Measurement and Uses of Soil Electrical Conductivity

This guide was produced as part of a project jointly funded by the North Central Soybean Research Program and the United Soybean Board. Research Team: William Wiebold and Harlan Palm (University of Missouri); Ken Sudduth and Newell Kitchen (USDA/ARS/University of Missouri); Bill Batchelor (Iowa State University); Kurt Thelen (Michigan State University); David Clay (South Dakota State University) Don Bullock and German Bollero (University of Illinois); Ron Schuler (University of Wisconsin).

Introduction

Soil electrical conductivity (EC) is just one of many measurements producers can make of their fields to help them prepare for site-specific crop management. But, it may be one of the most meaningful. Mapping EC is generally considered a one-time procedure for a given field. On a per acre basis, it is one of the least expensive soil measurements.

Measurement of electrical conductivity of the soil profile provides an indication of the depth of soil layers, soil texture, organic matter content, water content, cation exchange capacity, and salinity levels. Data are collected while the measuring device travels across the field with passes spaced 30 to 100 feet apart, dependent on the amount of spatial variability and desired accuracy. An implement equipped with a differential global positioning system (DGPS) receiver allows the collected data to be spatially referenced so that maps can be made. The digitized maps provide input for delineating management zones to guide future inputs that involve variable rate application from a spatial perspective.

Information gained from measuring EC can help the producer understand what has caused within-field yield variability. It can help characterize soil differences related to crop productivity. For example, depth of topsoil is typically the thinnest on eroded hill sides and deepest in the depositional toeslopes. The depth of the topsoil plays an important role in water holding capacity during dry spells and serves as the storage space for nutrients and anchoring of crop roots. Spatial variability in the depth of topsoil can explain at least some of the spatial variability in crop productivity. Weather patterns can influence whether or not soil depth is a limiting factor for a given season. Year-to-year variability in weather adds to the complexity.

As the producer understands more about the complex causes of within-field yield variability, the probability of making better management decisions increases. The outcome can be increased production of the field as a whole and/or reduced input costs which translate into profitability without impairing environmental stewardship of the land.

Glossary:

DGPS - Differential Global Positioning System that uses corrected position signals from a stationary base station (U.S. Coast Guard beacon) plus position signals from satellites.

Soil electrical conductivity - the ability of soil to conduct or transmit an electrical current.

Spatial - the location relationship of geographical features or specific points in a field.

Measuring soil electrical conductivity

Water, salts, and fine textured clay particles conduct electricity better than air pockets (soil pore space), organic matter, silt and sand. So, soil EC readings are related to the combination and mixtures of these variable.

There are two types of equipment that can measure soil EC. One type makes shallow contact with the soil while the other is non-invasive. The one in Figures 1uses a pair of shallow penetrating coulters as electrodes that emit an electric current into the soil. Another pair of coulters act as sensors to

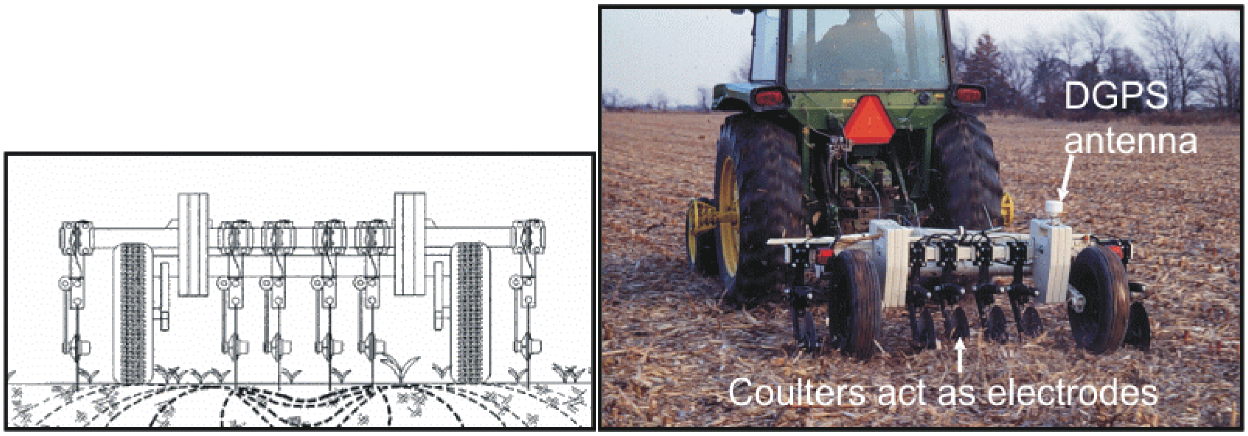


Figure 1: Drawing and photograph of a Veris 3100.

measure the electricity conducted from one set to the other. The drop in voltage is correlated with how effective the soil is in conducting electricity. The distance between the coulters determines the depth of the reading. The Veris 3100 as shown here measures EC to depths of 1 and 3 foot.

The non-invasive type of equipment induces a magnetic field into the soil profile. The Geonics EM38 as shown in Figure 2 measures EC to a depth of five feet. The sensor is mounted on a wheeled cart and rides close to the ground. The sensor must be spaced adequately from metal and the electronics of the towing vehicle to prevent electronic noise in the data. At usual operating speeds, data are collected every 10 to 20 feet.

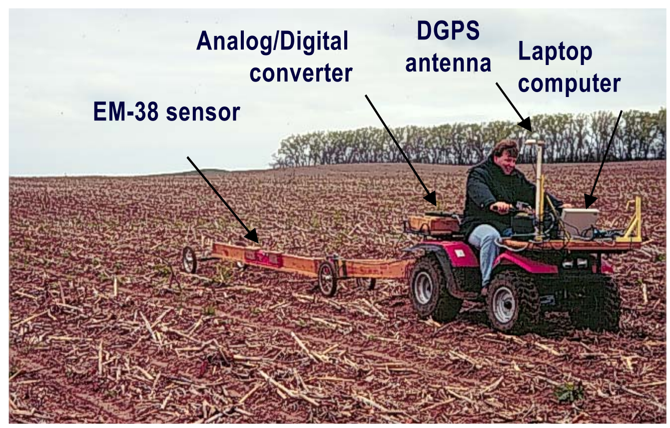


Figure 2: Geonics EM 38

Why collect EC data?

A map of a field's electrical conductivity can provide considerable insight into how the soil profile varies in the field. Even a flat field possesses variability beyond expectations. Topsoil depth can change independent of the visible landscape. The influence of glacial deposition and the sequence of alluvial deposition, erosion, or loess deposits cause the main variations. Thus, we can not accurately predict the properties of a soil profile by looking at the surface.

It is cost prohibitive to collect enough deep soil cores to characterize the soil profile because often it varies considerably across the field. Collection of soil EC can serve as a relatively inexpensive way of gathering several types of information. It can simultaneously give an indication of several profile characteristics and soil properties. Coupled with DGPS equipment, readings are typically collected at one second intervals. In a very short time, one can collect a large amount of data that is geo-referenced so that maps can be generated to show how the attributes spatially vary within the field.

Knowledge of the variability in topsoil depth is one inference that is gained from measuring EC. Spatial variability in topsoil depth frequently correlates with yield maps. Think of the topsoil as a sponge with varying thicknesses across the field. Areas with the thin "sponge" can not absorb and store as much rain during a heavy storm as areas with a thick "sponge". During ensuing dry spells, the crops are apt to show moisture stress over the thin topsoil. During wet years however, these thin topsoil areas may produce nearly as much as the other areas.

Because the productivity of the thin topsoil areas is more dependent on the weather than areas with thicker topsoil, yield variability from year-to-year is typically greater.

Geo-referenced information such as topsoil depth can be used to guide or direct soil sampling for nutritional analysis. Soil samples from similar areas would be combined and analyzed separately from samples of dissimilar areas. This would save sampling time, analytical expense, and provide a more meaningful description of the differences among the areas or zones within the field. This approach is an economical alternative to a grid-sampling approach.

The producer can also use the information to increase the probability of success in making the best management decisions for field inputs. Topsoil depth as it relates to productivity may be considered one of the factors in forming management zones. Variable rate of fertilizer application according to topsoil depth could improve the odds of success on the field. Success may be in terms of greater consistency in yield across the field, increased savings and profitability, or less impact on the environment.

The EC data also could provide valuable indications of spatial variability in soil texture, organic matter content, and cation exchange capacity. All of these could influence decisions in forming management zones relative to variable rate fertilizer application or variable seeding rate. EC data are also being used in some regions to delineate variability in salinity levels.

Potential uses of EC maps:

- Compare to soil survey and yield maps as mentioned earlier. This is a visual exercise to look for similarities in areas or zones of the field. Evaluation of EC and yield maps can also be done using statistical analysis to help explain yield variability within the field. Yield maps from multiple years may look dissimilar but trends will become apparent that relate back to patterns seen in EC maps.
- Direct soil sampling within zones of similar EC values within the field.
- Delineate management zones based on EC maps as a surrogate indication of water holding capacity. Water holding capacity is a function of depth of topsoil, soil texture, and soil structure which can be inferred by EC measurements.
- Variable rate fertilizer application within management zones can be based on EC indications of depth of topsoil, soil texture, and cation exchange capacity.
- Variable rate seeding within management zones can be based on water holding capacity which relates back to depth of topsoil, texture, and structure.
- Variable rate herbicide application of pre-emergence herbicides whose efficacy is affected by soil texture, organic matter content, and cation exchange capacity.

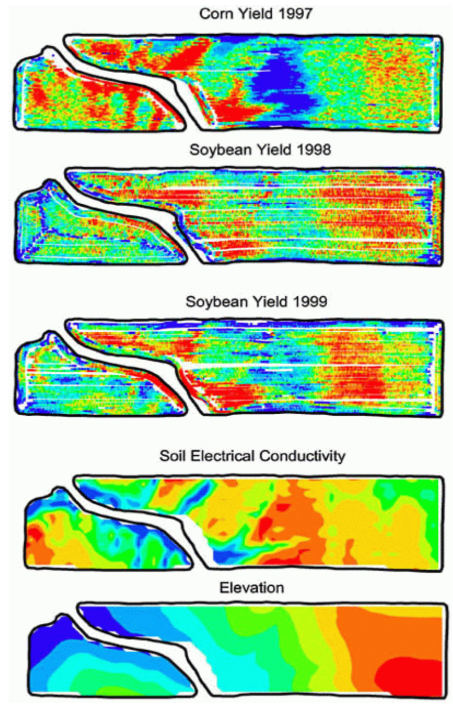
Options for collecting EC data:

Measurement of soil EC is a one-time measurement or expense because it is not expected to change unless there is significant surface disturbance. Large farming operations may justify the cost of purchasing equipment and computer software to process the data. Most operations could consider either renting the equipment or electing to hire a consultant or dealer to provide the equipment, collect the data, and process the information into field maps.

Information on obtaining and using the Veris equipment can be obtained by calling Veris Technologies at 785-825-1978 or visiting the web at www.veristech.com Information on the electromagnetic EM-38 can be obtained on the web at www.geonics.com

How to process the data into maps:

The geo-referenced data require computer software that can handle spatial values. Some examples are ArcView, Surfer, ENVI, Imagine and SSToolbox. Such software groups or classify the data into ranges. Each range should contain an equal count or number of data points. The result is a map that shows ranges or levels of electrical conductivity in the field. These ranges in EC measurement are surrogate or substitute estimates of depth of topsoil, soil texture, cation exchange capacity, organic matter content, or variability in internal drainage.



One can visually compare the EC map to a soil survey of the field. Expect to see some similarities and differences. Keep in mind that soil survey maps were generated with a considerable amount of human subjectivity. The EC maps were generated from a dense data set of electrical conductivity measurements.

The next step is to compare the EC map to yield map(s) if available. Once again, expect some similarities and some differences. Yield maps typically vary year-to-year because of the weather differences. EC maps will stay relatively constant from one year to the next. Note some similarities in the maps on the right.

More sophisticated analysis is needed if one wants to determine how strongly the EC map spatially correlates with the yield map. The data points are spatially grouped into grid cells of equal dimensions for EC and yield which is called rasterization. Each grid cell may be 30 x 30 feet or whatever spacing was left between passes while gathering EC data. The average EC value for a given grid is correlated with the average yield for that same grid. Linear regression analysis is applied to all grids of both data sets. High correlation values indicate a strong relationship between the two measurements.

Points of Caution:

- Most Midwest fields have enough variability to justify spacing between passes of 60 feet or narrower. Wider spacing may appear economical but narrow spacing is advisable in order to better define the spatial variation.
- There should be adequate moisture within the top 2 inches of the soil surface to provide electrical conductivity. Dry conditions will give erratic results.
- A smooth, untilled soil surface is desirable to help ensure uninterrupted electrical transmission.
- Normal amounts of crop residue on the surface are permissible. Side-by-side readings on no-till vs conventional tilled strips have given comparable EC measurements.
- Do not collect data when soil is frozen.
- Data are typically collected after harvest or by use of a unit that straddles one or two rows of a small crop.
- While collecting EC data, it is useful to pull soil samples from various points in the field to determine soil moisture content so EC readings can be interpreted and related to other EC readings. Geo-referenced deep cores can also help define what caused marked differences in the EC readings. The art of interpreting electrical conductivity is knowing what physical or chemical soil property causes spatial changes in soil EC.

- Some literature distinguishes electrical conductivity as referred to in this guide as “ECa” as an “apparent electrical conductivity” versus EC as measured under laboratory conditions using saturated soil paste.