Proximal sensing of soil organic matter using the Veris® OpticMapper™

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Abstract

Soil organic matter (OM) affects productivity and input usage in most crop production systems. Veris Technologies recently introduced a proximal optical sensor which measures soil reflectance in two wavelengths, and allows calibrations of the sensor values with lab-measured OM. Used in conjunction with ancillary proximal sensors, including Veris soil electrical conductivity (EC) modules, the OpticMapper generates maps which provide additional details compared to government soil surveys and EC maps. Results from multi-field studies in several states show the OpticMapper readings correlate well with laboratory-measured OM, even in fields containing relatively low OM.

Keywords: soil, organic, matter, sensing, optical

Introduction

Variations in soil properties can be detected, even with the human eye, based on differences in light reflectance. Darker soils contain higher levels of moisture or organic matter than light-colored soils. While this can be detected visually, light sensors in the visible and near infrared (Vis-NIR), can quantify the reflectance characteristics and provide the data needed to develop calibrations to soil properties. Soil reflectance has been studied extensively since the 1970's and is widely reported in the scientific literature as an effective means for approximating soil organic matter (Sudduth et al., 1993). Organic matter is an important factor in crop growth, as it affects soil moisture infiltration and retention, soil tilth, rooting depth, soil-applied herbicide activity, nitrogen release, and other aspects of nutrient cycling (Bauer and Black, 1994). A precise map of organic matter would provide growers with an important piece of information as they seek to vary nitrogen, seed population, herbicides, and other inputs.

Veris Technologies began development of soil optical devices in 2002 and has patents pending on commercialized Vis-NIR spectrophotometer systems for mapping soil (Christy et al., 2003). The level of technology inherent in a spectrophotometer may be required in soil research, and where carbon measurements require an extremely high level of precision, but are not practical for grower and consultant use due to expense and complexity. Veris Technologies has leveraged its expertise from the higher-end systems in developing a two wavelength device, the OpticMapper, which has has been commercially available since late 2010. The objective of this study was to evaluate the performance of the OpticMapper™ and soil EC sensing based on: 1) optical sensor repeatability, 2) correlation with lab-analyzed OM, and 3) utility of optical sensor versus EC-only measurements.

Materials and Methods

Soil optical and electrical conductivity (EC) data were collected with an implement designed and commercialized for the purpose of mapping with multiple soil sensors (Figure 1). The implement contains six coulter electrodes for EC measurements, and a specially-configured row unit for optical measurements. The optical module is mounted between two disks which operate at a slight angle, forming a V-shaped slot in the soil. A depth-gauging side wheel for each disk controls sensing depth. The row unit has a parallel linkage to follow ground undulations and adjustable down-force to match soil conditions. The optical module contains a light source and detector, collecting measurements in the red and near-infrared wavelengths through a sapphire window. The wear-plate with window is pressed against the bottom of the slot and the consistent pressure provides a self-cleaning function. Measurements were collected approximately 4 cm below the soil surface. The complete electronics package includes signal conditioning, A/D conversion, data logging and a GPS to geo-reference all data. Data were collected at a 1 hz rate on 15-20 m transects with typical field speed of 10-15 km/hr. Approximately 150-200 EC and optical data points per/ha were collected.

Figure 1. Veris OpticMapper with Soil EC and Optical Sensors.

The project covered more than 570 ha on 20 fields in 7 U.S. states, providing a wide range of soil types, conditions, and organic matter levels. From these fields,195 geo-referenced soil samples were analyzed for organic matter. A combination of wet digestion and dry combustion methods were used. These samples were a composite of a minimum of six 0-15 cm deep cores collected within a 10 m radius. The sensor data set was queried to select sensor values within a 5 m radius of the sample location centroid. Multi-variate regression (MVR) techniques were applied to the data set using optical, EC, and topography components. This process generated estimates of organic matter, and a leave-one-out cross-validation was used to select the optimal sensor combination.

Results

Sensor repeatability was evaluated by mapping fields at different time intervals, where soil moisture and tillage conditions had changed from previous mapping. Results showed that while absolute reflectance changed with soil conditions, the relative values and zone delineation were highly repeatable (Figure 2).

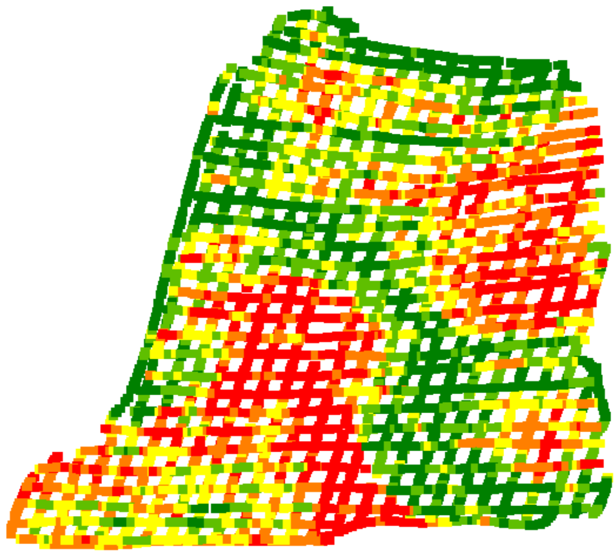

Figure 2. Raw sensor data from field mapped north-south on Aug. 28, 2010 and east-west on September 7, 2010.

Results from cross-validation showed strong correlation between sensor estimated organic matter and lab-analyzed organic matter (Table 1). The root-mean-square errors (RMSE) were less than .35 % OM in all but Ohio, where the standard deviation of OM was the highest, 1.57. The ratio of prediction to deviation (RPD) was > 1.5 on all sites, with all but two sites > 2.

Table 1. Organic matter lab analyses and relationships with sensor-estimated OM.

State	N	ha	# of flds	Std. dev.	Ave. OM %	OM % Range	R^2	RMSE	RPD
Kansas	24	132	4	0.54	2.3	1.6-3.5	0.93	0.14	3.86
Missouri	50	89	3	0.55	2.4	1.0-3.5	0.71	0.30	1.83
Iowa	41	65	2	0.51	4.3	3.4-5.5	0.57	0.33	1.55
Illinois	42	172	5	1.06	2.5	.4-5.1	0.95	0.23	4.61
Michigan	11	61	1	0.64	3.0	1.7-4.5	0.91	0.27	3.41
Ohio	13	85	3	1.57	2.8	1.3-6.9	0.85	0.59	2.66
Alabama	14	95	2	0.72	1.7	.9-3.5	0.79	0.32	2.25

Sensor-estimated OM maps exhibit strong spatial structure and visual correlation to lab-analyzed soil OM.(Figure 3).

One of the many properties that EC maps have been found to relate to indirectly is organic matter (Jaynes et al., 1994). This is likely due in part to spatial autocorrelation between soil texture and OM; for example, very sandy soils typically have low OM levels. To help determine whether optical sensing offers any additional utility to EC mapping, the relationship between EC and optical measurements was examined. The best correlation found was between EC shallow and the red wavelength, however that relationship was generally not strong, with an average of .33 R^2. Only three of the 20 fields showed a relationship > .60 R^2.

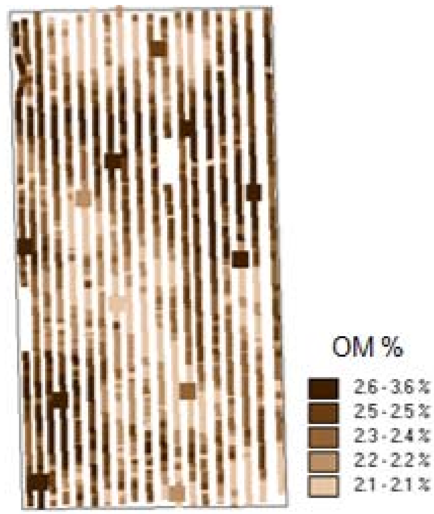

Figure 3. Lab-analyzed soil sample results overlaid on Veris OpticMapper map.

Conclusion

OpticMapper sensor measurements were reproducible and highly correlated with lab-analyzed OM. On most fields, optical and EC measurements were independent. The optical sensor represents an important addition to the proximal sensing options for improved soil mapping.

References

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