Where to install soil moisture sensors

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Grapegrowers are encouraged to use a combination of soil, plant and weather data when determining the length and frequency of irrigation events in vineyards. The most common questions that growers ask about vineyard irrigation are: How often should the vines be watered, and how much water should be applied per irrigation?

Estimation of daily evapotranspiration can tell a grower roughly how much water is removed from the soil, and it is the principal means by which growers can determine the amount of water to apply to a vineyard block. Plant data (such as leaf or stem water potential determined by means of a pressure chamber) is often used to determine how vines are responding to the amount and frequency of water applied.

For example, if a grower wishes to strategically apply less water than the amount lost to evapotranspiration (a deficit irrigation strategy), a plant water status measurement can be used to indicate the degree of water stress the vines are experiencing.

Why measure soil moisture?

Soil moisture sensors are a useful tool for assisting with vineyard irrigation scheduling.

For example, water status of the soil can be measured during the winter to determine if winter rainfall is reaching the effective rooting area of vines. Soil moisture sensors are also helpful to determine the irrigation time required to replenish water to a desired rooting depth.

The data provided by soil sensors can help growers to understand how water moves in soil and the areas where roots are most actively taking up water, poten-

KEY CONCEPTS

- Soil sensors must be installed in the location that best represents a vineyard irrigation block.
- Mapping soil (pre-and post-planting) and vine vigor patterns (post-planting) provides useful information for selecting sensor installation sites.
- A strategy must be developed to evaluate the soil in a block to verify placement of sensors in a representative soil profile.

Figure 1. Numerous soil moisture sensors are available for use in vineyards. Examples of different sensors include: Watermark Matric Potential Sensors (top left), AquaCheck Capacitance Probe Sensors (top right), and Decagon capacitance sensors (bottom). How and where you install the sensors is likely more important than the type of sensor chosen.

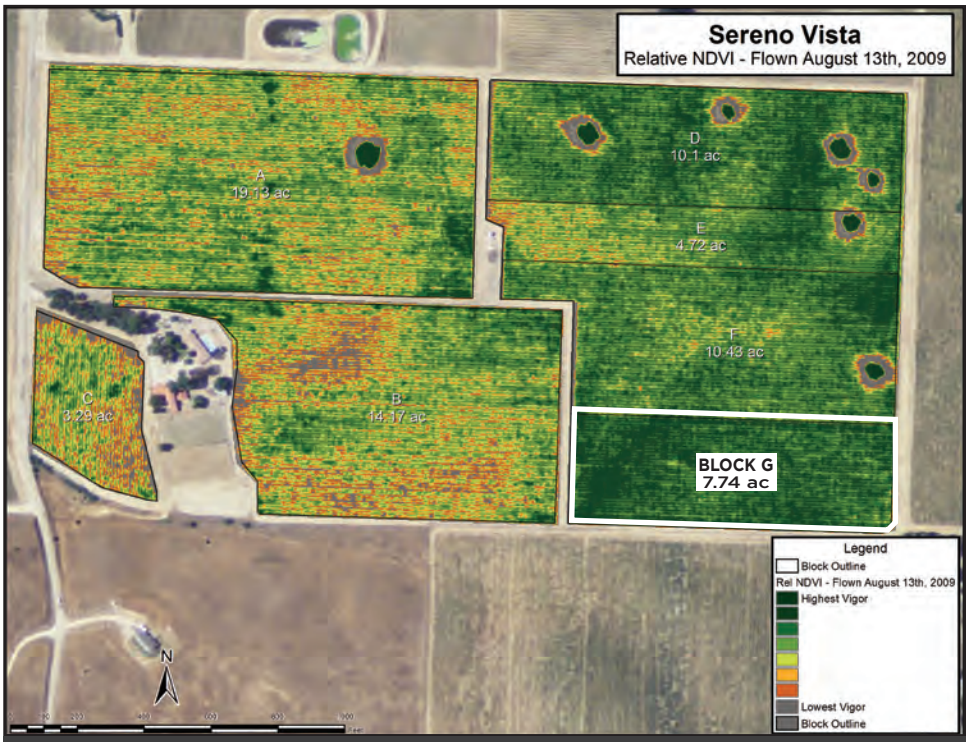

Figure 2. This normalized difference vegetative index (NDVI) map of an existing vineyard shows areas of high vigor in dark green and those of progressively lower vigor in yellow, orange and red. A combination of deeper clay soil and a drainage pathway of a swale to the west side of block G are the likely reasons for higher vigor in that area (darker green color). Soil sensors should not be placed in these areas if the data is to be representative of the majority of the block.

tially reducing excess water application. In areas where water quality is affected by high salt concentration, soil moisture sensors can provide valuable feedback regarding the effectiveness of irrigation or rainfall with regard to potential leaching of salts below the root zone.

Proper placement of soil sensors is critical for obtaining data that will be useful to improve vineyard irrigation scheduling.

Selecting a representative location

Ideally, a grower would install soil moisture sensors in multiple locations per irrigation block to obtain an average of soil moisture across a site. However, the cost of sensors and the associated telemetry devices required to retrieve data from a large number of data-logging stations is often a limiting factor when choosing the number of sensors to install. For this reason, it is most common for growers to install moisture sensors in only one or two sites within an irrigation block.

When implementing a small number of data points across a vineyard, it is important to choose a soil profile that best represents the majority of the irrigation block.

For example, installing soil moisture sensors in an area of shallow soil or with less water-holding capacity than is typical of the whole block can potentially result in sensor readings that overestimate the frequency of irrigation sets needed within that block. Conversely, the installation of sensors in an area having deep, heavy clay soil than is not typical of the block will result in sensor readings that potentially underestimate the water needs of the whole block.

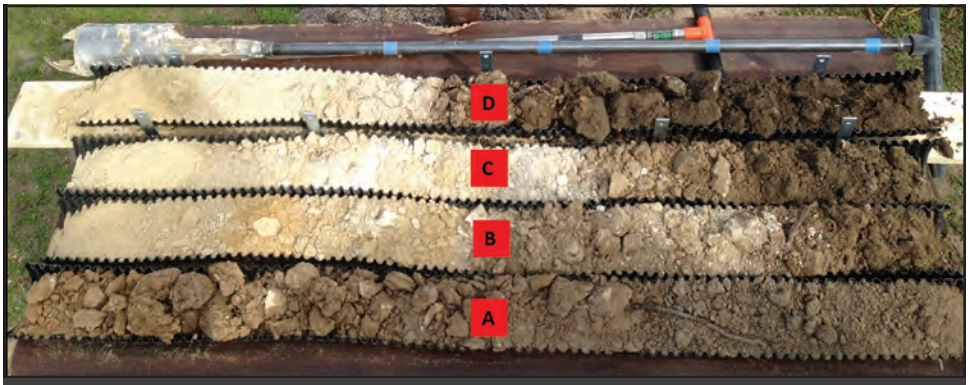

Figure 3: An 8-acre block of Cabernet Sauvignon (block G, Figure 2) is planned as a single unit for irrigation. Soil cores extracted to a depth of 4 feet from west to east (A, B, C, D) reveal differences in depth of soil horizons across the block. Soil cores B and C represent the soil profile observed in the majority of the block, where the soil moisture sensors should be installed.

Mapping vineyard soils

Ideally, a vineyard soil will be fully mapped prior to designing a vineyard and establishing irrigation blocks to be irrigated differently as needed. Soil maps are available online from the U.S. Department of Agriculture's National Resource Conservation Service (USDA-NRCS) Web Soil Survey. (websoilsurvey.sc.egov.usda.gov/)

These maps show the approximate boundaries of distinct soil series and can serve as a good starting point for determining where a soil may change within a site.

Maps from the USDA-NRCS are helpful to describe the soil type of an area, however they are not accurate enough to be used alone when selecting where to install a soil-moisture sensor. On-site mapping of vineyard soils by a soil scientist or vineyard soil expert is recommended to understand the precise boundaries of different soil types.

Soil characteristics that may change across a soil series include effective rooting depth, depth to bedrock or hardpan, soil texture and depth of distinct soil horizons.

The process of soil mapping involves the excavation of multiple soil observation pits across a site in order to establish where changes in soil characteristics occur. The potential influence of different soils on vine growth is then estimated based on the knowledge and prior experience of the soils expert.

Figure 4. Before installing soil-moisture sensors under the drip line, a series of observation points can be evaluated a short distance from the desired sensor placement location. This extra step can identify abnormalities in soil that influence water movement, such as hard pans or pockets of rock or sand.

Before a vineyard is planted, soil pits can be excavated using a backhoe. Additionally, hand-operated soil augers can be used to capture disturbed soil profile samples and assist in delineating changes in soil across a block. Hand- or electric-powered augers will disrupt less soil volume on a site. In established vineyards, large excavation equipment can be more difficult to maneuver, making use of portable hand or mechanical augers more accessible.

Figure 5. A typical soil-moisture sensor installation shows the placement distance about 4-6 inches from a drip emitter. Some trial and error may be needed to determine ideal distance from the emitter to correlate soil moisture readings with plant water stress measurements.

Mapping vineyard vigor

Differences in soil across a vineyard block often contribute to growth differences in vines as observed in the canopy. Vegetation index maps, often referred to as "vigor maps," are helpful tools for understanding differences in relative vigor across a mature vineyard block. Differences in vigor may be due to numerous factors, including changes in soil characteristics.

Normalized difference vegetation index (NDVI) mapping is one of the most commonly used tools for tracking differences in vegetative growth across a vineyard (Figure 2).

NDVI images provide a snapshot in time (such as mid-summer) when the relative canopy size and health can be compared within a vineyard block. Vines or areas of low NDVI will use less water, drying the soil at a slower rate than vines or areas with a higher NDVI.

Additional, low-tech measures can be taken to verify growth differences observed from NDVI maps, including dormant pruning weights of vines and visual observation.

Pre-plant considerations

Uniform vine growth is desired within a vineyard block. Variability of soil across a vineyard site should be considered when designing the layout of vineyard blocks and irrigation. In general, larger vineyard blocks are more economical to establish and manage, therefore it is not always practical to divide blocks by soil type.

However, irrigation design in the pre-plant phase allows a grower to customize a system across a block, such as developing separate irrigation zones to address differences in soil water-holding capacity. It is also useful to have historical photos or satellite images and crop use information to identify areas of the site that may have had large areas of soil disturbed (uprooted trees, trenching for pipelines or compacted roadways).

Choosing sensor locations in an existing vineyard

The goal when choosing sensor locations in an existing vineyard block is to locate an area of the vineyard with soil that best represents the majority of the irrigation block.

Placement of sensors in the outlying soils of lowest or highest water holding capacity can result in soil moisture readings that lead to either excess or under-irrigation. Supplemental irrigation may be needed in the weakest area of the vineyard block.

The series of soil cores in Figure 3 show the difference in soil across a block of Cabernet Sauvignon (Figure 2, block G). The soil core from the lowest elevation (A) is from the center of the high-vigor swale area on the west side of the block.

Note that the soil from the high-vigor area (A) of the vineyard has clay content as deep as 4 feet, whereas the soil core from the top of the hill (D) has heavy clay top soil down to about 2 feet, followed by a sharp transition to loam. The two cores from the center of the block (B, C) are of the most representative soil, having a sandy clay loam top soil, transitioning to clay loam, then loam subsoil.

After reviewing soil maps and vine vigor, a strategy should be developed to evaluate soil in the irrigation block, such as digging observation pits in a grid pattern across a block. This extra step will help to verify that the soil sensor placement is in an area that represents the most commonly observed soil profile.

Figure 6. A typical soil moisture sensor installation shows the placement distance about 18 inches from the vine trunk, and 4–6 inches from a drip emitter.

Depth of soil sensor placement

After determining the most representative location for placing soil-moisture sensors in an irrigation block, the depth of sensor placement must be considered. Choosing the depth to place individual soil moisture sensors requires careful evaluation of the soil profile. Due to the deep-rooting habit of grapevines, it is common to place sensors at increasing soil depths in order to capture the movement and potential availability of water.

When using a probe-type sensor with multiple sensor depths pre-set by the manufacturer, the most important decision is the total length of probe required to reach the desired soil depth. Be sure that the length matches the depth with which you wish to monitor water movement and that the soil depth is adequate for full insertion of the probe. A sensor at or near the bottom of the root zone is suggested to identify deep percolation.

Before final installation of soil sensors, observation points can be evaluated in the area immediately surrounding the sensor location (Figure 4). Evaluation of a soil profile within 2–3 feet of a proposed installation site is a helpful practice to make sure you do not install sensors in a disturbed spot. Note, any observation hole dug within a few feet of a sensor site must be carefully back-filled and tamped to prevent rainfall or other surface water from influencing sensor readings.

Sensor placement relative to emitters and vines

The location of soil moisture sensors relative to the vine root system and drip emitters (in irrigated vineyards) will influence the usefulness of the sensor readings. If sensors are placed too far from active roots, the effect of water movement in mass flow cannot be captured.

Likewise, placement too far from the emitter can lead to overwatering of vines if the sensor is not within the desired wetting pattern of a routine irrigation set. Most growers will tend to err on placing sensors closer to the emitter (within 4–6 inches) in order to avoid excess watering. Some trial and error may be necessary to find the best distance from emitters in a particular soil. Soil sensors are most commonly positioned within 18 inches of a vine trunk and in line with trellis and irrigation wires to reduce damage from machinery (Figures 5, 6).

Where to avoid placing sensors

In general, sensors should not be placed in the following areas of a vineyard:

- Areas of excessively high or excessively low vigor that do not represent the majority of the block.
- Soils that do not drain well or hold water longer than the majority of the block.
- Where soil depth is deeper or shallower than the majority of the block.
- Pockets of soil that do not represent the majority of the block (random sand pockets, or hard pan).
- Areas in line with surface runoff (bottom of swales) or drainage channels in a block.
- On the border of the vineyard or areas near competing vegetation.
- Areas that receive supplemental shade from structures or trees other than vines or trellis.
- Where natural soil structure has been disturbed in the past (backhoe pits, uprooted trees and backfill from erosion).
- Areas that may receive significantly more or less irrigation water than the rest of the block (this may be based on evaluation of distribution uniformity).
- Where vines are not representative of the block (weak vines, vines of different age or rootstock). PWV

This text was developed by the Vineyard Team, a nonprofit organization dedicated to promoting sustainable winegrowing since 1994. Materials are based upon work supported by industry contributors and the Natural Resources Conservation Service, U.S. Department of Agriculture, under No. 68-9104-3-177. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture.

Author's Note: Additional information on types of soil moisture sensors and tips for installation can be viewed on the Vineyard Team website at: vineyardteam.org/projects/vineyard-demonstration.php.

Bibliography

1. U.S. Department of Agriculture, National Resource Conservation Service - Web Soil Survey: websoilsurvey.sc.egov.USDA.gov/app/homepage.htm.