ON THE GO SOIL SENSOR FOR SOIL EC MAPPING

Ni Nyoman Sulastri, Sakae Shibusawa, Masakazu Kodaira

Laboratory of Environmental and Agricultural System
Tokyo University of Agriculture and Technology
Tokyo, Japan

ABSTRACT

The purpose of this paper is to describe the spatial variation of soil electrical conductivity (EC) obtained by spectroscopic and capacitance methods using the on-the-go soil sensor “SAS 1000,” commercialized by Shibuya Kogyo Co. The spectroscopic method is an approach utilizing a non-contact sensor with a soil reflectance range of between 350-1700 nm wavelengths at depths of approximately 0.2m, followed by the application of chemometrics to predict soil EC. Recordings are influenced by the mechanical vibration of the tractor and other factors. The capacitance method is an approach utilizing a capacitance contact sensor which incorporates electrode probes on the tip of the penetrator to monitor the cut soil. The quality of data is strongly influenced by the state of the interface between the soil and the blade. Results indicate significant differences in spatial variability patterns of soil EC maps when applying and comparing the spectroscopic and capacitance methods. The spectroscopic method appears to have a positive correlation (of approximately .75) with soil EC laboratory analysis. A few variables were identified that may cause inaccuracies in capacitance sensor readings. The findings from this study suggest that it may be beneficial to utilize both sensors simultaneously in measuring soil EC because they could work in a complementary fashion, compensating for the weaknesses of the other while strengthening the overall accuracy of the findings. Further investigation of a combined approach is recommended.

Keywords: soil electrical conductivity, spatial variability, on the go soil sensor, precision agriculture, capacitance sensor.

INTRODUCTION

Soil maps, describing the variability of soil within fields, are essential in an integrated precision agriculture system. For that reason, the mapping of soil electrical conductivity (EC) has become a popular practice because of its feasibility and convenience, as it can indirectly identify some physical and chemical properties of soil which may relate to yield variability. An on-the-go soil sensor, also known as a real time soil sensor (RTSS), has been developed and enabled to show the variability of soil EC, moisture content (MC), soil organic matter (SOM), nitrate-nitrogen (NO_3-N), total nitrogen (TN), total carbon (TC) and acidity (pH) (Shibusawa et al., 1999). The RTSS collects soil reflectance and soil capacitance data at any depth between 0.15 and 0.35m, and is comprised of two types of soil EC sensors, a visible/near-Infrared spectrophotometer (Vis-NIR) and an electrical conductivity sensor installed on the chisel penetrator.

Several commercial applications have been developed and marketed that utilize one of several EC sensor methods for on-the-go measurement of electrical conductivity. Buchleiter and Fahrani (2002), Fritz et al. (1999) and Sudduth et al. (2003) compared electromagnetic induction sensors and contact sensors while mapping agricultural fields. They reported similarities between those two sensor methods.

Spectroscopic and capacitance methods were compared in this study because: (1) no evidence of prior studies comparing spectroscopic and capacitance data in on-the-go field sensing could be found, (2) given that both methods have potential problems (i.e. mechanical vibration effects of spectroscopy and soil-blade interface effects of capacitance), it may be advantageous to utilize both sensors in a complementary way to help compensate for the weaknesses of each method. The objective of this study is to compare soil EC records via spatial variability maps generated from both the spectroscopic and capacitance approaches (assuming a positive correlation), as well as maps generated from lab analysis of control data.

MATERIALS AND METHODS

Site and sampling

The study was conducted over an area of 4 ha in Fields 3 and 4 of a commercial farm with an alluvial soil type in Hokkaido, Japan during November

2009. According to the soil texture triangle, Fields 3 and 4 are classified as "loamy sand" with only minor or no topographical differences. For laboratory analysis purposes, 144 soil samples were collected at the respective scanning points at the same depth as reflectance data was collected (i.e. 0.2m).

Reflectance data collection

The soil reflectance data was collected using the RTSS. The RTSS was equipped with a soil spectrophotometer mounted to the tractor and was operated at a speed of approximately 0.56 m/s. The RTSS captured several types of data simultaneously at a soil depth of 0.2m including: soil reflectance data in a Vis-NIR range of between 350-1700nm wavelengths with 5nm resolution, soil color images, soil EC, soil resistance and GPS data.

Soil analysis

All soil samples were taken from fresh soil crushed to pass through a 2 mm sieve. Twenty grams of soil samples were diluted using a 1:5 ratio of soil to distilled water prior to subtracting for soil moisture. The soil solution was stirred for 30 minutes and left for one hour. The measurements of EC were calculated using the EC meter "Horiba-D-24," calibrated using a KCl solution.

Analysis of Vis-NIR spectra

The NIR data statistical analyses were performed using the Unscrambler 9.8 (CAMO PROCESS AS, Oslo, Norway). To reduce light scatter effects influencing the baseline, enhance weak signals and reduce noise, each Vis-NIR spectrum was transformed and smoothed by a second order, 13 points, Savitsky-Golay derivative (Savitzky and Golay, 1964).

Spectra from the NIR region and for visible light were calibrated against soil EC resulting from laboratory analyses (reference measurement) by the multivariate linear regression technique partial least squares (PLS) using samples in the two Vis-NIR calibration data sets. Cross-validation through a full-cross-validation procedure was used to optimize the calibrations. The validations were evaluated by the r^2-value of the relation between the Vis-NIR-estimate of the soil EC and the reference measurement and root mean squared error of prediction (RMSEP).

GIS and map preparation

All spatial data were entered into a GIS using the commercial software package “ArcView 3.3”. Field 3 and 4 data were prepared by interpolating measurements at 72 sample points for each field using inverse distance weighting (IDW).

RESULTS AND DISCUSSION

Spectroscopic method

Table 1 shows the summary of the calibration and validation results for the Vis-NIR. The spectroscopic method appears to have a positive correlation (of approximately .75) with soil EC laboratory analysis.

Table 1. Summary of PLS regression model on spectroscopic method.

Parameter	Calibration	Validation
R^2	0.75	0.69
RMSE	1.32	1.48
Correlation	0.83	0.83
PC	6	6

Figure 1 shows a spectroscopic method analysis performed using the PLS as the regression model with full-cross-validation as the validation model.

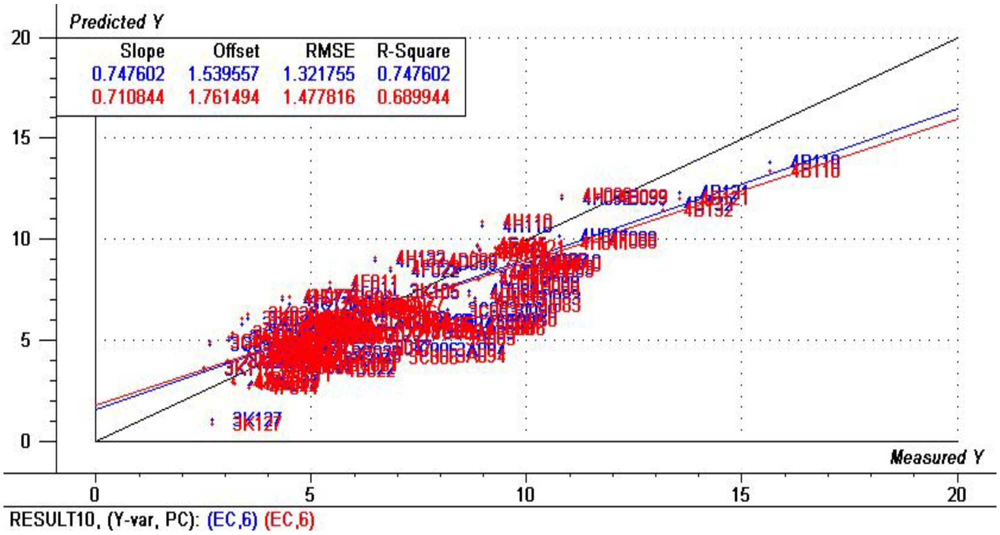

Figure 1. The prediction model using PLS as the regression model and full-cross-validation as the validation model.

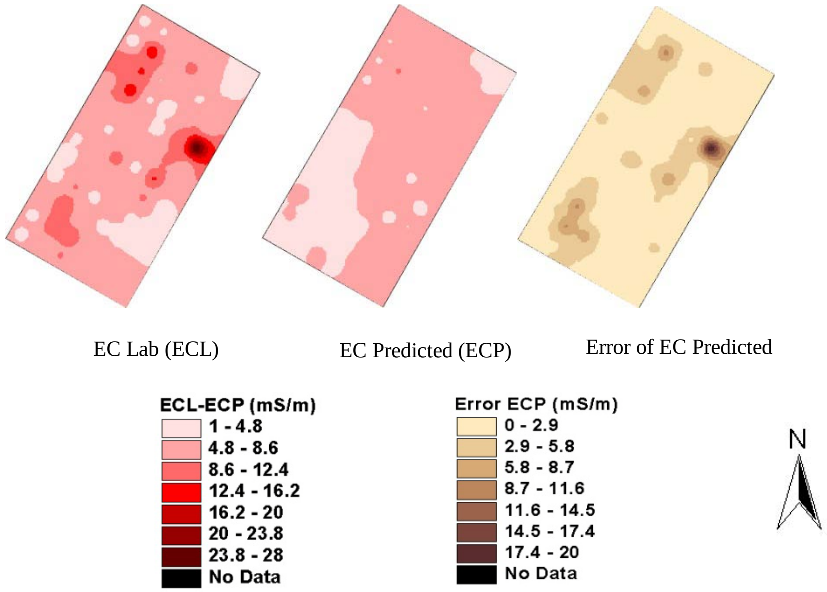
EC Lab (ECL)
EC Predicted (ECP)
Error of EC Predicted

Figure 2. IDW Interpolation maps of soil EC in Field 3 generated from ECL (soil EC by lab analysis), ECP (predicted EC from spectra) and error map of ECP.

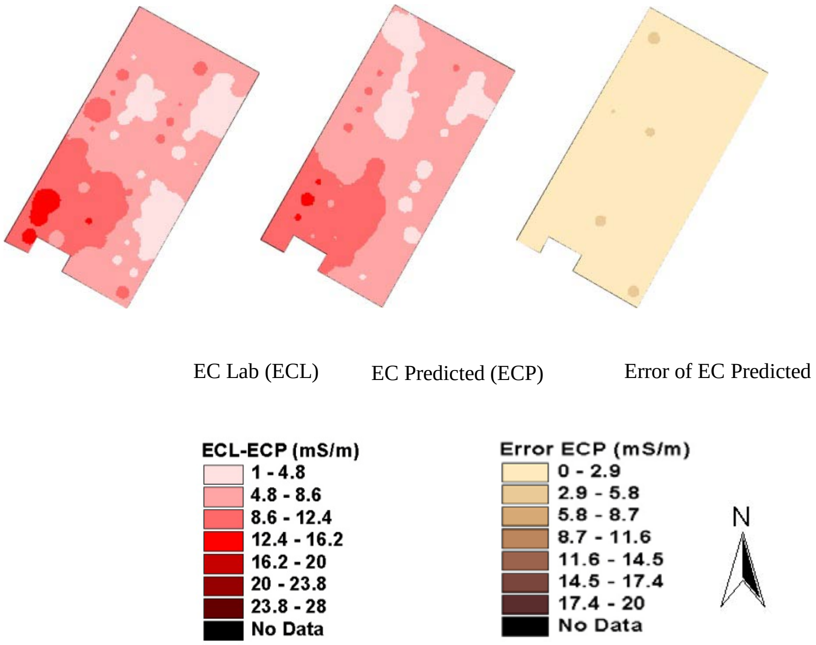

Figure 3. IDW Interpolation maps of soil EC in Field 4 generated from ECL (soil EC by lab analysis), ECP (predicted EC from spectra) and error map of ECP.

Figure 2 shows the spatial variability on soil EC between laboratory analyses (ECL) and the method of predicting EC from spectra (ECP). Results showed that the EC records of ECP values were lower than ECL. The higher error comes from areas which have higher EC values. This means that the regression model has a limitation in predicting higher EC values (approximately 15 mS/m).

Figure 3 shows that Field 4 has a similar spatial variability for ECL and ECP. The error of ECP for Field 4 is smaller than the error of ECP for Field 3. Error ECP is the difference between ECL and ECP.

Capacitance method

Simple regression analysis showed no correlation between ECL with soil EC front sensor (ECF) and side sensor (ECS) for both Fields 3 and 4 (Figures 4 and 5, respectively). For this reason, spatial variability maps were felt to be unnecessary and were therefore not created. EC data records were normalized using standard score normalization.

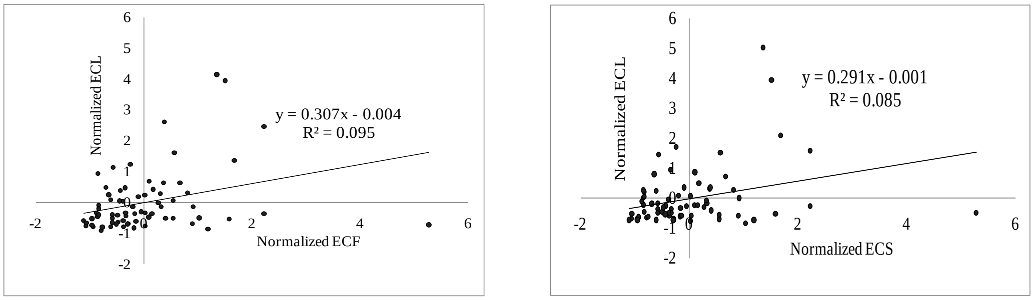

Figure 4. Correlation of soil EC by lab analysis records (ECL) with soil EC records at the front electrode of chisel tip (ECF) and soil EC records at the side electrode of chisel tip (ECS) Field 3.

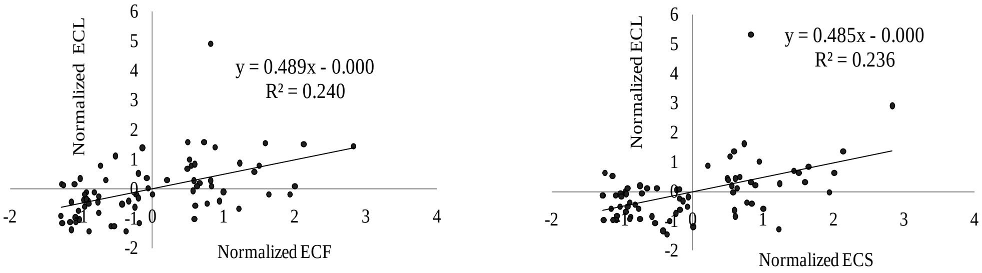

Figure 5. Correlation of soil EC by lab analysis records (ECL) with soil EC records at the front electrode of chisel tip (ECF) and soil EC records at the side electrode of chisel tip (ECS) Field 4.

Simple regression analysis shows a positive correlation between ECF and ECS (Figure 6). This indicates that the front and side sensors are capable of recording accurate soil EC data. The primary cause of the occasional extreme differences between ECL, ECF and ECS mean values is likely related to the calibration of the capacitance sensor itself.

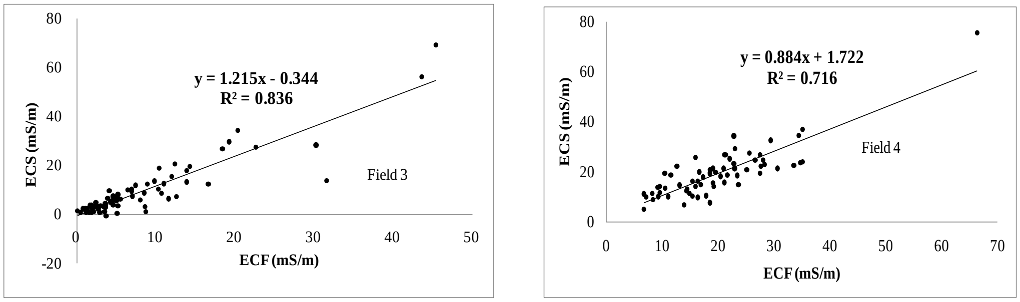

Figure 6. Correlation of soil EC records from the front electrode of chisel tip (ECF) and Soil EC records from the side electrode of chisel tip (ECS).

CONCLUSIONS

Spectroscopic and capacitance methods are two approaches to measure bulk soil EC, but both approaches don't appear to correlate well with each other. The spectroscopic method appears to have a positive correlation with soil EC laboratory analysis. In addition, capacitance methods need some adjustments so that both sensors may be utilized simultaneously and in a complementary fashion. By using a combined approach, benefits from both methods may be maximized while minimizing weaknesses of each individual method.

A few variables may cause inaccuracies in capacitance sensor readings and need further investigation. Capacitance sensor re-calibration may be necessary to help correct for changes in these variables.

REFERENCES

Bulchleiter and Fahrani. 2002. Comparison of electrical conductivity measurements from two different sensing technologies. Paper No. 02-506, ASAE. Michigan.

Fritz et al. 1999. Field comparison of two soil electrical conductivity measurement systems. In: Roberth et al., proceeding of the fourth international conference on precision agriculture. ASA-CSSA-SSSA. Michigan, p: 1211-1217.

Marten, H and Naes, T. 1989. Multivariate calibration. Chichester, UK. John Wiley and Sons.

Savitzky, A and Golay, M. 1964. Smoothing and differentiation of data by simplified least squared procedures. Anal. Chem. 36(8): p. 1627-1639.

Shibusawa et al. 1999. Spectrophotometer for real-time underground soil sensing. An ASAE Meeting Presentation Paper No. 993030. Toronto.

Sudduth et al., 2003. Comparison of electromagnetic induction and direct sensing of soil electrical conductivity. Agronomy Journal 95. p. 472-482.