summer and the Natural Resources Conservation Service states that no-till farmed soils can have a water penetration rate up to 5.6 inches per hour, twice as much as for conventionally tilled land. This makes no-till farming an excellent opportunity for drought stricken areas like California. Furthermore, because the soil is not being frequently agitated, no-till farming promotes biodiversity in and around the soil. Organisms like mycorrhizal fungi, which make commensal (i.e. benefit both the plant and fungus) associations with crop roots, and earthworms, which increase the water retention of the soil, are allowed to flourish through no-till farming. With all of this, no-till soils are more resilient and thus better adapted for uncertain weather patterns than tilled soils.

In addition to this, no-till systems have the potential to significantly reduce emissions of greenhouse gasses from the soil and equipment used. Currently, of the total greenhouse gas emissions that humans are responsible for, 10-12% is from agricultural practices. A reduction in

tillage translates directly into reduced equipment use. Current EPA estimates suggests that for every gallon of diesel burned, about 22.1 lbs. of CO_2 are generated, with higher estimates if considering old engines. In the case of soils, the disturbance caused by tillage promotes the release of greenhouse gasses such as CO_2 and N_2O from the soil into the atmosphere. Soil tillage and other methods of soil management may influence CO_2 and N_2O emissions because they accelerate the mineralization of organic carbon in the soil. How much of these greenhouse gasses may be released from soils depends on specific tillage practices, but some estimates suggest that soil tillage under conventional operations can cause emissions of about 1.42 tons of CO_2 and 3.8 lbs. of N_2O per acre.

3. Compost Application (CPS 484)

In this plan, compost application has been identified as the NRCS Conservation Practice Standard 484- Mulching Application, because all compost will be primarily top dressed under the vine and in the cover crop middles. Currently, there is no NRCS CPS just for compost application and it must be included as mulch application (CPS 484) or nutrient management (CPS 590).

Applying compost to soils is an efficient way to introduce organic carbon and nutrients. Carbon is at the center of fundamental physical, biological, and chemical processes in soils. According to Cornell University Cooperative Extension, "carbon is critical to soil function and productivity, and a main component of and contributor to healthy soil conditions. Soil and yield tend to improve when the soil organic carbon level increases. Higher soil organic carbon promotes soil structure or tilth meaning there is greater physical stability. This improves soil aeration (oxygen in the soil) and water drainage and retention, and reduces the risk of erosion and nutrient leaching. Soil organic carbon is also important to chemical composition and biological productivity, including fertility and nutrient holding capacity of a field. As carbon stores in the soil increase, carbon is "sequestered", and the risk of loss of other nutrients through erosion and leaching is reduced. An increase in soil organic carbon typically results in a more stable carbon cycle and enhanced overall agricultural productivity." Furthermore, according to the NRCS, "1% increase in soil organic matter results in an increase in soil water holding capacity of approximately 1-acre inch, or 27,152 gallons per acre. This water conservation will translate into less water pumping, which on its own can reduce greenhouse emissions.

In addition to this, carbon plays an essential role in maintaining a balanced microbiological community in the soil. The living part of soil organic matter includes a wide variety of microorganisms, such as bacteria, viruses, fungi, protozoa, and algae. It even includes plant roots and the insects, earthworms, and larger animals, such as moles, woodchucks, and rabbits that spend some of their time in the soil. Microorganisms, earthworms, and insects feed on plant residues and manures for energy and nutrition, and in the process, they mix organic matter into the mineral soil. In addition, they recycle plant nutrients. Sticky substances on the skin of earthworms and other substances produced by fungi help bind particles together. This helps to stabilize the soil aggregates, clumps of particles that make up good soil structure. Organisms such as earthworms and some fungi also help to stabilize the soil's structure (for example, by producing channels that allow water to infiltrate) and, thereby, improve soil water status and aeration. Plant roots also interact in significant ways with the various microorganisms and animals living in the soil.

4. Hedgerow/Tree/Shrub planting (CPS 422,612)

Hedgerows are rows of trees, shrubs, forbs and perennial grasses that border or surround farm fields. They are extremely beneficial for a number of reasons that include enhanced weed control, air and water quality protection, soil erosion control, increased biodiversity with wildlife habitat—and they enhance beneficial insect populations that serve as pollinators or provide natural enemy activity on pests in adjacent crops. Hedgerows also can harbor smaller populations of insect pests, but beneficials far outnumber the pests. In contrast, uncontrolled weeds can harbor twice as many pests as beneficials. Plants species for hedgerows should include natives as much as possible but can also include a secondary crop such as apple and olive trees.

See Appendix C for suggestions on plant species.

Summary of Planned Practices

Table 2 summarizes carbon sequestration and GHG emissions reduction potential from the implementation of the NRCS Conservation Practices listed above (see Map 3for location of practice implementation). Using COMET-PLANNER and published regional research, we estimate that Viader Vineyard currently sequesters a net 139.8 metric tons of CO_2 per year and has the potential to sequester or mitigated the emission of an additional 134.2 metric tons of CO_2 per year upon implementing the plan. This will represent a total of 274 8 metric tons of CO_2 per year, the equivalent of removing 58 typical passenger vehicles off the road every year. Compost application is the carbon beneficial practice that has the greatest carbon sequestration potential at Viader Vineyard (Table 2, Figure 2). Cover crop is the second most effective practice for carbon capture.

Table 2. Potential carbon sequestration and greenhouse gas emissions reductions that Viader Vineyard may achieve by implementing NRCS Conservation Practices described in this Plan.

COMET-Planner Carbon Sequestration and Greenhouse Gas Estimation Report

Project Name:
State: CA
County: Napa
Date Created: 12/30/2019 1:31:05 PM

	Enter Acreage	Carbon Dioxide	Nitrous Oxide	Methane	Total CO_2-Equivalent
NRCS Conservation Practices					
Hedgerow Planting (CPS 422) - Replace a Strip of Cropland with 1 Row of Woody Plants	1.0	8	0	N.E.2	8
	Total	8.00	0.00	0.00	8.00

1Negative values indicate a loss of carbon or increased emissions of greenhouse gases
2Values were not estimated due to limited data on reductions of greenhouse gas emissions from this practice

For more information on how these estimates were generated, please visit www.comet-planner.com.

Compost-Planner Carbon Sequestration and Greenhouse Gas Estimation Report

Project Name:

State: CA

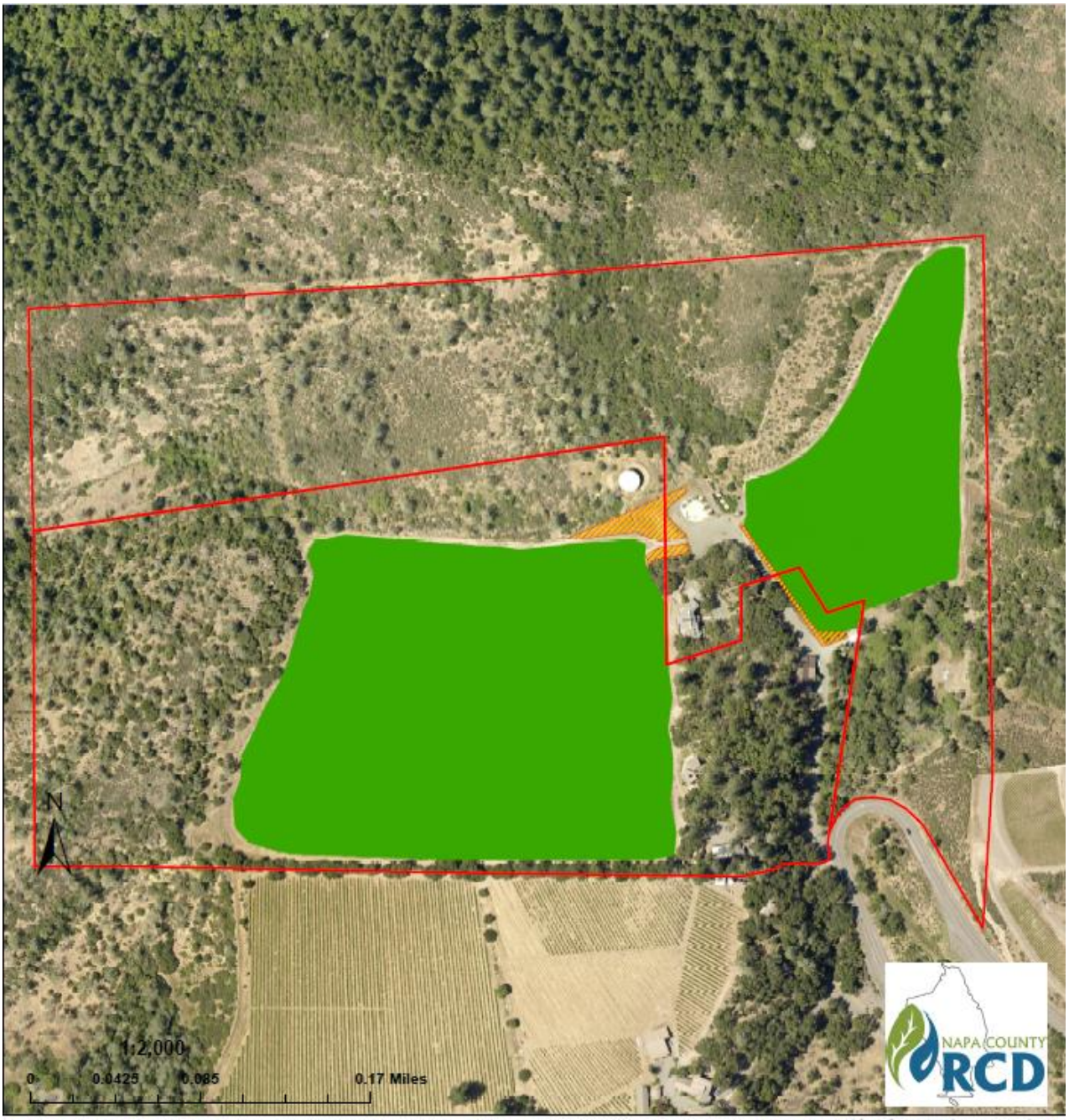
County: Alameda

Date Created: 12/30/2019 1:30:30 PM

	Enter Acreage	Carbon Dioxide	Nitrous Oxide	Methane	Total CO_2-Equivalent
Compost Application Practice					
Perennials, Orchards and Vineyards - Compost (C/N > 11) Application to Perennials, Orchards and Vineyards	28	130	-4	0.2	130
	Total	130.00	-4.00	0.20	126.20

1Negative values indicate a loss of carbon or increased emissions of greenhouse gases

For more information on how these estimates were generated, please visit www.compost-planner.com.



Viader Vineyard

Legend

Viader Vineyard Boundary

CFP Practices

Hedgerow planting

Reduced Till+compost

Maps prepared for informational purposes only. Image depicts publicly available data and needs to be considered with on-the-ground conditions and more accurate site-specific data that may exist. No liability is assumed for the accuracy of the information or data displayed.

Map Date: 12/30/19
Prepared By: NCRCD
Data Sources:
Slope - LiDAR DEM (2005)
Napa County Parcels (2019)
Napa RCD Hydrography (2015)
Napa County BDR Hydrography (2005)

Map 3. Carbon farming practices

DISCUSSION

Values presented in Table 2 are best understood as gross CO_2 sequestered through implementation of the various on-farm practices at the spatial and temporal scales outlined in the table and the Carbon Farm Plan as a whole. Average annual CO_2 reduction values in Table 2 are for illustrative purposes only. Actual sequestration of CO_2 in response to management and conservation practice implementation is not expected to be linear over time, rather, it is expected to vary annually (J. Creque and Fibershed 2016). Length of time during which practices will sequester carbon also varies among practices. Terrestrial carbon sequestration resulting from each practice tends to increase cumulatively to maturity and then tends to decline, though remaining net positive relative to baseline conditions for many years (Ryals et al 2015). As such, long-term maintenance of all carbon beneficial practices is important for maintaining high levels of carbon sequestration on the farm.

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

In some cases, rates of accumulation of CO_2 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. This suggests reapplication of compost sometime before the third decade after initial application may be warranted for sustained GHG reduction benefits from this practice (J. Creque and Fibershed 2016).

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

APPENDICES

Appendix A: Selected Cover Crop Seed Mixes For Napa County Vineyards

Hillside- Shallow Soils
"Erosion Control"

"Zorro" annual fescue	40%
"Blando" brome	27%
"Hykon" rose clover	23%

(seeding rate: 25lbs. per acre)

Hillside Quick Erosion Control
"Soil Builder"

Red Oats	65%
Crimson clover	13%
Austrian winter pea	22%

(seeding rate: 90 lbs. per acre)

Vineyard Terrace
"Slope Stabilizer"

'Blando" brome	45%
"Molate" red fescue	55%

(seeding rate: 25 lbs. per acre)

Hillside Soils
-Frequent Mowing-

"Zorro" annual fescue	40%
Subterranean clover	35%
"Hykon" rose clover	25%

(seeding rate: 30 lbs. per acre)

Quick Erosion Control
-Cold Soils-

Cereal rye	83%
Crimson clover	17%

(seeding rate: 90 lbs. per acre)

Native, No-till Blend
(Mature vineyards)

California meadow barley	36%
"Molate" red fescue	38%
California brome	26%

(seeding rate: 39 lbs. per acre)

United States Department of Agriculture
NRCS Natural Resources Conservation Service

Native, No till Blend
"Low growing"

Idaho fescue	50%
"Molate" red fescue	50%

(seeding rate: 30 lbs. per acre)

High Altitude
"Mountain Turf"

Perennial ryegrass	35%
Creeping red fescue	35%
"Covar" sheep fescue	30%

(seeding rate: 32 lbs. per acre)

Grassed Waterways**

Meadow Barley	41%
California brome	33%
"Blando" brome	26%

(seeding rate: 39 lbs. per acre)

** *straw mulch the seedbed and irrigate to germinate plants before fall rains.*

Emergency Winter Mix
"Quick Cover"

Common barley	85%
Annual ryegrass	15%

(seeding rate: 100 lbs. per acre)

Heavy Use Areas
-Vineyard Headlands-

Bluebunch wildrye	40%
Cal.meadow barley	27%
California brome	33%

(seeding rate: 45 lbs. per acre)

"Showboat"

Crimson clover	44%
"Hykon rose clover	44%
Wildflower blend-	12%
Yarrow	
Calif. Poppy	
Paper poppy	
Tidy tips	

(seeding rate: 27 lbs. per acre)

- Seed selection and use of fertilizers will vary depending on site conditions, including soil type.
- Seeding rates are based on the broadcast seeding method. If seed is drilled, rates may be lower.
- Check pure-live seed, (PLS) % on seed bag tags- rates listed above are based on 100% PLS.
- Seed variety selection may vary with site conditions. Check with NRCS or your agronomy consultant for site specific recommendations.
- Seed mixes listed, except "quick erosion" and "Emergency Winter Ground Cover" are for no-till management programs.

United States Department of Agriculture
NRCS Natural Resources Conservation Service

Napa Field Office

Suggested Napa County Vineyard Cover Crops

USDA Natural Resources Conservation Service - Phill Blake, District Conservationist

Seeding rate/ percent by weight			Annual/ Perennial	Native/ Introduced	Mowing tolerance	
Short-term Mixes	**For short-term use, alternating-row cover crops, may be cultivated after use.**					
90 lbs./acre	**Hillside Quick Erosion Control Soil Builder**					Has to be reseeded. Nitrogen and organic matter builder
65%	Red oats	*Avena fatua*	A	I		
13%	Crimson clover	*Trifolium incarnatum*	A	I		
22%	Austrian winter pea	*Pisum sativum*	A	I		Can substitute magnus pea or Russian pea.
90 lbs./acre	**Quick Erosion Control Cold Soils**				Yes	Grows in damp, north slope, cold soils. Organic matter booster.
83%	Cereal rye	*Secale cereale*	A	I		Will not reseed. Good for fallow vineyard land.
17%	Crimson clover	*Trifolium incarnatum*	A	I		
100 lbs./acre	**Emergency Winter Quick Cover**				Yes	
85%	Common barley	*Hordeum vulgare*	A	I		
15%	Italian ryegrass	*Lolium multiflorum*	A	I		Can be allelopathic. Not good with low vigor rootstock. Can be invasive.
Long-term Mixes	**For long-term use in no-till vineyard management**					
25 lbs./acre	**Hillside/Shallow Soils Erosion Control**					Grows in a wide range (depth, fertility, texture) of soils. Nitrogen booster. Reseeds well
40%	"Zorro" annual fescue	*Vulpia myuros*, "Zorro"	A	I		Early seed set
32%	"Blando" brome	*Bromus hordeaceous*, "Blando"	A	I		
27%	"Hykon" rose clover	*Trifolium hirtum*, "Hykon"	A	I		
25 lbs./acre	**Vineyard Terrace-Face Slope Stabilizer**					Establishes on exposed slopes with weak soils.
45%	"Blando" brome	*Bromus hordeaceous*, "Blando"	A	I		
55%	"Molate" red fescue	*Festuca rubra*, "Molate"	P	N		Likes full sun
30 lbs./acre	**Hillside Soils Frequent Mowing**				Yes	Low growing. Tolerates mowing
40%	"Zorro" annual fescue	*Vulpia myuros*, "Zorro"	A	I		
35%	Subterranean clover	*Trifolium subterraneum*	A	I		Needs frequent and low mowing to compete with grasses.
25%	"Hykon" rose clover	*Trifolium hirtum*, "Hykon"	A	I		
39 lbs./acre	**Mature Vineyard Native No-till, Tall**				Yes	For valley/shallow slopes- not steep hillsides. Will tolerate shade. Good companions.
36%	Meadow barley	*Hordeum brachyantherum*	P	N		
38%	"Molate" red fescue	*Festuca rubra*, "Molate"	P	N		
26%	California brome	*Bromus carinatus*	P/A	N		Establishes quickly. (Can substitute blue wild rye, *Elymus glaucus*, which does well in the vine skirt shade)
30 lbs./acre	**Mature Vineyard Native No-till, Low Growing**				Yes	Low stature. Less frost concern than 'tall'. Grasses have basal leaves.
50%	Idaho fescue	*Festuca idahoensis*	P	N		
50%	"Molate" red fescue	*Festuca rubra*, "Molate"	P	N		Low stature on weak soils.
32 lbs./acre	**High Altitude Mountain Turf**				Yes	Good in high elevations and fog belt.
35%	Perennial ryegrass	*Lolium perenne*	P	I		Somewhat short stature.
35%	Creeping red fescue	*Festuca rubra* ssp?	P	?		Likes shade and moisture.
30%	"Covar" sheep fescue	*Festuca ovina?*	P	I		Bunch grass
45 lbs./acre	**Heavy Vehicle Use Areas**				Yes	Good for staging/turnaround areas.
40%	Blue wild rye	*Elymus glaucus*	P	N		
27%	Meadow barley	*Hordeum brachyantherum*	P	N		Prefers moister areas. Can substitute tall fescue for drier areas and slopes.
33%	California brome	*Bromus carinatus*	C	N		
39 lbs./acre	**Grassed Waterways**				Yes	Long-term. Likes dampness. Tolerates close mowing.
41%	California barley	*Hordeum brachyantherum* ssp. *cali*	P	N		(Apply straw mulch and irrigate to germinate before fall rains.)
33%	California brome	*Bromus carinatus*	P/B	N		
26%	"Blando" brome	*Bromus hordeaceous*, "Blando"	A	I		
27 lbs./acre	**Color Showboat**					Nitrogen builder.
44%	Crimson clover	*Trifolium incarnatum*	A	I		
44%	"Hykon" rose clover	*Trifolium hirtum*, "Hykon"	A	I		
12%	Wildflower blend:					
	Yarrow	*Achillea millefolium*	P	N		
	California Poppy	*Eschscholzia californica*	P	N		
	Paper Poppy			I		
	Tidy Tips	*Layia* spp.	A	N		
	"Big 3"™				Yes	Good seedling vigor. Mow after seed set. Vines should be mature and able to tolerate competition well.
	Blue wild rye	*Elymus glaucus*	P	N		
	Meadow barley	*Hordeum brachyantherum*	P	N		
	California brome	*Bromus carinatus*	P/B	N		
	"Little 3"™				Yes	Slow to establish. Excellent erosion control. Mow high to avoid seedheads.
	"Molate" red fescue	*Festuca rubra*, "Molate"	P	N		Add Zorro fescue for better short-term cover.
	Idaho fescue	*Festuca idahoensis*	P	N		

NCRCD seed mix suggestions

Quick growing but mostly sterile cereal barley and triticale seed are available from Le Ballister's in Santa Rosa, although they should also be readily available from other vendors (we at NRCS are to avoid making specific vendor recommendations). They described:

Cover Crop Barley –Fairly sterile, and should be completely gone within 2-3 years with minor sprouting within this timeframe. Plenty on stock, and .33/lb.

Cover Crop Triticale - Fairly sterile, and should be completely gone within 2-3 years with minor sprouting within this timeframe. Taller in nature than barley, especially in good quality soil, and does well in water logged areas, and or colder environments. Plenty in stock, and .48/lb.

The broadcast seeding rate for both should be 80-100lbs/acre.)

For oak woodland or grassland setting we recommend a native seed mix designed specifically for erosion control:

The 'Holdfast' from LeBallisters is great. http://leballisters.com/product-category/native-mixes/

Harmony Farm supply in Sebastapol https://www.harmonyfarm.com/california-native-grass-mixes/

Hedgerow Farms in Winters https://www.hedgerowfarms.com/products

Wilsons Seed and Supply. Napa, Ca. 1700 Yajome St. (707) 252-0316

Wilbur – Ellis Co. 975 Vintage Ave, St Helena (707) 963-3495

Central Valley. In Napa, St Helena, and American Canyon. https://www.central-valley.com/

soil nutrient availability or drainage characteristics, may also limit growth of a single species. Providing different species in a mix may enable one species to thrive in areas where another might be weak, increasing the chances for a healthy stand throughout the vineyard. Vigorous polyculture stands may also reduce weeds that would otherwise fill the voids in the stand and may also attract a diversity of beneficial arthropods that may aid in pest management. However, the effects of polycultures versus monocultures on arthropod pests have not been tested in California vineyards.

Legume-grass mixtures complement each other in their soil-improving functions. Although both plant types take up soil nitrogen, grasses are usually much more efficient at doing so. As a result, legumes derive more nitrogen from nitrogen fixation than from soil uptake when they are grown with grasses. Typically, though not always, such mixes result in less total nitrogen fixed than would be the case in pure legume stands, simply because less legume biomass is produced. Cereals such as oat and barley also provide structural support for the trailing vetches and peas. The fragile stems of 'Blando' brome and 'Zorro' fescue do not support vetch and are seldom used in mixes with vetches. However, these two species are compatible with bur medic and annual clovers and with low densities of vetch. Dozens of grass-legume blends and seeding rates have been used, including annual-perennial combinations.

California native perennial grasses grown in vineyard middles are typically used in mixtures, with plant species or accessions of like statures grouped together. Because some species are short-lived, it is important to allow them to reseed in the vineyard. Although individual native grass species have been evaluated, mixes have received limited attention from researchers, and there is currently no published data on their use in vineyards. These species are increasingly being sown in vineyards mainly from the northern San Joaquin Valley northward. Seedling growth of many species is relatively slow, so native grasses are susceptible to weed competition during establishment. The lower-growing mixes may contain pine bluegrass, Idaho fescue, 'Molate' fescue, or a prostrate form of California barley. These grasses mature relatively early and are summer-dormant in hot, dry climates, although 'Molate fescue will persist with irrigation. This is thought to reduce competition for water with the vines. Taller species include meadow barley, blue wildrye, California brome, California melic, and purple needlegrass. Due to greater seedling vigor, meadow barley, blue wildrye, and California brome are more easily established on sandy, droughty soils than are the low-growing species mentioned earlier. We have seen no examples of legumes included in mixtures of California native grasses, but annual clovers and bur medic may be appropriate. Use of California native grasses as vineyard cover crops is on the rise, making it increasingly important to conduct formal experiments on the issues mentioned above.

Winter Annual Cover Crops for Tilled Vineyards

LEGUMES

Field Pea

Pisum sativum

Plates 2-1–2-4

Other Common Names: common pea, garden pea

Description: Stems trailing, round, weak; leaves compound with 1 to 3 pairs of leaflets and terminated by a branched tendril; leaflets oval or elliptic; stipules very large and leaflike; flowers solitary or in pairs, white or pink; pods variable in size and shape, containing 2 to 10 seeds.

Numerous field pea cultivars are available and are most often used in mixes. Those most commonly planted as cover crops include 'Austrian Winter,' 'Magnus,' and 'Miranda.' 'Austrian Winter,' which has pink and reddish flowers, is dormant during cold weather and produces most of its biomass during the spring (plate 2-1). However, it usually produces as much biomass as most other legumes if allowed to grow through the spring. 'Magnus' can be distinguished by its large light and dark pink flowers and its large tendrils (plate 2-2). Unlike 'Austrian Winter,' 'Magnus' grows rapidly through the winter and matures earlier and is therefore a better choice in vineyards disked early in the spring. 'Miranda' has white flowers, matures early, and usually produces less biomass than 'Austrian Winter' or 'Magnus' (plate 2-3).

Berseem Clover
Trifolium alexandrinum
Plates 2-5–2-6

Other Common Name: Egyptian clover

Description: Stems erect; leaves trifoliate; leaflets oblong to broadly elliptic; flowers clustered in dense elliptical heads, yellowish-white.

Berseem clover is a rapidly growing winter annual that flowers in late spring and early summer, much later than most annual clovers. It is very tolerant of waterlogging and can be used to remove excess soil moisture. It is an excellent forage plant and thus responds well to mowing, exhibiting basal branching and rapid regrowth from the crown. It can be mowed three to four times in late winter and spring. These clippings are nitrogen rich and may supply excessive nitrogen to vines. When mowed in this manner, they can produce up to 400 pounds of nitrogen per planted acre (448 kg/ha) per year under optimal growing conditions (Williams, Graves, and Cassman 1990), although under most conditions, they will probably produce less than 250 pounds per acre (280 kg/ha). Berseem clover is seldom used in vineyards. Where it is used it is often disked in the spring to conserve moisture and reduce the nitrogen contribution.

Bell Bean
Vicia faba
Plates 2-7–2-10

Other Common Names: faba bean, fava bean, small-seeded horse bean

Description: Stems coarse, upright; leaves compound, usually with 6 broad leaflets and no tendrils; dark purple extrafloral nectary on lower surface of stipule; flowers large and white with dark purple blotches; pods large and cylindrical, containing 6 to 8 seeds.

Although bell bean is a true vetch, it differs greatly from other vetches with its strong, upright growth (see below for discussion of other vetches). It also has a relatively shallow, thick taproot (plate 2-9), which may be useful for opening up heavy soils. Bell bean is often used in mixes with vetches, peas, or cereals. Because of its height and because it does not tolerate close mowing, it is often omitted from mixes in frost-prone areas. Bell bean is frequently infested by the bean aphid (*Aphis fabae*), which seldom affects its use as a cover crop. The aphid, which does not attack grapes, and the presence of extrafloral nectaries may attract beneficial insects into vineyards. Bell bean is more susceptible to frost damage than other vetches. It is very similar in growth to broad bean (also known as Windsor or horse bean), which has a much larger, flat seed. The smaller seed size of bell bean makes it more economical to sow.

Vetches
Vicia spp.
Vetches are among the most frequently planted cover crops in vineyards. The most commonly used vetches are 'Lana' woollypod, purple, common (plate 2-11), and 'Cahaba White' (plate 2-15); hairy vetch is occasionally used as well. Although bell bean is a true vetch, it is discussed separately above. Vetches are grown as monocultural stands or in mixes with other vetches (including bell beans), cereals, field pea, and occasionally clovers and medics. Vetches produce trailing stems with tendrils that allow them to climb erect plants and structures, including grape trellises (plates 2-12, 2-16). Whereas stems of some vetches often reach 5 feet (150 cm) or more in length, unsupported plants seldom attain a height of more than 2 feet (60 cm). They may produce slender taproots that are 1 to 3 feet (30 to 90 cm) deep, but are usually shallow rooted, with most roots in the top 8 inches (20.5 cm) of soil. Vetches can fix large quantities of nitrogen, which may prove excessive for vineyards if planted in every row or if grown in the absence of cereals. They are also susceptible to *Botrytis* disease if grown in monocultural stands year after year (Farr et al. 1989; A. Van Bruggen, personal communication). This disease is particularly damaging after periods of heavy rainfall. When planted every year for 3 to 4 years, the disease may largely kill the stand (plate 2-13).

Vetch species differ in several important ways. Hairy vetch is the most cold hardy, followed in descending order by common vetch, woollypod vetch, and purple vetch, the least cold hardy. However, all these species usually thrive in the major grape growing regions of California. The species also differ in rate of growth in winter and in overall aggressiveness. Whereas most of the biomass production of vetches occurs in the late winter and spring, woollypod, hairy, and purple vetch-

es have strong seedling vigor and grow substantially during the winter. Common vetch produces less growth during the winter and less total biomass during the season (Miller et al. 1989). Some grape growers prefer this slower growth because the vetch will not climb vines as readily; however, the vetch may be less effective at suppressing weeds during the winter. Because common vetch usually produces less biomass than woollypod and purple vetches, it often produces less nitrogen. Common vetch produces no hard seed, whereas other vetch species produce small proportions of hard seed and may therefore become weedy in vineyards.

Seed sizes of the various vetch species are variable, with common vetch being the largest followed in descending order by woollypod, purple, and hairy, the smallest. All vetches are relatively easy to establish. They are not compatible with close mowing after about late February if late-spring growth or reseeding is desired, and they are often not mowed until incorporated or are mowed once or twice in late winter or early spring to a height of no less than 5 inches (12.5 cm).

Purple Vetch
Vicia benghalensis
Plate 2-11

Description: Stems trailing; leaves compound with 10 to 16 leaflets and a tendril at the end of each leaf in place of a leaflet; leaflets hairy, slightly larger and more oblong than those of woollypod vetch; stipules rather large, tinted dark purple (hence the species name); flowers reddish-purple with tip very dark, 6 to 12 per inflorescence; pods plump, hairy, containing 3 to 5 seeds.

Purple vetch has been used commercially since the 1920s for forage, cover crops, and green manures. Like woollypod vetch, it produces excellent cool-season growth, but it blooms and matures later than woollypod vetch. Purple vetch leaves are markedly hairy, giving a silvery, downy appearance to shoot tips in the early spring. It also has reddish flowers, whereas other vetch cover crop species have purple flowers (plate 2-11). Although purple vetch is among the least cold hardy of the cultivated vetches, in most years it will thrive in all but the coldest mountain locations in California.

Common Vetch
Vicia sativa
Plates 2-11, 2-14

Other Common Names: Oregon vetch, spring vetch

Description: Stems trailing; leaves compound with 8 to 16 leaflets, with a tendril at the end of each leaf in place of a leaflet; leaflets truncated, with the midrib extended to form a distinct point; dark purple extrafloral nectary on lower surface of stipule; flowers usually in pairs, bluish purple; pods relatively small, nearly cylindrical.

Common vetch was once the most important vetch species in California, but now woollypod and purple vetches are also frequently used. Common vetch remains dormant through much of the winter, developing nearly all its biomass in March and April. For this reason, it is not the best choice in vineyards that will be disked in March. Some growers include common vetch in mixes because it has extrafloral nectaries on the stipules (plate 2-14), which provide a readily available source of nectar for beneficial insects. However, the role of nectaries in pest management has not been tested.

'Cahaba White' vetch, a hybrid cultivar (*Vicia sativa* × *V. cordata*) (plate 2-15), was developed at Auburn University. It has been shown to be resistant to most root knot nematode species except *Meloidogyne hapla*, which is not considered damaging to grapevines. It is therefore recommended for vineyard soils where these nematodes are a problem (Block 1990). Because the continued use of this cultivar over several years often results in soilborne diseases, it is advisable to blend or rotate it with other cover crop species.

Hairy Vetch
Vicia villosa
Other Common Name: sand vetch

Description: Stems trailing; leaves compound with 8 to 24 leaflets, with a tendril at the end of each leaf in place of a leaflet; leaflets slightly narrower and more pointed than those of purple and common vetches; flowers purple to violet, 10 to 40 per inflorescence; pods plump, containing 2 to 8 seeds.

In California, hairy vetch is used far less often than common, purple, or woollypod vetch. Hairy and woollypod vetches were once distinct species but, because hairy vetch is very similar to woollypod vetch, the two are now combined into *Vicia villosa* on the basis of plant characteristics. Hairy vetch usually grows less during the winter than woollypod or purple vetches. According to Duke (1981), many cultivars have been developed for particular areas of the United States. The 'Madison Vetch' cultivar, developed in Nebraska, is quite cold tolerant. Cold-tolerant forms of hairy vetch were also grown in Michigan, but most hairy vetch is now grown in Oregon, where less hairy, heat-tolerant forms have dominated. This seems to suggest that the most cold-tolerant forms are less available now than formerly. Hairier cultivars are typically more winter hardy (McLeod 1982), but this correlation does not always hold (Duke 1981). Hairy vetch grows well on most well-drained soils and is especially well adapted to sandy or sandy loam soils. For this reason it is also called sand vetch.

Woollypod Vetch
Vicia villosa* ssp. *dasycarpa
Plates 2-11–2-12, 2-16–2-17

Other Common Names: Lana vetch, winter vetch

Description: Stems trailing; leaves compound with 8 to 24 leaflets, with a tendril at the end of each leaf in place of a leaflet; leaflets slightly narrower and more pointed than those of purple and common vetches; flowers purple to violet, 6 to 12 per inflorescence; pods plump, containing 2 to 8 seeds.

'Lana' woollypod vetch is one of the most recently introduced vetch cultivar that grows successfully in California. It was selected and developed by the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service) in cooperation with the UC Davis Agronomy Department from material introduced from Turkey in 1937 (Williams et al. 1959). It is well adapted to many vineyards below 3,000 to 4,000 feet (915 to 1,220 km). It is the earliest flowering and maturing vetch available; in the warmest regions, it may mature by late April, but usually matures in mid- to late May. Woollypod and purple vetches usually produce similar quantities of biomass and nitrogen and are both quite vigorous (plate 2-11).

GRASSES

Oat
Avena sativa
Plates 2-18–2-20

Description: Culms erect, stout; leaves variable in size; auricles fairly small, upright, rounded or pointed at apex, whitish to transparent; inflorescence (panicle) loose, open, the slender branches usually horizontally spreading; awns often absent.

Oat is sown frequently in vineyards, often in mixes but also in monocultural stands. It is more tolerant than barley of wet and heavy soils and also tolerates a wide range of soil types. Under moderate fertility and drainage, it can tolerate a lower pH than barley; it tolerates a soil pH as low as 4.5 (Stoskopf 1985). However, oat is not as tolerant as other cereals of drought, sandy soils, or cold. Dozens of cultivars have been developed, primarily as forage species. Cultivars vary in their period of flowering—'Montezuma' heads the earliest, followed in descending order by 'Swan' 'Sierra,' 'Ogle,' 'California Red,' and 'Cayuse,' the latest (L. Jackson and R. Wennig, personal communication).

Barley
Hordeum vulgare
Plates 2-21–2-22

Description: Culms erect, dense; auricles well developed, usually wrapping around the stem; inflorescence (spike) erect, consisting of sets of 3 stalkless spikelets; awns long, straight, and erect, those of beardless barley suppressed, 3-cleft, the central division converted into a hooded lobe.

Barley is an inexpensive, fast-growing cereal that produces substantial biomass and competes well against weeds. It produces more tillers at the base than cereal rye and oat. It is the most salt-tolerant cereal and is more drought tolerant than rye or oat. Barley is not as tolerant of wet soil conditions as cereal rye or oat; it will not grow well in heavy, poorly drained, or low-permeability soils, especially after periods of heavy rainfall. Although barley is frequently sown in mature vineyards, it is also used during the development of new hillside vineyards to prevent soil erosion. After the terraces are created, barley is planted prior to the fall rains and is worked into the soil in the spring when the vines are planted.

Many barley cultivars are available. 'UC 476' is a popular tall-growing cultivar that has good disease resistance but poor self-regeneration; 'UC603' is a short-statured cultivar that is frequently used. Care should be given to cultivar selection, avoiding those that are not tolerant or resistant to yellow dwarf virus and rust.

Annual Ryegrass
Lolium multiflorum
Plates 2-23–2-25

Other Common Names: common ryegrass, Italian ryegrass, Oregon ryegrass

Description: Culms dense, pale or yellowish at the base; leaves dark green, glossy; auricles usually prominent; inflorescence (panicle) erect, relatively narrow.

Annual ryegrass is a fast-growing, self-reseeding grass that is infrequently sown in vineyards but often volunteers as a weedy species. It has a densely fibrous root system that aids in holding soil, increasing water infiltration, and improving soil tilth. It is a heavy user of water and nitrogen and may perform poorly on droughty or infertile soils. Annual ryegrass will tolerate periods of flooding when established. Because it matures late (June to September), it competes strongly with grapevines for water and nutrients during the spring and early summer. Because the stems are erect but weak, they are typically not used with vetches.

Cereal Rye
Secale cereale
Plates 2-25–2-27

Other Common Names: cereal ryegrain, Merced rye, rye

Description: Culms erect; leaves blue-green; auricles very small; inflorescence (spike) somewhat nodding (curved), relatively slender, awned.

Cereal rye grows rapidly in cool weather and forms a dense, tall stand with a more extensive root system than other cereals. Among the cereals, it is the most cold tolerant and is one of the best species to use if planting is delayed until late fall or winter. It is also the most drought-tolerant cereal and is best for sandy or rocky soils. It is particularly preferred on sandy soils in the San Joaquin Valley and is often planted by raisin growers, who incorporate it into the soil prior to the spring frost season. Cereal rye does not tiller heavily, so a relatively high seeding rate should be used, especially if it is seeded late. Residues of cereal rye clippings are more persistent than those of other cereals. The cultivar 'Merced' has been the most successful for cover cropping in California due to its excellent winter growth, early maturity, and wide soil adaptability.

Wheat
Triticum aestivum
Plate 2-28

Description: Culms erect, freely branching at base; auricles present; inflorescence (spike), long-awned to awnless.

Wheat is commonly cultivated as a small-grain crop and may be used as a forage crop. Like triticale, it is used in relatively few vineyards. It can be mixed with other species, such as other cereals and vetch. Wheat produces less fall biomass than oat, but is more drought tolerant and has more winter and early spring growth. Many types and cultivars are available.

Triticale
× ***Triticosecale***

Description: Culms erect; auricles present; inflorescence a spike.

Triticale is a cross between wheat and cereal rye, and is similar in productivity to both these species. Many types are available, with widely differing growth habits and maturity dates. It is used in a small number of vineyards compared to other cereals.

FORBS

Brassicas
***Brassica* spp.**
Plates 2-29–2-30

Description: Stems erect, branched; basal leaves pinnately cleft into lobes, stem leaves toothed or undivided; flowers showy, yellow or whitish, with 4 petals; fruiting structures (capsules or siliques) many-seeded, narrow, round or 4-sided.

Brassicas used as cover crops include white mustard (*Brassica hirta*, plate 2-29), which is also cultivated for greens; brown mustard (*B. juncea*); black mustard (*B. nigra*); rape (*B. napus*); and turnip (*B. rapa*). Oilseed radish (*Raphanus sativus*), which is in the same family, has also been used in vineyards. Field mustard (*Brassica campestris*) readily volunteers in many North Coast vineyards and is managed as a resident cover crop; it is not currently available in the seed trade. Most species produce some hard seed (Madson 1951). Green peach aphids (*Myzus persiae*) often build up on mustards during winter and early spring. Although these aphids do not affect vineyards, they may disperse and carry virus diseases to other crops such as potatoes.

Brassicas grow well in loam to clay soils. Most have deep taproots that are often said to help aerate heavy soils, although in one study, they were not found to significantly increase water infiltration (Williams 1966). Brassicas are also very efficient at removing soil nitrate, thus reducing nitrate leaching. Because they have a relatively low carbon to nitrogen (C/N) ratio (usually intermediate between legumes and grasses), they quickly decompose after disking or mowing, resulting in little tie-up of soil nitrogen.

Black mustard and brown mustard allelopathically inhibit other annual plants; the compounds involved probably include various isothiocyanates (Bialy et al. 1990). Allelopathic effects on grapevines have not been tested. Some brassicas also have nematicidal properties—white mustard and oilseed radish cultivars have been developed in northern Europe for their nematicidal properties in sugar beet rotations (Miller et al. 1989).

Tansy Phacelia
Phacelia tanacetifolia
Plates 2-31–2-32

Other Common Names: bee phacelia, phacelia

Description: Stems semierect, succulent; leaves pinnately divided, finely hairy, bearing glands; inflorescence (cyme) compact, densely hairy, containing many flowers in each; flowers blue, showy.

A native California annual wildflower, tansy phacelia is occasionally used in vineyards, mainly as a rotation cover crop in the North Coast. It grows rapidly in the winter, forming a dense, succulent stand. It takes up large amounts of nitrogen during the winter and rapidly decomposes after tillage due to its low C/N ratio.

Winter Annual Cover Crops for No-Till Vineyards

LEGUMES

Bur Medic
Medicago polymorpha
Plates 2-33–2-36

Other Common Names: burr medic, burclover, California burclover, toothed burclover

Description: Stems semierect or prostrate; leaves trifoliate, with middle leaflet extended on a stalk (petiolule); apical margins of leaflets obovate to heart shaped, slightly toothed or jagged, sometimes with purple and white flecks on upper surface or a small purple inverted V mark at the base; stipules rather small, many pointed; flowers very small, yellow; pods (burs) coiled 2 to 6 times, with spines hooked at the tip (burs of some cultivars are spineless), containing 3 to 11 seeds.

Bur medic is the most popular cover crop among the medics because it usually grows best and reestablishes reliably each year. Other medics that are seldom used or are included in mixes with bur medic include barrel (*Medicago truncatula*), snail (*M. scutellata*), gama (*M. rugosa*), and strand (*M. littoralis*) medics. Bur medic is in the same genus as alfalfa (*M. sativa*). Although it is frequently referred to as burclover, it is not a true clover (*Trifolium* spp.). It can be distinguished by its coiled burs and the short stalk extending from the middle leaflet—leaflets of the true clovers are attached basally at the same point (plate 2-35).

Bur medic is the most widely adapted of the medics to soils of different pH. With an abundance of acid-tolerant rhizobium bacteria indigenous to most California soils, bur medic will grow on most sites. Barrel and gama medics will grow and fix nitrogen only on soils with pH 7.5 or greater. In some areas, bur medic may be damaged by Egyptian alfalfa weevil (*Hypera brunneipennis*), and in extreme cases the weevil may skeletonize plants.

Bur medic is well adapted to California vineyard growing conditions. It lends itself well to drip-irrigated vineyards because it germinates readily in fall rains, grows rapidly during the winter, and produces many seeds by early May. Seedlings produce early taproot growth and therefore may be better adapted to early-season drought than subterranean clover. Because bur medic is low-growing and branches profusely at the base, it can tolerate frequent, relatively close mowing (to 3 to 5 in [7.5 to 12.5 cm] tall) and still reseed. It produces a large proportion of hard seed, which remain viable for many years. For this reason, it is particularly well suited to raisin vineyards, where a substantial amount of soil is moved to create terraces, burying some seed too deeply to germinate the following year. In later years tillage brings some of these seed to the surface layer of the soil where they may germinate.

Clovers

Trifolium spp.

Annual mixes of reseeding clovers are frequently used in no-till vineyards; these mixes often include bur medic as well (see plate 2-37). Although the various clover species and cultivars share several similarities, there are differences in some characteristics, such as growth habit and time of flowering and maturity. For example, because crimson and rose clovers grow upright and flower above the foliage, they do not need to be mowed to perform well and should not be mowed in late spring so they can reseed. Conversely, subterranean clover (and bur medic—see previous section) stems spread along the ground and should be mowed to reduce weed competition. Bur medic grows somewhat upright and may be mowed, but not as closely as subterranean clover.

Soil nutrition is important for the optimum performance of clovers. On highly fertile soils or where nitrogen fertilizers have recently been applied, clovers are often outcompeted by grasses or other nonlegume weeds. Also, clovers will benefit from addition of phosphorus, calcium, and sulfur.

Crimson Clover
Trifolium incarnatum
Plates 2-37–2-39

Other Common Name: scarlet clover

Description: Stems erect but often leaning over at the base by the spring, branching at the base but largely unbranching above; leaves trifoliate; leaflets broad, obovate and pointed at the base, softly hairy, usually unmarked but sometimes with a few dark red spots; stipules large, sharply veined; flower heads terminal, solitary, elongated, containing dozens of flowers; flowers showy, scarlet or dark red.

Crimson clover performs well in annual clover mixes. Like other mowable clovers, it can be mowed to 3 to 5 inches (7.5 to 12.5 cm) tall during the winter and early spring. However, because it produces its flower heads above the foliage, it must be allowed to grow from mid-March or early April onward until the seed mature in late spring to ensure reseeding. Whether used alone or in mixes, crimson clover often produces a brilliant display of red flowers.

Rose Clover
Trifolium hirtum
Plates 2-40–2-41

Description: Stems semierect, branching, softly hairy; leaves trifoliate; leaflets obovate, pointed at the base, light green, very hairy, marked with a pinkish-white watermark and sometimes with a few dark-red spots; stipules large, sharply veined; flower heads terminal, solitary, round, subtended by uppermost leaf, containing many flowers; flowers showy, pink to rose.

Rose clover is similar in stature and phenology to crimson clover but branches more and is slightly lower growing. It grows well on rocky, dry soils and in acid to neutral soils of low fertility but grows poorly on wet, heavy soils. Because it is well adapted to rangeland use, rose clover usually reseeds effectively, but weeds often encroach and reduce stands on fertile soils. It produces a high proportion of hard seed.

Several rose clover cultivars are available. According to Miller et al. (1989), 'Hykon' is the earliest maturing, and 'Kondinin' the most tolerant of soil acidity. 'Wilton' is the latest maturing and is adapted to areas with greater than 14 inches (35.5 cm) annual rainfall. 'Overton 18' is a relatively late and tall cultivar that produces a very high proportion of hard seed. 'Hykon' is popular and is used frequently in seed mixes; however, other cultivars also perform well.

Subterranean Clover
Trifolium subterraneum
Plates 2-42–2-44

Other Common Name: subclover

Description: Stems spreading; leaves often with a watermark that forms a circle with the three leaflets; leaflets broadly heart shaped but often flat or rounded at the apex; stipules rather small; inflorescence a few-flowered fascicle; flowers whitish, inconspicuous; pods (burs) formed on long peduncle, containing 2 to 5 seeds, variable in shape and size, with calyx teeth adhering, in some cultivars giving a shooting-star appearance, and in others the calyx of the numerous sterile flowers form an intertwined bur mass.

Subterranean clover is an excellent cover crop species for many vineyard sites. It is frequently used on pasture and rangeland sites and is relished by livestock. It performs well in mowable clover mixes and usually requires periodic mowing to stimulate vigorous growth. In the spring it often forms a dense mat of stems below the height of mowing, which helps reduce soil erosion and suppress weed seed germination. It is even more tolerant of very close mowing than bur medic due to its low, spreading habit. In addition, the peduncle reflexes and elongates downward after flowering, driving the seedhead slightly underground in some cultivars (plate 2-43).

There are dozens of subclover cultivars, and differences exist among them in the time of flowering and maturity (see Miller et al. 1989) and in soil pH requirements. In general, subclovers are best adapted to acid (no lower than about pH 5.0 to 5.5) or moderately acid to neutral soils. Some cultivars, particularly 'Clare,' 'Koala,' and closely related cultivars, also perform quite well on soils with high pH.

GRASSES

'Blando' Brome
Bromus hordeaceus
Plates 2-45–2-48

Other Common Names: Blando bromegrass, soft chess

Description: Culms erect; leaves softly hairy; auricles small, whitish, membranous; inflorescence (panicle) compressed; awns rather stout.

'Blando' brome is well suited to no-till vineyards, particularly drip-irrigated ones. It is a selection of soft chess that was cooperatively released by the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service) and the University of California Agricultural Experiment Station in 1960. It is low growing and mowable and matures early; in a Mendocino County trial, seeded 'Blando' brome matured earlier than the resident brome (Bugg, Zomer, and Auburn 1996). It also has strong seedling vigor, excellent reseeding ability, and dense, fibrous roots. For these reasons it can reduce soil erosion while not competing excessively with grapevines. 'Blando' brome is widely adaptable to a range of soils and climates. It is often grown in monocultural stands, but can also be mixed with clovers or other low-growing cover crop species.

'Zorro' Fescue
Vulpia myuros* var. *hirsuta
Plates 2-48–2-50

Other Common Names: annual fescue, foxtail fescue

Description: Culms erect; leaves very narrow; auricles absent; inflorescence (panicle) erect, narrow.

'Zorro' fescue is a fast-growing, early-maturing grass. It is a selection of foxtail fescue that was cooperatively released by the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service) and the University of California Agricultural Experiment Station in 1977. It is short statured and noninvasive. It is well suited to drip-irrigated vineyards with sandy, low-fertility, or serpentine soils, including soils containing rocks, gravel, and volcanic pumice. Good seedling vigor and early growth make it an excellent choice for obtaining quick initial erosion control with minimal seedbed preparation. It can be mowed to 4 inches (10 cm) but should not be mowed in April to allow for reseeding. 'Zorro' fescue can be used as a substitute for 'Blando' brome where quicker fall growth, earlier maturation, and greater drought tolerance are needed. Otherwise, 'Blando' brome is recommended because it is cheaper, reseeds more effectively, is more aggressive, and has seed that flows better through drills.

Perennial Cover Crops for No-Till Vineyards

LEGUMES

Birdsfoot Trefoil
Lotus corniculatus
Plates 2-51–2-52

Description: Stems arising from a single crown, well branched, spreading; leaves compound with 5 broad leaflets, the 2 lower leaflets stipulelike; inflorescence attached in clusters on long stalks, 4- to 8-flowered; flowers yellow, sometimes with orange; pods small, cylindrical, brown to almost black.

Birdsfoot trefoil is a long-lived, drought- and cold-tolerant perennial legume. It is strongly taprooted and tolerates a wide range of soils, including poorly drained, saline, and alkaline soils. Birdsfoot trefoil will grow well on clay to sandy loam soils and will survive flooding for more than a month.

Because birdsfoot trefoil has low seedling vigor, it should be mowed during stand establishment. Including a short-statured grass such as 'Blando' brome at seeding can aid in weed control and help reduce erosion during the establishment phase. When established, it should be mowed no lower than 2 to 4 inches (5 to 10 cm) tall so axillary buds can regrow.

Strawberry Clover
Trifolium fragiferum
Plate 2-53

Description: Stems (stolons) creeping, branching, rooting at nodes; leaves trifoliate; leaflets broadly elliptic to narrowly obovate, flower heads round, dense, many-flowered; flowers light pink.

Strawberry clover is a long-lived perennial that roots at the nodes of stolons and grows year-round. It tolerates saline and alkaline soils, wet or submerged soils, infrequent irrigation, and frequent, close mowing. When established, it often outcompetes weeds and is useful for erosion control; it is also very resistant to most herbicides. However, it is very invasive, competes with vines for water, and attracts pocket gophers. The cultivar 'Salina' is well adapted to California conditions; it was developed in California from selections of 'Palestine,' a productive Australian cultivar.

White Clover
Trifolium repens
Plates 2-54–2-55

Other Common Names: Dutch white clover, Ladino clover, New Zealand white clover

Description: Stems (stolons) creeping, branching, rooting at nodes; leaves trifoliate; leaflets obovate and pointed at the base to broadly oblong, green or with white V, sometimes with dark red flecks; stipules membranous, lance shaped; flower heads round, rather loose, many-flowered; flowers white, later turning pinkish then brown.

White clover is similar in habit and growth to strawberry clover but is less invasive and may attract fewer pocket gophers because of its smaller taproot. It tolerates a wide range of soil conditions but thrives best under cool, moist growing conditions; it is also shade tolerant once established. It performs better in heavy, moist soils than on sandy soils that may be droughty and contain less nutrients. It is the least drought tolerant of the perennial legumes discussed here.

White clover cultivars are arbitrarily classified by size of the plants: small, intermediate, and large (Duke 1981). The small types often have "wild white" in their names. Intermediate types often include the term "common" and indicate locally harvested or unknown cultivars; most unnamed U.S. cultivars are intermediate types. The large type was introduced from Italy into the United States as "Ladino" in the early 1900s. Seed derived from this ecotype were designated Ladino until the early 1950s, when new cultivars were developed in the United States.

GRASSES

California Brome
Bromus carinatus
Plate 2-56

Other Common Name: Mokelumne brome

Description: Culms erect, stout; leaves flat, rough or sparsely hairy; inflorescence (panicle) with spreading or drooping branches; awns relatively long.

California brome is a large, leafy, short-lived perennial bunchgrass with strong seedling vigor. It

grows in open and wooded sites in Central and Northern California. California brome has many varied forms.

Orchardgrass
Dactylis glomerata
Plates 2-57–2-58

Other Common Name: Berber orchardgrass

Description: Culms coarse-tufted, spreading with short rhizomes; leaves long, flat; inflorescence (panicle) with few distant, stiff, solitary branches.

Orchardgrass is a very vigorous perennial bunchgrass that is used mostly for hay and pasture. It is one of the more competitive cover crops and should only be used where extreme reduction of vine vigor is desired (Wolpert et al. 1993). It is fairly late maturing and does not respond well to close or frequent mowing. The cultivar 'Berber' is used most frequently in California vineyards.

Blue Wildrye
Elymus glaucus
Plate 2-59

Description: Culms erect, loosely to densely tufted; leaves rough, usually flat; inflorescence a spike, erect to somewhat nodding, dense; awns relatively long.

Blue wildrye is a large green or bluish perennial bunchgrass that has no rhizomes. It is found throughout much of California below 8,200 feet (2,500 m) and has many varied forms. It is common in the foothills and lower mountain slopes, usually in association with open stands of oaks and conifers. Blue wildrye is generally more drought tolerant than meadow barley. It will continue summer growth only when irrigated.

Tall Fescue
Festuca arundinacea
Plates 2-60–2-61

Other Common Names: Fawn tall fescue, turf-type tall fescue

Description: Culms erect, robust; leaves stout and flat, with rough edges; inflorescence (panicle) narrow with numerous branches and spikelets.

Tall fescue is a fast-growing perennial bunchgrass that is occasionally planted to reduce excessive vine vigor. It is also planted in wet areas of vineyards to aid in wheel traction in the spring. Although it grows primarily in the cool season, it continues to grow in the summer if adequate water is provided. Tall cultivars of tall fescue are aggressive and will compete strongly against grapevines for water and nutrients. This grass requires frequent mowing and will often not survive in drip-irrigated vineyards. Some growers plant alternating rows of tall fescue for winter access and use green manure cover crops in the other rows. Tall fescue is very tolerant of alkali and waterlogged soils. The tall cultivar 'Fawn' is commonly planted. Short-statured (dwarf) turf cultivars are also available; these are less competitive and require mowing less frequently.

Idaho Fescue
Festuca idahoensis
Plates 2-62–2-63

Other Common Name: blue bunchgrass

Description: Culms densely tufted; leaves slender, firm, inrolled; inflorescence (panicle) narrow.

Idaho fescue is a densely tufted perennial bunchgrass that is very closely related to sheep fescue (*Festuca ovina).* Although it is one of the most common and widely distributed grasses in the western United States, it is rare in the southern portions of California, Nevada, and Arizona (U.S. Forest Service 1937). It is found in open woods and rocky slopes below 5,900 feet (1,800 m). Idaho fescue is very drought tolerant, with greatly reduced or no growth during the summer; it is also very shade tolerant. Its clumping nature can make it bumpy to drive over if planted sparsely.

Sheep Fescue/Hard Fescue
Festuca ovina
Plates 2-64–2-66

Description: Culms densely tufted; leaves slender, curved inward; inflorescence (panicle) narrow.

Sheep fescue is a short-statured, noncreeping bunchgrass that forms a dense turf. Because it is long-lived and relatively summer dormant, it is suited to coastal drip-irrigated vineyards. The cultivar 'Covar' is frequently used; it is somewhat slow to establish but is competitive once established.

Hard fescue (*F. ovina* var. *duriuscula*) establishes more slowly than sheep fescue and has little spreading tendency. It is more drought-tolerant than chewings or creeping red fescue, but less so than sheep fescue. It does not tolerate waterlogging. Both hard and sheep fescues perform well on sandy soils.

Like other fine-leafed fescues, sheep and hard fescues tolerate certain grass herbicides used to control most weedy grasses.

Red Fescue (Creeping Red/Chewings/'Molate'/ 'Mokelumne' Fescues)
Festuca rubra
Plates 2-67–2-68

Description: Culms loosely or closely tufted, stems bent at the reddish or purplish base; leaves smooth, narrow, usually folded or curved inward, dark green (creeping red, chewings, 'Mokelumne') or bluish green ('Molate'); inflorescence (panicle) usually contracted and narrow, the branches mostly erect or ascending; spikelets pale green or yellow-green, often purple-tinged.

Red fescue is a low-growing, fine-leafed perennial grass that requires little mowing after establishment. It is found below 8,200 feet (2,500 m) in bogs, meadows, and marshes in the cooler parts of the northern hemisphere extending south in the Coast Range to Monterey County and in the Sierra Nevada to the San Bernardino Mountains. It grows on a wide range of soil types and is very tolerant of waterlogging. Red fescue is slow to establish and is susceptible to weed competition. It tolerates mowing to reduce weed growth.

Many red fescue cultivars have been developed and introduced for use in turf. Two of these, creeping red fescue and chewings fescue (*F. rubra* var. *commutata*) are also used in vineyards, mostly in Northern California. Creeping red fescue (plate 2-67) spreads by short rhizomes, whereas chewings fescue is a noncreeping bunchgrass that produces a firmer sod.

'Molate' and 'Mokelumne' fescues are drought-tolerant California native selections that develop short underground rhizomes. 'Molate' fescue (plate 2-68) was originally collected on dry, well-drained, inland sea level slopes at Point Molate, California (Contra Costa County). It is planted in many North Coast vineyards as well as the Suisun and Delta regions. It will grow in summer only when irrigated.

Meadow Barley
Hordeum brachyantherum* ssp. *brachyantherum
Plate 2-69

Description: Culms erect; inflorescence (spike) erect or sometimes nodding, sometimes purplish.

Meadow barley is a short-lived bunchgrass with strong seedling vigor and loose green foliage. It grows in meadows, salt marshes, and grassy slopes below 8,000 feet (2,440 m). It is found throughout California, except in the desert areas. Meadow barley is particularly adapted to soils that are waterlogged in the spring. It is tolerant of alkaline soil and will establish on infertile and compacted sites. Generally, it will not persist on very dry sites.

California Barley
***Hordeum brachyantherum* ssp. *californicum* (syn. *Hordeum californicum*)**
Plates 2-70–2-71

Description: Culms densely tufted, erect; inflorescence (spike) erect, mostly purplish.

California barley is a short-lived bunchgrass that has adapted to very dry conditions. It is found in meadows, dried creek beds, and brushy flats and slopes in Oregon and California. The prostrate type (plate 2-71) has finer, light green foliage, is much lower growing, and requires less mowing than do erect forms.

Perennial Ryegrass
Lolium perenne
Plate 2-72

Other Common Names: English ryegrass, Lynn ryegrass

Description: Culms erect or reclining at the usually reddish base; leaves glossy; inflorescence (spike) often somewhat sickle shaped.

Perennial ryegrass is a short-lived (3 to 4 years) perennial bunchgrass that is frequently used in lawns. Of the many cultivars, 'Elka,' a short-statured cultivar, has been the most frequently used in cover crop mixtures. It grows well on heavy soils

but needs a large amount of extra water. Although it is similar to tall fescue in growth and management, it is less aggressive and not as well adapted to poor or submerged soils.

California Melic
Melica californica
Plate 2-73

Other Common Name: California oniongrass

Description: Culms densely tufted, stems reclined and more or less bulbous at the base; leaves blue-green; inflorescence (panicle) narrow, rather dense, brownish to purplish.

California melic is a medium-sized, loosely tufted perennial that spreads from the base with rhizomelike stems that curve upward. It is also called oniongrass because it produces a small, edible onionlike thickening at the crown. It grows in the lower elevations of the foothill rangeland throughout California below 6,900 feet (2,100 m). Seedlings of California melic germinate slowly and lack vigor; but once established it is a very robust plant that competes well against weeds. It exhibits strong summer dormancy and is very drought tolerant. It does not form strong tufts and therefore provides an even driving surface.

Nodding Needlegrass
***Nassella cernua* (syn. *Stipa cernua*)**
Plate 2-74

Other Common Name: nodding stipa

Description: Culms erect, clumping; leaves blue-green; inflorescence (panicle) open with slender flexuous branches.

Nodding needlegrass is generally smaller and has a finer leaf than purple needlegrass. It is found in chaparral, juniper, woodland, and grasslands below 4,600 feet (1,400 m). Although it is adapted to many soil types, the soil must be well drained. Commonly found on poor soils throughout the state including those in Southern California, nodding needlegrass is a better choice for low rainfall areas than purple needlegrass. The two species are also commonly found in grass savannas and can therefore be used in combination.

Purple Needlegrass
***Nassella pulchra* (syn. *Stipa pulchra*)**
Plate 2-75

Other Common Name: stipa

Description: Culms erect; leaves long, narrow, flat or curved inward; inflorescence (panicle) nodding, loose, with spreading slender branches.

Purple needlegrass is a large, long-lived bunchgrass that is well adapted to many soil types. It is found in oak woodland, chaparral, and grasslands in the Coast Range and in the Sacramento Valley from Sacramento County north to Tehama County. It is tolerant of extreme summer drought and heat and is therefore well suited to drip-irrigated vineyards throughout much of California. It is slow to establish and does not compete well against weeds on highly fertile soils, making weed control important until it is well established.

Pine Bluegrass
***Poa secunda* ssp. *secunda* (syn. *Poa scabrella*)**
Plate 2-76

Other Common Name: one-sided bluegrass

Description: Culms erect, slender; leaves mostly basal, soft; inflorescence (panicle) usually narrow, contracted.

Pine bluegrass is a small, tufted bunchgrass with soft, basal foliage that is found throughout California from sea level to timberline and into the desert. At low elevations pine bluegrass becomes dormant with the onset of hot weather; in the mountains, it grows all summer. It is thought to have once been abundant in the Central Valley (Bishop 1996) and has excellent persistence in drip-irrigated vineyards. Pine bluegrass is relatively shallow-rooted and persists on shallow, gravelly soils. It does not compete well against weeds on fertile soils.

Summer Annual Cover Crops for Tilled Vineyards

Buckwheat
***Fagopyrum esculentum* (syn. *Fagopyrum saggitatum*)**
Plates 2-77–2-78

Description: Stems erect, succulent; leaves arrowhead shaped but with basal lobes turned outward; flowers several per cluster, white, with 5 petals and nectar-bearing yellow glands between the stamens.

Buckwheat is a fast-growing summer annual that is occasionally used in vineyards as a green manure cover crop or to attract beneficial insects. Although it is fairly drought tolerant, it can often be seen wilting in vineyards on hot days but recovering by morning. It produces less biomass than many other cover crops and breaks down rapidly after incorporation. Flowering can begin within a month of seeding. Numerous insect parasitoids have been documented visiting buckwheat flowers, but the effects of using buckwheat on grape pest management have not been tested.

Sudangrass
Sorghum sudanense
Other Common Name: Sudan grass

Sorghum-Sudangrass
Sorghum bicolor* (syn. *Sorghum vulgare*) × *S. sudanense
Plate 2-79

Description: Culms coarse, erect; leaves flat, long, either wide or narrow; inflorescence (panicle) relatively compact.

Sudangrass and sorghum-sudangrass hybrids are fast-growing tall summer annual grasses. Sorghum-sudangrass is a hybrid of grain sorghum (*Sorghum bicolor*) and sudangrass (*S. sudanense*).

Sudangrass and sorghum-sudangrass are occasionally used in vineyards to reduce dust, sunburn, and heat problems and to add large amounts of organic matter to the soil. They can also be used to reduce vine vigor, as they compete with vines for water and nutrients. However, nitrogen fertilizer should be added if reduced competition for nitrogen is desired. Sudangrass and hybrids can be mowed as close as 4 to 6 inches (10 to 15 cm) to reduce competition and improve vineyard access; or they can be allowed to grow unmowed and disked when a desirable stage of growth has been reached. They usually flower 2 to 3 months after planting.

Cowpea
Vigna unguiculata* ssp. *unguiculata
Plate 2-80

Other Common Names: blackeyed pea, crowder pea, southern pea.

Description: Stems erect or suberect and spreading, often purple-tinged; leaves trifoliate, alternating, the terminal leaflet often bigger than the two asymmetrical lateral leaflets; leaflets ovate to diamond shaped, sometimes slightly lobed; flowers 2 to 4 per cluster, dull white to yellow or violet; pods curved, straight or coiled.

Cowpea is a legume that is occasionally planted as a summer green manure crop to add nitrogen. It often harbors lygus bugs that may attack grapevines.

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Appendix C: Habitats for Beneficial Insects

Biodiversity Conservation Practices in California Vineyards: Learning from Experiences

Bulletin from the California Sustainable Winegrowing Program

Prepared by L. Ann Thrupp, Michael J. Costello & Glenn McGourty

Introduction: Why consider biodiversity in vineyards?

The conservation of biodiversity is considered an important element of sustainable agriculture. Numerous scientific studies and practical experiences have shown that biological diversity (as defined in Box 1) is a crucial factor in maintaining or increasing the sustainability and stability of farming systems.[1] The maintenance of biological diversity is also regarded as a key principle in organic farming operations, according to the U.S. National Organic Program guidelines and scientific evidence.[2]

Increasing numbers of winegrape growers in California are interested in the role of habitat conservation in their vineyards. Some are effectively implementing practices to conserve and enhance the diversity of plant and animals and landscapes in and around their vineyards.[3] These growers report positive impacts from these practices for both organic and non-organic vineyards, and for conservation purposes in the broader landscape. However, very few studies have been undertaken to measure and document the effects of these practices in specific vineyards. Responding to the need for more information, the California Sustainable Winegrowing Alliance, along with collaborating winegrape growers, and scientists from UC Cooperative Extension and Cal Poly San Luis Obispo, carried out an assessment of biodiversity conservation practices, focused on sites in the North Coast region. *(See end of report for acknowledgements.)*

The following is a summary of information from the study and from other related research and experiences. This bulletin is intended to provide insights that can be used for vineyard operations, throughout California, as part of sustainable winegrowing initiatives.

Box 1: What is biodiversity? How is it relevant to agriculture?

Biodiversity consists of genes, species, population, and landscapes, along with the composition, structures, functions, and interactions that occur at each level of the ecosystem.[4] Natural biodiversity has provided the foundation for all agricultural plants and animals. In addition to producing valuable crops and livestock species, biodiversity in agricultural systems performs many ecological services, including recycling of nutrients, pollination, management of organisms that are undesirable for agriculture, regulation of the local hydrological cycle and microclimate, and storage of carbon.[5]

Biodiversity as Part of Ecosystem Management in Sustainable Winegrowing

Biodiversity conservation and enhancement is a key element of ecosystem management – which is encouraged in the California Sustainable Winegrowing Program and in other sustainable agriculture initiatives. Ecosystem management refers to *the application of ecological science to resource management to promote the long-term sustainability of landscapes and the delivery of essential goods and services produced in them to society.*[6]

In vineyard operations, ecosystem management includes practices that conserve or enhance natural resources and ecological processes in order to produce grapes. Ecosystem management practices protect or enhance ecosystem "services" that are normally provided by nature – meaning factors such as nutrient cycling, decomposition of wastes, pest and disease regulation, generation of soils, water flow, and climate regulation.

Examples of practices used for managing, conserving and enhancing biodiversity include habitat conservation and enhancement around or in vineyards, planting and incorporation of cover crops and other vegetation, protection and attraction of diverse wildlife species (such as raptors) and beneficial arthropods, use of compost and soil amendments that increase soil biodiversity, and other forms of species protection (See Box 2). These practices help growers produce grapes while minimizing negative impacts on natural resources. Effective ecosystem management also helps sustain vibrant and healthy communities and landscapes beyond vineyards. (*See Ecosystem management chapter in the Code of Sustainable Winegrowing Practices.)*[7]

Box 2: Practices for Biodiversity Management in and around Vineyards

A. Conservation and management of existing biodiversity

- Protection and conservation of native trees in and around vineyards
- Protection and conservation of vernal pools
- Conservation of native habitat and plant species and/or oak woodlands
- Protection of riparian habitat (including trees) along rivers or streams
- Maintenance or mowing of native vegetation between vine rows, serving as cover crops
- Maintenance of native vegetation on vineyard edges and landscaping
- Protection of native birds and wildlife (e.g. avoid fencing, avoid hunting, etc.)

B. Enhancement of biodiversity (planned)

- Planting trees in/around vineyards
- Planting vegetation in or around vineyards -- eg, hedgerows
  - Habitat corridors
  - "Islands of flowers/vegetation"
  - Insectaries and/or landscaping on edges
  - Planting diverse cover crops
- Use of compost or other soil amendments to enhance soil biodiversity
- Practices to attract birds (eg, birdboxes, perches)
- Practices to attract wildlife (eg, planting hedgerows, slash piles, providing food sources)
- Incorporating sheep, goats, or chickens for weed control or cover crop management

Project Objectives and Case Studies

A biodiversity project was undertaken by the California Sustainable Winegrowing Alliance and collaborators from August 2006 to December 2007, with the support of the National Fish and Wildlife Foundation. Features of the study are noted below.

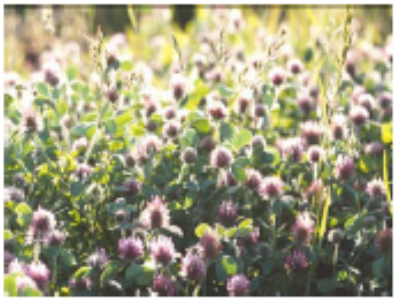
Objectives and Case Study Focus

Two of the main objectives of the project were to:

- document the benefits of biodiversity and habitat protection in California vineyards (based on case studies), and
- identify practices for conserving or enhancing biological diversity in and around vineyards.

The study sites were five North Coast vineyards with habitat corridors or islands, including mature hedgerows or riparian vegetation (See Box 3 below). The analysis included monitoring of species of plants, arthropods, birds and small vertebrates to better understand their role in the vineyard ecosystem. The arthropod analysis focused on the western grape leafhopper (*Erythroneura elegantula*) and spider mites (*Eotetranychus willamettei* and *Tetranychus pacificus*), which are the two most significant arthropod pests in the region, and also looked at their natural enemies, including the leafhopper parasitoids *Anagrus* spp., predatory mites, and generalist predators such as minute pirate bugs and black hunter thrips.





Study Methods and Materials

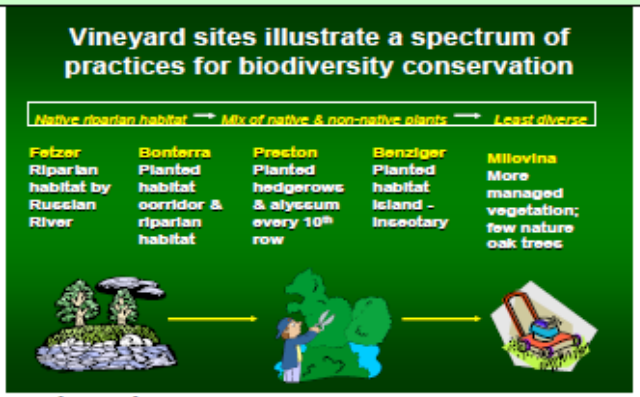
The resources available for this project allowed for analysis during one season (2007). Data on insect and mite species were collected every two weeks during the main growing season (May to September 2007). The methods used for gathering data included placing sticky traps within the plant border habitat on the vineyard margin and in the vine canopy starting from the hedgerow at intervals of 10-20 meters. These traps were collected and changed every two weeks. *Anagrus* spp. (the most important parasite of leafhoppers), minute pirate bug nymphs (*Orius* spp.) and black hunter thrips (*Aelothrips* spp.) were counted on the cards as a measure of their activity.

Nymphs of the leafhoppers were counted on 30 leaves per plot every two weeks; results are presented in average nymphs per leaf. Three times during the season, roughly at the end of the first, second and third generations, 30 leaves per plot were collected and analyzed to determine if the leafhopper eggs were live, hatched, and parasitized by *Anagrus* spp. Results are presented as percent parasitism, meaning parasitized eggs per total eggs per leaf. Spider mites and predatory mites were counted by brushing the insects from 10 leaves on a glass plate, and then counting 20% of the plate surface for an estimate of mites/leaf. (Only two of the five sites had high enough mite populations to analyze.)

Methods used for gathering data on the plant species and cover crops included observation and assessment by a botanist, and conversations with the vineyard managers. The methods used for gathering data on the small mammals and birds included field observation and inventory of species every two weeks, and placing planks in the vineyards, which serve as refuges for amphibians and small mammals, that were monitored regularly.

Box 3: Case Study Sites
The project team selected five sites in the North Coast. In four cases the vineyard operators had already implemented practices that were deliberately aimed to conserve habitat or protect biodiversity – specifically hedgerows, and/or habitat corridors or "islands," and also planted annual cover crops. All sites are certified organic with the exception of Milovina, which represented a more conventional approach to vegetation management, and did not have deliberate biodiversity conservation practices beyond a tree row at one end of the vineyard and non-tilled floor vegetation. These vineyards and their general locations are:

- Fetzer Vineyards – Hopland, California, Mendocino County
- Bonterra Vineyards – McNab Ranch, Ukiah, Mendocino County
- Preston Vineyards - Healdsburg, Dry Creek, Sonoma County
- Benziger Vineyards - Glenn Ellen, Sonoma County
- Milovina Vineyards - Hopland, Mendocino County



Summary of Results and Conclusions:
The vineyard sites included in this study have an abundance of predators and beneficial insects that can help manage pests. During 2007, none of these vineyard sites had suffered economically significant damage from insects, and the vineyard operators did not use insecticides. Most of these vineyard operators have not used insecticides in previous years as well, since insect pests have not been major problems. In 2007, two of the vineyards (Bonterra and Milovina) had signs of some insect predation, but the damage was not serious enough to affect grape yields.

The presence of habitat – including hedgerows, corridors, islands, or riparian habitat – in and around the vineyard seems to be correlated with the high density of beneficial arthropods. In most of the cases, the presence of beneficial arthropods was higher close to the habitat corridor or hedgerow, and likewise, the pest insects tended to be lower in those locations. In the case of Preston Vineyards, there were unusually high populations of predatory mites relative to spider mites, throughout the growing season. It appears likely that this elevated presence of beneficial mites is associated with the addition of alyssum as a cover crop, which was planted between the vines every 10 rows in the Preston vineyard. (See case studies following for more detail.)

Although the benefits of the wildlife species were not possible to quantify in this study, it is clear that the habitat management practices help to conserve and attract a diversity of wildlife species. Previous studies have also confirmed the value of habitat corridors for maintaining wildlife.[8]The only animals that are seen as pests are deer (which are kept out with deer fencing), gophers, voles, and ground squirrels. The vineyard managers have reported the value of raptors in and around their vineyards, mainly for gopher control. Several vineyard managers also express appreciation of having wildlife species that are protected in and around the vineyards. Further research is needed to quantify the ecosystem services provided by mammals and birds in vineyard systems. It would be valuable to continue monitoring and collecting data for at least one more season, to gain information over time and in additional sites.

Case Study Information and Results

Bonterra Vineyards, McNab Ranch

Bonterra Vineyards' McNab Ranch is located in Mendocino County, between Hopland and Ukiah. The vineyard features an abundance of biodiversity, including planted habitat corridors, oak woodlands, and tree-lined riparian vegetation. The McNab Ranch is in Knight's Valley, a classic "box canyon" that opens to the Russian River valley on the east side. The McNab Creek runs through this valley, and drains into the Russian River. The valley floor is surrounded by the Mendocino Mountains on three sides, which rise steeply to over 2200 feet elevation.

The ranch has been farmed using certified organic methods over ten years, and it is also certified biodynamic. Besides having 134 acres of vineyards, the ranch includes an acre of lavender, which is harvested for oils, two acres of olive trees, bee hives, landscaping with drought-resistant plants such as rosemary and lavender, a pond, and over 100 acres of conserved oak woodlands. Chickens are also allowed to graze in the vineyards, rotated through different sections, which can help to control some cut worms and beetles, and add fertility to the soil.

The riparian vegetation in this ranch has been deliberately maintained and conserved to protect the streams and the natural biodiversity. Several habitat corridors have also been planted throughout the vineyard (in the mid-to-late 1990s) to enhance biodiversity. These habitat conservation management practices are viewed by the vineyard managers as ways to increase the ecological stability of the vineyards, to attract beneficial insect species, and to create corridors that allow the passing of wildlife. Himalayan Blackberry, elderberry, and poison oak have been removed from the riparian zones, to avoid species that are known to harbor Pierce's Disease. Birdboxes and perches are also installed near the vineyard.

The study focused on the planted habitat corridor (or mature hedgerow) next to a Merlot block on the northwest side of the ranch. The vineyard is on a vertical shoot positioned trellis with an 8 foot by 5 foot spacing. The rootstock is 5 C. This vineyard site is on a gently sloping escarpment. The habitat corridor is on an ephemeral stream that drains into McNab Creek. The channel is approximately 5 feet wide and 3 feet deep. The stream banks were stabilized with mortared rock walls and then planted on both sides to form a corridor that is approximately 250 feet long and 30 feet wide. The habitat corridor consists mostly of exotic herbaceous flowering perennials, woody shrubs and small trees. There are some native willow trees as well. This corridor originally was established with 106 plant species, and the majority of these plants are still living. Of these, the predominant plants are listed in Table 1. These plants provide flower resources from early spring to October, which attract a variety of insect natural enemies and pollinators. The insect and mammal monitoring was done in the Merlot vineyard next to this habitat corridor or hedgerow. The planting also adds beauty and interest to the site.

Table 1: Plant Species in Bonterra Vineyards Habitat Corridor (hedgerow)

Species under 4 feet in height	***Species under 4 feet (continued)***
Asters (*Aster frikartii*)	Feather Grass (*Stipa arundinacea*)Euphorbia
Butterfly bush (*Buddleia davidii*)	(*Euphorbia lathyris*)
Lavender (*Lavendula angustifolia, L. dentat*)	Cone flower (*Echinacea purpurea*)
Rosemary (*Rosmarinus officinalis*)	Verbena (*Verbena peruviana*)
Willow (*Salix exigua*)	Crabgrass (*Digitaria sanguinalis*)
Cat mint (*Nepeta x fassenii*)	Flax (*Linum perenne*)
Scarlet gaura (*Gaura lindheimeri*)	
Hybrid rose (*Rosa* sp.)	***Species over 4 feet in height***
Coreopsis (*Coreopsis verticillata*)	Rosemary (*R. officinalis* 'Tuscan Blue')
Fever few (*Chrysanthemum parthenium*)	Butterfly Bush (*Buddleia davidii*)
Blanket flower (*Gallardia X grandiflora*)	Medlar (*Mespilus germanica*)
Fig (*Ficus carica*)	Pampas grass (*Cortaderia selloana*)
Oregano (*Origanum vulgare*)	Red Willow (*Salix exigua*)
Climbing rose (*Rosa* sp.)	Rose hybrids (*Rosa sp.*)
Pomegranate (Punica)	Pomegranate (*Punica granatum*)
Artemesia (*A.* X 'Powis Castle')	Fig (*Ficus carica*)
Fennel (*Foeniculum vulgare*)	Peach (*Prunus persica*)
Yarrow (*Achillea millefolium*)	Pineapple guava (*Feijoa sellowiana*)

The vineyard practices used in this Merlot block at Bonterra included the following:
Cover crops: Mix of bell beans, vetch, clover, planted in the fall; mowed in spring and summer, cultivated every other row.
Pest/Disease management: 2 applications of wettable sulfur and an organic copper fungicide (Nordox®), and 5 sulfur dustings. No treatments were used for insects or mites.
Soil amendments: Compost (2-3 tons per acre), fish emulsion and biodynamic preparations.
Weed control: Mechanical methods, under vines.

Results of Insect and Mite Monitoring: *(Please refer to Appendix for details.)*

- The highest densities of *Anagrus* spp. was nearest the hedgerow, and declined in subsequent plots. *Anagrus* spp. density was quite high at Bonterra compared to other sites, averaging about 40 per card overall.
- No *Anagrus spp.* were found in the hedgerow until late June-early July, and even then relatively few were found.
- Overall, the first generation leafhopper nymphal density peaked between 7-12 per leaf, whereas second generation peak was 1-3 per leaf. At first generation peak, the lower leafhopper densities were found in the two plots nearest the hedgerow (3m and 21m)
- At the peak of second generation leafhopper nymphal density (Aug. 10 & Aug. 27), the highest densities were found in the plot nearest the hedgerow (3m), although it should be noted that overall, density was 3-4 times lower in the second generation than the first.
- Spider mite density was relatively high, with overall peak between 20-80 mites/leaf. During the peak of spider mite activities, densities tended to be lowest in the two plots nearest the hedgerow, but there was no such pattern for predatory mites.



Observations revealed a great diversity of wildlife species at Bonterra Vineyards, as listed below. The only species that cause occasional problems are gophers and wild turkeys. Deer could also potentially damage the vines, but they are kept out of the vineyards with fencing.

Table 2: Wildlife Species observed at Bonterra

Mammals and amphibians		**Birds** (species undetermined)
• coyote(*Canis latrans*)	• mice *(uncertain species)*	• owl
• skunk (*Mephitis mephitis*),	• bobcat (*Lynx rufus*)	• hawks
• opossum *(Didelphis virginiana*	• mountain lion (*Felis concolor)-rare*	• vulture
• raccoon *Procyon lotor*),	• *porcupine (Eurethizon dorsatum)*	• eagle
• deer (*Odocoileus hemionus*)	• snakes - *several species*	• ducks
• gray fox (*Urocyon cinereoargenteus*),	• lizards - *several species*	• geese
• wild pigs (Sus scofa)	• frogs – *several species*	• heron
• rabbit*(Lepus californicus*),	• salamander – *unknown species*	• egret
• gray squirrel (*Sciurus griseus*)	• bats – unknown species	• woodpecker
• vole (*Microtus californicus*)		• mockingbird
• gopher (Thomomys bottae)		• pheasant
		Other unidentified birds

Preston Vineyards, Dry Creek, Sonoma County

Preston Vineyards, in Dry Creek, northern Sonoma County, is a diversified operation, and includes several planted hedgerows, a garden with diverse fruits and vegetables, and many planted trees and shrubs in the riparian zone along the creeks. Chickens are also maintained on site for egg production. The entire operation is certified organic, and is also certified by the Fish Friendly Farming® program. The Preston vineyard site is situated on an alluvial fan that slopes gently from the south to Dry Creek. The remnant native vegetation of the region outside of the vineyard is oak woodland consisting of valley oak, blue oak and interior live oak. The vineyard floor is managed with summer tillage and winter annual cover crops. In the spring, cover crops are mowed and incorporated into the soil.

The vineyard owner has incorporated five hedgerows (also called habitat corridors or insectary corridors), spread out through the vineyards. These hedgerows were established in 2004, in collaboration with a non-profit organization called Circuit Riders and with the Sotoyome Resource Conservation District, which received government funding for conservation projects. The study focused on the hedgerow planted next to a block of Zinfandel, a heritage clone. The vineyard spacing is 10 foot by 8 foot and it has a three-wire "California sprawl" trellis. This hedgerow consists of a mix of native and non-native herbaceous perennials and woody shrubs that covers an area 12 feet wide by 275 feet long. It is not associated with any stream or water course. The planting is not mature, and the plant material is actively expanding in size.



Most of the plant material is under 4 feet in height, and there are a few small trees. The hedgerow is in very good condition, and is regularly maintained, irrigated and mulched with rice straw. This block also includes corridors of alyssum (*Lobularia maritima)*, a plant species that is well known for attracting beneficial insects, planted every 12 rows between the vines, which is irrigated with microsprinklers. Alyssum is an annual plant that regenerates itself.

Table 3: Hedgerow Plants included in Preston Vineyards (next to Zinfandel block)

Plant Species	**Plant Species (continued)**
Asters (*Aster frikartii*)	Toyon (*Heteromeles arbutifolia*)
Penstemon (*Penstemon gloxinoides, P. heterophylla*	White thorn (*Ceanothus leucodermis*)
Butterfly bush (*Buddleia davidii*)	Lavender (*Lavendula angustifolia, L. dentata*)
California Buckwheat (*Eriogonum fasciculatum*	Scarlet sage (*Salvia splendins*)
Coffee berry (*Rhamnus californica*)	Sage (*Salvia greggii*)
Purple sage (*Salvia leucophyll)*	Coyote bush (*Baccharis pilularis*)
	Sticky monkey flower (*Mimulus aurantiacus*)

Vineyard practices used in this block include the following:
Cover crops: "Soil Builder" mix of cover crops seeded in October, disked under in March-April. The mix consists of bell beans, peas, vetch, oats, and mustard for nematode control.
Pest/Disease management: During the first 3 - 4 weeks of growth, used a combination of compost tea and milk whey from a goat dairy - a total of 6 applications of compost tea and whey, every 10 days. 3 applications of sulfur dust were then used, started 3 weeks later than the norm.
Soil amendments: Compost after harvest and before seeding cover crop; 5 tons/acre in 2006, 3 tons in 2007. Application of broad spectrum minerals.

Results of Insect and Mite Monitoring: *(Please see Appendix for details.)*

- *Anagrus* spp. and leafhopper density were generally low at this site, with overall Anagrus spp. Density about 10 per card, leafhopper density between .5 and 1.5 nymphs per leaf in the first generation and less than 1 per leaf in the second generation.
- There was no clear pattern between *Anagrus* spp. and either the hedgerow or alyssum.
- An interesting finding was that, although spider mite density at Preston was extremely low (less than 8 mites per leaf at peak), predatory mite density was relatively high (between 102 mites per leaf from mid-June to mid-September). It cannot be said with certainty that this is related to the hedgerow or alyssum corridors, but it is an unusual situation that warrants further study. (The vineyard owner feels this may be partly related to the very low use of sulfur, since the mite populations were higher before he significantly reduced his sulfur use.)

Many wildlife species have been observed regularly at Preston Vineyards, as noted below. The majority of these species are perceived by the vineyard owner as beneficial. The only animals which pose problems to the vineyard are gophers, but the vineyard owner has seen birds hunting gophers. Deer are rare in this area, partly due to the blockage by Dry Creek, so deer fencing is not used in most parts of this vineyard.

Table 4: Wildlife Species observed at Preston Vineyards

Mammals and amphibians		**Birds** (species undetermined)
• coyote(*Canis latrans*)	• bobcat (*Lynx rufus*) rare	• owl
• skunk (*Mephitis mephitis*),	• mountain lion (*Felis concolor)-rare*	• hawks
• opossum *(Didelphis virginiana*	• snakes - *several species*	• vulture
• raccoon *Procyon lotor*),	• lizards - *several species*	• eagle
• gray fox (*Urocyon cinereoargenteus*)	• frogs – *several species*	• ducks
• rabbit*(Lepus californicus*),	• salamander – *unknown species*	• geese
• gray squirrel (*Sciurus griseus*)	• bats – unknown species	• heron
• vole (*Microtus californicus*)		• egret
• gopher (Thomomys bottae)		• woodpecker
• mice *(uncertain species*)		• jay
		• mockingbird
		• starlings (and others)

Fetzer Vineyards, Sundial Ranch

The Sundial Ranch of Fetzer Vineyards is in Hopland, Mendocino County, and is planted along the Russian River in Sanel Valley directly across from the Fetzer winery. The site is on a flood plain formed between the Mendocino Mountains on the west, and the Mayacama Mountains on the East. The flood plain is formed in a fairly wide portion of the Sanel Valley (approximately 2 miles). The soil is a deep well-drained Russian River loam. The vineyard was planted in 1986 to Chardonnay on AXR-1 rootstock. The spacing is 6 x 10 feet and it is trained on a California 3 wire sprawl system. It is a productive certified organic vineyard, planted mostly in Chardonnay grapes. Phylloxera has been present in the vineyard since 1994.

The vineyard floor is usually managed by seeding every other row with a mixture of annual clovers every three years (similar to the McNab Ranch plantings), and then the resulting growth is mowed at least twice annually to a height of 4 inches. Alternate rows are tilled annually and seeded to a mix of annual grasses and legumes that include oats (*Avena fatua*), bell beans (*Vicia faba*), common vetch (*Vicia*), purple vetch (*Vicia*), Daikon radish and other mustards (*Brassica* sp.) After three years, the middles are rotated. (In 2007, however, the cover crops were different, as indicated below.)

The focus on the study in this site was the riparian area adjacent to the vineyard which is mature, healthy and vibrant. The channel of the river is approximately 100 feet wide and 20 feet deep. The area that we surveyed is 300 feet long by 50+ feet wide. The vegetation in this area is typical of a climax riparian forest found in Northern California, consisting mostly of native trees and shrubs. The species in the riparian habitat are noted in Table 3 below. The vineyard owners have attempted to remove and cut back poison oak and blackberry, which are known to be a host species for Pierce's Disease. Several birdboxes are also installed in this vineyard.

Table 5: Species in the Riparian Habitat in Fetzer Vineyards, Sundial Ranch

I. Composition of Adjacent Riparian Area Vegetation, 0-6 Feet in Height	II. Composition of Adjacent Riparian Area Vegetation, 6-100+ in Height
Himalayan Black Berry (*Rubrus procerus*)	Box Elder (*Acer negundo*)
Wild Rose (*Rosa multiflora*)	Red Willow (*Salix exigua*)
Teasel (*Dipsacus sylvestris*)	Valley Oak (*Quercus lobata*)
Snow berry (*Symphoricarpos albus*)	Northern California Black Walnut (*Juglans hindsii*)
Poison Oak (*Rhus diversiloba*)	Grey Willow (*Salix sp.*)
Poison Hemlock (*Conium maculatum*)	Oregon Ash (*Fraxinus latifolia*)
	Fremont Cottonwood (*Populus fremontii*)

The vineyard management practices in 2007 for the Sundial Ranch included the following:
Cover crops: 97% clover (including crimson closer and rose clover) and 3% Queen Anne's Lace, seeded in the fall.
Soil amendments: Compost applied at 2 tons per acre in the fall.
Disease/Pest management: 3 applications of stylet oil - 1% solution in 75 gallons of water per acre, and 5 applications of sulfur dust 10-12 pounds per acre. No treatments were used for insects.
Weed management: Tillage under the vines.

Results of Insect and Mite Monitoring: (*Please see Appendix for details.)*

- Overall, leafhopper density was low at this site. (First generation peak was less than 1.5 nymphs per leaf.)
- Leafhopper density was consistently lower in the section nearest the riparian corridor from May 30 to July 6.
- *Anagrus* spp. density was low overall (about 20 per card), and showed no relationship to the riparian corridor.
- Minute pirate bug and black hunter thrips densities were high from May 18-June 24 (peaking at over 90 percent), and there appeared to be a relationship with the riparian corridor, as the highest densities of these generalist predators were in the section nearest the corridor for the first six weeks of this period.

The wildlife species observed in this vineyard were nearly identical to those observed at Bonterra Vineyards (See Table 2). However, mountain lions have not been seen, and coyotes and bobcats are rare in this site, probably because it is located much closer to a well-traveled road and buildings, compared to the Bonterra site.

Benziger Vineyards, Glen Ellen, Sonoma County

Benziger Vineyards is located in Sonoma County. Benziger has also incorporated many practices to protect and enhance biodiversity, including protecting trees and riparian habitat on the creeks that run through the vineyard, and planting various species in the landscaping. They have also established a wetlands reed-bed pond which is used for treating the winery wastewater, and also enhances biodiversity and attracts birds.

The study focused on an "island" of diverse insectary plants in the midst of a vineyard block. This island includes flowering herbaceous annuals and perennials at the center of the vineyard, which serves as a refuge for beneficial insects. The mix of plants provide flower resources from early April to late September, as noted in a previous study of this vineyard.[9]

Insects were monitored in the vineyard next to this insectary island. The insectary consists of mainly flowering plants which are very attractive for beneficial insects, butterflies, and birds. It also has a value for tourism, since Benziger receives thousands of visitors each year. The vineyards next to the insectary are Sauvignon Blanc and Cabernet Franc grapes. These vineyards are farmed with certified organic and biodynamic practices.

The vineyard practices in the block near the insectary are the following:
Cover Crop: Mix of peas, common vetch, barley, and oats.
Soil amendments: Compost applied at 2-3 pounds per acre, and biodynamic preparations (including 2 sprays of horn manure).
Disease/pest management: 2 sulfur dustings and one wettable sulfur application, and 6 applications of Serenade® (a biofungicide). No applications for insects and mites.
Weed control: Mechanical, under the vines.

Table 5: Plants in the Insectary "Island" at Benziger Vineyards

Plants that are intended to attract hummingbirds	Plants that are intended to attract butterflies and beneficial insects
	Butterfly Plants
Orange Carpet (*Zauschneria garrettii)*	Yellow Kangaroo Paws (*Anigozanthus flavidus)*
Sunset Hyssop (*Hyssopus officinalis)*	Wine Cups (*Callirhoe involucrata*)
Autumn Sage (*Salvia elegans)*	Whirling Butterflies *(Gaura lindheimeri)*
Texas Red Yucca (*Yucca gloriosa)*	Arctic Summer *(Verbascum bombyciferum)*
Firecracker Penstemon (*Penstemon gloxinoides)*	
Pineleaf Penstemon (*Penstemon pinifolius)*	***Insectary Plants***
Desert Beard Tongue (*Penstemon antirrhinoides)*	Moonshine Yarrow (*Achillea tomentosa*)
Mexican Sage (*Salvia leucantha)*	Blue Catmint (*Nepeta faassenii)*
Malibu Yellow (*Kniphofia uvaria)*	Prairie Coneflower (*Ratibida columnifera)*
Red Hot Popper (species unknown)	Russian Sage (*Perovskia atriplicifolia)*
	Blackeyed Susan (*Rudbeckia hirta)*
	Purple Coneflower *(Echinacea purpurea)*
	Monch

Results of Insect and Mite Monitoring: (*Please see Appendix for details.)*

- Overall, leafhopper and *Anagrus* spp. density was quite low at this site (less than 1 nymph per leaf), as was *Anagrus* spp. density (about 3 per card overall); and no spider mites or predatory mites were found.
- Despite low density of *Anagrus* spp., there was a pattern of declining density with increasing distance from the insectary.

A previous study undertaken in this site also showed the effectiveness of the insectary island in attracting beneficial insects. [10] Wildlife species observed at Benziger are similar to the species found at Bonterra (See Table 2) and Preston Vineyards, although mountain lions are rare in this area. Additional observations are needed to evaluate the wildlife in this site.

Milovina Vineyards, Hopland, Mendocino County

The Milovina Largo Vineyard is located between Hopland and Ukiah, in Mendocino County, in the Crawford Creek watershed. The land form is a broad box canyon. The valley floor is surrounded by the Mendocino Mountains on three sides, which rise steeply to over 2000 feet elevation. Parent material is uplifted marine sand stones with intrusions of basaltic serpentine rock.

The vineyard site for this study is on a small flood plain formed by alluvium from the surrounding steep hillsides. The soil is a well drained Cole loam. The study focused on the Chardonnay block, next to a streambed. In this vineyard, most native vegetation has been removed, but there are remnant large trees from an oak woodland that once covered the site. The stream channel is stable, but only a few large trees remain. The stream flows west to east, and drains into the Russian River approximately 1 mile to the east. Most of the streambank is covered with non-native grasses and forbs including annual ryegrass, wild oats, rip gut brome, soft chess and other low succession plants that are neatly mowed up to the rim of the water course. These plants are dry and brown by mid-summer. The channel is on the average 11 feet wide and 4 feet deep.

The vineyard is planted to Chardonnay on 101-14 rootstock. The vines are trained on a vertical shoot position trellis system. The vineyard floor is mowed in the spring. No cover crops are seeded, and annual grasses and forbs are mowed to under 4 inches in the spring. Weeds found include shepard's purse, annual bluegrass, scarlet pimpernel, annual ryegrass, soft chess and wild oats. The vineyard floor is dry and mostly free of green vegetation during the growing season. Along the small creek which is approximately 154 feet long, there are 6 mature Valley Oak trees *(Quercus lobata)*. Most of the trees are over 70 tall. Other vegetation is regularly removed. This site is by far the simplest of the five case studies from a floristic perspective.

Vineyard practices on this block included:
Cover crops: Only natural vegetation between vines which is mowed to under 4 inches in the spring for maintenance; no seeded cover crop.
Disease/Pest management: 4 wettable sulfur applications, 2 sulfur dustings, one application of Rally® (sterol inhibitor); No treatments for insects and mites.
Soil amendments: Potassium 3 times in season, Nitrogen one time in drip.
Weed control: Glysophate application one time under the vines only.

Results of Insect and Mite Monitoring: (*Please see details in Appendix)*

- This site had high densities of *Anagrus* spp. (about 70 per card overall), which seemed to decrease 50 meters from the tree line, increase at 70 meters, and decrease again at 90 meters.
- Leafhopper nymphal density was moderately low, but consistent (about 2 per leaf for a period of several weeks), but did not exhibit a clear generational distinction, and no pattern with respect to the tree line.
- This site had one of the highest densities of minute pirate bugs and black hunter thrips (peaking at between 15 and 40 per card). On most sampling dates the lowest density of these generalist predators was in the plot nearest the tree line.

The wildlife observed at this site included: deer, rabbits, gophers, raccoons, bobcats, coyote, heron, hawks, vultures, crows, owls, and heron. Once again, we do not have quantitative data on the frequency of siting, but it appears that the populations of wildlife in this site are less than in other sites, given the proximity to a very busy highway (101), and the relatively low amount of natural habitat. Nevertheless, there seems to be an abundance of large birds, which frequently pass through this valley.

See Appendix A for details and graphs from insect monitoring from all five sites.

Gaps and Further Research Needs

The data from these case studies showed interesting findings about the potential beneficial effects of plant and habitat biodiversity on the presence of insect populations and other species in these vineyards, as mentioned on page 4. Moreover, the vineyard sites had relatively abundant populations of beneficial insects, and they did not have any major pest problems. However, there are still gaps in understanding of the specific functions and impacts of the habitat conservation practices such as hedgerows and habitat corridors. Given the complexity of these vineyards and the ecosystem conditions, it is difficult to identify specific cause-effect conclusions. Limitations of time and resources for the project did not allow for further analysis at this stage. The results from these studies cannot be easily generalized to all vineyard systems in California's North Coast, but they do provide some noteworthy indications about the useful role of biodiversity conservation.

More research is needed to analyze biodiversity conservation practices in these sites and in other sites over time, and to address other questions and variables in the system such as:

- what are the specific effects of the different cover crop mixes (compared to the hedgerow/corridor effects) on the insect species in each case;
- what are the preferred plant species (or mix of species) to use in the habitat corridors/hedgerows that are effective for attracting beneficials;
- what variations are caused by climate-related or geographical variables in each case;
- what are the effects of timing of vineyard practices, particularly mowing of the cover crops (which usually releases more insects into the canopy, according to previous studies)[11], and shoot-thinning, or leaf removal (which can also reduce insect predation); and
- what climatic/site-specific factors influence the incidence of insects and other species.

We hope that these questions can be addressed in future studies, to provide further insights about functions and values of biodiversity conservation in agricultural ecosystems.

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Appendix D: California native plants that grow in part shade

Achillea millefolium lanulosa, Mountain Yarrow can grow only few inches tall or a few feet according to how it's pruned. It has soft lacy foliage. Flower stalks are a few feet tall and terminate in large white flower clusters. It makes an excellent groundcover for part shade. It tolerates sea side conditions.

Diplacus (Mimulus) aurantiacus, 'Sierra' Sticky Monkey Flower In the demonstration garden we have a Sierra Sticky monkey flower under a coast live oak in nearly full shade. It will flower more in part shade than in full shade. This monkey flower was watered 3 times when we planted it 5 years ago. Now it thrives on rain alone (~15 in).

Diplacus (Mimulus) puniceus, Southern Monkey Flower Southern Monkey flower likes part or full shade. This monkey flower fries in full sun here. This plant was watered three times when we planted it two years ago.

Ramona Monkey flower, *Diplacus aurantiacus australis* grows int a neat little bush in sun or part shade.

Diplacus (Mimulus) longiflorus Var. rutilus, Pasadena Red Monkey Flower, Pasadena red monkey flower was planted in full shade here and has never been watered. Although we've used it in full sun everywhere else, we've lost every one we've put in full sun here.

Fremontodendron californicum, California Flannel BushCalifornia Flannel Bush is an evergreen shrub that can reach 10 ft high. It is drought tolerant and cold tolerant. It prefers well drained soil.

Heteromeles arbutifolia, Christmas BerryChristmas berry or Toyon is a large dense evergreen shrub. Toyon grows 6 to 8 ft tall and 4to 5 ft wide. It is covered with red berries around Christmas. The birds love this shrub. They use it for cover and eat the berries. It will grow in part shade or full sun.

Heuchera merriamii, Siskiyou Alum RootSiskiyou alum root has bright green foliage and cream colored flowers. It is very cold tolerant.

Heuchera rubescens glandulosa, Jack o the rocks This hearty alum root tolerates -10 deg F. It grows to 3 ft tall and has tall reddish flowers. It likes part shade,

Keckiella cordifolius, Climbing PenstemonThis is also called heart leafed Penstemon. The foliage is a dark shiny green and heart shaped. The branches are arching and terminating in multiple orangish-red Penstemon-like flowers. This isn't a vine but it will hold on to neighboring shrubs when the branches get to long to support their own weight. In part shade it will get around 6 to 8 ft tall. It is very drought tolerant. Hummingbirds like it.

Lepechinia ganderi, San Diego Pitcher sage This is our most delicate Pitcher sage. New stems are dark brown showing of large faint purple flowers.

Lonicera hispidula, California Honeysuckle California Honeysuckle is a showy pink honeysuckle. It is popular with hummingbirds. It is very drought tolerant and does well in part sun.

Lonicera involucrata ledebourii, Twin berryTwin berry is a deciduous shrub with orange flowers that emerge in pairs. Later fat black berries take their place. Birds like the berries.

Monardella subglabra, Mint Bush isn't much of a bush but it is bigger and bushier than the other Monardellas. It is also very popular with the butterflies. It likes a little moisture and part sun.

Prunus ilicifolia, Hollyleaf Cherry reaches about 15 ft high. It will grow in part shade or full sun. It is very drought tolerant. The berries are edible. It is a good bird plant.

Prunus lyoniii, Catalina Cherry is a cherry native to the islands. It likes part shade of full sun. Young trees are not cold tolerant. It produces large black berries that are mostly seed with little meat on them.

Philadelphus lewisii, Wild Mock Orange has lots of white flowers that smell like orange blossoms. It can survive in dry conditions but it prefers part shade and a little moisture. It grows any where from 3 ft to 6ft tall. Generally it is shorter in full sun.

Spiraea douglasii, Western Spiraea is a 4 to 5 ft tall deciduous shrub with long arching branches. It has attractive foliage that turns red and orange in the fall. It likes moist areas in part or full sun.

Calycanthus occidentalis, Spice Bush is a rounded shrub that reaches about 4 ft high and 4ft wide. It has large shiny leaves and is deciduous. The flowers are red and smell like red wine. It is deciduous in the winter. The attractive seed pods dry on the plant and hang around through the winter.

Cercis occidentalis, Western Redbud is a small deciduous tree. It has a nice upright form. It is popular for its showy, burgundy flowers that emerge in spring before the leaves. The leaves are glossy and heart shaped.

Adelaide Monkey Flower in the demonstration garden is growing in an area with morning sun in the shade of Cercocarpus alnifolius. It has never been watered.

Dwarf Flannel Bush, *Fremontodendron californicum ssp. decumbens.*We've lost more Fremontias to under watering than to over watering in sandy soils that they prefer. (In clay soils plant them on a rock mound.)

Fremontodendron californicum ssp. californicum X californicum ssp. decumbens, 'Ken Taylor'. We planted 4 barely rooted plants a year ago, then watered them 2 to 3 times and forgot about them. The ones in the shade died and the ones in part shade (not much just enough to take the heat off) are 6 ft. across and 3 ft. tall.

Heuchera hirsutissima, Idyllwild Rock Flower likes moist areas. It does well in part shade. It is very cold tolerant as it is native at high elevations.

Heuchera maxima, Island Alum Root has large palmate leaves and tall creamy flower stalks. It likes part or full shade. It seems pretty drought tolerant if it has a lot of mulch.

Heuchera micrantha, Alum Root is very floriferous. Flowers are cream colored and denser than H. maxima,not as cold tolerant as Siskiyou alum root but more tolerant than Island alum.

Iris douglasiana, Douglas Iris is a delicate native iris with deep purple flowers. It is very drought tolerant in the shade. It likes a little mulch. It does well in part or full shade.

Keckiella ternata, Summer Bush Penstemon is a bush Penstemon is similar to climbing bush Penstemon but it is a bit neater. It makes a nice open shrub about 3 ft tall. The foliage is shiny and dark green.

Lepechinia fragrans, Wallace's Pitcher sageWallace's Pitcher sage has fuzzy foliage and purple flowers. It is very floriferous even in shade. It doesn't like dense shade. It is drought tolerant.

Lonicera interrupta, Chaparral Honeysuckle Chaparral honeysuckle is very drought tolerant.

Mahonia neviniii is a very showy shrub with prickly but just don't plant it near a walk way. It has gray holy-like leaves. In spring it is covered in yellow flowers that are popular with insects.

Monardella antonina, Butterfly Mint BushButterfly mint is a fragrant little perennial with purple flowers. The flowers are a big hit with butterflies. Butterfly mint likes part shade or full sun.

Prunus virginiana demissa, Choke Cherryhas large white flower clusters. It has soft foliage and an open erect form.

Sambucus mexicana, ElderberryElderberry is a small tree with fragrant yellow flowers and bluish black berries. The berries are used to make wine and cobbler. It makes an excellent little shade tree.

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