Radar Application in Agriculture

GPR Geophysical Imaging of Agricultural Soils

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Introduction

We present preliminary near surface geophysical data collected during the 3rd Agricultural Geophysics Workshop organized by the City College of New York Geophysical Society and the agricultural stewardship program of the Cornell Cooperative Extension of Suffolk County. Our data collection activities took place at Cornell University's Long Island Horticultural Research and Extension Center in Riverhead, New York, on September 22nd, 2015. Our student group was guided by graduate student Gordon Osterman of the Department of Earth and Environmental Sciences of Rutgers, the State University of New Jersey in Newark, in the application of Ground-Penetrating Radar (GPR) in agriculture. In the presence of our field activities was Maurer Hansruedi, professor for exploration and environmental geophysics at ETH Zürich, Switzerland, who was the 2015 Near Surface Honorary Lecturer for the Society of Exploration Geophysicists (SEG). Professor Hansruedi delivered the keynote lecture during the same event titled "The Curse of Dimensionality in Exploring the Subsurface," which included a section on GPR data acquisition methods. The field-work was conveniently concluded with a vineyard tour and wine tasting at the "One Woman Wines and Vineyards" in Southold, New York. We present here essential background information on the GPR method and highlights of our data collection efforts.

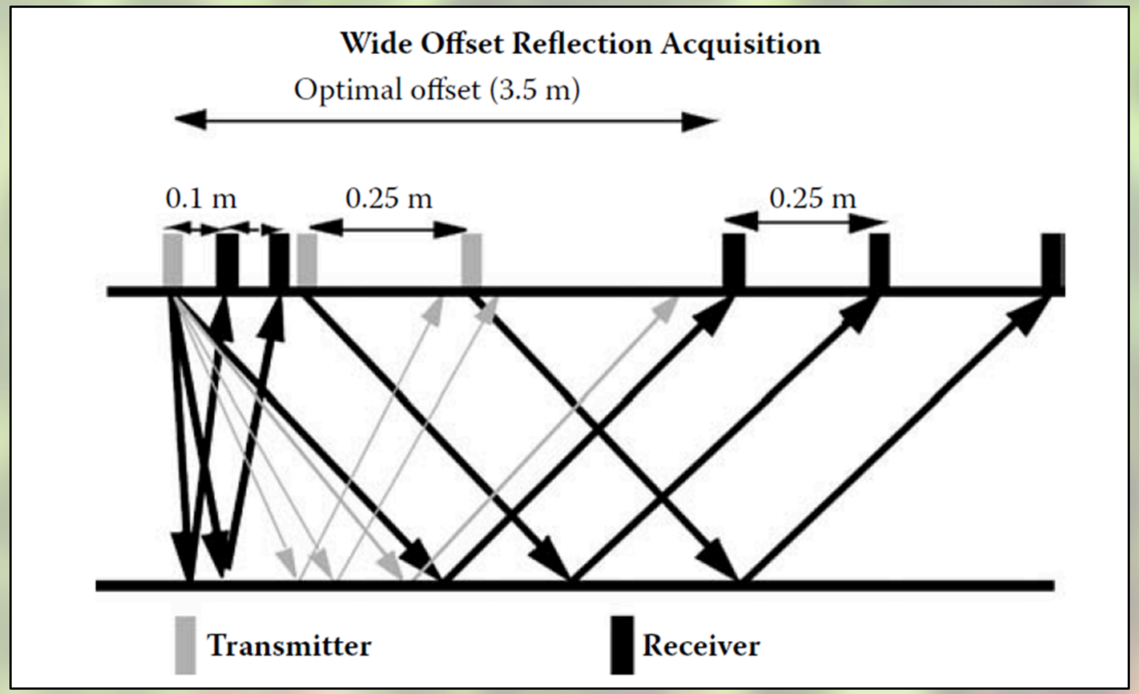
City College of New York students at the Cornell Cooperative Extension in Suffolk County in Long Island. Photo Credit: Clyde Thomson

Background

Agriculture is not nearly as cut and dry as plowing fields, planting seeds and watering on a daily basis. Before the land is even used, it is a good idea to figure out what is beneath the surface before doing anything. Just as a doctor would not operate on a patient without first having ordered a CT scan or an MRI, farmers should model the subsurface before digging into the ground. In agriculture, it is beneficial to know what is going on in the soil to maximize growing conditions.

In recent years, GPR has proven itself to be a useful tool in a wide range of applications. It can be applied in agriculture, environmental site characterization, archaeology, hydrology, and geology. GPR is a non-invasive geophysical method for subsurface characterization. It produces high resolution imaging using the dielectric properties of the subsurface. The imaging depths can range up to tens of meters and these images can be interpreted to assist in modeling the architecture of the subsurface. Due to its non-invasive nature, it has become a popular alternative to traditional subsurface characterization such as drilling or taking samples, which can disturb the subsurface.

Method



Acquisition geometry for wide-offset reflection GPR. A transmitter is stationary and sends signals into the ground while a receiver collects the signals after it travels through layers in the soil. The signals will move faster or slower due to the contents in the soil. Described by William P. Clement and Andy L. Ward in "GPR Surveys across a Prototype Surface Barrier to Determine Temporal and Spatial Variations in Soil Moisture Content." Adopted from the Handbook of agricultural geophysics (2008) by Barry Allred, Jeffrey J. Daniels, and Mohammad Reza Ehsani.

GPR works by analyzing the interactions of Electromagnetic (EM) waves with the subsurface. Different contents in the subsurface have different EM properties. Some of the properties analyzed by GPR include propagation velocity, relative permittivity, travel time, conductivity, and attenuation. A signal in the form of an EM pulse is emitted into the ground from a transmitter. The pulse interacts with the various contents and are reflected, scattered, or refracted back into the surface. The returning signal is picked up by a receiver with information of the contents the signal traveled through. The data is stored in a computer and can be processed later on.

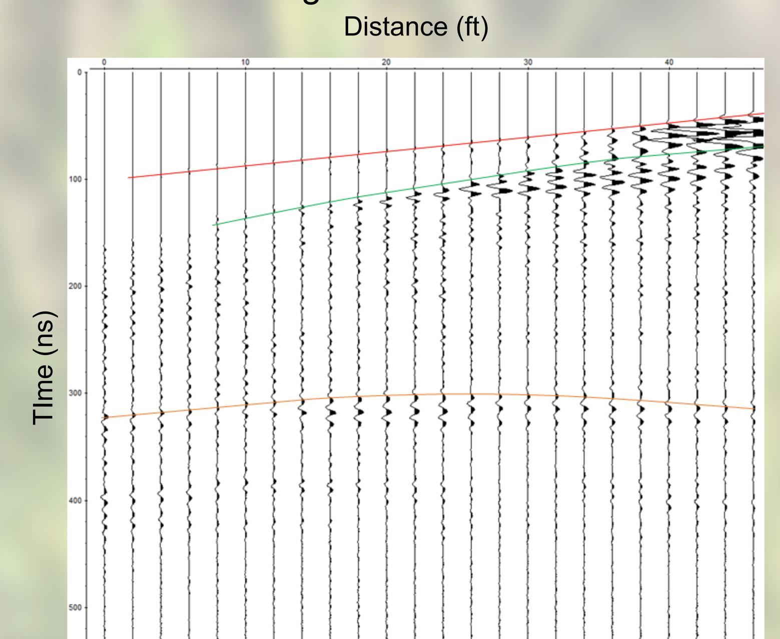
Given the right conditions and the proper execution of the process, GPR can give an accurate subsurface imaging of the surveyed area. It can reveal information about water content, buried matter, or different layers of material in the ground.

However, this tool is not without its drawbacks. Conditions in the ground may not always be ideal for GPR. High electric conductivity, for example, will cause the EM waves to attenuate much faster and less information can be obtained. The user must also make a choice between resolution and depth. Low frequency EM waves will allow the wave to travel to a lower depth, but the resolution of the imaging will be low. Higher frequency waves have low penetration, but will allow for a crisper image.

Long Island Field Demonstration

Common Midpoint Method

At the Cornell Agricultural Center, we were given a demonstration on two different methods of GPR data collection. The first method is called the Common Midpoint (CMP). This method uses a separate transmitter and receiver. The data collection begins with the two antennas at the point of collection. A low frequency pulse is emitted, travels through the ground, and then collected by the receiver. With each pulse, the distance between the two antennas increases by 2 feet along a linear path. As the two antennas move farther apart, the imaging will have greater depth and resolution. This technique requires multiple people to handle the equipment and is only good for data collection at a single point. As a result, CMP can be expensive and not viable for a large area.



Results from the CMP data collection during the demonstration. These waves indicate the different layers of soil in the ground

Red Line - Air Wave

Green Line - Plough Plan

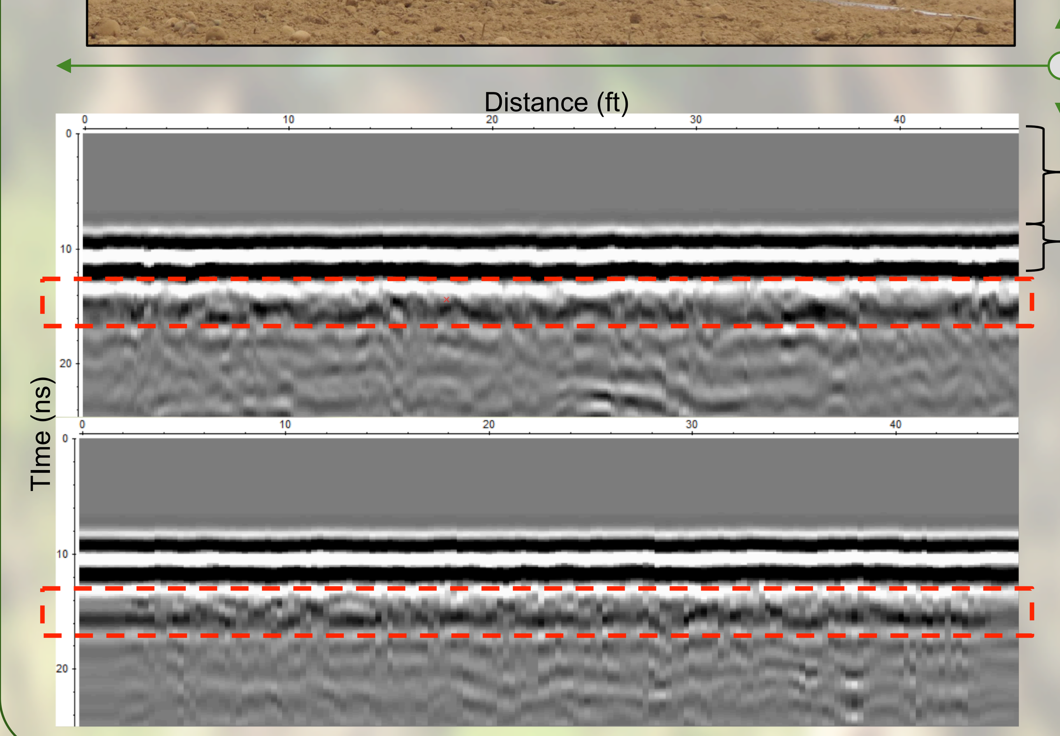
Orange Line - Off Angle Reflector

Preliminary results courtesy of Gordon Osterman.

Common Offset Method

The second method, Common Offset, is preferred for surveying large areas. Unlike the CMP method, both the transmitter and receiver are located within a small enclosure. The enclosure sits in a pushcart and is suspended very close to the ground. The GPR will then collect data at the point directly under the enclosure. The cart can then be pushed along a survey line, and data will be collected at equal time intervals. Common Offset uses a higher frequency, so the resolution will be higher but the penetration will be lower. The result will be a 2D cross section along the survey line. This method is much more convenient and is used more often than the CMP method.

Honor students Claudia Yan and Edwin Cho collect data across a potato field using the Common Offset method. The GPR is located in the enclosure at the bottom of the cart and the information is collected by a computer.
Photo Credit: Clyde Thomson



Results from the Common Offset data collection during the demonstration. A cross-sectional image is produced of the survey line. Different layers are indicated with darker lines.

Red Box - Plow Plan

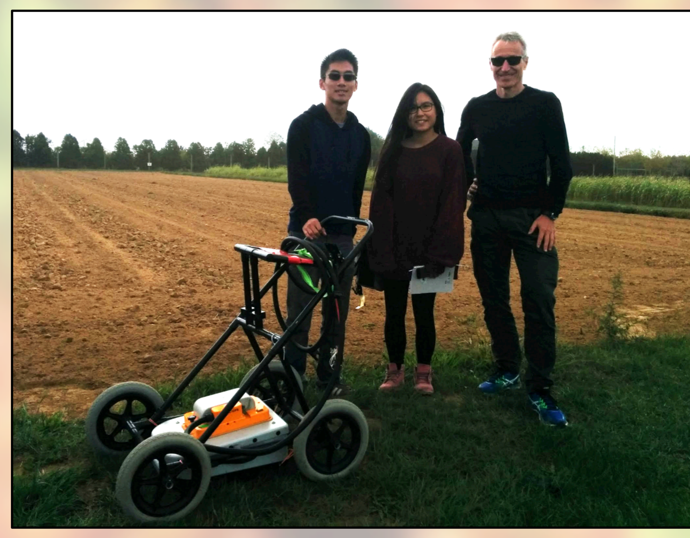
Preliminary results courtesy of Gordon Osterman.

Vineyard Geophysics

Grapes at One Woman Wines & Vineyards in Long Island. Fine grape growing require extensive knowledge in viticulture and geophysics can be used to monitor conditions of the ground.
Photo Credit: Claudia Yan

In order to produce the best yield of grapes for winemaking, soil moisture must be closely monitored since different soil conditions can affect the growth of the vine. If the soil is too wet, the grape will swell up and have no taste. If the soil is too dry, the plants will not get enough water and the grapes will die. The ideal crop is a small grape concentrated with flavor. Over the span of a vineyard soil properties can vary over different distances, as a result "spot" tests are not always sufficient to produce a uniform crop. GPR is an affordable and effective way at monitoring ground conditions. Electromagnetic pulses are sent into the soil and the time it takes the signal to be reflected back is recorded. The speed in which the waves are reflected back is affected by the water content of the soil; the wetter the soil, the slower it takes for the signal to return to the receiver. With the GPR, farmers can know the exact amount of water needed to efficiently irrigate the vineyard.

The Curse of Dimensionality



Honor students Claudia Yan and Edwin Cho stand with honorary speaker, Hansruedi Maurer during demonstration of GPR data collection.
Photo Credit: Angelo Lampousis

Data collection and analysis becomes more expensive as the number of dimensions are increased. In one dimension, properties of the ground only vary with depth. Data is only affected by variations in the layers of the subsurface. Only a handful of data points are needed to model that point. In two dimensions, analysis varies by both depth and profile of the land. With each increase in dimensionality, the number of data points we must collect to acquire an accurate imaging increases exponentially. To create a three dimensional model of the subsurface, data must be collected at many points across the surface of the area. This can take months to organize and process. More points of collection would mean a more accurate model, but it also means more time and money to perform the procedure. Ultimately the goal is to find the balance between the information retrieved with the money spent to collect the data.

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