United States Department of Agriculture

Natural Resources Conservation Service

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Subject: Soils -- Geophysical Assistance

Date: 15 May 2006

To: Margo L. Wallace
State Conservationist
USDA-NRCS,
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Purpose:
When nursery stock is dug-up, a ball of soil is removed around the plants roots. The soil and roots are wrapped in burlap or plastic to hold it together and retain moisture. Known as "Ball and Burlap" by the nursery industry, this method of preparing nursery stock for transplanting is a form of soil mining. Many Connecticut soils used for nursery stock have loamy caps overlying coarser-textured glacial drift. The presence and thickness of this loamy cap affects soil classification and interpretations. The purpose of this investigation was to assess whether ground-penetrating radar (GPR) and/or electromagnetic induction (EMI) could be used to facilitate the mapping and assessment of lands used for nursery stock. For this study, an area of Merrimac and Raypol soils was selected that was previously used for nursery stock.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Lisa Krall, Soil Scientist, USDA-NRCS, Tolland, CT
Harvey Luce, Retired Professor, University of Connecticut, Storrs, CT
Shawn McVey, Assistant State Soil Scientist, USDA-NRCS, Tolland, CT
Donald Parizek, Soil Scientist, USDA-NRCS, Windsor, CT
Debbie Surabian, Soil Scientist, USDA-NRCS, Tolland, CT

Activities:
All field activities were completed on 15 and 16 May 2006.

Summary:

1. Correlations between apparent conductivity (EC_a) measured with the GEM300 sensor and the thickness of the loamy cap was low. Low correlations are attributed to multiple layers of different textures and thicknesses, and the lack of sufficiently contrasting electromagnetic properties between the loamy cap and the sandy substratum.

2. Measurements obtained with the EM38DD meter in the horizontal dipole orientation were noticeably influenced by background noise and provided erroneous measurements (greater drift). Spatial patterns appearing on plots of EC_a data suggest variations in soil moisture contents.

3. On Merrimac soil, GPR provide adequate penetration depth and resolution of subsurface features. Multiple textural layers within the loamy cap and the lack of more contrasting electromagnetic properties between the loamy cap and the sandy substratum impaired and weakened radar interpretations.

4. The continuation of this study is encouraged. Returning to this site or other sites when soils are moister and the contrast between the loamy cap and the sandy substratum are greater may improve interpretations. The use of GPR and EMI to assess the loss of a loamy cap through “Ball and Burlap” mining should be expanded to soils with more abrupt and contrasting materials.

It was my pleasure to work in Connecticut and to be of assistance to your staff.

With kind regards,

James A. Doolittle
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National Soil Survey Center

cc:
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Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000, manufactured by Geophysical Survey Systems, Inc. (North Salem, New Hampshire).[1] Daniels (2004) discusses the use and operation of GPR. The SIR System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. The 400 and 900 MHz antennas were used in this investigation.

Radar records contained in this report were processed with the RADAN for Windows (version 5.0) software program (Geophysical Survey Systems, Inc).[1] Processing included setting the initial pulse to time zero, color transformation, marker editing, and range gain adjustments.

Two electromagnetic induction devices, the EM38DD meter and the GEM300 sensor, were used in this study. These devices are portable and require only one person to operate. No ground contact is required with either device. Lateral resolution is approximately equal to the intercoil spacing.

The EM38DD meter is manufactured by Geonics Limited (Mississauga, Ontario).[1] Operating procedures for the EM38DD meter are described by Geonics Limited (2000). The EM38DD meter has a 1-m intercoil spacing and operates at a frequency of 14,600 Hz. When placed on the soil surface, the EM38DD meter provides theoretical penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively.

The Geonics DAS70 Data Acquisition System (developed by Geonics Limited) was used with EM38DD meter to record and store both EC_a and Global Positioning System (GPS) data.[1] The acquisition system consists of an EMI meter, an Allegro field computer (Juniper Systems, North Logan, Utah), and a Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack).[1] With the acquisition system, the EMI meter is keypad operated and measurements are automatically triggered.

To help summarize the results of the EMI survey, SURFER for Windows (version 8.0) software, developed by Golden Software, Inc. (Golden, Colorado), was used to construct a two-dimensional simulation.[1] Grids were created using kriging methods with an octant search.

The GEM300 multifrequency sensor is manufactured by Geophysical Survey Systems, Inc.[1] Won and others (1996) describe the use and operation of this sensor. This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed coil separation of 1.3 m. With the GEM300 sensor, the penetration depth is considered “skin depth limited” rather than “geometry limited.” The skin-depth represents the maximum depth of penetration and is frequency and soil dependent: low frequency signals travel farther through conductive mediums than high frequency signals. Theoretical penetration depths of the GEM300 sensor are dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequencies. Multifrequency sounding with the GEM300 theoretically allows multiple depths to be profiled with one pass of the sensor. The GEM300 sensor is keypad operated and measurements can either be automatically or manually triggered. The simultaneous measurement of apparent conductivity in both dipole orientations is not possible with the GEM300 sensor; the sensor must be rotated to measure both dipole orientations. In addition, the simultaneous recording of EMI and GPS data are not possible with the GEM300 sensor.

Study Site:
The site is located in tobacco field on the Vincent Farm in West Suffield Connecticut. The site is located in areas of Merrimac sandy loam, 3 to 8 percent slopes (map unit 34B), and Raypol silt loam (map unit 12) (Shearin and Hill, 1962). The very deep, somewhat excessively drained Merrimac soil formed in sandy outwash. Solum thickness ranges from 18 to 30 inches and closely corresponds with the depth to the sandy outwash. The very deep, poorly drained Raypol soil formed in loamy over sandy and gravelly outwash. Thickness of the

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[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

solum ranges from 18 to 36 inches. Merrimac is a member of the sandy, mixed, mesic Typic Dystrudepts family. Raypol is a member of the coarse-loamy over sandy or sandy-skeletal, mixed, active, acid, mesic Aeric Endoaquepts family.

The study site is shown in Figure 1. The site is located very near the Massachusetts state border (white line across the upper part of the image). In Figure 1, the investigated field has been highlighted with a red rectangle. The majority of the field is located in an area of Merrimac sandy loam, 3 to 8 percent slopes. The eastern portion of the field forms an off-drainage transitional area into a unit of Raypol silt loam. At the time of this investigation, the field was planted to tobacco and soils were relatively dry.

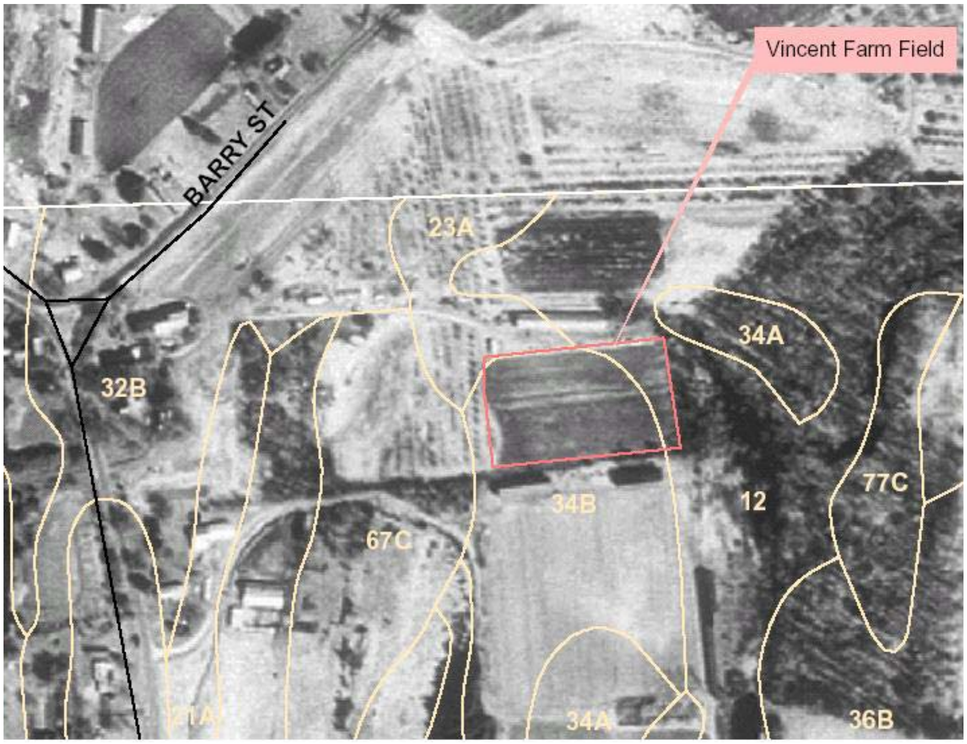

Figure 1. Location of the tobacco field in West Suffield surveyed with GPR and EMI (courtesy of Debbie Surabian).

Results:

<u>EMI:</u>

The thickness of the loamy cap was measured with the aid of a shovel and auger at 20 observation points. At these observation points, the averaged thickness of the loamy cap was 20.9 inches with a range of 12 to 37 inches. At one half of the observation points, the loamy cap was between 15 and 25 inches thick. Thicknesses less than 18 inches are outside the lower depth range for the solum of Merrimac and Raypol soils.

Correlations between apparent conductivity (EC_a) (measured with the GEM300 sensor) and loamy cap thicknesses were low. At a frequency of 9810 Hz, the correlation coefficient (r) between EC_a and cap thickness was 0.25 and 0.39 in the vertical and horizontal dipole orientations, respectively. At a frequency of 14610 Hz, the correlation between EC_a and cap thickness was 0.36 and 0.27 in the vertical and horizontal dipole orientations, respectively. In general, EC_a decreased with increasing soil depth, and increased with increased thickness of the loamy cap. Loamy caps have higher clay and moisture contents than the underlying sandy substratum. Low correlations are attributed to multiple layers (sandy loams and loamy sands textures) within the loamy cap, and the lack of greater contrasts in electromagnetic properties between the loamy cap and the sandy substratum. The lack of an abrupt and strongly contrasting contact between the loamy cap and the underlying sandy substratum weakened the electromagnetic gradient and reduced the strength of correlations.

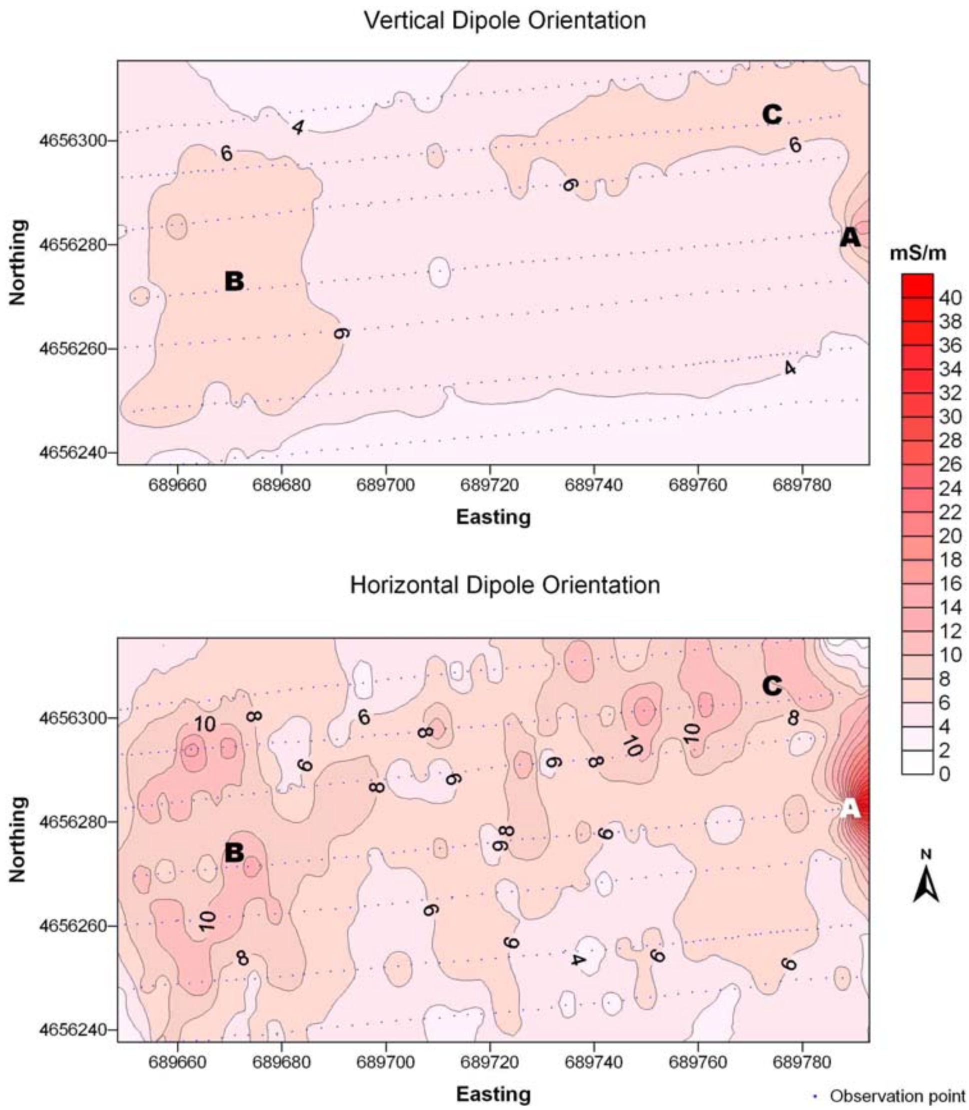

Figure 2. Spatial patterns of apparent conductivity measured with the EM38DD meter across the tobacco field.

Figure 2 shows spatial patterns of EC_a measured with the EM38DD meter in the shallower-sensing, horizontal dipole (lower plot) and the deeper-sensing vertical dipole (upper plot) orientations. In each plot, the isoline interval is 2.0 mS/m. With the exception of interference from a metallic feature located in the eastern portion of the study site (see A in each plot in Figure 2), EC_a was very low. Based on 410 observations; EC_a decreased and was less variable with increasing depth of observation. This relationship is attributed to the higher and more variable clay and moisture contents in the loamy cap than in the sandy substratum. In the shallower-sensing horizontal dipole orientation, EC_a averaged 7.4 mS/m with a standard deviation of 3.15 mS/m. At one-half of the observation points, EC_a was between 5.8 and 8.9 mS/m in the horizontal dipole orientation. In the deeper-sensing vertical dipole orientation, EC_a averaged 5.2 mS/m with a standard deviation of 1.4 mS/m. At one-half of the observation points, EC_a was between 4.2 and 6.1 mS/m in the vertical dipole orientation.

In the accompanying plots, two zones of slightly higher EC_a (> 6 mS/m in vertical dipole orientation; > 8 mS/m in the horizontal dipole orientation) are apparent. The area surrounding "B" is located in a slightly wetter area of Merrimac soil at the base of a slope. The area surrounding "C" is located on a level area of Raypol soil that was noticeably moister at the time of this survey.

More intricate patterns and a greater range in EC_a are apparent in the plot of the data collected in the horizontal dipole orientation (see lower plot). These patterns are attributed in part to the higher EC_a and the variable thickness of the loamy cap. However, in the horizontal dipole orientation, the EM38DD meter was noticeably more sensitive to background noise and provided less stable measurements (greater drift) than in the vertical dipole orientation. Measurements collected in the horizontal dipole orientation are considered too unstable for use and analysis. Because of these observations and results, the EM38DD meter has been returned to Geonics Limited for system checks and recalibration.

GPR:
Figure 3 is a radar record from the study site that was collected with the 400 MHz antenna. The depth scale shown in Figure 3 is based on the two-way travel time to a known object buried at a depth of 48 cm. The velocity of propagation through the upper part of the soil was estimated at 0.236 m/ns. The relative dielectric permittivity was 1.6.

In Figure 3, a thin white line (see above "A") has been used to show the interpreted thickness of the loamy cap and the depth to the underlying sandy outwash. Although the 400 MHz antenna provided poorer resolution (ability to discriminate two closely spaced features) than the 900 MHz antenna, the imagery was more readily interpretable and was better correlated with the measured depths to the upper contact of the sandy outwash. Slight measurement errors were noted with each antenna. The substratum near "B" in Figure 3 is composed of distinctly inclined strata. This imagery is characteristic of glacial outwash. The substratum near "C" in Figure 3 is more chaotic, a signature that is characteristic of glacial till.

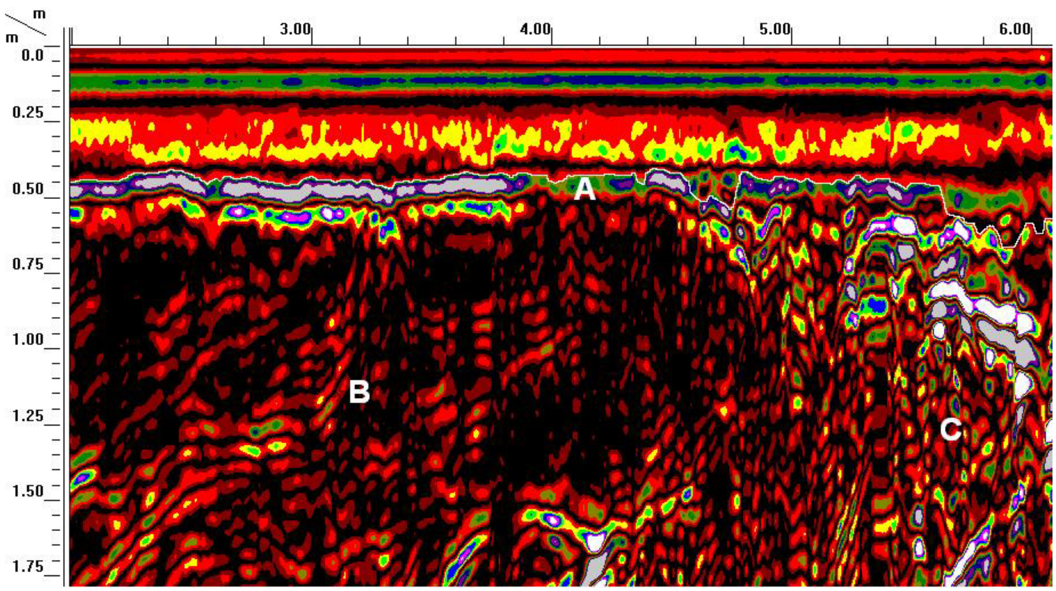

Figure 3. Radar record collected with a 400 MHz antenna.

In areas of Merrimac soil, GPR provide adequate penetration depth and resolution of subsurface features. Multiple textural layers in the loamy cap and the lack of more contrasting electromagnetic properties between the loamy cap and the sandy substratum impaired and weakened interpretations. Returning to this site when the soils are moister and the contrast between the loamy cap and the sandy substratum are greater may improve interpretations. The use of GPR to assess the loss of a loamy cap through "Ball and Burlap" mining should be explored in Connecticut on soils with more abrupt and contrasting materials.

References:

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