SPATIAL ANALYSIS OF AGRONOMIC PROPERTIES IN TWO PRODUCTION COTTON FIELDS IN WEST TEXAS

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Abstract

With high input and high value of cotton, cotton growers may be interested in precision agriculture for cotton production. The successful application of this technology is mainly dependent on the identification of key limiting factors and the adjustment of controllable factors. More data are needed to support precision agriculture on cotton. The objectives of this study were 1) to evaluate spatial variability of cotton yield and soil parameters within irrigated fields and 2) to identify relationships between the soil and plant parameters. This research was conducted on two irrigated cotton fields in West Texas in 1998. Growing season precipitation was less than 40% of average. Cotton yield had a high variability within the fields we studied. Yield tended to be negatively related to clay content and positively related to sand content across soil types within a field during this season. Soil parameters and other factors influencing variability within a soil type are being further examined. Soil parameters that influence yield may or may not be amenable to variable rate application. If lint yield is related to nutrient level, it is possible to variably apply nutrients. If yield is influenced by moisture availability due to soil texture and organic matter content at a point in a field, it still may be possible to vary fertilizer or other inputs based on moisture availability.

Introduction

Traditional agriculture treats crop fields uniformly with respect to production inputs. However, soil type, fertility, soil water content, and other characteristics can vary spatially and temporally and affect crop production (Sudduth et al, 1996). As a result, agricultural inputs may be over-applied in some areas and under-applied in other areas. Furthermore, yield can vary temporally as conditions (climate, pests, etc.) change from season to season. Precision agriculture technologies are available that allow variable application of crop production inputs within a field. The successful application of precision agriculture will depend on the characterization and management of the key limitations to optimum profitability and environmental protection (Mulla and Schepers, 1997).

Preliminary studies indicate that variation in cotton yield is common. Lint yield was found to vary from 901 to 1902 lb./acre in an investigation conducted by Kepple (1988). Elms et al. (1997) showed that the lint yield ranged from 242 to 1102 lb./acre in a research field. Like other crops, cotton yield is affected by many factors; some factors such as nutrition and seeding rate can be controlled easier than other factors such as sunlight and CO_2 concentration. It is quite important to manage the controllable factors according to the demand from plants and to minimize the adverse effects on the environment.

Since cotton is a high-value crop with high input costs, cotton growers are interested in site-specific farming (O'Brien-Wray, 1996). However, insufficient data hinder the application of this technology in cotton production. The objectives of this study were 1) to evaluate spatial variability of cotton yield and soil parameters within irrigated fields and 2) to identify relationship between the soil and plant parameters.

Materials and Methods

This study was conducted on two irrigated fields near New Deal (Field 1) and Anton (Field 2), TX. Field 1 contains three soil types – Acuff loam, Amarillo fine sandy loam, and Olton clay loam. Field Two is composed of Amarillo fine sandy loam. Both fields have center pivot LEPA systems.

Cotton was planted on May 13 and May 14, 1998 in the two fields. The 1998 growing season was extremely dry and hot. There was no rainfall in May. Irrigation after planting in the two fields was 6.5" and 7". Additionally, each field received about 5.5" of rain during the growing season. In-season rainfall was less than 40% of the normal rainfall.

A grid system of 2.5 acres (330 by 330 feet) was the basic unit for soil sampling. On May 23 and 24, samples were collected by compositing three samples within the center of each grid at a depth of 0 - 6", 6 - 12", 12 - 24". One grid representing each soil type was subdivided into 64 intensive sampling grids (41 by 41 feet) for further estimation of spatial soil variation (Fig. 1 & 2). Sampling positions were georeferenced by means of DGPS. The soil samples were analyzed for water content, nitrogen, phosphorous, organic matter, zinc, copper, iron, manganese, texture, and pH. Yield measurement and yield component investigation were conducted on a 0.001 acre area (43.6 square feet) from 2 rows of cotton near the soil sampling points for each grid.

The variation of soil characteristics and cotton yield were processed with classical statistics and geostatistics. Spatial variability maps were developed by using Arc Info[â], ArcView[â]. The latitude and longitude degrees in Geographic Reference System from GPS were converted to coordinate system in the unit of meter with the projection of the Universal Transverse Mercator (UTM). Measured data positioning with the coordinate system were input to GS_{TM}^{+} GeoStatistics to determine their spatial variations. The isotropic variogram model with the lowest reduced sums of

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squares (RSS) was used for kriging. Kriged estimates served as the basic data in Arcview for mapping their variability.

Results and Discussion

Cotton Lint Yields

Lint yields ranged from 601 to 1310 lb./acre in Field 1 (Fig. 3). The coefficient of variation (CV) for yield was 19% in Field 1. To facilitate graphing spatial relationships, the yield was divided into quartiles. The spatial variability of yield in this field was shown in Figure 4. This figure indicated that the highest yields tended to be associated with the Amarillo soil.

Cotton lint yields were affected by soil type in Field 1 (Fig. 5). Yields in the Amarillo fine sandy loam were significantly higher than the yields in the Acuff loam and Olton clay loam in Field 1. On average, the Amarillo fine sandy loam produced 38% and 43% more cotton than the Acuff loam and the Olton clay loam separately. There were no significant yield differences between the Acuff and Olton soils.

Lint yield ranged from 572 to 1295 lb./acre in Field 2 (Fig. 6). The CV for yield was 20% in Field 2. The high variability in Field 2 is essentially the same as that observed in Field 1, even though Field 2 contained only one soil type. The relatively high CVs observed in these fields are similar to those observed by Elms et al. (1997). The spatial variability for yield quartiles for Field 2 is shown in Figure 7.

Spatial analyses showed that cotton yields in the two fields had similar spatial variation according to the spatial parameters from their semivariances (Fig. 8). However, cotton yields in Field 1 had slightly larger range. To make better estimations, searching radii were one fourth of lag range for linear models and one half of lag range for spherical models.

Soil Characteristics

Summaries of soil chemical and physical properties are shown in Table 1 and 2. Comparing soil nutrients in two fields, Field 2 tended to have higher soil fertility levels (Table 1). This higher soil fertility could be one reason for higher average yield in Field 2. The higher yield in Field 2 may be explained in part by the fact that the entire area studied consisted of the Amarillo fine sandy loam, which was the highest yielding soil type in Field 1. However, direct comparisons between fields should be done with caution due to differences in many production factors between the two fields.

Based on the observed CVs, the soil chemical properties exhibited a high level of variability within each field. Of the soil chemical properties listed in Table 1, the least variability was found for calcium and potassium saturation. Silt content was the most variable soil physical property (Table 2).

Relationships between Cotton Yield and Soil Parameters

Yield patterns in Field 1 showed that the Amarillo fine sandy loam had the highest yield among the three soil types. It seems that the effect of soil type on yield could be due to texture. Further analysis indicated there was a weak negative relationship between soil clay content and cotton yield (Fig. 9) and a weak positive relationship between sand content and cotton yield (Fig. 10). Such relationships between texture and yield are often observed in dry years in West Texas. Amarillo fine sandy loam contained less clay and more sand than the Olton clay loam and Acuff loam in Field 1. The water contents before irrigation in the spring were highest in Olton clay loam. Although water contents are generally higher in soils with higher clay contents, soil water availability may not be higher. Oosterhuis et al (1991) indicated that response of cotton yield to stress was associated with soil clay contents, which also caused the variations in cotton growth by crusting and emergence problems as well as damping-off disease connected with clay contents. Furthermore, infiltration rates are higher in the sandier soil and this may facilitate greater water collection and reduce runoff and evaporative loss. While soil water availability may partly explain yield differences between soil types, it probably can not sufficiently explain yield differences within a soil type. Further relationships between soil and plant parameters are being investigated.

To successfully adopt variable rate technology to cotton production it is necessary to determine relationships between soil parameters and lint yield. However, the soil parameters that influence yield may or may not be amenable to variable rate application. For example, if lint yield is related to nutrient level, it is possible to variably apply nutrients within a field in an effort to maximize lint yield. However, if yield is limited by insufficient moisture availability due to soil texture at a point in a field, it may be possible to reduce inputs at that point; the amount of fertilizer applied and the seeding rate could be reduced. This could increase profitability by reducing inputs (i.e., production costs) of factors that are not limiting. Conversely, by maximizing inputs (increased plant population or increased fertilizer rates) in areas of a field that are naturally more productive, yields can be increased; this results in more cotton production. Furthermore, the most productive parts of a field in a drier year may or may not be the most productive in a wetter year. Therefore, it may be necessary to modify precision agriculture management to reflect climatic conditions.

Summary

Cotton yield had a high variability within the fields we studied. Yield tended to be negatively related to clay content and positively related to sand content across soil types within a field. Soil parameters and other factors influencing variability within a soil type are being further examined. Soil parameters that influence yield may or may not be amenable to variable rate application. If lint yield is related to nutrient level, it is possible to variably apply nutrients. If yield is influenced by moisture availability due to soil texture at a point in a field, it still may be possible to vary fertilizer or other inputs based on moisture availability.

Acknowledgement

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References

Elms, K. and C. Green. 1997. Spatial variability of yield in irrigated cotton. National Cotton Council of America. Proceedings of Beltwide Cotton Conferences. v. 1 p. 598-601.

Kepple, W. D. 1988. Unlocking mysteries of cotton yield variations. Agrichemical age. Oct. 1988. p 24A-24B.

Mulla, D. J., and J. S. Schepers. 1997. Key processes and properties for site-specific soil and crop management. p 1 -18. The state of site-specific management for agriculture. Soil Science Society of America, Inc. Madison, Wisconsin.

O'Brien-Wray, K. 1996. Cotton growers ready for precision farming. Soybean digest. Aug./Sept. 1996. p46-47.

Oosterhuis, D. M., E. M. Rutledge, C. A. Stutte, S. D. Wullschleger, R. E. Hampton, and C. R. Bell. 1991. In-field growth variability. Arkansas Farm Research. 40:(4)9-10.

Sudduth, K. A., S. T. Drummond, S. T. Birrell, and N. R. Kitchen. 1996. Analysis of spatial factors influencing crop yield. p129-139. *In* Robert, Rust, and Larson (eds). Precision agriculture. Proceedings of the 3rd international conference. Minneapolis, Mn.

Table 1. Summary of selected soil chemical properties of top 6" of soil

Parameter	Field & soil type	Mean	Min	Max	CV
					%
O.M.	F1; Ol	0.76	0.4	1.2	20
(%)	F1; Ac	0.85	0.4	1.3	21
	F1; Am	0.64	0.4	1.3	25
	F2; Am	1.03	0.7	1.5	17
NO_3	F1; Ol	30.5	9.7	66.5	41
(ppm)	F1; Ac	29.0	8.9	60.0	39
	F1; Am	23.7	10.7	59.9	42
	F2; Am	28.6	5.4	67.0	42
Olsen P	F1; Ol	5.4	1.9	16.3	48
(ppm)	F1; Ac	4.8	1.7	11.2	46
	F1; Am	4.6	1.3	12.3	50
	F2; Am	10.4	4.4	27.3	46
Ca sat.	F1; Ol	61.5	50.2	74.7	7.5
(%)	F1; Ac	61.1	40.7	70.5	6.4
	F1; Am	56.2	49.8	71.1	6.1
	F2; Am	63.4	52.6	75.5	6.0
K sat.	F1; Ol	7.6	5.2	10.1	15
(%)	F1; Ac	8.0	5.5	10.8	12
	F1; Am	9.3	4.7	11.6	11
	F2; Am	8.6	3.9	10.8	13
Zn	F1; Ol	0.66	0.3	2.1	43
(ppm)	F1; Ac	0.71	0.3	2.4	57
	F1; Am	0.53	0.2	1.2	40
	F2; Am	2.71	0.8	7.2	44
Cu	F1; Ol	1.29	0.5	2.0	30
(ppm)	F1; Ac	1.25	0.6	2.0	26
	F1; Am	1.05	0.5	1.9	33
	F2; Am	1.12	0.7	1.3	38
Mn	F1; Ol	13.5	5	36	34
(ppm)	F1; Ac	15.0	8	28	28
	F1; Am	14.9	7	27	32
	F2; Am	15.1	17	28	36
Fe	F1; Ol	9.5	2	33	87
(ppm)	F1; Ac	8.9	2	28	83
	F1; Am	11.2	2	29	83
	F2; Am	14.6	4	100	90

F1, Field 1; F2, Field 2. Ol = Olton clay loam, Ac = Acuff loam, Am = Amarillo fine sandy loam.

Table 2. Summary of selected soil physical properties of top 6” of soil

Parameter	Field & soil	Mean	Min	Max	CV
		… … … … % … … … …			
Water					
	F1; Ol	11.4	6.9	15.2	14
	F1; Ac	11.2	6.5	15.1	15
	F1; Am	8.6	5.8	13.3	15
	F2; Am	11.1	7.6	16.3	14
Clay					
	F1; Ol	22.0	16.7	31.5	18
	F1; Ac	19.1	15.6	24.4	22
	F1; Am	15.8	15	17.7	7
	F2; Am	24.7	21	28	7
Silt					
	F1; Ol	14.7	7.8	22.6	28
	F1; Ac	14.8	9.5	24.0	42
	F1; Am	7.1	6.0	9.8	26
	F2; Am	18.2	14.3	23.0	11
Sand					
	F1; Ol	63.4	46.2	73.8	11
	F1; Ac	66.2	51.6	74.9	16
	F1; Am	77.1	73.8	78.9	3
	F2; Am	57.1	49.1	62.2	6

F1, Field 1; F2, Field 2.

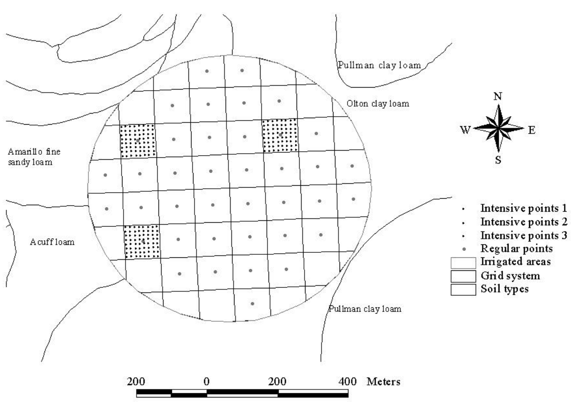

Figure 1. Sampling points in Field 1

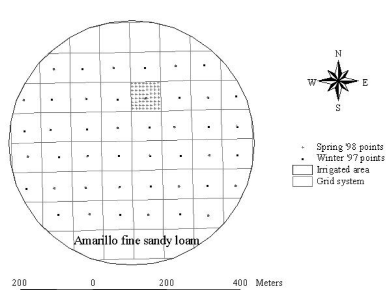

Figure 2. Sampling points in Field 2

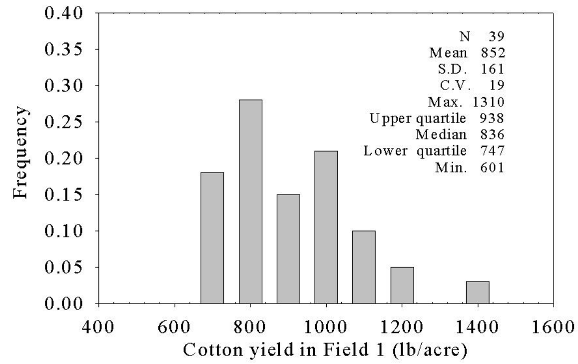

Figure 3. Frequency distribution and summary statistics for lint yeild in Field 1

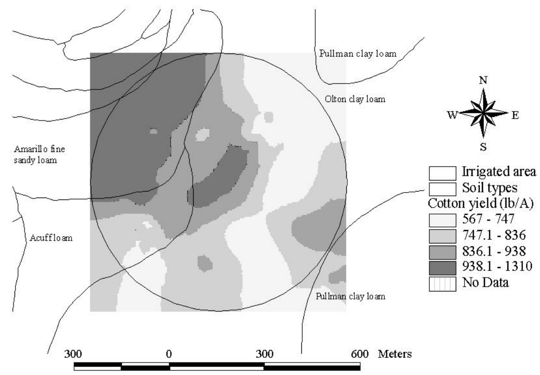

Figure 4. Spatial variability of kriged yield in Field 1

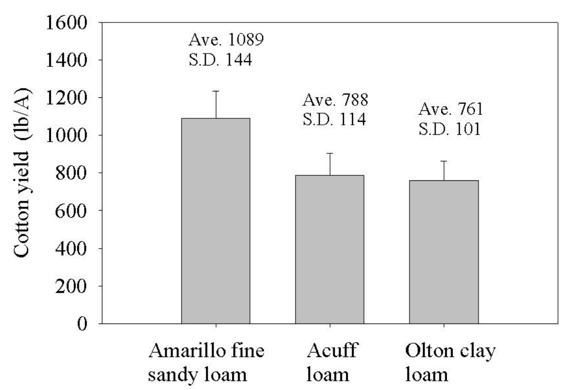

Figure 5. Average lint yield by soil type for Field 1

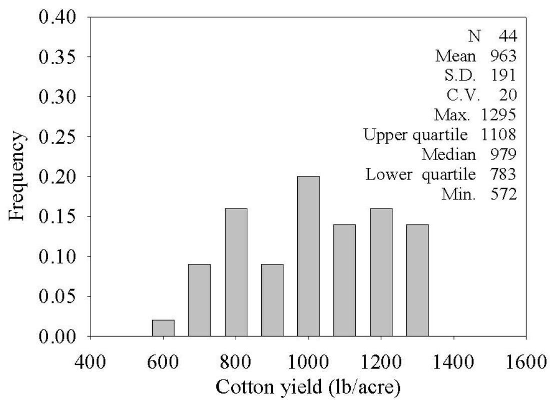

Figure 6. Frequency distribution and summary statistics for lint yield in Field 2

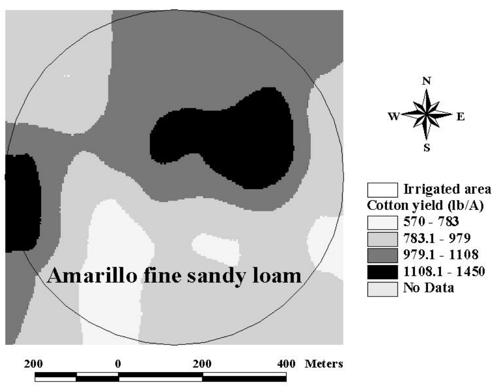

Figure 7. Spatial variability of kriged yield in Field 2

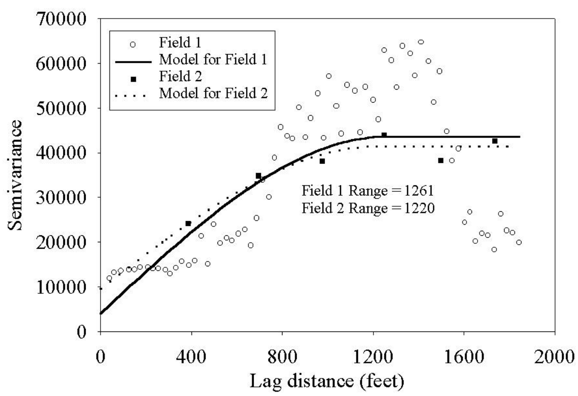

Figure 8. Semivariogram of yield in the two fields

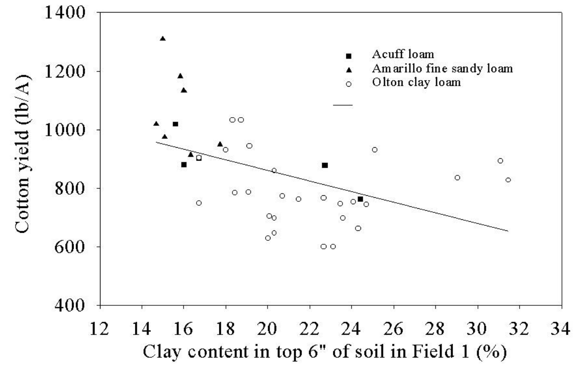

Figure 9. Relationship between yield and clay content for Field 1

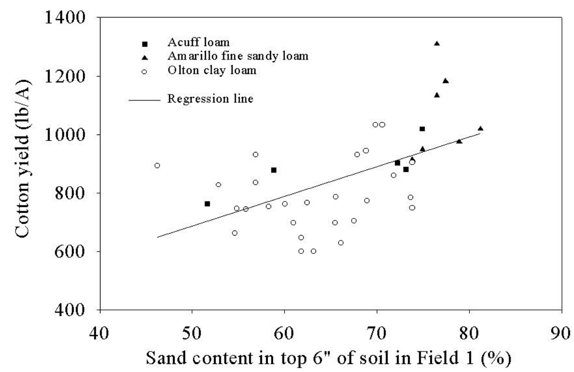

Figure 10. Relationship between yield and sand content for Field 1