Spatial Variability of Apparent Electrical Conductivity and Cone Index as Measured with Sensing Technologies: Assessment and Comparison

Introduction

Assessment and interpretation of spatial variability of soil physical and chemical properties are very important in precision farming. Because of this, farmers need new, quick, reliable and inexpensive sensing technologies to measure soil properties, such as soil compaction and apparent electrical conductivity (ECa) that characterize soil variability in their fields. To meet this need, on-the-go sensors have been developed and are available that can take measurements continuously and provide detailed soil maps while traveling across a field (Sudduth and Kitchen, 2004).

Surveying agricultural fields for soil electrical conductivity (ECa) and cone index (CI) using Veris 3100 (coulter) and Veris 3000 (penetrometer) sensors (Veris Technologies, 2002) is considered one of the most accurate and powerful methods of characterizing soil variability for a variety of important soil properties such as bulk density, particle size distribution, water content, and salinity.

The objectives of this study were to evaluate ECa and CI for identifying and quantifying soil variability, and to compare the two Veris sensors for their ability to estimate soil properties in the field. (For study methodology, see orange panel.)

Results and Discussion

Classical Statistics

Descriptive statistics of log transformed of ECa and CI parameters measured using Veris 3100 and Veris 3000 sensors are given in Table 1. The CV values for the ECa and CI were slightly higher than 10%, suggesting low to medium variability for the soil at this site. Further, the range values were small, indicating low soil variability within the study area.

Table 1. Statistical Summary

<table>
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<tr>
<th>Soil property</th>
<th>Mean</th>
<th>SD</th>
<th>CV</th>
<th>Range</th>
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<td>ECa (mS/m)</td>
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<td>CI (mPa)</td>
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The mean values of ECa from both sensors were compared (SAS Institute, 2003). ECa means of Veris 3100 and Veris 3000 differed significantly at the 0.05% probability level. The Me in ECa measurements between Veris 3100 and Veris 3000 devices was significantly different from zero (Me=0.04 mS/m; t=3.15, p(0.01)). Further, probe functions and probability frequency distributions (not shown) exhibited lognormal distributions for the ECa property from both sensors while the CI resembles a normal distribution.

The coefficient of variation, CV, has also been used for classical statistics and describes the variability of the ECa and CI soil parameters measured using the Global Positioning System, and ECa and CI data (SAS Institute, 2003). Statistics are based on log transformed ECa data.

The Pearson’s correlation coefficient (r) between the Veris 3100 and Veris 3000 sensors was calculated based on the ratio of nugget (C0) to the sill (C+) obtained from the experimental semivariance data. Semivariance is expressed as:

\[ \gamma(h) = \frac{1}{2N(h)} \sum \left| y(x) - y(x+h) \right| \]

where \( \gamma(h) \) is semivariance for the interval distance class, \( h \) the lag distance, \( y(x) \) the ECa or CI at the reference point, and \( y(x+h) \) the ECa or CI at the target point.

The spherical model that was best fitted to the experimental semivariance data. Semivariance is expressed in Eq. [4]

\[ \gamma(h) = \left( C_0 + C_s \right) \left( 1 - \frac{h}{a} \right) I(a) \]

where \( C_0 \) is the nugget effect; \( C_s \) is the sill variance; and \( a \) is the range of spatial dependence.

The sum \( C_0 + C_s \) is the total variance (sill) for the spatial variable. If the ratio is > 0.75, the variable is considered strongly spatially dependent; and if the ratio is > 0.25 and < 0.75, the variable is considered moderately spatially dependent. The structural variance of ECa measurements from the coulter sensor was very low (0.20) indicating a strong spatial dependence in the sampling area of the field, while the structural variance of soil ECa and CI parameters from the penetrometer sensor were higher than that of coulter sensor (0.53-0.60) which characterized a moderate spatial dependence in the study area.

Regarding the spatial dependence aspect, the spatial model [Eq. (4)] is used to fit the actual semivariograms, presenting nugget effect, sill and range values to the ECa and CI soil parameters (Figs. 5, 6, and 7).

Table 2 presents a summary of the geostatistical parameters nugget, variance, sill, proportion of structural variance and the range for the ECa and CI soil parameters measured using the Global Positioning System.

In order to evaluate the spatial dependency of soil ECa and CI parameters, a criterion suggested by Cressie and Shih (1996) was used. These simple linear regression models were proposed for predicting ECa-Veris 3100 measurements from those of ECa-Veris-3100 (Fig. 8 and Eq. 5).

Conclusions

New sensors’ based measurements of soil ECa and CI can provide important information for assessing and examine spatial variability for precision farming.

Interpolated spatial maps for ECa and CI using a 1 m² grid pixel may be used as a baseline for precision farming and future management decisions.

Under both descriptive and spatial statistics, the ECa and CI maps clearly showed uniformly representing a small scale trend of variability in the field.

The soil ECa and CI variability was spatially structured and spatial maps had the potential of explaining the variability within the field.

References Cited

J.D. Jabro, R.G. Evans, Y. Kim, W.B. Stevens, and W. Iversen

Description of Veris 3000 Profiler Model

The coulter sensor mapping system (Veris 3100) consists of a coulter sensor that is mounted on a platform that can be pulled by a pickup truck (Veris Technologies, 2000). The coulter sensor consists of two pendulums, each containing four double sharp wire cross-cutting cylinders (1, 3, 5 and 8) are spaced to measure voltage drop due to the electrical conductivity of soil. A deep penetration probe (diameter of 10 mm) has a penetration depth of 20 cm (shallow) and 60 cm (deep). The coulter sensor is mounted on a platform that can be pulled by a pickup truck (Veris Technologies, 2000).

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Figure 4. Ordinary Kriging spatial mapping for CI in the field at depth of 0-30 cm.

Figs 2, 3 and 4 show the distribution of ECa and CI parameters measured using the Global Positioning System, and ECa and CI data (SAS Institute, 2003). Statistics are based on log transformed ECa data.

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