WINEGROWING

SOIL MAPPING TECHNOLOGY

Identifying reserve-quality soils in vineyards

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Grape growers want to achieve several basic objectives. We want to maintain our vineyard's health and productivity. We also want to be good stewards of the land and conserve resources. Most of us are proud of the grapes we deliver to wineries and want the fruit quality to meet everyone's expectations, especially our own.

As a consulting soil scientist and viticulturist for more than 20 years, I have helped many growers and wineries achieve those goals. Uniformity of growth and fruit maturity within each vineyard block or sub-block is one of the keys to those successes. A common limitation in many vineyards is excessive variability within the vineyard blocks.

A uniform vineyard block or sub-block is much easier to manage and allows growers to direct valuable inputs only where they are needed. If the vast majority of the fruit is of similar physiological maturity then selecting a harvest date is easier and the wine is potentially improved. The major factor responsible for variability in growth and ripeness in most vineyards is the soil.

It is important to know your vineyard's soils and group them into

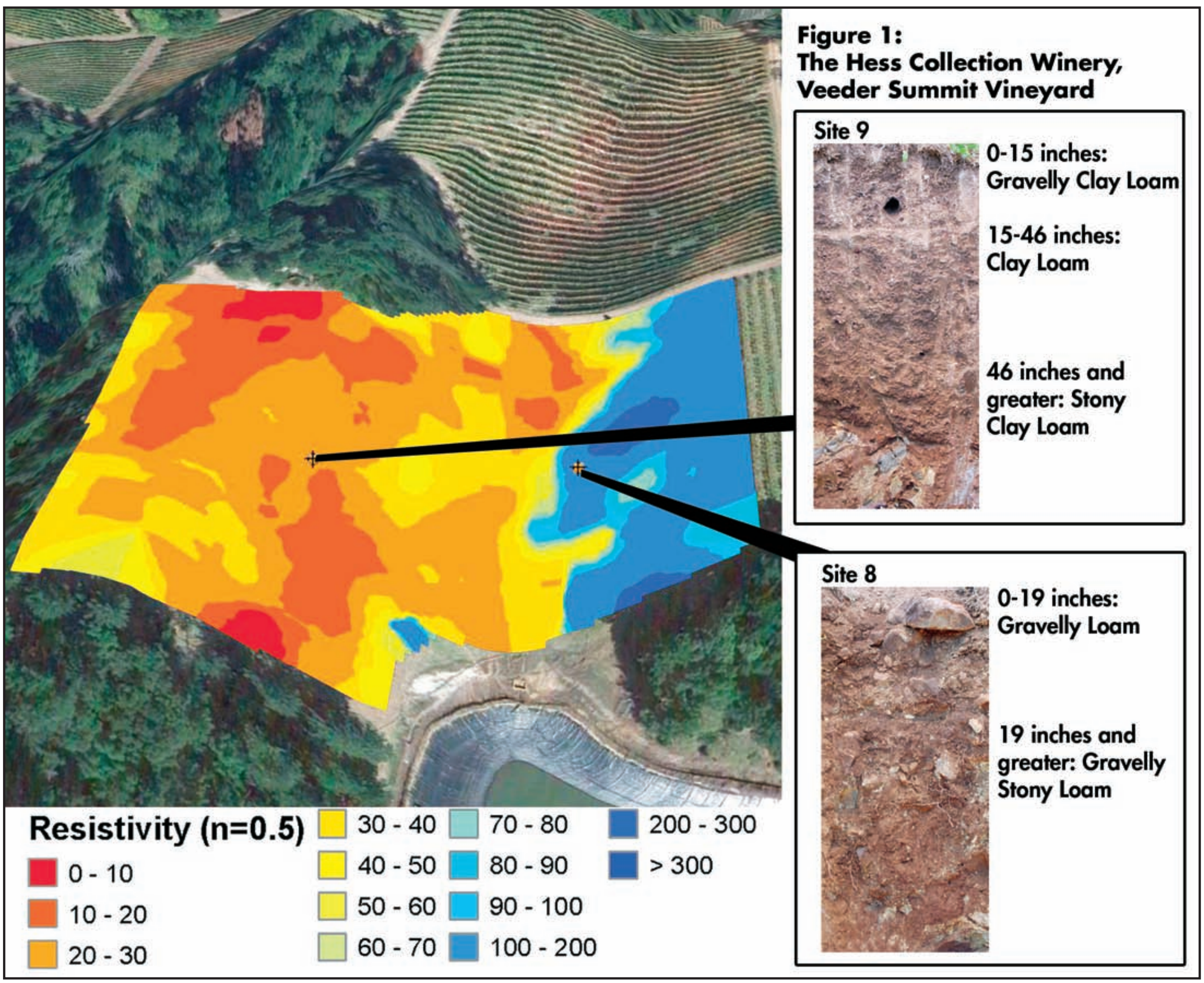
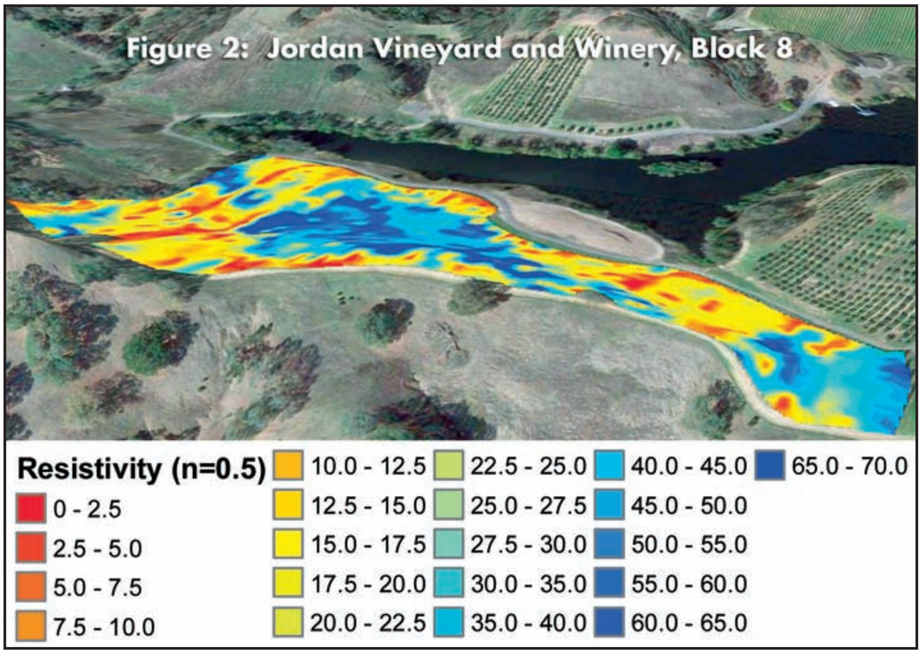


Figure 1: The Hess Collection Winery, Veeder Summit Vineyard



Block Lake 8 soil resistivity with topography data.

Corresponding view of Jordan Block Lake 8.

units with similar characteristics. Successfully irrigating, fertilizing, or harvesting a vineyard block with very different soil characteristics is difficult. Fruit quality will usually suffer. Over-irrigating deep soils while under-irrigating rocky soil areas is a typical scenario. Trying to farm somewhere in the middle or averaging the two distinctly different soils reduces fruit quality in both areas.

One of my mentors told me years ago: if you put one foot in boiling water and the other foot in ice water then on average you should feel fine. In other words, "using averages" sometimes does not work.

Evaluation and mapping of soils

There are several methods to physically evaluate and map soils. Soil augers or probes can be used to collect soil samples. My preference is using a backhoe or mini-excavator to expose soil profiles for physical evaluation and sampling. This, in my opinion, is the best method to thoroughly evaluate soil profiles to the potential depth of rooting (sometimes six feet or more).

Once you have selected the tools, the next question is where do you dig? National Resource Conservation Service web-based soil maps are a good place to start (www.websoilsurvey.nrcs.usda.gov). The maps are a great resource; however, not usually sufficient to design a vineyard.

If your vineyard contains very different soils then where are the boundary limits of each soil type? Accurately delineating soil type boundaries can be challenging.

An experienced soil scientist can use topography, vegetation, surface soil color, and other clues to help delineate soil boundaries. Another approach is to layout a grid across the study area and dig a pit at each point where the grid lines intersect. The grid method is more labor-intensive. Both of those methods do work, however, there is a better way.

"Non-invasive" soil mapping technologies, when properly employed, can accurately delineate soil changes. One of my initial concerns in using these technologies in vineyards is possible interference from metal stakes, trellis wires, and end posts. The potential for interference depends upon the technology used, sounding depth (the depth of measurement below surface grade), and width of the tractor row. The likelihood of interference from metal wire and trellis increases as tractor-row width decreases.

For example, there is research (Lamb, D.W., A. Mitchell, and G. Hyde. 2005 "Vineyard trellising comprising metal posts distorts data from EM soil surveys." *Australian J. of Grape & Wine Research* 11: 24-32.) that indicates that electromagnetic technologies are prone to significant interference issues in existing vineyards with a tractor row that is 3 meters (+/-10 feet) wide or less. This can be a serious limitation when soil mapping in existing vineyards.

However, other non-invasive technologies can be successfully employed in vineyards with an all metal trellis system. My intent here is not to compare these technologies or select one method as the "best." This article is intended to report how Coastal Viticultural Consultants (CVC) successfully employs non-invasive technology in soil mapping projects.

First a few basics: CVC uses an instrument that measures apparent soil resistivity at two (or more) depths below surface grade. Soil resistivity is a measure of the soil's resistance to carrying an electrical current. Resistivity is the inverse of conductance; the ability to carry an electrical current.

The equipment used in the mapping consists of a GPS receiver, data logger, and a towed array of sensors. An ATV tows the sensors back and forth in a pattern of lines across the study area. Approximately 1,000 geo-referenced data points per acre are collected and processed to produce soil resistivity maps.

A geo-referenced soil resistivity map accurately delineates soil changes in the study area. Sample locations are improved using these maps. "Directed sample" soil evaluations are an improvement over less precise sample site selection methods (topography, vegetation, surface soil color, etc.) and less costly and less labor-intensive than grid pattern soil evaluations.

The collected GPS data, light detection and ranging or other data sources can be used to create a Digital Terrain Model (DTM) that is a three-dimensional map of the study area. CVC uses Digital Terrain Models to determine topographic derivatives (slope, aspect, surface curvature) for use in soil mapping, vineyard design, and delineating management units within existing vineyards. Presenting the soil resistivity data in a three dimensional format enhances visualization of the soil units in relation to topography. Examples of DTM soil resistivity maps are Figures 1 and 2.

Soil texture, percent of rock or gravel, and moisture content have the greatest impact upon apparent soil resistivity readings in most vineyard soils. However, total salt concentrations and other soil characteristics can also impact soil resistivity.

CVC identified a resistivity measuring technology where the sounding depth can be adjusted. This is an important feature because adjustments to the sounding depth can be used to help eliminate interference from stakes, wire, and end posts. Changing the distance between the receivers and transmitter varies the sounding depth (depth of measurements).

Using variable sounding depth resistivity technology, CVC has successfully mapped soils in existing, metal-trellised vineyards with tractor rows as narrow as six feet. However, experience with the instrumentation is required to properly set up the equipment and interpret soil resistivity maps, as is true with other similar technologies.

Collecting soil resistivity data in an existing vineyard.

TWO CASE STUDIES

The Hess Collection

The Hess Collection Winery (Napa, CA) retained CVC in 2009 to map 65 acres of soils in vineyards slated for redevelopment on Mount Veeder in Napa County. The Hess Collection Winery produces premium estate Cabernet Sauvignon and Chardonnay.

THE PLAN:

The first step was to map the soils using soil resistivity technology. Two soil depths were mapped for apparent resistivity: one-meter and two-meters. The system geometry was set up for the appropriate sounding depths and the instruments were dragged at set intervals on the soil surface throughout the vineyard. Resistivity data was collected twice every second and recorded with GPS data in the data logger.

SOIL RESISTIVITY MAPS:

The recorded data was filtered and processed using two software programs. The result is a geo-referenced soil resistivity map (Figure 1) that identifies and locates soil variability within the study area. If you work with enough resistivity maps then you can begin to infer some things about the soil properties by using the resistivity data.

In general, the lowest soil resistivity readings reflect clay loam or clay-textured soils and/or wetter soil conditions. The more moderate readings typically represent loam-textured soils. The highest readings (most resistive) are usually sandier or rocky soil conditions.

Soil resistivity will also delineate soils derived from different parent materials (sandstone, shale, metamorphic rock, etc.). Parent materials are the materials that, through weathering, provide the basic components that form soils. The parent material of the soil can have a profound impact on vineyard performance and the flavors imparted to the fruit and wine.

Soil resistivity maps do not thoroughly evaluate soil properties. The maps show where the variability is located. The next step is to evaluate the different soil groups identified in the soil resistivity maps. It is important to always ground-truth any soil map produced with non-invasive technology. Finally, an interpretation of the soil characteristics is needed to design a vineyard or formulate a management plan using soil map data.

A mini-excavator was used to expose the soil profiles in each soil unit for evaluation. A thorough soil evaluation was performed by a certified professional Soil Scientist from CVC to quantify each mapped soil unit. Soil profiles were described using standard methods of soil classification employed by the Natural Resource Conservation Service (NRCS) and soil samples were collected from the strata observed for laboratory analysis.

Individual soil units should be evaluated for chemistry, soil physical factors, available water holding capacity, soil pests, and other pertinent information. Soils, geology, water quality, and climate are all important components of a vineyard study.

The soil data was then evaluated by CVC and used to formulate soil amendment and fertilizer inputs, vine and tractor-row spacing, row direction, irrigation sets, rootstock selections, and sub-blocks.

CVC presented this information in geo-referenced soil chemistry and vineyard block maps. For example, two very different soil units were identified and located in Block 3, Soil Study Sites 8 and 9 (Figure 1). The rockier soil area (Site 8) can now be accurately separated from the deeper, less rocky soils at Site 9. The soils mapped in this block require separate irrigation sets, different soil amendments, and different rootstocks to optimize wine quality. New vineyard development will be designed and installed to best match existing soil conditions.

Available waterholding capacity (AWC), soil chemistry, soil physical conditions and nematode presence impact the vigor capability of vineyard soils. Rootstock selection was based upon the soil vigor capability ratings, vineyard spacing, and irrigation water availability. The rootstocks that best matched the existing soils were primarily 420A and 3309C. Some Riparia, 101-14, and 1616C rootstock was also planted.

Sander Scheer (Hess Collection viticulturist), worked with CVC personnel in the design phase of the redeveloped vineyards. Scheer reports, "Soil resistivity has given me a great starting point to work from when laying out new vineyards. We can make a plan for backhoe pit locations prior to heading out into the field based on the variability identified in the resistivity mapping. This technology allows us to consistently find where one soil type ends and another begins. Knowing with confidence where soil breaks occur has allowed us to address each soil unit separately. Uniformity within each vineyard sub-block has lead to more balanced vineyards and increased fruit quality, no question."

Jordan Vineyard and Winery

Jordan Vineyard and Winery (Healdsburg, CA), retained CVC to map soils in 100 acres of existing vineyards (ten blocks). Jordan Winery produces premium Cabernet Sauvignon and Chardonnay. The vineyards are primarily hillside Cabernet Sauvignon with a 5x9 vine and row spacing trained on a VSP trellis.

BACKGROUND:

In the late 1970s and through the 1980s, Rob Davis (Jordan Winery's winemaker for 35 years), traveled extensively with Andre Tchelistcheff (renowned winemaking consultant) in Europe, particularly France and Italy. During these many journeys Davis experienced the influence soil had on wine flavors. Eventually Davis was convinced that he could identify the soil type by tasting wines. At that time the idea of soil impacting wine flavor was not readily accepted in the U.S.

Davis believes a "reserve (Grand Cru) quality" area must have two things: the proper soil and climate. Davis knows vineyard management techniques (husbandry) can impact wine quality greatly and is required to produce a reserve quality wine.

However, Davis also believes without the soil and climate, husbandry alone can only achieve so much in the wine.

He questioned the wisdom of making major inputs into vineyard blocks that are not likely to make the quality grade for Jordan's wine program.

Davis knew that there were certain soils that would give Jordan Winery wines the characteristics that they desired. "When I taste wines, I go straight to the soil type," says Davis. "I can identify certain characteristics in wines derived from soils."

The Plan:

Soil mapping was used to identify "Reserve" potential within the hillside vineyards at Jordan Winery. CVC would map each vineyard block with a soil resistivity system in order to efficiently locate soil variability within each block. Each block was mapped at two depths, one meter and two meters below surface grade. Each of the soil units (25 sub-blocks [smallest acreage = 0.6]) identified in each block was evaluated by a Certified Professional Soil Scientist from CVC.

Fertility and irrigation strategies were recommended by CVC for each soil unit using the soil analysis, soil profile information, and resistivity mapping.

A rating system was applied by CVC to each soil zone according to its potential to reach "Reserve" status. The criteria used to rate soils included geologic parent materials, available water-holding capacity, cation balance, soil physical factors (soil texture, depth, compaction, etc.), fertility status, and organic matter content.

Each soil unit sub-block was marked in the field with flagging tape. Brent Young, Jordan Winery's viticulturist, uploaded CVC's georeferenced soil resistivity maps into their GPS unit to locate the appropriate areas for flagging within each vineyard block.

Brent Young and Dana Grande used the soil resistivity maps and field flagging to direct inputs and cultural practices per the management plan for each sub-block. Fertilizer inputs included varying amounts nitrogen, calcium, and potassium applied through the drip system. Minor elements (zinc, boron) were applied with foliar sprays.

Irrigation strategies were fine-tuned by sub-block according to accurate, volumetric soil moisture measurements (neutron probe) and plant mapping data (shoot growth, phenological stages, stress index, etc.) collected by CVC during the growing season.

Composite fruit samples were collected in 2009 using the sub-block maps. Composite fruit samples were crushed and Jordan Winery's winemaker, Rob Davis and assistant winemakers Maggie Kruse and Ronald Du Preez made sensory evaluations of the juice samples as the fruit ripened to evaluate the quality and potential of each sub-block.

Results:

Each sub-block received the treatments per the custom farming plan. The "Reserve Wine Potential" rating system and soil mapping was verified with the winemakers' palates as they tasted composite juice samples from various sub-blocks.

Each of the sub-blocks were harvested and fermented separately. The resulting wines confirmed that the custom, sub-block farming plan employed by Jordan Winery is yielding results.

"The fruit in Block 8 (12-acre Merlot vineyard) is the best it has ever been," says Davis. "This technology is definitely better than using aerial imagery (to design custom vineyard plans). Our sensory evaluations correlated strongly to soil types. The application of this technology is fantastic."

Jordan's viticulture staff also has a better understanding of the soils effect on wine flavors. Brent Young described this soil maping technology "as a window to see into the soil." Jordan Winery can now manage each area according to its' potential to produce wine with desired characteristics. Resources can be applied more efficiently and identification of areas where a more likely return from inputs is now possible.

Summary

Non-invasive soil technologies can be successfully employed to both improve the design of new vineyards and management of existing vineyards. Separating the soil units in your vineyard can improve sub-block vineyard uniformity, efficiency of vineyard inputs, help better manage your vineyard and identify reserve wine potential in your vineyards. ■