Extension FactSheet

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Soil Electrical Conductivity (EC) Sensors

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Soil electrical conductivity, which is known as EC, is the ability of soil to conduct electrical current. EC is expressed in milliSiemens per meter (mS/m). Traditionally, soil scientists used EC to measure soil salinity. However, EC measurements also have the potential for estimating variation in some of the soil physical properties in a field where soil salinity is not a problem. Recent developments in EC sensors and their ability to produce EC variation maps has attracted much attention among producers about potential applications of this sensor for improving field management. The goal of this fact sheet is to provide the producer with facts and information about EC sensors.

How to collect soil EC data in the field

There are two types of EC sensors currently on the market to measure soil EC in the field. They can be divided into two types based on the method of EC measurement: contact or non-contact.

1. Contact method

This type of sensor uses electrodes, usually in the shape of coulters that make contact with the soil to measure the electrical conductivity. In this approach, two to three pairs of coulters are mounted on a toolbar; one pair applies electrical current into the soil while the other two pair of coulters measure the voltage drop between them (Figure 1). Soil EC information is recorded in a datalogger along with location information. A Global Positioning System (GPS) provides the location information to the data logger. The contact method is more popular for precision agriculture applications, because with this method it is easier to cover more area and it is less susceptible to outside interference. The disadvantage of this system is that it is usually bulky and cannot be used in some small farms and plots. Currently, Veris Technology manufactures the contact type of EC measuring device. There are two types of Veris units commercially available: the 300XA and the 200XA. The 300XA provides EC readings from two different depths (1 foot and 3 feet). The 200XA provides EC measurements at only one depth. However, the depth is adjustable and is normally set at 3 feet. The 200XA is smaller in size and easier to maneuver on smaller farms. The Veris unit can be pulled behind a truck through the field at speeds of up to 10 mph and covers swaths 20 to 60 feet wide, depending on the needed resolution or amount of soil variability in the field.

2. Non-contact method

This type of EC sensor works on the principle of Electromagnetic Induction (EMI). EMI does not contact the soil surface directly. The instrument is composed of a transmitter and a receiver coil (Figure 2) usually installed at opposite ends of a non-conductive bar located at opposite ends of the instrument.

EM38 (Geonics Limited) and GEM-2 (Geophex) are two popular models of non-contact sensors that are available on

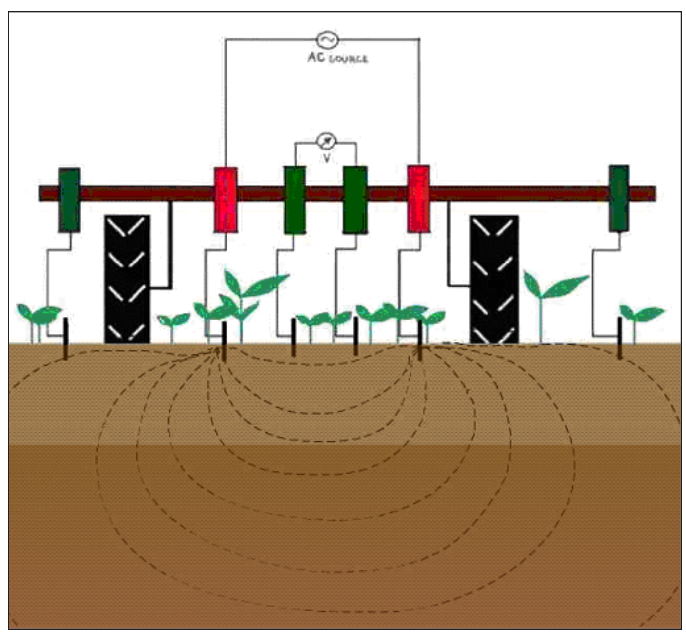

Figure 1. Principle of operation for the contact type EC sensor

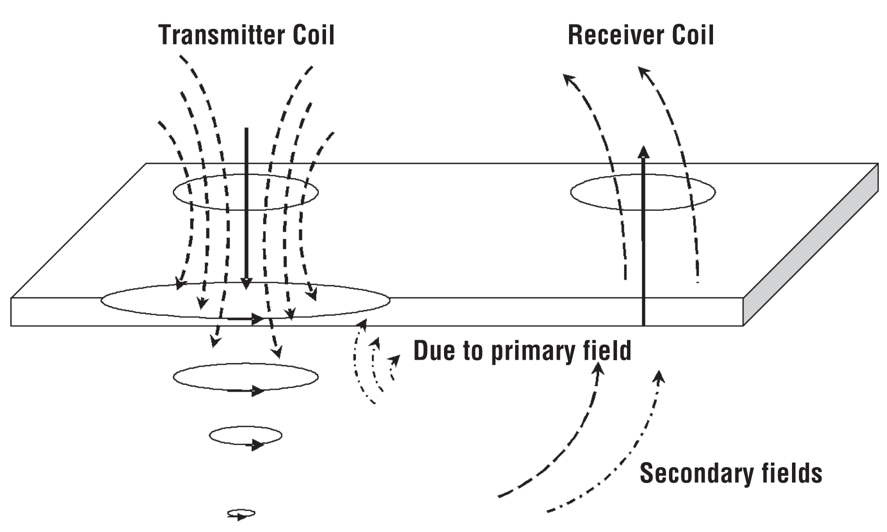

Figure 2. Principle of operation for the non-contact type EC sensor

the market. GEM-2 (Figure 3) is a digital and multi-frequency sensor that can operate in a frequency range of 300 Hz to 24 KHz. The GEM-2 is capable of measuring EC at different depths. EM-38 works only with a fixed frequency and has an effective measurement depth of 1.5 m (5 ft.) in horizontal dipole mode or 0.75 m (2.5 ft.) in vertical dipole mode.

How to create an EC map

As a vehicle equipped with an EC measuring device drives through the field, data are collected at one-second intervals. The data are recorded in a file and stored on a PCMCIA card. An EC data file from the Veris unit has four columns. The first and second columns contain longitude and latitude information. The third and fourth columns contain EC data at shallow depths and deep depths, respectively. Figure 4(a) shows a plot of raw EC data. It shows where the vehicle was in the field as it drove through the field, and the color shows the EC variation for shallow depths. A software program is needed to create an EC map, as shown in Figure 4(b). There are different software programs available on the market that can create maps from datapoint files such as, Surfer (GoldenSoftware, Inc.), ArcView (ESRI), and Global Mapper (Global Mapper).

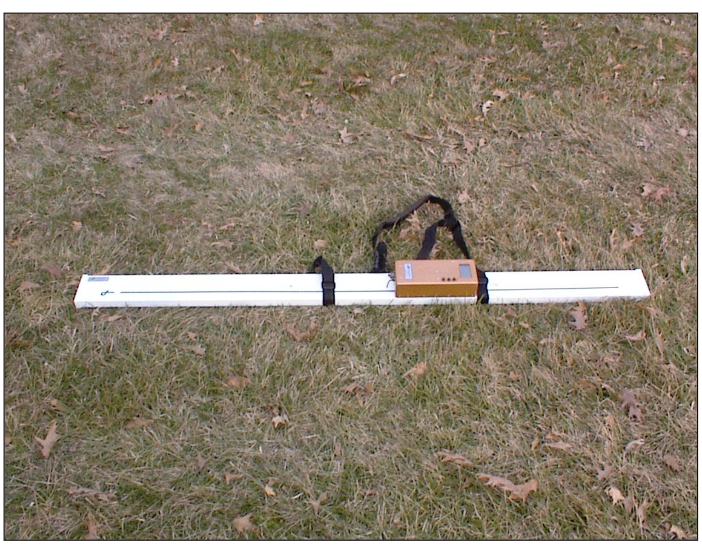

Figure 3. GEM-2 non-contact EC measuring device

Factors affecting EC

The conduction of electricity in soil takes place through the moisture-filled pores that occur between individual soil particles. Therefore, the EC of soil is determined by the following soil properties (Tom Doerge, 1999):

1. **Porosity**—The greater soil porosity, the more easily electricity is conducted. Soil with high clay content has higher porosity than sandier soil. Compaction normally increases soil EC.
2. **Water content**—Dry soil is much lower in conductivity than moist soil.
3. **Salinity level**—Increasing concentration of electrolytes (salts) in soil water will dramatically increase soil EC. The salinity level in most Corn Belt soils is very low.
4. **Cation exchange capacity (CEC)**—Mineral soil containing high levels of organic matter (humus) and/or 2:1 clay minerals such as montmorillonite, illite, or vermiculite have a much higher ability to retain positively charged ions (such as Ca, Mg, K, Na, NH_4, or H) than soil lacking these constituents. The presence of these ions in the moisture-filled soil pores will enhance soil EC in the same way that salinity does.
5. **Temperature**—As temperature decreases toward the freezing point of water, soil EC decreases slightly. Below freezing, soil pores become increasingly insulated from each other and overall soil EC declines rapidly.

How to interpret an EC map

The simplest way to interpret an EC map is to compare it with other maps of the same site with similar sampling patterns or intensities. This may give insight into the relationship between EC and yields or other factors.

Another way to interpret an EC map is to divide the map into NxN cells and compare the average of one cell with the value of the same cell on a map (for example: elevation, plant population). Statistical methods can be employed to find the similarities among different layers and to obtain relationships between EC and yield or with certain soil characteristics. If there is a similarity between yield variation on the yield map and EC variation on the EC map, it could be an indication that the soil physical properties are the main cause of yield variation, in particular, water holding capacity.

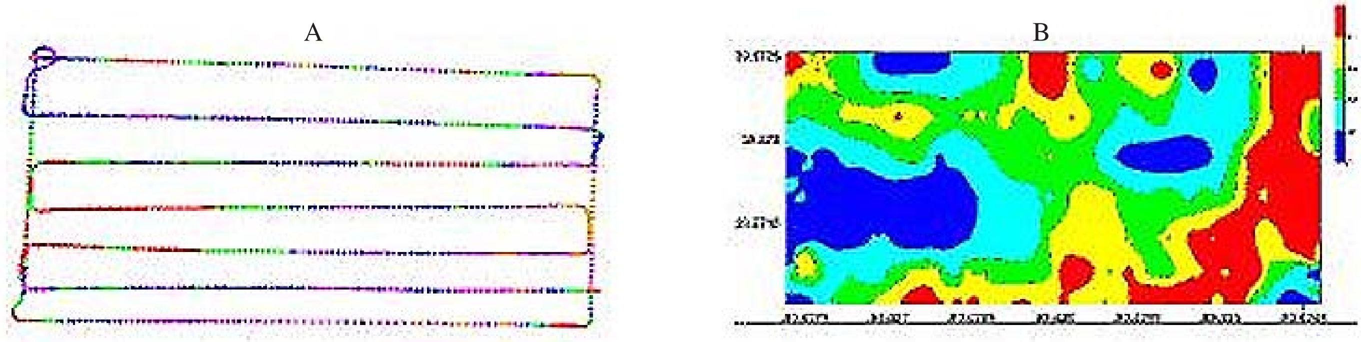

Figure 4. (a) Actual EC data and (b) EC contour map of research plots

Possible uses of EC

Application of EC Mapping	***Soil Properties Estimated***
Directed soil sampling within more accurate soil boundaries	Soil texture, organic matter, CEC, drainage conditions
Variable rate seeding	Topsoil depth
Variable rate nutrient application based on soil productivity	Depth to claypan subsoil or parent material, soil texture
Variable rate herbicide application	Soil texture and organic matter
Interpretation of yield maps	Soil factors that most influence yield, particularly plant-available water content
Fine-tuning of NRCS soil maps by refining soil type boundaries and identifying unmapped inclusions	All soil factors
Guidance for placement and interpretation of on-farm tests	All soil factors
Soil salinity diagnosis	Electrolytes in soil solution
Drainage remediation planning	Water holding capacity, sub-soil properties, water content

(Tom Doerge, 1999)

Pros and cons of EC maps

The EC value is a combined result of physical and chemical properties of soil. It has potential applications in precision agriculture for management decisions and the delineation of management zones. For precision agriculture applications, EC information works best when yields are primarily affected by factors that are best related to EC, for example, water holding capacity, salinity level, depth of topsoil, and so on. As a result, it may not work well in areas when other factors (such as disease, pests, etc.) are more predominant.

References and websites for EC information

Tom Doerge. 1999. Soil Electrical Conductivity Mapping, *Crop Insights,* Vol. 9 No. 19.

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