Lemelson Vineyards (Carlton, OR), uses a PGT On-Target electrostatic sprayer to apply wettable sulfur, Serenade, Sonata, solubore, or Humisol (kelp). Applications of pesticides contribute to atmosphereic volatile organic compounds (VOCs) and the subsequent formation of ozone. Pesticides should be selected and used to minimize this problem. Precision technologies, such as electrostatic sprayers, can reduce VOCs from pesticide application by increasing on-target deposition and allowing low rates to achieve pest control.

SUSTAINABLE PRACTICES

Improving AIR quality

BY Joe Browde, Project Manager
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When Senate Bill 700 became California state law in 2003, it ushered in an era of significant change for California agriculture. The law mandated that agriculture is no longer exempt from provisions of the 1990 Federal Clean Air Act and has resulted in an intense scrutiny of sources of and means to mitigate problematic air emissions from farms, dairies, and other agricultural operations.

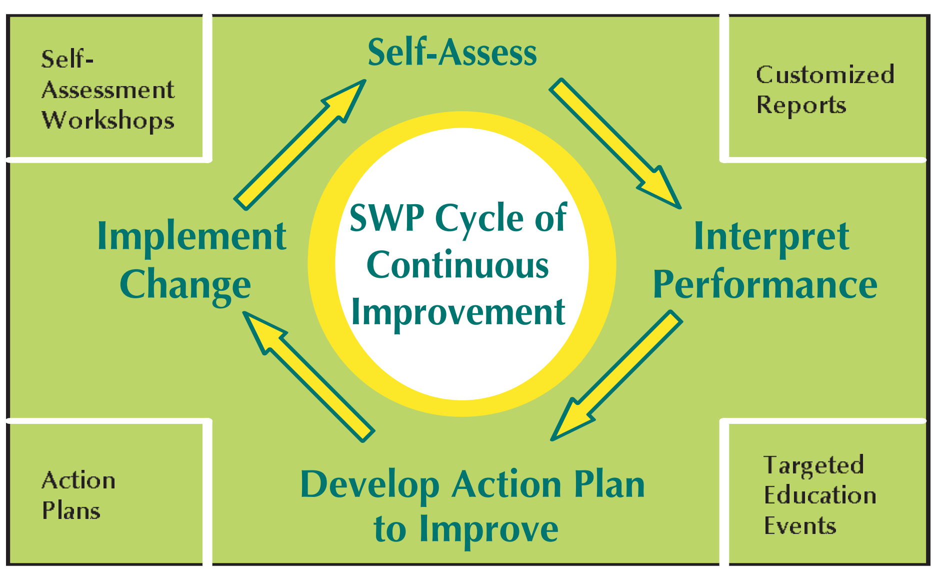
The California Sustainable Winegrowing Alliance (CSWA), through its proactive Sustainable Winegrowing Program, has extended its industry-driven sustainability outreach to growers and vintners to include air quality and practices and technologies that meet and exceed regulatory compliance in reducing air emissions.

Air emissions and agriculture

Two important categories of air emissions affected by agriculture are: 1) the criteria air pollutants and 2) greenhouse gases. The criteria or common air pollutants (Table I) are regulated by the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB).

The EPA establishes nationwide standards for criteria air pollutants based on human health effects. CARB generally adopts more restrictive standards for these pollutants to meet the requirements of the California Clean Air Act, although current regulations are focused on attaining national standards. Geographic areas in which the level of a criteria air pollutant exceeds national and/or state standards are classified as non-attainment areas.

There are 15 air basins within California that are designated as being in attainment or non-attainment status for each criteria air pollutant. Regional or county air districts associated with non-



The use of equipment for managing vineyard floors can stir up dust and contribute to PM10 problems. Equipment should be selected and operated to minimize dust generation.

attainment areas for one or more pollutants must prepare management plans that detail means for ensuring future compliance with national standards. Regional or county plans are incorporated into the State Implementation Plan submitted to the EPA describing how California will attain and maintain national standards.

Robert Sinskey Vineyards (Napa, CA) uses a HARDI Arrow B11 pneumatic sprayer to apply Serenade and Sonata and a calcium foliar spray, or wettable sulfur and a potassium foliar fertilizer and a seaweed spray like organic trigger. Drift reduction is achieved as the sprayer-spouts direct the air to where it's needed and nowhere else. The amount of air is adjusted according to the growth stage via a two-speed gearbox. The turbine has a higher capacity than actually needed in most occasions that allows the tractor to run at lower rpm and save fuel.

The two criteria pollutants associated with agriculture and non-attainment status in several winegrowing regions in California are particulate matter and ozone.

Airborne particulate matter is a complex mixture of miniscule solid and liquid particles. Particles less than or equal to 10 microns in diameter are known as PM10 and pose serious respiratory and heart-related concerns, because they can migrate past the nose and throat and penetrate the lungs. Ten microns is about one-seventh the diameter of a human hair.

The PM10 spectrum is subdivided into "coarse" and "fine" particles. Coarse particles range between 2.5 and 10 microns and often are produced during crushing or grinding operations.

Most important for winegrowers, however, are fugitive dust particles (such as dust from vineyards or roads) stirred up by wind, vehicles, or equipment.

Fine particles (PM2.5) are less than or equal to 2.5 microns and are directly emitted during combustion of fossil fuels (especially petroleum diesel) and wood or are produced by atmospheric conversion of gaseous pollutants. PM2.5 exposure can lead to significant health concerns.

Ground-level ozone occurs in the troposphere, the atmospheric layer closest to earth. It is important to distinguish this problematic ozone from the beneficial ozone that provides ultraviolet light protection in the more distant stratosphere.

Ground-level ozone is formed through atmospheric reactions of nitrogen oxides (NOx) with volatile organic compounds (VOCs) in the presence of sunlight. NOx are produced during the combustion of fossil fuels, especially petroleum diesel.

Agricultural sources of VOCs include the handling and combustion of fossil fuels, certain pesticides, winery fermentation and storage processes, and livestock production.

The highest concentrations of ground-level ozone occur in the summer and fall during hot and sunny conditions ideal for ozone formation. Ozone is linked to various respiratory ailments. Moreover, ozone can adversely affect crops and other vegetation by decreasing growth and yield and increasing susceptibility to pests and other stresses.

Greenhouse gases

Emissions of greenhouse gases and their effects are high profile issues on the global scale. Although not currently classified as air pollutants nor directly linked with human health issues, carbon dioxide (CO_2) and other greenhouse gases emitted during the combustion of fossil fuels are associated with global warming and related climatic ramifications, such as rising sea levels and altered precipitation patterns.

Some agricultural activities produce greenhouse gases, including burning, soil tillage, livestock production, and excess application of fertilizers. It is essential to note, however, that agriculture can also provide a significant benefit by sequestering CO_2. Grapevines, cover crops, and other vegetation in and around vineyards and wineries fix CO_2 from the air through photosynthesis and store a portion of the carbon in their tissues.

Where appropriate, under-the-vine mowing can adequately suppress vegetation while producing less dust and PM10 than mechanical methods that significantly disturb the soil. However, for total air quality impact, the amount and type of fuel required for equipment operation also should be considered because of emissions of PM2.5, VOCs, NOx, and CO_2.

Industry-driven initiatives

The California Sustainable Winegrowing Program began in 2001 as a partnership between members of the winegrowing community to promote sustainable vineyard and winery practices that are sensitive to the environment, responsive to the needs and interests of society-at-large, and economically feasible to implement.

Program leadership is provided by the CSWA, a non-profit organization consisting of leaders from the two key statewide organizations affiliated with California winegrapes and wine — the California Association of Winegrape Growers (CAWG) and the Wine Institute. Technical integrity is ensured by a diverse, 50-member committee of growers and vintners and external partners.

Some tools used for mechanical weed control cause minimal soil disturbance, producing less dust and PM10 than others.

Program funding is provided by the Wine Institute, CAWG, and grants. In-kind contributions of time and expertise from individual growers and vintners, regional organizations, university extension staff and researchers, government agencies, and other external participants constitute a large proportion of total program costs.

CSWA utilizes a vast partnership network to maintain its cycle of continuous improvement (Figure I), consisting of grower and vintner self-assessment, customized reporting, targeted education, and action planning.

A key element to the program, *The Code of Sustainable Winegrowing Practices Self-Assessment Workbook* (second edition released November 2006), covers a broad range of farming and winemaking practices in 14 chapters and 227 criteria (specific management areas within each chapter) and provides additional educational information and links. Each criteria includes four categories of practices based on increasing sustainability (scale of 1 to 4; 4 is highest).

The program does not involve a third-party certification system, with participants' practices certified against a set of defined standards. Instead, it relies on voluntary involvement and strict confidentiality of individual assessments for purposes of optimizing participation while fostering collective progress along the continuum of sustainability.

To complement self-assessment, the program employs a systematic extension model for advancing grower and vintner performance against statewide benchmarks, such as those published in the *California Wine Community Sustainability Report 2004* and the *California Sustainable Winegrowing Program Progress Report 2006* (reports available at www.sustainablewinegrowing.org).

Table I: The Criteria Air Pollutants (from the California Sustainable Winegrowing Workbook)

Criteria Air Pollutant	Key Sources
Ozone (ground level)	Formed by photochemical reaction involving volatile organic compounds (VOCs) and nitrogen oxides (NOx)
Volatile organic compounds (VOCs)*	Released from handling and combustion of fossil fuels (e.g., diesel, gasoline, oil, coal, natural gas); livestock; solvents, paints, glues, pesticides, and other petroleum-derived products; and respiration by plants and decomposition of organic matter
Nitrogen dioxide	Combustion of fossil fuels (especially petroleum diesel)
Particulate matter (PM10 and PM2.5)	Combustion of wood and fossil fuels (especially petroleum diesel), dust from industrial and agricultural operations and unpaved roadways, some applications of pesticides, and atmospheric conversion of gaseous pollutants
Sulfur dioxide	Combustion of coal and oil
Carbon monoxide	Combustion of fossil fuels, especially during cold temperatures
Lead	Leaded aviation gasoline, paint, smelters, and manufacture of lead storage batteries

*Although not criteria pollutants, VOCs are included because they are important ozone precursors.

Detailed information about the criteria air pollutants and associated human health and environmental effects is at www.epa.gov/oar/oaqps/peg_caa/pegcaa11.html. Glossaries of air pollution terms are at www.arb.ca.gov/html/gloss.htm and www.epa.gov/oar/oaqps/peg_caa/pegcaa10.html.

Implementation of the extension model begins with regional and statewide analyses and interpretation of assessment data collected from growers and vintners. Accordingly, specific management areas (criteria) of strength and for improvement are identified for each winegrowing region. Follow-up targeted education then is prioritized with regional leaders to focus on those areas most needing improvement.

A combination of peer-to-peer education and presentations by technical and regulatory experts is used to deliver information about sustainable practices.

Growers and vintners are encouraged to use the targeted education along with information from the workbook and other sources to develop action plans. Execution of this model for targeting educational needs by region has proven to be a cost-effective method to increase adoption of sustainable practices.

In 2004, CSWA was awarded a National Conservation Innovation Grant by the U.S. Department of Agriculture, beginning a partnership for applying the cycle of continuous improvement to air and water quality.

Objectives relevant to air protection were to develop criteria and then conduct assessments for air quality, to upgrade the program's assessment and reporting software for online use and reporting, to deliver targeted education to growers about practices to protect air, and to measure progress in the adoption of recommended practices.

Assessment criteria to improve air quality

The CSWA and partners developed an Air Quality chapter for the second edition of the self-assessment workbook that includes 10 criteria, 17 sidebars with associated educational information, numerous resource links, and other information. Growers and vintners are using this chapter to assess their performance in minimizing particulate matter, ozone precursors (NOx and VOCs), and greenhouse gases.

The 10 criteria and relevant practices for attaining high marks in sustainability are summarized below. California growers and vintners can obtain more information and guidelines by actively participating in the program (see www.sustainablewinegrowing.org) and using the workbook.

1. Planning, monitoring, goals, and results

The establishment and execution of vineyard and/or winery plans to achieve measurable reductions in problematic emissions is key. Growers and vintners achieving higher levels of sustainability must have specific knowledge of emission sources and types, regularly review updated information on air quality, monitor emission quantities, conduct pertinent employee training, and track emission reductions against annual goals.

2. Vineyard floor management

Dust stirred up from the vineyard floor is a source of PM10. To address some of the poorest air quality in California and reduce PM10, growers in the San Joaquin Valley with 100 or more acres of continuous, or adjacent, farmland must prepare and implement Conservation Management Practices (CMPs) Plans (http://valleyair.org/farmpermits/updates/cmp_handbook.pdf) as mandated by the San Joaquin Valley Air Pollution Control District's Rule-4550.

To achieve the highest level of sustainability, growers from all winegrowing regions must exceed this regional requirement by implementing comprehensive plans that must include permanent or no-till cover crops, no or minimally disruptive under-vine tillage, and other soil conservation practices (such as maintaining unfarmed vegetative areas, planting trees and hedgerows, and minimizing equipment passes).

3. Unpaved surfaces — roadways and equipment staging areas

Unpaved surfaces in and around vineyards and wineries are sources of PM10. Growers and vintners reaching higher levels of sustainability must implement soil conservation plans that include effectively timed applications of water or regulatory compliant antidust materials and/or more permanent solutions, such as seeding or paving their roads and equipment yards. Furthermore, speed and travel on these roads are reduced and employees are trained to minimize dust creation.

4. Irrigation

Growers and vintners need to be aware of relationships between irrigation and air emissions. Much energy is used to pump water, resulting in PM2.5, NOx, VOCs, and CO_2 in amounts that vary with the energy expenditure and source of energy.

Practitioners realizing significant reductions in problematic emissions proactively design and manage irrigation systems to expend the least amount of energy and water to meet yield and quality goals. This includes optimizing the efficiency of the pumping plant; maintaining operational efficiency of lines, filters, drip emitters, and other system components; and conserving water (through deficit-irrigation, for example).

Additional reductions are realized by adjustments made at the power source. This includes replacing or retrofitting old diesel engines with cleaner-burning technology, using lower emission fuels (such as biodiesel, propane, or natural gas), or installing electric motors.

The cost of diesel engine replacement may be shared by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) through grants from its Environmental Quality Incentives Program (EQIP) and/or by local California air districts through grants from the Carl Moyer Memorial Air Quality Standards Attainment Program.

EQIP cost-share information about diesel engine replacement and other practices to protect air is available at www.ca.usda.gov/programs/eqip/2007/statepriorities2007.html.

In order to achieve optimum sustainability, growers and vintners incorporate these cost-efficient and environmentally sensitive measures to reduce energy expenditure and air emissions during irrigation.

Table II: Estimated VOC Content by Pesticide Formulation* (from the California Sustainable Winegrowing Workbook)

Formulation Category	Emission Potential
Pressurized products	100.00
Emulsifiable concentrates	39.15
Solution/liquid (ready to use)	7.30
Liquid concentrate	5.71
Suspension	5.71
Pellet/tablet/cake/briquet	5.18
Flowable concentrate	4.80
Granular/flake	3.70
Oil	3.47
Wettable powder	1.85
Dust/powder	1.53
Soluble powder	1.15
Dry flowable	1.02

*The emission potential is that percentage of the product assumed to potentially contribute to atmospheric VOCs. Understanding the relationship of estimated laboratory emission potentials displayed here to field emission rates and subsequent ozone formation is evolving. Nonetheless, growers should be alert to current understandings and consider limiting use of pesticides with higher estimated potentials, e.g., fumigants and emulsifiable concentrates. Additional information about VOCs and pesticides is available at www.cdpr.ca.gov/docs/pur/vocproj/vocmenu.htm.

5. Pest management strategy

Growers using more sustainable approaches include elements of air protection in their pest management programs. Integrated strategies that first emphasize biological and cultural tactics to maintain pests at tolerable levels generally will reduce tractor passes and pesticide applications.

By making fewer tractor passes, growers reduce soil disturbance and PM10 production and limit fuel consumption and emissions of PM2.5, NOx, VOCs, and CO_2. Growers achieving higher levels of sustainability also base decisions for pesticide applications on economic thresholds and/or weather-based decision indices.

6. Pesticide stewardship

Many active and inert ingredients in pesticide products are sources of VOCs. Moreover, inappropriate applications of some pesticides (such as sulfur dust) can result in drift and PM10 concerns.

Each pesticide product has a different capacity to volatilize and produce VOCs and each VOC varies in its potential to form ozone. These processes are also affected by meteorological (air temperature, light intensity, and relative humidity) and physiochemical (pesticide formulation, spray drift potential, spray retention and absorption by foliage or soil) variables.

Despite this complexity, growers can take general steps to limit VOCs from pesticides by choosing low VOC products, restricting applications and rates, and ensuring that a high proportion of the applied material reaches the intended target. Excellent efficacy at low rates often is achieved by the use of precision technologies such as electrostatic canopy sprayers or shielded vineyard floor sprayers with remote sensors that enhance on-target deposition, decreasing drift and the potential for increased volatilization.

To achieve higher levels of sustainability, growers must avoid use of pesticide formulations with higher estimated VOC contents (Table II) and follow recommended practices detailed in the workbook to reduce pesticide use, drift, and PM10.

7. Agricultural/winery chemicals and materials

Besides pesticides, other chemicals and materials used by growers and vintners can emit VOCs (such as solvents, paints, and glues). Although used decreasingly, ozone-depleting substances include chlorofluorocarbons, hydrochlorofluorocarbons, halons, methyl bromide, carbon tetrachloride, and methyl chloroform.

Growers and vintners implementing higher levels of sustainability execute a plan for chemical acquisition and use that considers and minimizes use of products with higher VOC content, proven or suspected potential to deplete ozone, and greater toxicity.

8. Energy sources/efficiency

Improvements in energy efficiency and the use of alternative energy sources impact air quality and costs. Growers and vintners exhibiting increased sustainability consciously carry out cost-effective plans to conserve electricity; optimize efficiency of power equipment; track and limit fuel consumption; and use biodiesel, solar systems, or other options that reduce reliance on fossil fuels and decrease emissions of air pollutants and greenhouse gases.

9. Transportation

Fuel consumed during transportation can represent a significant portion of the energy budget and air quality footprint. Environmentally and cost-conscious growers and vintners consider and employ means to limit business travel (such as car, truck, airline, and train), set emission reduction goals for transportation, and track and measure progress. Higher levels of sustainable performance also include pertinent employee training.

10. Agricultural burning

Some growers continue to burn prunings, removed vines, and organic waste, thereby increasing problematic emissions. To achieve optimum sustainability, no organic waste is burned in a vineyard and extracted vines and prunings are chipped and utilized as mulch or compost or processed to generate energy. The most proactive growers lead outreach to educate peers about alternatives to burning.

To address poor air quality in the Central Valley, the San Joaquin Valley Unified Air Pollution Control District will prohibit burning of most categories of agricultural waste (including removed vines and prunings) by 2010.

No vineyard stakes or end-posts treated with the preservative chromated copper arsenate can be burned or chipped but must be disposed at certified Class II or specified Class III composite-lined landfills. Growers in the San Joaquin Valley can check with their local NRCS office about cost-sharing for treated wood disposal.

Pairing self-assessment with targeted education

Approximately 120 growers and vintners have already assessed their performance against the 10 criteria in the Air Quality chapter. Many of these participants farm within the San Joaquin Valley, an important non-attainment area for particulate matter and ozone.

Use of the second edition of *The Code of Sustainable Winegrowing Practices Self-Assessment Workbook* and the new online system for assessment and customized reporting will increase self-assessments for air quality, leading to needed targeted education and action plan development.

Numerous education events (field days at demonstration vineyards, workshops, and seminars) have already been initiated across California's winegrowing regions to address criteria and practices suggested in the Air Quality chapter.

Partners extending information include experienced growers and vintners, NRCS, Sustainable Conservation, University of California Cooperative Extension, California State University, farm bureaus, private companies, CARB, and the California Department of Pesticide Regulation.

Topics have included applicable laws and regulations; road design and maintenance; energy efficiency; alternative energy sources (such as biodiesel and solar); low-emission engines; carbon sequestration; diesel engine upgrades and conversions; alternatives to burning; customized cover cropping and other vegetative enhancements; low-drift and targeted sprayers; environmentally friendly weed and floor management equipment; integrated pest management tactics and pesticide characteristics; and incentive programs (such as EQIP) for initiating protective practices.

Summary

The CSWA continues to implement the interrelated elements of its cycle of continuous improvement to protect and improve air quality and increase sustainable winegrowing. Collected assessment data will be used to track statewide and regional performance, set goals, and prioritize needs for follow-up targeted education.

Future publications will report progress in the adoption of practices for mitigating emissions of particulate matter, ozone precursors, and greenhouse gases. Through the Sustainable Winegrowing Program, CSWA and the California winegrowing community demonstrates its leadership in sustainable agriculture by balancing the economics of producing exceptional grapes and wine with high standards for environmental quality, human health, and social responsibility. ■