Advanced Characterization Techniques for Defining Vineyard Management Zones

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I. INTRODUCTION

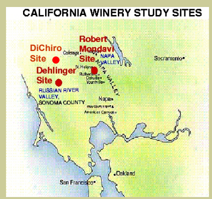
Winegrape quality is linked to the physiological status of grapevines, and specifically to their water status. Targeted viticulture strategies, focused on promoting uniformly high winegrape quality throughout vineyard blocks, requires an understanding of the soil and climatic parameters that influence grapevine water use. Although micrometeorological factors are often considered when developing an irrigation approach or assessing fruit quality, the influence of small-scale soil variations and their control on water use and associated fruit quality is poorly understood. We have explored advanced characterization approaches for providing high resolution information about soil properties within existing and developing California vineyards through a series of studies that are described on this poster:

Section II: At a **Robert Mondavi vineyard** in Oakville, we used a Ground Penetrating Radar (GPR) groundwave technique to map shallow soil moisture

Section III: At a **Dehlinger vineyard** in Sonoma County, we used a GPR reflection technique to map deeper soil water content and to explore soil-vegetation relationships.

Section IV: Integration of geophysical data with NDVI and micrometeorological data were used to estimate the date of critical stress onset and variable irrigation needs over the growing season.

Section V: At a developing **DiChiro Winery vineyard** near Healdsburg, we are using GPR, EM, NDVI, and Cone Penetrometer datasets to delineate 'management zones' prior to choosing row and vine spacing, and irrigation parameter.



These studies suggest that early stage use of such advanced characterization approaches offers the potential to improve vineyards layout and irrigation schemes to best reflect the natural variations at the site while at the same time reducing the labor, cost, and water use associated with precision viticulture.

II. SOIL WATER CONTENT ESTIMATION AT THE MONDAVI VINEYARD USING GPR GROUNDWAVE DATA

Surface Ground Penetrating Radar (GPR) approaches have recently been used to map the dielectric properties of the soil and subsequently to estimate soil water content within vineyard sites in a non-invasive and manner and with high spatial resolution.

- •GPR uses high frequency electromagnetic waves (~50MHz to 1200 MHz) to probe the subsurface.
- •GPR is pulled along the ground surface as is illustrated in Figure 1 and an electromagnetic pulse is sent from the transmitting antenna (Tx) into the soil.
- •Energy from the pulse travels directly through the air (A in Figure 1) to the receiving antenna (Rx), along the ground surface (the groundwave; G in Figure 1), and through the soil. Energy penetrating the soil is reflected at soil interfaces having differing dielectric constants (R in Figure 1).
- •The travel-time of the wave is measured, and if the length of the travel path is known, the electromagnetic wave velocity can be estimated and converted into dielectric constant values.
- •The dielectric constant of soils is most sensitive to soil water content and thus GPR techniques can be used to estimate spatially variable vineyard soil water content (Figure 2)
- •As different soils have different water holding capacities (Figure 3), GPR should indicate soil heterogeneity.

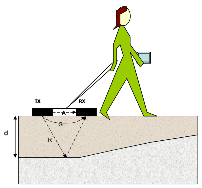


Figure 1

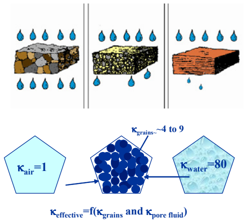


Figure 2

Figure 3

We tested the concept of using the GPR groundwave technique to estimate water content within a Robert Mondavi Vineyard, located in Napa Valley, California. Water content measurements were obtained using conventional sampling techniques (**TDR, gravimetric, and neutron probe techniques**). **Remote sensing data** sets were acquired using the airborne ADAR Multispectral System 5500 (Johnson et al., 2001, 2003). **GPR data** were collected several times over a period of 18 months using a 900 MHz PulseEKKO 1000 System. A map of the study site is shown in Figure 4.

We estimated the electromagnetic velocity using the groundwave data and subsequently water content at each GPR sampling location (Figure 5, 6). We found that:

- ***•The GPR groundwave estimates were accurate to within 1% by volume relative to TDR measurements***
- ***•The GPR provided dense information; each image in Figure 5 has ~20,000 data points;***
- ***•The 900 MHz groundwave sampled approximately the upper 15-20 cm of the soil layer.***
- ***•The spatial pattern of water content remained fairly consistent over time.***
- ***•Soil moisture, soil texture, and vegetation density were spatially correlated.***

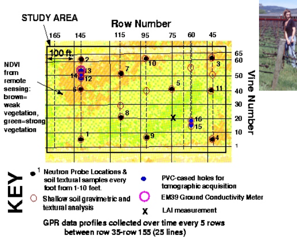


Figure 4

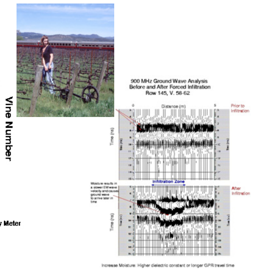


Figure 5

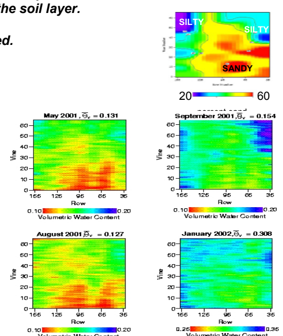


Figure 6

III. SOIL MOISTURE ESTIMATION AT THE DEHLINGER WINERY USING GPR REFLECTION DATA

We tested the concept of using GPR reflection arrivals to **map water content in deeper soils** at the Dehlinger vineyard in Sonoma County. As illustrated in Figure 2, a GPR reflection occurs where there is a dielectric contrast between two subsurface units. In order to estimate the velocity of the reflected event from the recorded two-way travel time of the signal, information about the depth of the reflector must be independently determined, for example, from borehole measurements. Data were collected during several data acquisition campaigns using 100 MHz GPR antennas (Figure 7). A consistent GPR reflection, imaged using 100 MHz antennas, was detected and interpreted to be associated with a thin (~0.1 m thick), low permeability clay layer located 0.8 to 1.3 m below the ground surface and identified from borehole information (Figure 8). Measurements of travel time to the GPR reflector (obtained using the 100 MHz antennas) and estimates of the depth of the reflecting clay layer (obtained using borehole measurements) were used within a Bayesian estimation approach to estimate deeper, depth-averaged volumetric water content (Figure 9). This study illustrated that:

- *•Compared to average water content measurements from calibrated neutron probe logs over the same depth interval, the estimates obtained from GPR reflections at the borehole locations* ***had an error of 1.8%;***
- *•As was observed at the Mondavi study site, there is a* ***consistent spatial pattern of water content variation over time;***
- *•The Dehlinger Winery vineyard manager, Marty Hedlund, has recognized that* ***the area that is consistently wetter also consistently has lower grapevine vegetative growth than that of the surrounding area.***

Details of the Dehlinger GPR reflection study are provided by Lunt et al. (2005) and Hubbard et al., (2006).

Figure 7

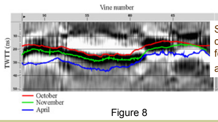
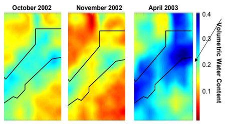


Figure 8



High water content coincides with low vigor area

Figure 9

IV MEASUREMENTS TO MANAGEMENT

We used a numerical model, parameterized with micrometeorological and spatially variable soils and plant data to predict vineyard water balance. For these simulations, we used the Vineyard Soil Irrigation Model (VSIM) (Pierce et al., 2003), which was parameterized using spatially variable data. Simulations from VSIM provided spatially variable estimates of soil moisture, water stress onset, and irrigation needs over the study site (Figure 10).

The simulations suggested that the sandier and typically drier portion of the study site demands more irrigation water than does the more silt-rich and consistently wetter soils, and that the sandy area requires water earlier in the growing season than the more silt-rich areas. As too much water or too early application of water reduces grape quality, these results suggest that the current practice of applying uniform irrigation water from the same starting date across the block to sate the 'thirstiest' (sandy) portions of the block can result in decreased fruit quality and water efficiency in the more silty regions.

With such predictions, vineyard management zones can be defined, which can be farmed preferentially to increase both fruit quality and water savings.

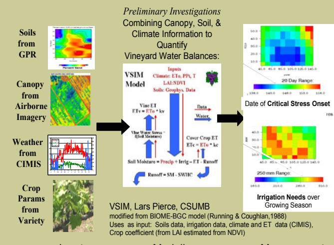


Figure 10

V. DEFINING VINEYARD MANAGEMENT ZONES USING ADVANCED APPROACHES

We are currently working with Dr. Phillip Freese of WineGrow on the development of the Dichiro Vineyards, located approximately five miles north of Healdsburg in Alexander Valley of Sonoma County, California. At this 20 acre site, we are using a variety of measurement methods, including GPR, surface electromagnetic data, cone penetrometer, neutron probe, TDR, and remote sensing data (Figure 11) to delineate small scale soil variability. Examples of these datasets are shown below (Figures 12-16). To date, we have delineated gross features using with EM, CPT, NP and soil texture data and delineated finer scale variations obtained with NDVI and GPR. We have found that the soil properties at the site are extremely variable vertically and horizontally, and that restrictive layers likely play a role in drainage.

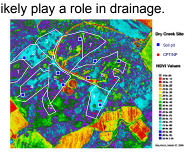


Figure 11. Site boundaries. NDVI data collected By Jay Hutton, GrayHawk

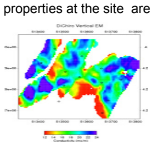


Figure 12 Example of surface Electromagnetic data collected at one point in time

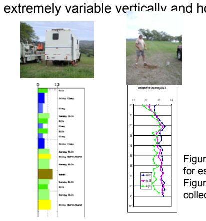


Figure 13 (left). Cone Penetrometer (CPT) data, used for estimating lithology
Figure 14 (right) Example of neutron probe data collected at different times.

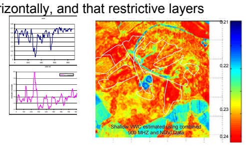
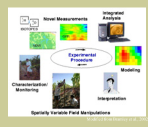


Figure 15 (left). Comparison of NDVI and dielectric values from 900 MHz GPR groundwave data collected along same transect.
Based on relationship developed from such data, the NDVI data (Figure 11) was interpreted in terms of shallow moisture content (Figure 16, right).

IV SUMMARY, REFERENCES AND ACKNOLWEDGEMENTS

Summary Our work has shown how geophysical approaches can be used to map soil properties that control drainage and vigor in high resolution and in a minimally invasive manner. Because of the high gross revenue per acre and large financial premiums associated with improving wine quality, developing such abilities to map soil properties and use these as a guide for precision irrigation could prove economically feasible for optimizing winegrape production as well as reducing overall water use. We expect that the use of geophysical techniques for guiding precision viticulture will increase as the competition for high fruit quality and the demand for water supplies and the interest in understanding and managing micro-terroir increase.



Modified from Rob Bramley

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