MISSOURI

Using Electromagnetic Induction to Characterize Soils

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Electrical conductivity measurements have been used for years to determine salinity and moisture in soils. Probes were inserted directly into the soil to determine how well the soil conducted an applied current. This process was slow and labor-intensive and was usually reserved for scientific studies. A more recent technique for measuring conductivity is electromagnetic induction (EM), a non-invasive, non-destructive sampling method. No probes are required using EM, and measurements can be done quickly and inexpensively.

How Does EM Work?

We have used the EM-38, a commercially available instrument from Geonics Ltd., Ontario, Canada. The EM-38 is about 3 ft. long and is light-weight enough to be carried in one hand. The unit is powered by a single 9 volt battery that lasts approximately 16 to 20 hours. The principle of operation of the EM-38 is shown in the drawing in **Figure 1**.

The transmitting coil induces a magnetic field that varies in strength with depth in the soil. The relative strength of the magnetic field is illustrated by the relative diameter of the circles in **Figure 1**. The magnetic field is strongest about 15 inches below the soil surface and has an effective sensing depth of about 5 ft. A receiving coil reads primary and secondary "induced" currents in the soil. It is the relationship between these primary and secondary currents that measures soil conductivity. In **Figure 1,** the thicker circles illustrate soils that are better conductors of electrical current. Clayey soils have a higher electrical conductivity than coarser textured soils, so when a clay horizon is nearer the surface (*b* in **Figure 1**), the EM sensor reading is higher. Deeper topsoils having a clay horizon further below the soil surface (*a* in **Figure 1**) are less conductive to electrical current and have lower EM readings.

Researchers are studying use of electromagnetic induction as a convenient and low cost method for measuring variability beneath the surface, particularly for claypan soils. The information may help identify optimum nitrogen (N) rates for various field areas.

How Are EM Measurements Used?

Electromagnetic induction technology was originally developed for the mining industry, and has been used in mineral, oil, and gas exploration, groundwater studies, and archaeology. In these applications, differences in conductivity of subsurface layers of rock or soil may indicate stratified layers or voids that could be of interest. In agriculture, the EM sensor was first used to measure soluble salts and soil moisture. Other agricultural applications now include determining soil mapping units, estimation of topsoil depth in claypan soils, depth of sand deposition after river flooding, estimation of herbicide degradation, and crop productivity. For each of the applications described above, a relationship must be established between the EM sensor reading and the soil feature of interest. Once the relationship is established, however, the readings can be gathered rapidly.

A mobile EM data collection unit is shown in **Figure 2**. The EM sensor is mounted on a wooden trailer away from metallic objects and vehicle engine interference that can affect EM readings. A differential global positioning system (DGPS) receiver is mounted on the vehicle, with an analog-to-digital converter and a computer that records EM sensor

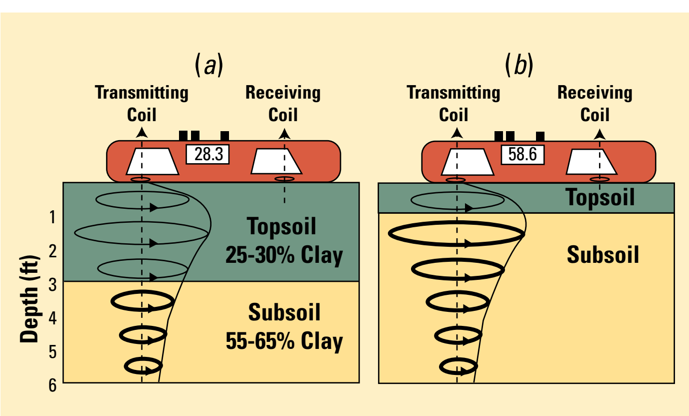

Figure 1. EM-38 principle of operation in soils.

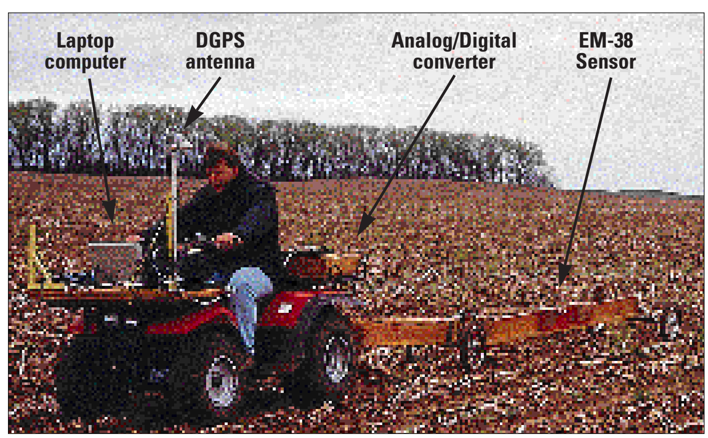

Figure 2. Mobile EM-38 sensor unit is pulled behind a four-wheel ATV, equipped with analog/digital converter, laptop computer, and DGPS antenna.

readings along with a DGPS location. Using this equipment, data from whole fields can be taken quickly, and then maps of soil conductivity can be made. Data for a 20-acre field can be collected in about one hour.

EM Research on Claypan Soils

Claypan soils are important agricultural soils in the southern Corn Belt, covering 10 million acres in seven states. They comprise a significant portion of cropland in Missouri, and can present farmers with difficult management choices. They have an abrupt and marked increase in clay content between the upper soil layer and subsoil. The clay content increases by at least 20 percent, and this layer of high clay soil impedes the movement of water and air, restricting the growth of plant roots.

Topsoil depth and corn grain yield measured along a field transect is shown in **Figure 3**. The depth to the claypan layer varies from a few inches to more than 40 inches, and it is apparent that grain yield is related to the depth to the claypan layer. Within a field, the variation in depth to the claypan can be seen by spatial patterns in crop water stress. The areas having shallow topsoils (often on eroded side-slopes) are the first to have water-stressed plants. Clearly, having information on the depth of topsoil would be a valuable tool in tailoring management for crop needs.

A management example using N fertilizer for corn production is shown in **Figure 4**. The first step is to collect EM sensor data for the field using the mobile EM unit. In this case, transects for EM data were taken at a very close interval (about 15 ft.). In most cases, a transect interval of 40 to 60 ft. gives sufficient data density to map the field. For selected points in the field, topsoil depth (measured using a soil probe) and soil conductivity (by EM) were determined concurrently. From these data points, a regression equation between EM sensor reading and topsoil depth was calculated to produce a map of topsoil depth for the field. Finally, an N recommendation map was made based on topsoil depth (*c* in **Figure 4**). Nitrogen recommendations in Missouri and other Corn Belt states often use expected yield (or yield goal) as one of the parameters for estimating crop N needs. Yield goals are usually established for a whole field, and may be adjusted for previous crop, organic matter content, and/or residual nitrate. Missouri studies have shown that yield goal potential is related to topsoil depth:

Yield goal = 98 bu/A + 2.2 x topsoil depth (inches).

We used this relationship to produce a map of yield goal. From this yield goal map we made an N application map.

In **Figure 5**, the EM map is compared to an aerial photo of corn crop cover in late July. Patterns of low EM sensor readings (deeper topsoil) match patterns of darker green crop cover. Areas of shallower topsoil (high EM sensor readings) are also areas where crop cover is less dense and yellowing due to moisture stress. Using the photo of crop cover, it is easy to see differences in potential productivity within this field and how well patterns of potential productivity are correlated to soil conductivity readings, using the EM-38.

Other work with the EM sensor is ongoing with alluvial and loess soils. These soils do not have the abrupt layer boundaries characteristic of claypan soils. However, soil texture can be related to EM readings and work is continuing to relate these readings to crop response. BC

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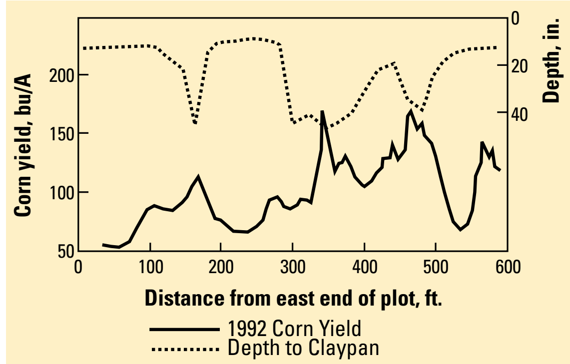

Figure 3. Corn yields and depth to claypan layer along a transect at Centralia, Missouri.

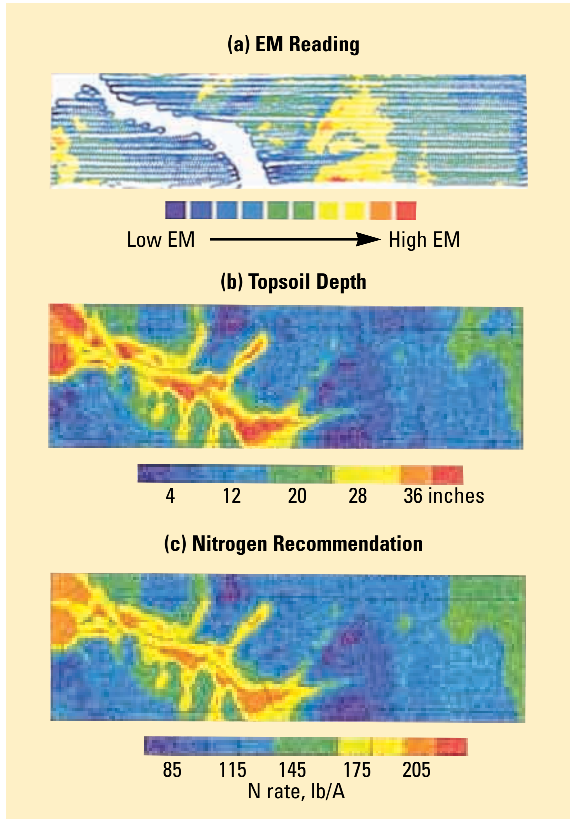

Figure 4. EM-38 soil conductivity, topsoil depth, and N recommended for corn at Centralia, Missouri.

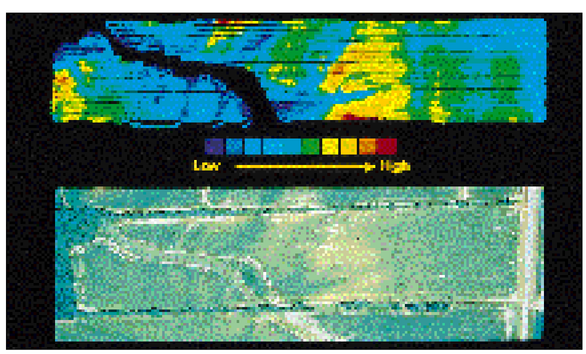

Figure 5. EM-38 sensor readings (a) and aerial corn crop cover photo (July 25, 1997) at Centralia, Missouri site.