CARBON-REDUCTION METHODS IN NORTHERN CALIFORNIA VITICULTURE

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ABSTRACT
California's wine industry is among the first commercial sectors to recognize the importance of identifying standards to calculate a carbon footprint for business operations and integrating new methods within its own operational practices to reduce it. In response to the ongoing cycle of drought and wildfire in their region, Sonoma, Napa and Mendocino wineries have introduced significant carbon-reduction measures in their processes, both in the vineyard and the production facilities. Utilizing case studies of select wineries in this region, we will provide representative examples of carbon reduction through regenerative agricultural practices in fertilizer and other vineyard inputs, onsite renewable energy installations, water conservation and green practices in facility construction. We will also review current trends in packaging materials and distribution impacts, the newest focus of carbon input reduction in the industry. Our paper will provide examples on how the wine industry's move toward a more sustainable business model can be replicated by other agricultural businesses.
Keywords: biodynamic® winemaking, carbon reduction, Napa County, regenerative agricultural, Sonoma County, sustainable farming, viticulture, climatic influence, climate change, adaptation measures.

1 INTRODUCTION

Wine regions around the globe are grappling with the impact of a changing climate [1]. A warming climate with unpredictable extremes in seasonal temperature is a direct existential threat to winemakers. Each harvest lost to a late frost or wildfire smoke taint has long-term impacts on annual profit and future business growth for the wine grower. Grape varietals impacted by hotter growing seasons have increased alcohol content or altered taste which pose challenges to winemakers working in traditional appellations [2].

California's wine industry has a long history of utilizing organic practices in viticulture and has expanded focus in recent years to incorporate carbon-reduction technologies into viticulture and enology. One of the earliest studies was conducted in 2005, when researchers at University of California at Davis published the results of their 10-year comparative study on carbon sequestration in organic and non-organic systems and concluded that organic systems were significantly more successful [3]. In 2007, the Wine Institute, an association of 1,000 California wineries and affiliated businesses, began a literature review of information about greenhouse gas (GHG) emissions and vineyards and commissioned a study from sustainability consulting firm PE International on the carbon footprint of California's wine industry in 2011. The findings detail the relative impacts for the carbon footprint of packaged wine, cradle-to-retail gate, providing baseline percentages of carbon emissions in four main categories: vineyard, winery, packaging and transport [4]. In 2012, the California Sustainable Winegrowing Alliance (CSWA) introduced performance metrics to further assist growers and winemakers in tracking their specific resource use and related emissions.

Agriculture is one of the five economic sectors tracked annually by the U.S. Environmental Protection Agency (EPA) in an inventory of trends in U.S. GHG emissions and sinks. Transportation, electric power, commercial and residential, and industry are the other four. In 2021, agriculture accounted for 10% of U.S. GHG emissions, including sources such as livestock, enteric fermentation, and manure management, N_2O emitted from managed

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agricultural soils from fertilizers and other inputs, and agricultural equipment fossil fuel combustion [5]. In 2022, the California Air Resources Board approved a scoping plan that called for an acceleration of the transition to healthy soil management to 80,000 acres annually by 2025 and also set a goal that at least 20% of all cultivated acreage in the state use organic methods by 2045.

Trends over time show that the agricultural sector has not been successful in reducing carbon emissions nationally. From 1990 to 2021 emissions from soil management increased by 2.1% nationally and emissions caused by overall agricultural activities increased by 9.1%. In California, however, some progress is being made. Although emissions from overall agricultural activities in the state continue to climb, particularly in the categories of liming amendments and manure management, the category of soil management has decreased by 2.7% [6].

Grapes constitute California's second highest valued agricultural commodity, representing $5.23 billion in revenue in the 2021 crop year [7]. As grape growers and winemakers in the state have already begun their industry-wide shift to carbon-reducing practices without sacrificing profit or product quality, their progress provides a template for other industries in the agricultural sector to follow.

The following are some of the key methods they use.

2 SOIL HEALTH AND REMEDIATION

The 2011 Wine Institute report on the carbon footprint of winemaking in California identified bio-chemical field emissions as the leading contributors of GHGs in the vineyard category followed by raw material production in the manufacture and shipment of materials such as fertilizers and pesticides. Together these two factors can represent 27% of a winery's overall carbon emission and is the second largest contributing factor surpassed only by wine bottle packaging, which is categorized at 29% in the report. Overall, vineyard field emissions are considered one of the four key areas, or 'hot spots' as they are known in industry terminology, where wineries could make significant impacts in carbon-reduction.

Winemakers and grape growers are early adopters of carbon reducing methods and practices in cultivation and soil management, largely through the pioneering work of Robert 'Amigo Bob' Cantisano. His knowledge has been collected in *KNOW YOUR SOIL*, published in 2022 by Felix Gillet Institute working with wife and partner Jennifer Cantisano.

For over 30 years, wineries throughout Napa Valley, including Sutter Home, Frog's Leap, E. & J. Gallo, Stag's Leap, Tres Sabores and others sought Cantisano's advice on closed system farming, which aims to reduce external inputs such as chemical pesticides and fertilizers. His consultancy from vineyard to vineyard created a research network on soil fertility, drought management and pest resistance within the region and beyond.

Cantisano disapproved of surface-level transitions to organic viticulture as a selling point or a label winemakers could market to consumers. In 1973, he became a founding member of the California Certified Organic Farmers (CCOF), a non-profit organization of farmers, ranchers, processors, retailers, consumers, and policymakers that has sponsored legislation and awareness nationwide.

When Cantisano approached a vineyard transitioning from conventional to regenerative methods, his first step was to identify the root of the problem: neglect or over-attention. Neglected soil is considered easier to transition, because although poor soil may be depleted, it is easily remediated with the application of compost and other specific amendments. Conventional over-attention, common in the agricultural sector, is characterized by high usage of fertilizers, water, and chemical additives. Conventionally farmed vineyards pose the bigger challenge in transition in part because the soil is soaked with chemicals. Populations of beneficial insects, fungi, and bacteria are decimated, and vines are often in very poor condition.

Conventional over-attention soil management through fertilizers and other inputs creates a runaway treadmill effect, that is, a feedback loop, where the farmer has to apply more and more treatments to alleviate those negative effects. Each conventional application can have side effects. Using chemical fertilizer depletes the soil of nutrients, degrades organic soil matter, and alters the biological composition. Additional nutrients then have to be applied to remediate. Depleted soil does not drain water as well as rich, healthy soil, so water pools on or near the surface, which drives the root systems of the vines to stay shallow. Shallow roots are more susceptible to insect and vermin attacks, which can distress vines, making them more vulnerable to disease and forcing them to require more frequent irrigation.

Cantisano identified three main subgroups on the over-attention side based on a simple metric of how many products were currently used in the growing cycle:

- Minimalists (~10 products)
- Moderates (11–25 products)
- Intensivists (25+ products)

Soil analysis is done through approximately 10 samples per section of the vineyard, from various positions within each block of crops. Soil extracted by shovel or soil probe is drawn from 12 inches deep, enough to fill a cup with dirt from each sample. Samples from that block are mixed together but each block's soil is chemically analysed separately. Results of the analysis indicate what nutritional deficiencies or chemical abundances are present, which informs what soil amendments and cover crops to use for the first year. A geologic or soil map may be referenced as well to look at what type of soil is present and where it may have originated. For new vineyards, 12 to 36 subsoil samples, in addition to the topsoil samples, are usually taken before planting.

Once the soil's root problems are identified and a remediation proposed, Cantisano advised his clients to start their transition with a smaller section, keep their changes simple, and measure the differences. He recommended 10% of the planted acres for the first season, as a safeguard to protect the bulk of the harvest in the event of unexpected results. The method also allowed comparative analysis of the quality of the vines and grapes under each treatment.

This phased approach has an additional benefit of slowly moving growers and owners away from conventional farming preferences. Vineyard managers in particular often have serious concerns with transition, which they are pushed into doing by owners who may not be very involved with what happens in the field.

Transition from conventional to organic in California is a time-intensive process. It now takes 3 years from the last chemical input date for a grower to certify organic, but Cantisano noted that many chemicals take much longer than that to decompose. For instance, a study by Cornell University found that Roundup®, specifically, can take anywhere from 1 to 174 days for half the product to break down in soil, or approximately a year at maximum to fully break down [8]. This represents only one of many additives that may be present in conventionally treated soil that will need time to break down once the conventional treatment has stopped.

Regenerative transition in grape growing begins from the ground up, with soil ecology and an emphasis on biodiversity, exactly the opposite of the 'destroy all intruders' approach of conventional methods. Winemakers who follow Cantisano's methodology today start by encouraging the soil's natural fertility through increasing diversity, helping the soil to work within the system as it once did. Slowly, the approach creates a new, closed system that no longer requires constant outside inputs to produce fruit, while increasing the quality of the grapes and greatly increasing the value and quality of the wine.

2.1 Case study: Frog's Leap Vineyards

Located in Napa Valley's Rutherford region, Frog's Leap opened its doors in 1981. The man behind the venture is John Williams. Frog's Leap has deep roots in Napa Valley, from the Old Red Barn to its connection to Stag's Leap Winery. The philosophy at Frog's Leap Winery is that what is best for the earth is best for the grapes, making sustainability worthwhile. It operates 160 dry-farmed grape acres, plus 15 acres of other crops. Frog's Leap grows 30+ crops commercially, including peaches and other fruit trees. Through this practice of polycropping, Frog's Leap is able to support healthy populations of beneficial insects, birds, and soil.

Convinced that organic farming produces a healthier vine and a better wine, John was introduced to Amigo Bob Cantisano through a contact at Fetzer Winery in 1988, and a year later, Frog's Leap received CCOF status. Realizing he was just one link in the chain, John went to his grape grower partners and pitched organic farming to them, offering a financial incentive to make the transition. Pat Garvey, Lee Hudson, Mike Wolfe, Frank Leeds and Andy Hoxsey agreed to join John in becoming among the first to transition to organic.

Following the tenants of Cantisano's approach, Williams believes that healthy, vibrant, microbial-dense soil is more suited to absorbing winter rains and become a source for the nutritional and water needs of the plant all year long. He is a proponent of maintaining biodiversity through cover crops and insectary borders. His approach is minimally interventionist, allowing the vines to be free to use their canes and leaves to measure the angle of the sun, the length of the day and warmth of the evening air.

In 1996, Williams purchased a long-time conventionally farmed vineyard. The vines present on that property were nearly dead from Phylloxera most likely caused by excessive glyphosate use. His first step to bring the vineyard back to life was remove the old vines and plant new ones. Prior to his acquisition, the field had been replanted three times over 30 years due to illness and poor soil health. After initial replanting and a transition to organic farming methods, the new vines are now nearing 30 years of productivity.

In 2010 Williams received a 'Susti' Lifetime Achievement Award at the Ecological Farming Conference. In 2013, Frog's Leap Vice President and Senior Advisor of Viticulture and Farming, Frank Leeds, was named 'Grower of the Year' by the Napa Valley Grapegrowers.

3 RENEWABLE ENERGY INSTALLATION

In the 2011 Wine Institute report, industry assessors identified vineyard and winery electricity usage for operations as another key area where the greatest opportunities for reduction of overall carbon footprints could be found. In a table of relative impacts for the carbon footprint of packaged wine, cradle-to-retail gate, the report places energy consumption from the winery itself as a 7% contribution to overall carbon footprint and electricity consumption in the vineyard at an additional 4%, for a total of 11% [4].

The Wine Institute report also outlined three improvement opportunities for wineries interested in implementing renewable energy in their operations. Conducting an energy audit of vineyard and/or winery is the first recommended step, followed by implementation of energy efficient measures. Installation of on-site renewable energy options is the third step, a significant investment in infrastructure that, in time, offers the most value in operating costs as well as carbon-reduction.

3.1 Case study: Marimar Estate, Sebastopol, California

In April 1993, far-flung members of the famed Spanish winemaking family, Torres, gathered in Green Valley, Sonoma as Marimar Estate opened the doors of its newly built 16,000 case winery and 56 acre vineyard. Over time, Marimar Estate would expand its main property to 81 acres, acquire additional 180 acres in a West Sonoma property for a second vineyard, launch a popular wine club program noted for its celebrations of food and wine, welcome Spanish royalty as guests, champion the introduction of Spanish varieties to the region, and become renowned for its high-quality Chardonnays and Pinot Noirs.

The first thing that greets visitors on the hillside drive to Marimar Estate is an elegant line of solar panels. As part of its commitment to sustainable business practices, the Estate became 30% solar in 2007. It completed the transition in 2015, when the entire winery and the two houses on the property became 100% solar-powered.

Marimar's conversion to solar began with conventional rooftop panels on the main structure. This initial installation was overseen by Premier Power of Eldorado Hills, California, a company that has developed commercial solar projects in six countries. To complete the winery's full conversion to solar power, Marimar Estate then worked with Westcoast Solar Energy in Sonoma County to install three additional solar panel grids along the property entrance. The overall project size is a 65.835 Ground Mounted PV System kW DC using 209 SolarWorld SW315XLMono Modules, two SMA Tripower20000TL-US-10 inverters and one SMA Tripower 15000-TL-US-10 inventor.

Marimar Estate utilizes the Westcoast Solar Energy solar monitoring dashboard, an application designed for tablets and mobile devices. The dashboard offers commercial clients a real-time measurement of how much energy was produced and how many resources were saved by utilizing the sun's natural energy. For wineries and businesses reporting on overall carbon-reduction metrics, this tool provides factual accountability on carbon energy reduced through adoption of solar energy sources. The monitoring dashboard also plays a key role in solar panel maintenance, alerting owners through key performance metrics when it is time to clean the panels.

Westcoast has worked with other winemaking and beverage manufacturers in the county, including Michel-Schlumberger, Healdsburg, Battaglini Winery and Estate, Santa Rosa, J. Rickards Winery, Cloverdale and Lagunitas Brewing Company, Petaluma.

In addition to successfully harnessing solar energy, Marimar Estate incorporates composting of natural waste materials on site, including post-harvest grape pomace, cow and horse manure, kitchen scraps, garden trimmings, and even straw from the stables. Soil health is boosted through cover crops such as peas, vetch, oats and clover. These crops are also chosen for their ability to provide habitats for beneficial insects and pollinators and to aid in water conservation and erosion control. Both vineyards as well as the winery are certified sustainable by the CSWA.

4 GREEN PRACTICES IN FACILITY CONSTRUCTION

In the summers of 2017, 2019 and 2020, devastating wildfires impacted the Northern California wine industry. In Sonoma, Napa, and Mendocino counties, numerous wineries lost outbuildings, cellars and, in some cases, whole facilities. Rebuilding offered an opportunity for many to embrace green construction, with an emphasis on renewable materials and components that contribute to the mission of carbon-reduction.

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4.1 Case study: Frey Vineyards, Mendocino County, California

Frey Vineyards is a third-generation family-owned and operated winery located in Redwood Valley, Mendocino County, California. They produce vegan, gluten-free wines with no added sulphites and are one of America's oldest certified organic and biodynamic wineries. Established in 1980, Frey owns and operates approximately 350 acres of productive vineyards in Mendocino County. These vineyards have been certified as organic by the CCOF, a USDA-accredited agency for the National Organic Program. The vineyards have also received biodynamic certification from Demeter USA. In addition to their own vineyards, Frey also sources grapes annually from roughly 40 certified organic producers, predominantly in Mendocino and Lake Counties.

In October 2017, Frey Vineyards lost office buildings, tasting room, bottling line, livestock and 10% of their periphery acreage of their original estate vineyard on Tomki Road in the Redwood Valley fire. This fire merged with the Potter Valley fire to become the Redwood Complex fires which burned from 8 October 2017 until containment 9 February 2018. During that time, the fires destroyed 36,523 acres in Mendocino County, hundreds of homes and businesses, and claimed nine lives.

Extensive loss of their original facilities in the Redwood Valley fire accelerated the winery's plans to expand operations at a new location within the county, utilizing a 40 acre plot with 25 acres of active vineyards that had been acquired in 2006. According to General Manager, Jonathan Frey, the decision to build a new facility rather than rebuilding on the original site offered several benefits, including improved accessibility for employees, visitors, grape delivery, and shipping. Some non-customer facing operations remained at the Tomki Road facility.

Throughout the construction, Frey Vineyards made green building practices and sustainable energy systems a priority. The new winery is a 43,000 square foot metal structure with a 37 foot tall ceiling to accommodate interior wine tank storage, thereby offering greater energy-efficient control over temperature and humidity. Utilizing a sandwich design with 4 inches of insulation between metal panels on the walls and roof, the building is capable of maintaining cool interior temperatures throughout the year and achieving a total R-value of R28.6.

Materials utilized in construction included NorCal Concrete recycled concrete blocks, maple wood recycled from flooring of a school gym, redwood recycled from water tanks, and even wood salvaged from trees lost to the Redwood Valley fire. Surviving equipment from the original Tomki Road building was repurposed for use at the new facility as well.

Frey Vineyards has future plans to reduce carbon emissions as well as dependence on external energy sources, which include installation of a solar system on the roof of the main building. Solar PV panels have been acquired and the initial solar system will have a capacity of 55 kW. Other plans include an installation of a CiCi carbon capture system, developed by Earthly Labs, to harness CO_2 produced during fermentation for other processing operations. Monitoring and reporting software are integral to the system, as a tool for accountability and in anticipation of a developing carbon market for CO_2 incentives and credits.

Most notably, Frey Vineyards used the new construction as an opportunity to introduce vermifiltration, also known as worm-based biofiltration, to process wastewater onsite without chemical inputs. Water capture is made possible through floor drains in the main building and then treated in two open-top basins measuring approximately 40′ × 80′ and 5′ tall through a patented biodynamic aerobic system from Biofiltro, a company located in Davis, California which has also worked with brewers in California and Texas.

Vermifiltration is a low-cost method of water conservation that utilizes the digestive power of earthworms and beneficial microbes [9]. As they feed on grape skins, seeds, sugars and other organic compounds commonly found in a winery's grey water, they are capable of filtering up to 99% of contaminants within 4 hours through a simple strata of wood shavings, river cobble, and drainage basins. This passive water-treatment process results in a significant reduction of energy expended by other traditional treatment systems, such as aerobic filtration ponds, which require electricity to pump and circulate the water.

The result is a closed loop system. Reclaimed water irrigates Frey's vineyards and landscaping and is also used for frost-protection. Additionally, the process produces worm castings and vermicomposting as byproducts which are incorporated into the soil management.

Construction on Frey's wastewater treatment commenced in 2018, with the pouring of concrete for the two filtration basins. By 2019, the winery began treating of 10,000 gallons of grey water daily.

5 CARBON REDUCTION IN PACKAGING: THE NEXT STEP

This paper focused primarily on technologies and practices that California winemakers are utilizing to reduce the carbon footprint of their operations within their vineyards and production facilities. In the case studies we presented, these practices proved to be beneficial in water conservation and soil management and added profitability to the winemaker's bottom line through cost-savings in energy use and reduced inputs.

In their 2011 report, the Wine Institute noted two other key areas contributing to a winery's overall carbon footprint: packaging and transport. Packaging includes glass bottles, corrugated case boxes and natural cork closure with aluminium foil as well as treatment of waste generated by packaging manufacture, and accounts for 29% of carbon-emission. Transportation includes fuel production and transit combustion of the winery's distribution network, and accounts for an additional 13%. Both categories pose an opportunity for cooperation between winemakers and their partners and vendors within the industry's supply chain.

For packaging, in particular, there is the additional challenge of altering a consumer-facing aspect of the product, which has ignited public discussion and debate outside the academic field [10], [11].

Once again, some California winemakers are in the forefront of this next phase of industry transition. Tablas Creek Winery in Paso Robles transitioned from a 31.5 ounce Esprit bottle to a 16.5 ounce Burgundy bottle [12]. Jackson Family Wines reduced bottle weight by 2 ounces for their Kendall-Jackson and La Crema lines and reported a $1 million savings in production costs [13]. Industry discussion on expanding and rehabilitating the image of boxed and canned wine is also under way [14]. Coming in 2024, in coordination with B.E.V., Cornell University and industry leaders, we will present a white paper on wine industry packaging. In 2025, we will report on trends in the transportation and logistics industry, a field which is rapidly working toward carbon-reduction practices.

As an industry already impacted by climate change, California's grape growers and winemakers were uniquely incentivized to be early adopters of carbon-reduction technology. As brand leaders in lifestyle, agritourism, and culture, the California wine industry is also positioned to play a leading role in educating consumers about climate issues and popularizing fundamental shifts away from traditional methods and materials as desirable solutions.

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