Soil electrical conductivity mapping: 
A tool for within-field soil variability assessment

The assessment of within-field variability is a key component of precision agriculture, especially when considering variable-rate application (VRA) of inputs. For that reason, mapping soil electrical conductivity (ECₐ) has become a popular practice among producers, scientists, and ag. consultants to assess within-field soil spatial variability since it can indirectly identify some soil properties which are sometimes related to yield variability. Field-measured soil ECₐ is highly influenced by soil texture, but other soil properties can correlate with soil ECₐ such as soil water content, soil organic matter content, and cation exchange capacity (CEC). In such a manner, soil EC mapping is not used to identify singular causes of variability, but used to identify variability in fields to help stratify ground-truthing, sampling and management applications.

What is Soil ECₐ and how it is measured in the field?
Soil conducts electrical current through the moisture-filled pores between individual soil particles, however, the conductivity changes according to soil properties. Soil ECₐ is a measure of electric current flow through the soil which allows differentiation of various soil characteristics, e.g. texture. Smaller soil particles such as clay retain more moisture and have higher surface area resulting in higher conductivity than larger silt and sand particles, which produces higher soil ECₐ values.

Two types of commercial sensors commonly used to collect soil ECₐ data include: (a) VERIS 3100 (direct soil contact sensor) and (b) EM38 (indirect soil contact sensor); Figure 1.

Figure 1. On-the go soil ECₐ sensors.
The VERIS 3100 (VERIS Technologies®) is the most popular; however both sensors provide comparable results. The Veris 3100 has six coulter-electrodes (disks) mounted on a toolbar. As it is pulled through the field by a tractor, one pair of disks in contact with the soil transmit an electrical current, while another pair of disks measures the drop in voltage. The separation between the disks determines the depth to which soil EC\textsubscript{a} can be measured. In the most commonly used configuration, soil EC\textsubscript{a} is measured every second simultaneously from zero to one feet (shallow) and zero to three feet (deep).

**Soil EC\textsubscript{a}: Survey and Mapping**
On-the go soil EC\textsubscript{a} mapping requires five components: (1) soil EC\textsubscript{a} sensor (VERIS 3100 or EM38), (2) a differential global positioning system (DGPS) receiver, (3) data logger, (4) vehicle to pull the sensor (20-50 hp tractor, 4WD pickup or Jeep, or ATV), and (5) mapping or spreadsheet software. A Differential Global Positioning System (DGPS) receiver with sub-meter (3 ft.) accuracy mounted on the soil EC\textsubscript{a} instrument or on the vehicle is necessary to record the field location of each soil EC\textsubscript{a} measurement point. Georeferenced soil EC\textsubscript{a} readings, measured in milliSiemens per meter (mS/m), are collected by pulling the sensor in a series of parallel passes spaced from 40 to 60 feet apart. Usually, 40 soil EC\textsubscript{a} readings per acre can be collected if the sensor is pulled at a ground speed of 5-7 mph, with a logging interval of one second and passes spaced 60 feet apart.

A soil EC\textsubscript{a} survey requires several considerations:
- When the VERIS sensor is used, a good soil-couler contact is required. Therefore, collect the EC\textsubscript{a} readings when the soil is neither excessively moist nor extremely dry. Avoid taking readings when soils are dry in the upper horizons.

- Collection conditions are best with a firm but non-compacted soil, and a smooth field surface. These conditions are often encountered following crop harvest or prior to planting in prepared fields.

- Avoid data collection following application of high rates of soil amendments including fertilizers, lime, manure or biosolids. Due to the salt content of these materials, soil EC\textsubscript{a} readings may not necessarily reflect the true soil conductivity, but rather reflect variations in application patterns.

- If you are using the EM sensor, keep the sensor 4 to 5 feet apart from metal objects.

Mapping within-field variability of soil EC\textsubscript{a} is possible by displaying the output file (text file) from the VERIS sensor in any of the commercial Ag. Geographic Information System (GIS) software. Each observation in the file corresponds to a georeferenced point location (X,Y coordinates) and two soil EC\textsubscript{a} values: shallow and deep. The most common way to visually display the EC\textsubscript{a} readings on a map is by classifying the data into three to five ranges. The number of ranges selected is often adjusted to the spread of variation within the data set. The classified map depicts areas or zones with low, medium and/or high soil EC\textsubscript{a} values which can be used along with terrain attributes (i.e. elevation and/or slope) to differentiate areas in a field where differences in soil properties such as texture or drainage class exist (Figure 2). Often, ground-truthing of these maps is conducted to determine the actual cause of EC variability.
Soil EC$_a$ maps and Precision Agriculture

The fact that soil EC$_a$ maps correlate with different soil properties suggests it can be used as a component of site-specific management. The applicability and benefits of the soil EC$_a$ maps vary from one region to another. In Alabama Coastal Plain (CP) landscapes, soil EC$_a$ maps have been shown to be useful in discriminating subsoil textures (e.g., coarse loamy vs. fine-loamy soils) and depth or thickness of sandy surfaces (e.g., Typic vs. Arenic vs. Grossarenic Soils). In the Tennessee Valley region, soil EC$_a$ maps often do not provide a straightforward depiction of soil texture variability due to several reasons. However, a soil EC$_a$ map combined with elevation mapping in many cases helps identify areas or zones within a field with different yield potential where variable rate management might be beneficial. Usually areas or zones with low EC$_a$ values correspond to coarser textured soils compared with areas that have high EC$_a$ values (Figure 2). Research has shown that soil EC$_a$ maps combined with terrain attributes can be used to delineate management zones (MZ) which can be basic data for:

- **Precision soil sampling.** MZ can be used as a guide to identify areas within a field where soil samples can be grouped, therefore reducing the number of samples required to represent the within-field variability (directed soil sampling).

- **Erosion mapping.** Soil EC$_a$ maps can often be used to separate more highly eroded from uneroded areas. Usually, higher EC$_a$ readings are typically found where clayier subsoils are exposed at the surface.

- **Fertilization management.** The discrimination of zones with differences in soil properties (e.g., soil texture) facilitates the implementation of variable rate application of fertilizers.

- **Irrigation.** MZ of different soil texture/water content can signify variations in soil water holding capacity which can be used to generate variable-rate irrigation maps.

- **Nematode management.** Southern Root Knot Nematodes (RKN) prefer sandy areas which can be identified on a soil EC$_a$ map, particularly in some coastal plain soils. Therefore, soil

Figure 2. Soil EC$_a$ maps (a – Shallow, b – Deep) and EC$_a$ zones delineated from the EC$_a$ readings.
ECa MZ may suggest different risk levels for high populations of RKN leading to variable-rate application of nematicides.

- **Improvement of USDA-NRCS soil surveys.** Available soil surveys (Order 2) in most cases do not provide the level of detail required for a site-specific management. However, these digital maps can be used in combination with soil ECa and elevation maps to improve the resolution of soil variability.

### References


### Disclaimer

The mention of trade names and commercial products is for informational purposes and does not necessarily imply endorsement by the Alabama Cooperative Extension System.

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