CSREES National Water Quality Program

Title: Soil Water Monitoring and Water Resources Management Using Geophysical Techniques

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Theme: Water Conservation and Agricultural Water Management

Situation: Monitoring of soil water content and matching it with irrigation needs is a vital component for agricultural and ecological programs, and the key component for rational water resources management. The information obtained from soil moisture monitoring is critical for optimizing crop yields, achieving high irrigation efficiencies, planning irrigation scheduling, and minimizing lost yield due to waterlogging and salinization. Such water content monitoring is also important for addressing issues of water quantity and quality, both relevant for managing the environmental impacts of irrigated agriculture and for protecting functional ecosystems. Leaching of agrochemicals and salts into the groundwater and downstream ecosystems, for example, can be minimized if irrigation water infiltrates only to the bottom of the root zone. High resolution, continuous water content distributions allow one to design optimal irrigation and chemical application programs that make possible such "prevention at the source." No current technique can provide such information quickly, reliably, and at low cost. Our project is focused on investigating the applicability a surface geophysical method, ground-penetrating radar (GPR), for use as a water content estimation tool; development of such a tool could lead to increased water savings and better control on the ecology of natural vegetation.

Objectives: Our research objectives include the following: 1) Acquisition: Investigation of optimal acquisition and inversion methods for ground wave and reflected GPR travel time information under different field moisture conditions. 2) Survey Analysis and Development of Interpretation Methods: This task entails field data calibration, development of the petrophysical relationships needed to transfer the geophysical measurements into water content or soil type, and development to the geophysical data analysis procedures. 3) Validation: Comparison of soil water content point estimates obtained from GPR data with co-located measurements from available from conventional tools such as gravimetric, neutron probe, time-domain reflectometry, and soil textural analysis techniques indicated the viability of this method as a reliable and efficient water-content field tool. 4) Geostatistical Analysis: Comparison of water content spatial correlation structure obtained from GPR data with correlation structure obtained from conventional moisture content/soil texture measurement techniques as well as remote sensing over space and season. 5) Comparisons between GPR-, plant- and airborne-based measurements; assessing the utility for GPR within precision farming practices: This task entailed comparison of point and spatial correlation estimates of water content/soil texture, obtained from GPR, with plant and remote sensing information that are currently being used to guide vineyard farming operations.

Methods: Investigations of the use of GPR reflected and groundwaves for near subsurface water content estimation were performed under both controlled and natural conditions. We investigated the use of GPR travel time data by analyzing both GPR ground and reflected wave events. By analyzing the travel time of the GPR signal and by knowing the length of the travel path, estimates of velocity and subsequently dielectric constant can be obtained, which can then be translated into estimates of water content. A controlled experiment was carried out at constructed test pits, using stacked metal plates as reflectors. These studies were carried out to test the potential of GPR methods under different moisture conditions and with different reflecting plate geometries, and to compare the GPR results with measurements collected using a benchmark electromagnetic conductivity meter method. An important component of our investigation is the testing of GPR water content estimation approaches under natural field conditions, where soil texture and moisture vary spatially, and where soil moisture varies temporally. Our plan called for exploring alternative data acquisition techniques, and for identifying their capabilities in terms of accuracy and depth of exploration.

Partnerships: 1) This project is managed in collaboration with the staff at the Mondavi and Dehlinger wineries. 2) We partnered with researchers from NASA and CSU-Monterey to develop and implement vegetation simulation models based on the soil moisture data based we are developing. 3) Supplementary funding was provided by the Water Resources Center of the University of California, and by NSF. 4) We are working with the American Vineyard Foundation to extend the water resources management part of this project.

Research: The education mission of this project was achieved in two ways. First, through participation of undergraduate and graduate students as well as postdoctoral researchers in the fieldwork and in data interpretation. Secondly, through frequent meetings with vineyard managers throughout Napa, as well as with their technical consultants.

Resources: NSF and University of California's Water Resources Center provided matching funds. In-kind support was provided by Mondavi, who provided personnel and equipment to support our field development efforts.

Results: Our research has assessed the utility of GPR groundwave data for shallow water content estimation. It has shown that GPR methods offer a good, reliable, and relatively easy to use geophysical approach for field-scale estimation of shallow water content. Although the GPR reflection approach yielded accurate estimates of water content at greater depths than the groundwave approach, this approach has limitations as a field tool, as the interpretation is more time consuming and expertise is needed to identify the source and depth of the reflector. Both GPR groundwave and reflection information can be used for a variety of subsurface investigations where understanding water infiltration and distribution over space and time is important.