Measuring Soil Electrical Conductivity to Delineate Zones of Variability in Production Fields

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Summary

Production fields in southeast Kansas are highly variable. Differences in elevation and changes in soil texture contribute to unevenness in plant-available moisture and nutrients, resulting in significant inconsistencies in crop production and yield within a field. These variabilities complicate management and impact the return on investments from different areas of the field. Identification of the regions of variability is possible through several methods, including visual inspection, remote imagery, and yield maps. An additional method of assessing soil variability is by measuring the electrical conductivity of the soil. Measuring apparent electrical conductivity gives a map of the spatial distribution of soil properties, which can be used to identify potential limitations to production and develop site-specific management. Delineation of within-field variability can be used to target production inputs to better match potential crop yield with inputs to maximize return on investment.

Introduction

The productive capacity of soil is one of the key components determining yield and quality of crops. While some soil factors can be altered through management, other characteristics cannot be modified and instead must be managed. Soils of southeast Kansas are potentially productive silt loam underlain with an impermeable clay layer. The soils within a field can be highly variable, in part due to fluctuating depths of the silt loam topsoil. Other factors, including topographic position in the landscape, such as whether the area is at the top of a hill or at a low point in the field, alter the productivity of the soil through modification of drainage.

Precision agriculture is a management strategy that seeks to optimize return on investment by matching the production potential of a region within a field with the needed inputs for that level of productivity. The production potential, or productive capacity, is the capacity of the soils to produce at a given level (yield per acre). In precision agriculture, prescribed rates of inputs are developed to apply reduced inputs on areas within a field that have limited production potential, while highly productive areas are given more inputs to support that high level of productivity. This strategy improves net return by putting resources where they are most likely to give the highest return, and reducing application of costly inputs on poorly-performing regions within a field. Precision agriculture is a powerful technology, but requires accurate mapping of within-field spatial variability and knowledge of factors contributing to that variability.

Soil variability is a key component of the spatial variability of plant production and yield observed in production fields. The change in soil characteristics across a field are modified by the growing environment (temperature and rainfall) and management practices (tillage, fertility, etc.). Delineating zones of soil productivity allows development of prescriptions to match management practices and inputs to the productive capacity of each distinct production zone within a field. Changes in soil characteristics can often be visually detected using changes in soil color. Publically available imagery allows examination of entire fields from aerial images at different times during the production year. Grid or zone sampling measures details of soil characteristics, including texture (sand, silt, and clay content), organic matter, and nutrient content. Soil sampling has its limitations, due to the expense of analysis, and limited coverage.

Electrical conductivity is a measure of how well a material, in this case soil, conducts electricity. The soil's ability to conduct electricity changes as a function of the soil texture (clay, silt, and sand content), organic matter, cation exchange capacity, water content, and the salinity. Soil electrical conductivity varies as a function of several key factors important in crop production. It is also relatively stable, changing very little over the course of a year or for different management practices. Thus, it is a useful tool in defining productivity zones within a crop field. Moreover, it can be used to map the entire field relatively quickly, giving a good measure of the spatial variability of soils over the entire field. These maps can then be used to identify zones of variability to direct soil sampling, or develop prescription maps for site-specific applications.

Experimental Procedures

Crop production fields were selected in collaboration with farmer-cooperators. Yield and plant growth information was collected at harvest. Yields were recorded with commercial yield monitors on production-scale combines, and mapped in SMS Advanced (AgLeader, Ames, IA). Profit maps were developed based on K-State Research and Extension Cost-Return Budgets for corn, soybeans, and wheat grown in southeast Kansas (Ibendahl et al., MF992, MF993, and MF994). A Veris 3100 system (Veris Technologies, Salina, KS) was used to measure soil electrical conductivity. Soil samples were taken at discrete locations throughout the fields and tested at the Kansas State University Soil Testing Lab in Manhattan, KS for determination of soil texture and nutrient content.

Historical images of the crop production fields were downloaded from Google Earth. Digital elevation maps (DEMs) were downloaded from the Kansas Data Access and Support Center (http://www.kansasgis.org/resources/lidar.cfm), and were used for terrain analysis of the production fields using ArcGIS 10.1 (Esri, Redlands, CA).

Results and Discussion

Visual inspection of fields gives immediate information on potential regions of variability. Publically available imagery is also available from Google Earth and other providers (http://nationalmap.gov). By selecting previous years, historical information on field conditions can be examined in Google Earth. This visual imagery can be used to identify potential low-lying areas that may hold water (darker soils), or potential zones of high runoff (lighter soils; Figure 1A). The production field shows a region in the center of the field with wetter (darker) soils, as well as along the terraces. Terraces are seen to drain into the grassed waterway in the west-central southern portion of the field. A region of very light soil is seen in the southeast corner.

Information on specific soil types in the field is available from the Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Three predominant soils are identified in the field: Dennis silt loam, Parsons silt loam, and Kenoma silt loam (Figure 1B). The complete description, available from the Web Soil Survey, describes the Dennis silt loam as a silty and clayey residuum weathered from shale, with a typical profile of silt loam from 0 – 10 inches, with silty clay loam from 10-15 inches and silty clay below 15 inches. Dennis silt loam is in hydrological class C, indicating a layer in the lower soil profile that impedes downward water movement. The Parsons and Kenoma soils have silt loam extending from 0 to 13 inches, with silty clay beginning at 13 inches. Both Parsons and Kenoma are classified in hydrologic soil group D, indicating a very low rate of water infiltration due to a claypan or clay layer near the surface. The Kenoma is weathered from limestone and shale. The restrictive layer begins at about 80 inches in all three soil types. Soils throughout the field are classified as prime farmland.

A Veris 3100 system was used to map apparent electrical conductivity (EC_a) across the entire field (Figure 2). The Veris system measures EC_a through the soil using two arrays of electrodes on coulters. The arrays measure EC_a at two depths in the field: 0-10 inches and 0-30 inches. In our measurements, clay content was the largest determinant of soil EC_a. High EC_a measurements are indicative of soil with high clay content. This is seen to coincide with the region of lighter soil in the southeast corner of the field, and also in the soils to the north of the grassed waterway in the center of the field (Figure 3A). The soils with the lowest EC_a are observed in the center of the field.

Corn yield corresponds closely with EC_a, as the lowest yields were measured in the southeast corner, which had the highest EC_a (Figure 3B). The best yields corresponded with the regions of soil with the lowest measured EC_a, in the center of the field. Using yield maps from one complete crop rotation (corn/winter wheat/soybeans) over 2 years, and the K-State Cost-Return budgets, we can develop a profitability map of the field (Figure 4). The southeast corner of the field and the area just to the north of the grassed waterways had the lowest profitability. The center of the field had the greatest return. The area to the north of the field had intermediate return.

The measurements demonstrate the extent of soil variability within a production field, and methods of identifying potential sources of that variability. Clay content is one factor contributing to the observed variability in crop production. The EC_a measurements of soil gives a spatial map of the variability in soil characteristics throughout the field. We can use this to develop a zone sampling strategy to further delineate sources of soil variability. Other factors contributing to variability in crop production may include topographic position and soil moisture content, which are correlated, as soils at higher elevation will tend to dry out more quickly while low-lying areas will stay wetter. The knowledge can be used to develop site-specific management practices for the field. Implementing precision management practices could improve net return by reducing inputs on regions with low productive capacity.

References

Gregg Ibendahl, Daniel M. O'Brien, and Douglas Shoup, Wheat Cost-Return Budget in Southeast Kansas, Kansas State University, April 2015. MF992. https://www.bookstore.ksre.ksu.edu/pubs/MF992.pdf

Gregg Ibendahl, Daniel M. O'Brien, and Douglas Shoup, Corn Cost-Return Budget in Southeast Kansas, Kansas State University, April 2015. MF993. https://www.bookstore.ksre.ksu.edu/pubs/MF993.pdf

Gregg Ibendahl, Daniel M. O'Brien, and Douglas Shoup, Soybean Cost-Return Budget in Southeast Kansas, Kansas State University, April 2015. MF994. https://www.bookstore.ksre.ksu.edu/pubs/MF994.pdf

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Figure 1. A. Visual images of crop production fields are an easy way to identify regions of variability. This bare-soil image was downloaded from Google Earth (https://www.google.com/earth/). Darker regions of the fields are most likely caused by low-lying areas that are holding moisture. B. Description of the soils in the fields from the Web Soil Survey add additional information about the potential variability. For this field, three predominant soil types are identified in the field, 8679 Dennis silt loam, 1 to 3% slope, 8863 Parsons silt loam, 0 to 1% slope, and 8775 Kenoma silt loam, 1 to 3% slope. (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm).

Figure 2. A Veris 3100 system was used to measure apparent soil electrical conductivity across the entire field.

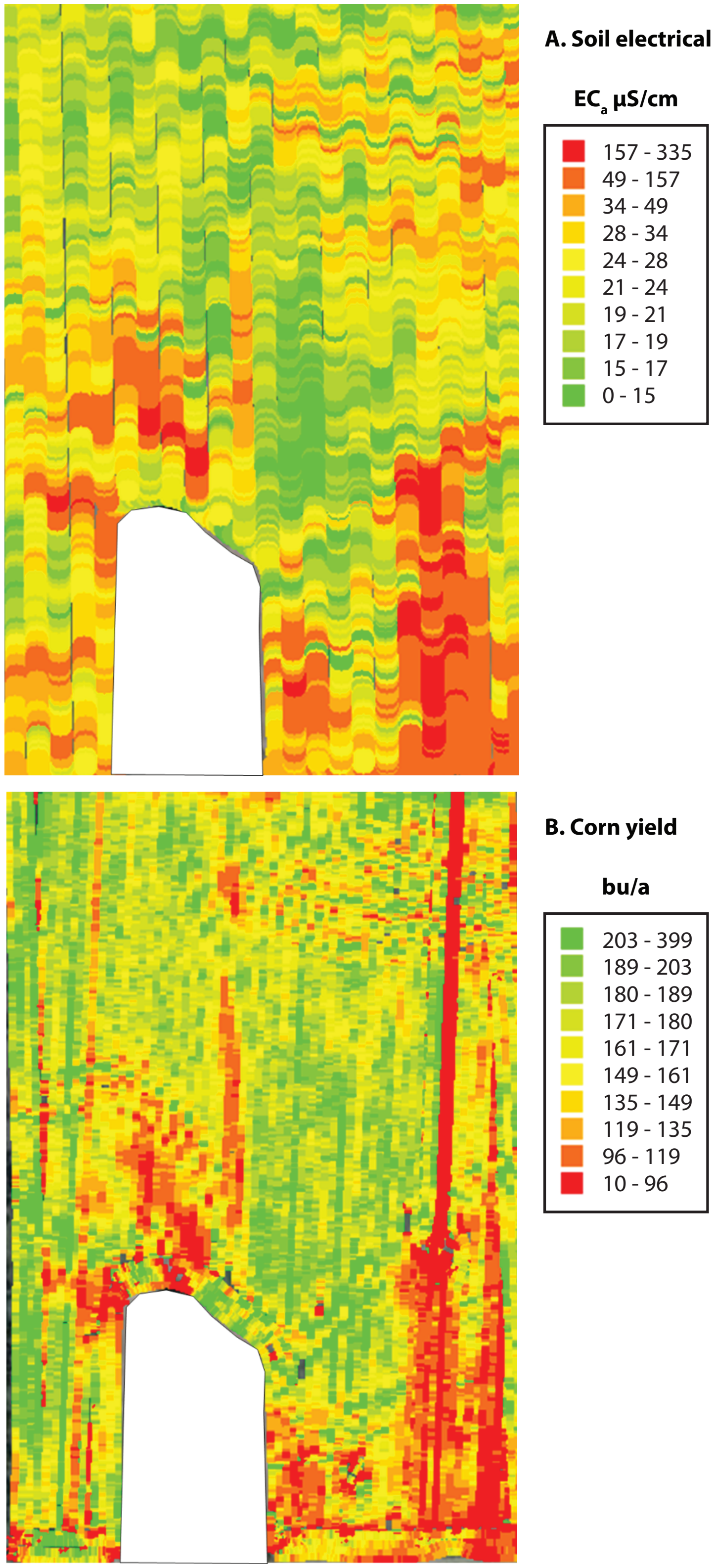

Figure 3. A. Soil apparent electrical conductivity, EC$_a$, measured in a production field with a Veris 3100 System. B. Corn yield measured with a yield monitor.

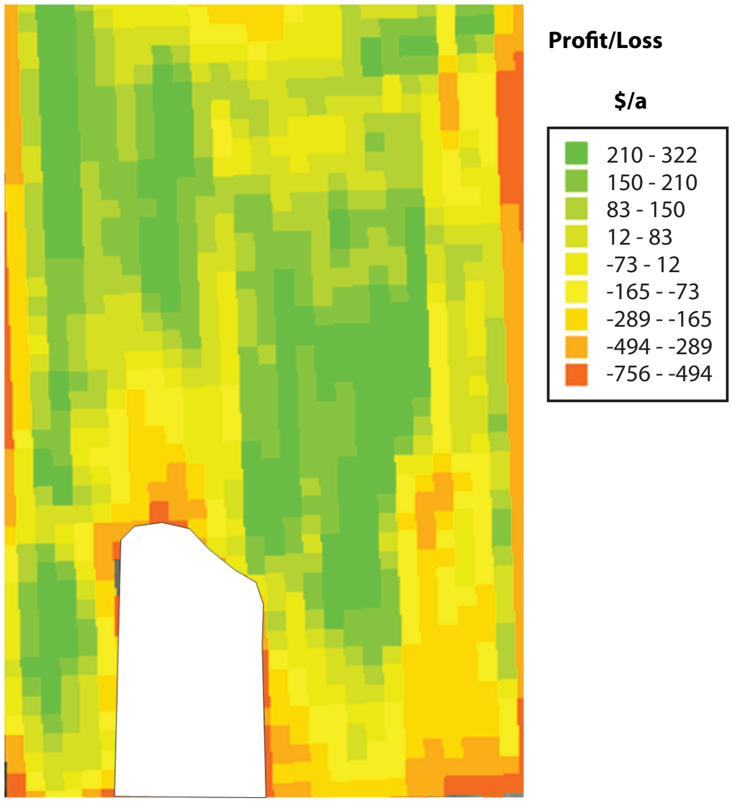

Figure 4. Crop profitability map. The spatial distribution of return on investment was calculated for a complete crop rotation (corn/winter wheat/soybeans) for two years based on measured crop yields and cost-return budgets (see resource list).