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Potential Use of the Veris Apparent EC Sensor to Predict Soil Texture under the Semi-arid conditions of Central Arizona

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Abstract. *The operational details of the apparent electrical conductivity (ECa) sensor manufactured by Veris Technologies have been extensively documented in literature reports, but the geographical distribution of these research studies indicate a strong regional concentration in the US Mid-west and Southern states. The agricultural lands of these states diverge significantly to the soil conditions and water regime of irrigated land in the US South-western states such as Arizona where there is no previous research reports of the use of this particular sensor. The objectives of the present study were to analyze the performance of this sensor under the conditions of typical soils in irrigated farms of Central Arizona. We tested under static conditions the performance of the sensor on three soils of contrasting texture. Observations were collected as time series data as soil moisture changed from saturation to permanent wilting point. Observations were repeated at the hours of lowest and highest temperatures. In addition, this study included soil penetration resistance and salinity determinations. Preliminary results indicate that soil temperature of the upper layer caused the most dynamic change in the sensor output. The ECa curves of the three soil textures tested had well defined distinctive characteristics. Final multivariate analysis is pending.*

Keywords. Precision Agriculture, Soil Electrical Conductivity, Soil Texture, Soil Salinity

Introduction

Soil characterization plays an important role in precision agriculture, especially in the area of prescription mapping for variable rate application of energy intensive inputs. The continuous measurement of the soil apparent electrical conductivity (ECa) with the Veris 3100 sensor holds promising potential for this type of applications. The operational details of this sensor have been extensively documented in literature reports, but the geographical distribution of these studies indicates a strong regional concentration in the U.S. Midwest and Southern states. The agricultural lands of these states diverge significantly from the soil conditions and water regimes of irrigated land in the Southwestern states, such as Arizona, where there are no previous research reports on the use of this particular sensor.

In farming systems of the semi-arid US, there are many aspects of farm management that can be improved by incorporating information from ECa sensors into a scheme of variable rate application of energy-intensive inputs. These sensors can provide real-time information on soil variability that can be used by rate controllers, bringing significant savings. Some of the potential applications to these farming systems include:

a) Fumigant applications. This is the case of materials injected in the soil for the control of nematodes. Cotton growers suffer significant losses due to Root-knot nematodes (Meloidogyne incognita) which thrive in sandy soils, and at the same time are the dominant series in soils of the semi-desert. Recent work by Norton and McClure (2007) tested a scheme of variable rate application of fumigants based on ECa data. Their approach is based on the fact that there is a well defined relationship between ECa and soil texture. In particular, ECa and sand content exhibit a consistent inverse relationship. This linear relationship makes possible to know the distribution of sandy soils in the field, which is information used to program rate controllers.

b) Fertility Management. Production in the semi-arid requires using vast amounts of energy-intensive fertilizers that are costly. ECa data has the potential to be used as a surrogate variable that will show the spatial distribution of soil attributes such as texture and water holding capacity. This type of information can be used to define management zones which in turn will define site-specific application of fertilizer materials. Fridgen et al (2004) have incorporated ECa as an input variable in their Management Zone Analyst software.

c) Salinity Assessment. The combination of dry weather and highly mineral soils makes undisputable that the sustainability of farming systems in the semi-arid rests on our ability to secure enough water resources of adequate quality. Nonetheless, both the quantity and quality of water in these regions have been reduced, with a well defined trend to continue. Constant monitoring of salinity conditions is possible with ECa sensors. Even in the form of relative measures, annual readings of ECa data from the same field under the same conditions will reflect accumulations of salts if irrigation management does not cover the leaching requirements of these soils.

Objectives

The overall objective of the present study was to analyze the performance of the Veris 3100 ECa sensor under the conditions of typical soils in the irrigated farms of Central Arizona. Different spatial scales and modes of operation of the ECa sensor were combined in the formulation of the following two specific objectives:

1. Exploratory determination of ECa and soil texture relationships at the field scale in continuous mode of operation.
2. Detailed monitoring of ECa changes in three sites of contrasting texture through point measurements in static mode of operation.

Methods

The Veris 3100 soil electrical conductivity sensor

Figure 1 shows a drawing of the ECa sensor. On the outside, this sensor has the appearance of an agricultural tillage implement mainly due to the set of disc coulters that engage the soil and keep tight contact in the metal-soil interface. The Veris 3100 ECa sensor works on the principle of making the soil part of an electrical circuit where electrical current flows through one pair of disc coulters (2-5) and what is measured is the voltage drop between the other two pairs of disc coulters (3-4, 1-6). This drop in voltage is proportional to the resistivity of the soil in bulk. The output of this sensor is recorded in units of miliSiemens per meter (mS/m). Two signals are collected simultaneously: a) The “shallow Eca” which comes from measuring the voltage drop between disc coulters 3-4, and b) the “deep ECa” that uses discs 1-6 for a total depth of 1 m.

The Veris 3100 was designed to be operated in the field as a trailed implement attached to a power unit (i.e. tractor). A GPS receiver is connected to the controller unit to geo-reference the output of this sensor. ECa data is stored in this controller at 1 Hz frequency.

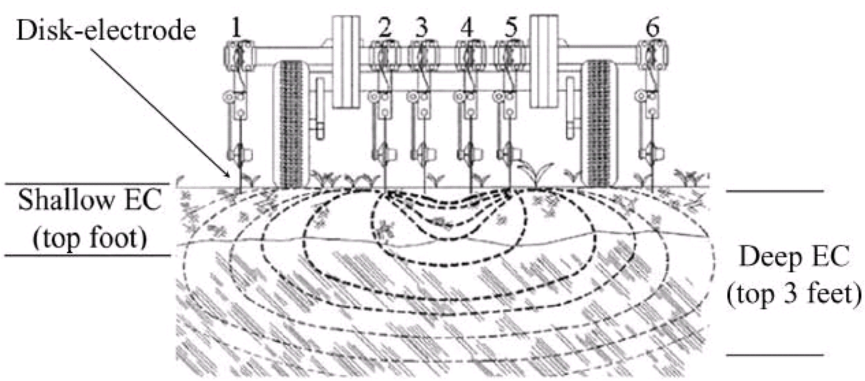

Figure 1. Drawing of the Veris 3100 showing the trailer cart frame and wheels, and the disc electrodes (1-6). The system acquires two signals simultaneously at different depths.

Field scale test

The set up for field level test consisted of running the sensor continuously in transects following the same direction of the furrows in a 20 Ha commercial farming field located in NE Arizona, near the town of Safford AZ with coordinates 32^{o} 50’ 58” N, and 109^{o} 33’ 33” W. This field contains three main soil series (Anthony clay, Grabe clay loam, and Pima clay) and exhibits significant soil variability given its proximity to the Gila River.

Transect runs were separated 5.8 m (6 rows) from center to center. After completion of this high-density survey, the sensor output was then processed using the ESAP-95 (v2.01R) software to determine the location of 19 sampling points based on the geo-spatial structure of the survey data (see Figure 2). Based on this procedure, soil samples were manually collected from 0-30 cm. and soil analyses, including textural classification via the wet density method, were performed in the laboratory setting of the Maricopa Agricultural Center. ECa and texture data were statistically analyzed in a linear regression scheme to find their degree of association.

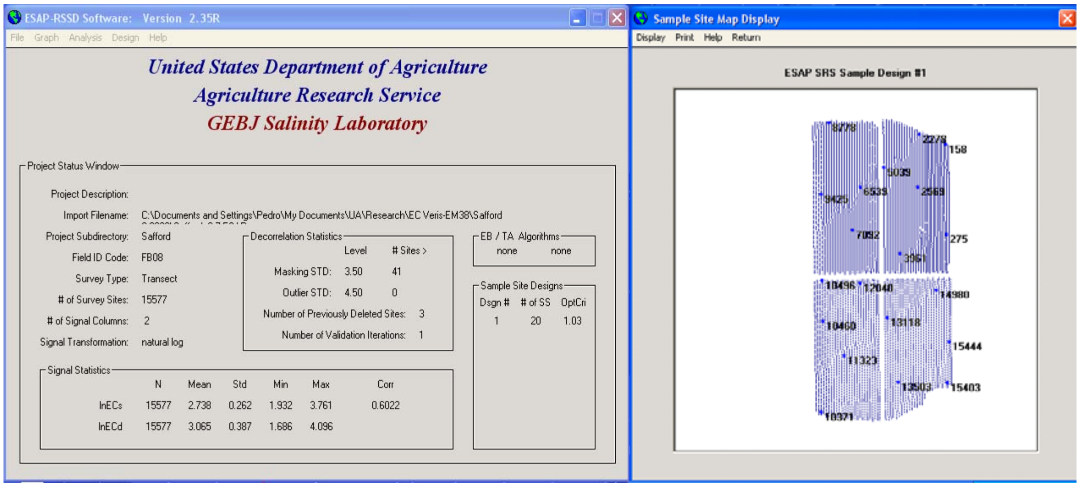

Figure 2. Output of ESAP indicating the location of sampling points.

Point measurements

For this type of tests we selected three locations in the Maricopa Agricultural Center in Maricopa AZ, which is located between the coordinates 33° 04' 07" N, and 111° 58' 18" W. These three sites were of contrasting texture. Some of their soil properties are outlined in table 1. Time-series data were collected as soil moisture changed from saturation to permanent wilting point. Daily measurements of ECa, soil temperature and moisture content were recorded at the hours of lowest and highest temperatures. Figure 3 displays a picture where the see the typical set up used for this type of tests. For soil temperature we used high-precision encapsulated thermistors and for moisture content we used TDR probes, both of these soil sensors were installed right before saturation and were left undisturbed until the last of day of measurements on each location.

As it was mentioned before, the Veris 3100 sensor was designed to operate in continuous motion, therefore in order to run these tests we devised a scheme where the sensor frame was static but the antenna of the GPS receiver was in constant motion for 120 seconds and the data stream containing ECa data was collected by the system controller.

Table 1. Some soil properties of the three locations selected for static tests of the ECa senor.

Location/depth (cm)	Sand (%)	Clay (%)	Salinity - from paste extract - (dm/m)	Cone Index (MPa)
1 – 0-30	69.4	24.9	0.425	1.637
1 – 30-60	74.9	24.9	0.507	3.004
2 – 0-30	53.7	38.9	0.164	1.805
2 – 30-60	37.7	62.4	0.188	2.798
3 – 0-30	47.8	37.7	0.177	1.699
3 – 30-60	49.9	34.9	0.188	2.541

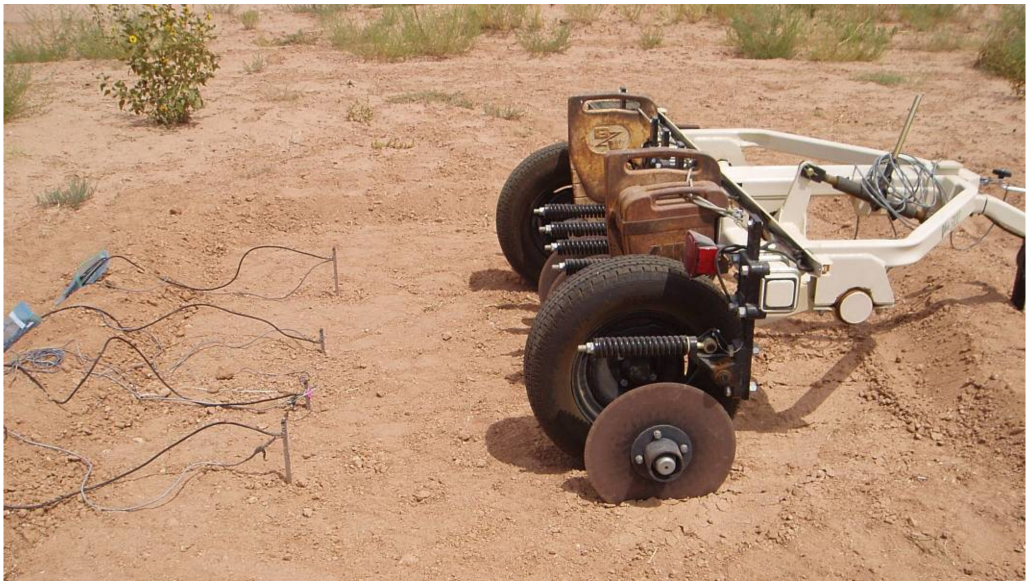

Figure 3. Set up of the Veris 3100 sensor for static measurements of ECa. On the left side of the picture are shown a set of four TDR probes for measurement of moisture content.

Results

Field scale test

The raw data file generated with the Veris 3100 was processed with a generic type of GIS software (Manifold v8.0) to generate the maps of the ECa survey shown in Figure 4. Visual inspection of this map shows the spatial distribution of ECa values within an overall range from 10 to 40 mS/m

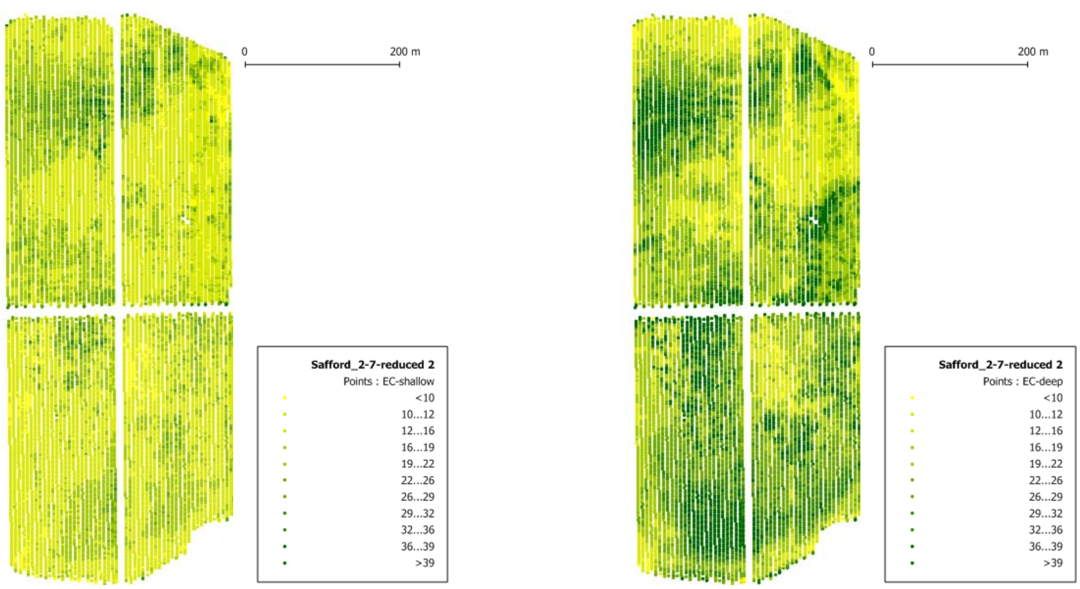

Figure 4. Maps showing spatial variability of ECa in a field near Safford AZ. Map on the left corresponds to the shallow depth (0-30 cm); the map on the right is the deeper reading (0-1 m).

The relationship between textural characteristics and ECa is summarized in the plot presented in Figure 5. This linear relationship is consistent with the results of Sudduth et al (2003, 2005).

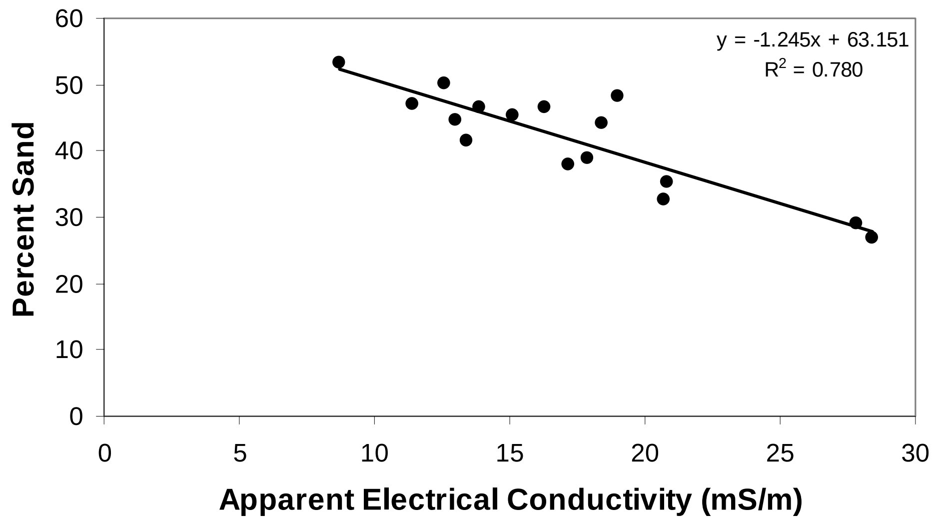

Figure 5. Linear regression plot of ECa generated with the Veris 3100 and percent sand values determined with laboratory techniques.

Point measurements

It is worth to mention that the strongest driver of ECa output was the soil moisture content. This effect is clearly seen in Figure 6 and by far, this factor dominates the sensor output. The ECa curves of the three soil textures tested have well defined and distinctive characteristics.

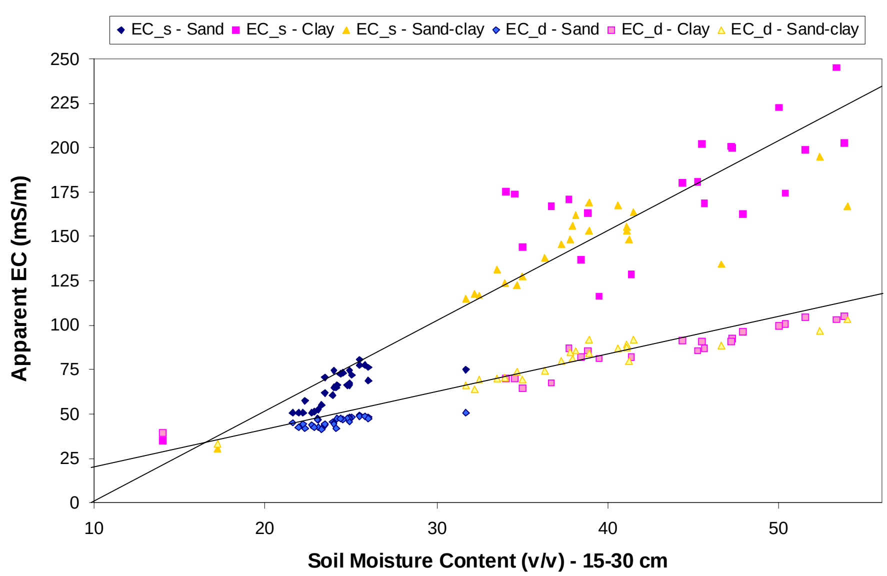

Figure 6. Effect of soil moisture content on the Veris 3100 output in three locations of different soil textural characteristics.

No formal statistical analyses have been performed on these data sets yet, but time series graphs of observations from two locations are presented in Figure 7 in order to show the overall trends. Preliminary results indicate that temperature fluctuation in the upper soil layer caused the most dynamic change in the sensor output.. Final multivariate analysis is pending.

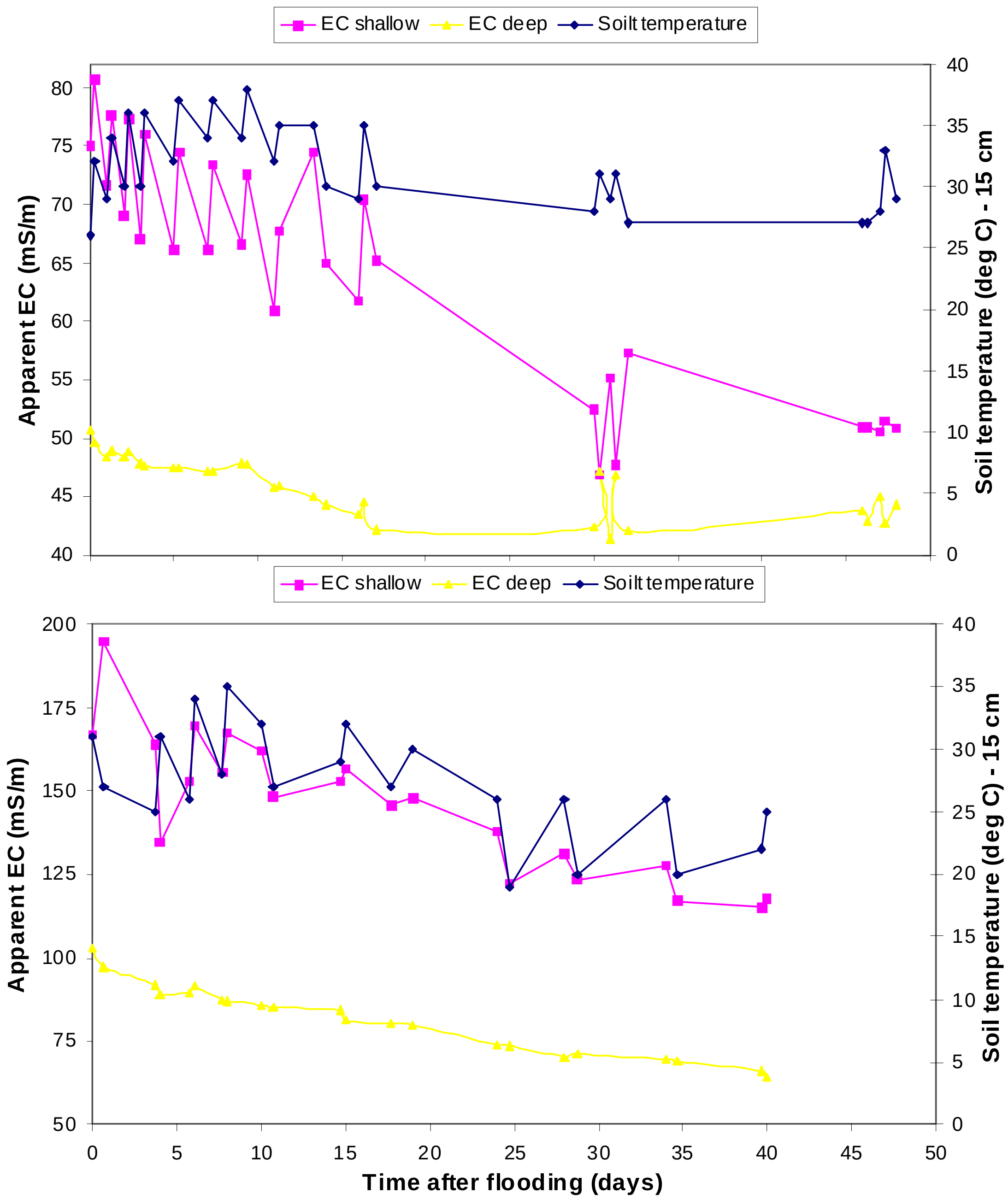

Figure 5. Times-series plots showing fluctuations of ECa due to soil temperature and time elapsed after flooded irrigation. Plot on top corresponds to the site with Sandy clay loam texture; meanwhile the bottom plot corresponds to a location with Sandy clay texture.

Conclusion

The Veris EC sensor has shown good potential for implementation in precision agriculture practices in the US Semi-desert. When used in commercial fields, our experience has been that ECa maps display field variability that growers identify and relate to different levels of productivity. In the near future we should be able to integrate ECa information to define algorithms for variable rate controllers.

More research is needed in the following areas:

- Normalize the sensor output
- Differentiate the drivers of soil bulk EC
- Integrating EC data with other plant/soil/ambient variables

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