SPATIAL YIELD ANALYSIS IN NORTHEAST ARKANSAS FIELDS

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INTRODUCTION

Precision agriculture is implemented through five major steps namely, data collection, knowledge discovery (information extraction), management decision making, variable rate application, and evaluation. Many new methods have evolved in the past decade for collecting within-field variability data from the field. Variable-rate control systems and machineries have been developed for site-specific application of agricultural inputs. Nonetheless, not much progress has been made in knowledge discovery and knowledge-based decision-making areas. One major reason for this lack of progress is that we do not know the yield functions that relate yield to all the factors that affect yield. The final yield is affected by a complex system of soil, crop, weather, and operational parameters and their interacted effects. The second major drawback is the quality of the data collected from the field. Grid sampling from every 2 to 10 acres of land does not provide a clear picture of the actual variability in a field. Therefore, it is necessary to use high-quality (high-resolution) data for research and to develop methods for knowledge discovery from the field data and guidelines to use this information for developing field management decisions. Research shows that availability of high-density and high-quality data on spatial variability of yield-limiting factors within a field is valuable, and the use of this data to manage the field site-specifically will tremendously increase the yield profitability from a field (Bullock et al., 1998).

In Arkansas, some growers have adopted some of the precision agricultural practices such as soil-grid sampling, precision land leveling, and yield monitoring. Recently, apparent electrical conductivity of soil collected using VERIS soil mapping equipment was also collected by a few growers and researchers. The VERIS data were reported as a good indicator of soil physical and chemical properties and a good estimator of yield-limiting variability factors such as soil texture, Ca, Mg, K, and CEC in

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claypan, Mississippi Delta, and deep loess-hill soils (Kitchen et al., 2000). However, most of the field data collected by growers were not processed or used for making any site-specific management decisions. This study was undertaken with the general objective to gather and synthesize some of the spatial data collected by growers in northeast Arkansas. The specific objectives were to study whether VERIS data represent the spatial variability in yield and yield-limiting soil fertility factors.

RESEARCH DESCRIPTION

The experimental data included VERIS data on soil apparent electrical conductivity and soil fertility data collected on a grid basis. The data were collected from the Wildy Farms located in Mississippi County in northeast Arkansas. The farm consisted of 6405 acres of cotton. Two fields, namely Field 7 (27.4 acres) and Field 66N (70 acres), were selected for the study mainly because of the availability of past data starting from 1998. Both farms were under continuous corn irrigated by center-pivot irrigation systems. Soil fertility data were obtained from both fields by soil sampling on a 100 m grid and analyzing the soil samples in a laboratory. The apparent electrical conductivity ($EC_{a)}$ of the soil was measured using a VERIS soil mapping system that is a direct-contact soil EC_a meter. The VERIS shallow represents the EC_a for the top 33 cm of soil and VERIS deep represented the EC_a for the top 100 cm of soil. The soil electrical conductivity measurements are strongly correlated to water content (Fritz et al., 1999) and have long been used to identify contrasting soil properties in the geological and environmental fields (Lund et al., 1999). The distance between successive passes of VERIS data varied from 15 to 20 m. The yield data were collected at the end of the season with a yield monitor. The yield monitor data were calibrated to lint yield using the actual total lint yield from the field with the software program called AGRIPLAN.

Initially, the spatial distribution of yield and VERIS data was compared by matching the krigged surface generated from the respective point data. The different data sets used in this study were collected at different resolutions. The soil grid data were collected on 100 m grid. The distance between adjacent passes of VERIS data was approximately 20 m and that for yield data was approximately 10m. Therefore, the field data were processed using two different schemes, namely scheme 1and scheme 2. In scheme 1, buffer zones of 10 m radius were selected around the soil sampling point at 100 m spacing (Fig. 1). The VERIS and yield data that fell in the buffer area were averaged and aggregated with soil-test data for that point. Since the VERIS data were collected at 15 to 20 m distance between adjacent passes, a grid scheme with 15 m horizontal size and 15 to 20 m vertical size was manually laid out centering VERIS data (Fig. 2) in scheme 2. The yield data and VERIS data were averaged over this 15- to 20-m grid and aggregated with each other. The aggregated data were used to study the spatial distribution and correlation of yield with VERIS and soil fertility measures.

RESULTS AND DISCUSSION

Correlation analysis of soil fertility factors with respect to VERIS data showed strong correlation of soil fertility factors such as P, Ca, Mn, S, Mg, Zn, B, organic matter, cation exchange capacity (CEC), and pH with both VERIS shallow and deep (Table 1 and 2). Other minerals such as copper, manganese, and iron were poorly correlated to VERIS measures of soil electrical conductivity. This result showed that VERIS could be used as a measure of several of the soil fertility factors. Correlation analysis between soil fertility factors and yield did not show any consistent patterns over the three years. In different years, the yield-limiting factors appeared to change. The trends between yield and soil fertility factors also seemed to change over the years. In some years, yield may show a positive trend with respect to a particular soil factor. In some other years, it may show a negative trend. For example, organic matter revealed iron content of the soil showed a positive correlation with yield in 1999, indicating higher yields in areas of high iron content. In 1998 and 2001, iron content showed a negative correlation with yield, showing lower yields in areas with high iron content. This vacillating trend is an indication of the complexity of the combined effects of different parameters acting on crop and causing yield variations.

In both field 7 and field 66N, the spatial variation in yield (Fig. 3) did not match with the spatial variations in VERIS (Fig. 4) on visual observation. The yield pattern in field 7 showed some similarity to VERIS surface in 1998 (Fig. 3C and 4). Correlation analysis between VERIS and yield data showed contradictory results between scheme 1 and scheme 2 especially in Field 7 (Table 3). Scheme 1 showed a significant correlation in 1999 and a very strong correlation (0.63 and 0.78) in 2001 between yield and VERIS data. However, the higher resolution analysis in scheme 2 resulted in a poor correlation in 1999 and 2001 and a strong correlation in 1998. Such contradictory correlation coefficients resulting from the two schemes show the importance of data resolution in obtaining reliable results. Low-resolution of the soil data may be one reason for the wavering trend between yield and soil parameters observed in Table 1 and 2.

The results from this study show that VERIS data are a good indicator of soil fertility. However, VERIS may or may not indicate the spatial variations in yield. The critical task is to investigate why VERIS and various fertility measures did not show a consistently good correlation with yield. This may be due to the fact that some factors that were not considered in this study had influenced how different fertility measures affected yield. We need to investigate what additional soil-based or weather-based factors could have caused these variations in the yield. We also need to identify the dominating or delimiting soil factors from an array of fertility measures based on their estimated impact on yield in a given year. Such accurate analysis, as indicated by Bajwa et al. (2001), requires field data collected at relatively high resolution.

CONCLUSIONS

This study found that the VERIS data were a good indicator of soil fertility measures such as P, Ca, Mg, CEC, etc. However, various fertility measures and VERIS data did not show any consistent correlation with spatial yield. Data resolution is found to be a critical factor that influenced the accuracy and reliability of spatial analysis results.

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Table 1. Correlation analysis of soil fertility factors with respect to yield and VERIS data in Field 66N.

Soil fertility factors	VERIS-s	VERIS-d	Yield98	Yield99
Phosphorus	0.56	0.35	0.13	-0.20
Potassium	-0.10	-0.07	-0.07	-0.04
Calcium	0.71	0.51	0.30	-0.05
Magnesium	0.72	0.46	0.24	0.01
Sulfur	0.34	0.18	0.08	-0.06
Zinc	0.50	0.52	0.22	-0.31
Boron	0.76	0.50	0.16	-0.06
Organic matter	0.72	0.59	0.22	-0.10
pH	0.58	0.34	0.23	0.17
CEC	0.70	0.51	0.32	-0.12

Table 2. Correlation analysis of soil fertility factors with respect to yield and VERIS data in Field 7.

Correlation factors	VERIS-s	VERIS-d	Yield98	Yield99	Yield 01
Phosphorus	0.39	0.42	-0.45	0.25	-0.06
Potassium	-0.28	0.08	-0.32	-0.25	0.21
Calcium	0.71	0.51	-0.16	0.59	0.14
Magnesium	0.74	0.50	-0.19	0.51	0.17
Sulfur	0.67	0.43	-0.19	0.21	0.32
Zinc	0.21	0.07	-0.37	0.13	-0.16
Iron	-0.03	-0.05	-0.35	0.35	-0.48
Manganese	0.04	0.14	0.27	-0.47	0.51
Copper	0.22	0.15	-0.24	0.42	0.46
Organic matter	0.33	0.21	-0.46	0.47	0.01
pH	-0.23	-0.28	-0.20	0.35	-0.54
CEC	0.80	0.60	0.16	0.55	0.31

Table 3. Correlation between yield data and VERIS data, analyzed using two schemes.

		Scheme 1		Scheme 2	
Fields	Yield-year	VERIS shallow	VERIS deep	VERIS shallow	VERIS deep
Field 7	1998	-0.21	-0.35	-0.53	-0.50
	1999	0.47	0.44	0.10	0.05
	2001	0.63	0.78	0.17	0.25
Field 66N	1998	0.09	0.28	0.09	0.09
	1999	0.19	0.12	0.12	0.09

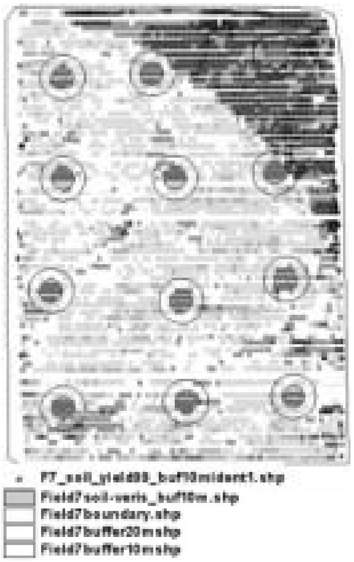

Fig. 1. Data analysis scheme 1. In this scheme, soil data collected over 100 m grid were analyzed with respect to VERIS and yield data averaged over 10 m buffer radius around the sampling location.

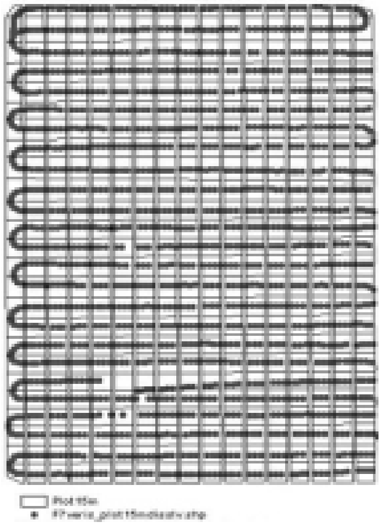

Fig. 2. Data analysis scheme 2. In this scheme, yield and VERIS data were analyzed over a 15 by 20 m grid laid around VERIS data. Both VERIS and yield data were averaged over the grid and aggregated for further analysis.

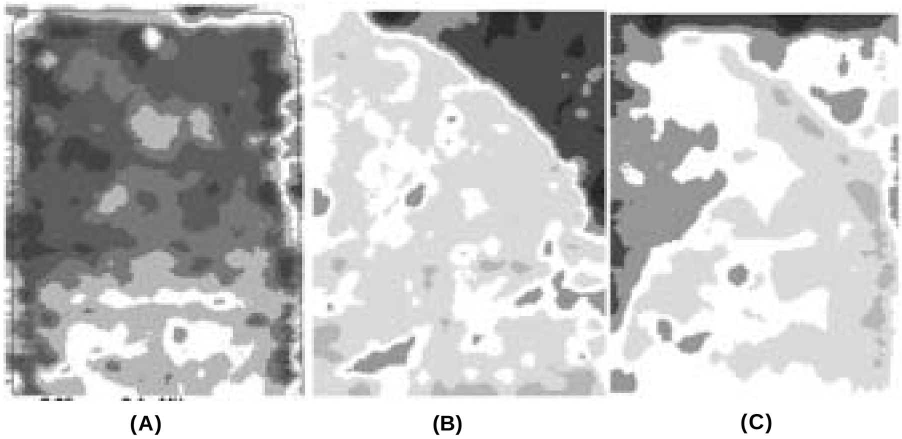

Fig. 3. Spatial distribution of yield from (A) 2001, (B) 1999, and (C) 1998 from Field 7. Yield surfaces were developed from yield monitor data by krigging interpolation.

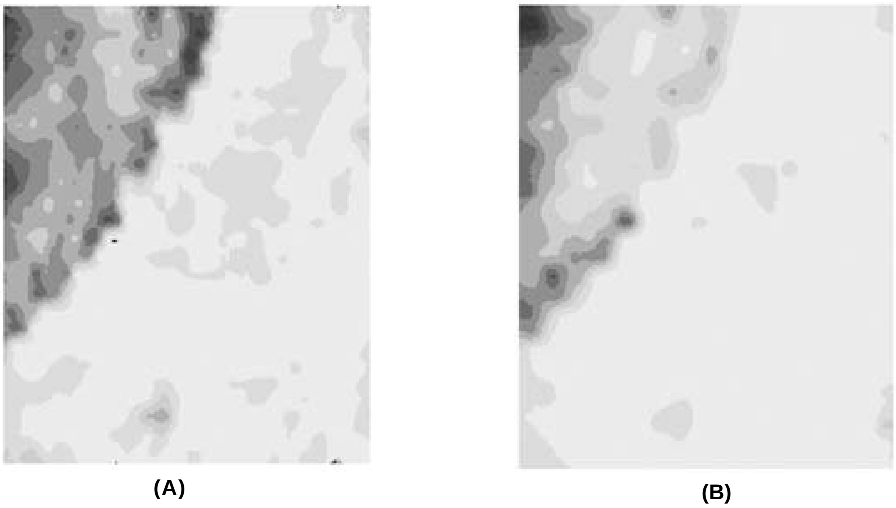

**Fig. 4. Spatial distribution of VERIS data in Field 7.
(A) VERIS deep, and (B) VERIS shallow.**