CONTINUED EVALUATION OF THE INFLUENCE OF SOIL PARAMETERS ON COTTON AND CORN YIELDS AS DETERMINED WITH GPS/GIS TECHNOLOGY

M. W. Ebelhar and J. O. Ware
Mississippi Agricultural and Forestry Experiment Station
Delta Research and Extension Center
Stoneville, MS

Abstract

Producers are continually being exposed to new technologies and the Computer Age. Site specific management in agriculture has been gaining acceptance and use in some areas of the country and continues to grow across the Cotton Belt. Global Positioning Systems (GPS) and Geographic Information System (GIS) make it possible to geo-reference fields which become the framework for multi-layered data that can be used to describe relationships or events occurring in the field or a specific management zone. This study on 15-acre field at the Delta Research and Extension Center was initiated in 1998 in an effort to evaluate the spatial variability of corn and cotton yields as wells the spatial variability of topsoil and subsoil soil characteristics measured in the same areas. Corn grown in 1998 had yields which ranged from a low 132 bu/A to a high of 186 bu/A and a field average of 156 bu/A. In 1998, the same area had corn yields which ranged from 151 bu/A to a high of 222 bu/A and a field average of 182 bu/A. The area was rotated to cotton in 1999 with total lint yields ranging from a low of 949 lb/A to a high of 1508 lb/A and a average across the field of 1248 lb/A. Regression analysis was used was used to examine the the soil characteristics with respect to corn yields. When considering a single factor in 1998, the highest correlation occurred between yield and subsoil P ($r^2 = 0.2460$) followed by topsoil P ($r^2 = 0.2394$). When two factors were considered in the model, the highest correlation occurred with subsoil P + subsoil K ($r^2 = 0.2725$). Adding the second factor did not greatly increase the correlation. With the second corn crop in 2000, subsoil P was again the factor with the highest correlation to yield ($r^2 = 0.0751$). The correlation was poorer in 2000 than had been observed in 1998 indicating that other factors were exhibiting a stronger influence than before. The soil pH became more of a factor in 2000 with the second highest single factor correlation ($r^2 = 0.0657$). These two factors together increased the correlation to $r^2 = 0.1344$. When evaluating factors that influenced cotton lint yields, soil characteristics such as topsoil exchangeable acidity ($r^2 = 0.0979$) and both subsoil CEC ($r^2 = 0.0971$) and topsoil CEC ($r^2 = 0.0960$) had a stronger influence than P. Crop response to P was different depending upon the crop grown. While corn yields increased with increasing P levels, cotton yields decreased. With the data collected and analyzed to date, it is apparent that the yield controlling factors are complex and are also not consistent from crop -to-crop or year-to-year. While the technology is new and exciting, many questions and concerns are yet to be answered. The new technology does provide many useful tools for examining the variations occurring in the field

Introduction

Producers are continually being exposed to new technologies and the advancement of the Computer Age. Site specific management or precision agricultural are just a few of the terms used to describe new technologies that offer promise for incorporation into current agricultural management schemes. Global positioning systems (GPS) have made it possible to geo-reference areas which become the basic framework for multi-layered data that can be used to describe events taking place in a particular management zone. Yield monitors on grain harvester have made it possible to measure yield variations in the field while moving across the landscape. The data collected from the yield monitors can then be related back to a GPS framework. Since GPS sets a land-based reference system, the most logical place to start is the soil and soil nutrient analysis. This on-going study was initiated in 1998 to examine the relationship between soil testing parameters (pH, phosphorus [P], potassium [K], exchangeable acidity, exchangeable cations [K, Ca, Mg, Na], cation exchange capacity [CEC], organic matter [OM], an estimate of sulfur [S], and zinc [Zn]) and yields of corn (1998 and 2000) and cotton (1999). Other data such as harvest moisture, plant stands, bushel test weight, seed weights can also be collected and correlated to soil test results. When cotton is grown, seedcotton and lint yields can be measured along with maturity as determined by the percent first harvest (PFH).

Much of the application of technology so far has been related to the soil variability without actually trying to determine what the relationship between yield and the soil characteristics might be. Variable-rate applicators are proposed for trying to even out some nutrients in the field while the relationship to yield of that nutrient may not be known. The first objective of the this study was to examine the natural variability in a field and build yield maps which show the extent of the spatial variability. The second objective was to determine whether the patterns of variability were consistent from crop to crop and year to year. The second part of the was designed to examine the relationship between yield and soil characteristics and determine which factor or factors may explain spatial yield variability in both corn and cotton. This research paper will address the relationships that occur and also the extent that these relationships can be observed from year to year and crop to crop.

Materials and Methods

The research area was a 15-acre field on the Delta Research and Extension Center at Stoneville, MS containing three soil classification units as delineated in the Soil Survey Report for Washington County, Mississippi. The general soil type was Dundee (Aeric Ochraqualfs) with three different textural classes. The classes included very fine sandy loam, silt loam, or silty clay loam. The field was divided into 496 plots (cells) with each cell consisting of four 40-in rows 82 feet in length (0.025 acres). The 496 cells were arranged in eight tiers and 62 ranges with alleys between tiers. All plots were planted to corn in 1998 (variety: Pioneer 32K61) and maintained uniformly during the entire season with all cultural practices consistent across all cells. The center two rows of each plot was harvested, weighed, and a moisture sample taken so that the yield could be adjusted to a constant moisture. In 1999, cotton (variety: STV-474) was planted and maintained uniformly as in the previous growing season. The two center rows were again harvested with a commercial spindle picker modified for plot harvest. Grab samples were taken at each of two harvest to determine lint yields. The area was rotated back to corn in 2000 (variety: Pioneer 3223). Corn samples were taken during the harvest and used to determine the harvest moisture and bushel test weight. The grab samples taken during each cotton harvest was ginned through a 10-saw micro-gin. The lint percent was then used to determine lint yield.

Cells were geo-referenced prior to harvest in 1998 with an ATV-mounted GPS equipped with differential correction. Initial soil samples were taken from each cell following harvest in 1998. Eight to ten subsamples were taken and composited from each cell. The 12-in core was divided into topsoil (0 to 6 in) and subsoil (6 to 12 in) samples. All samples were dried, ground, and mixed prior to leaving the experiment station and were then analyzed by the Soil Testing and Plant Analysis Laboratory at Mississippi State University operated by the Extension Service. Additional 0-6" soil samples were taken following the 1999 and 2000 harvests.

Several tools have been used in the summary and explanation of the data collected. These tools included Lotus 123 spreadsheet and Freelance Graphics (Lotus Development Corp.), ArcView Geographical Information System (GIS, Environmental Systems Research Institute, Inc.), Statistical Analysis Systems (SAS), and TableCurve 2D (Jandel Scientific). These products made it possible to look at correlations between the yields and measured soil characteristics.

Results and Discussion

Corn Production - 1998 and 2000

The research area described in this study had been in continuous cotton for many years prior to the initiation of the present study. Corn was chosen as the starting point because it is less influenced by environment factors, insects, and disease. In the first year of the study corn yields ranged from a low of 132 bu/A to a high of 186 bu/A with an overall field average of 156 bu/A (Table 1). The actual distribution of yields in the field which have been adjusted to a standard 15.5% moisture is shown in Figure 1998Y. The yield map did show areas with distinctly higher yield especially in the northwest corner of the field. The west side of the field was the sandiest and graded toward the silt loam and silty clay loam as one moves east in the field.

Soil samples were taken following harvest from each individual cell. The samples were analyzed and the data entered into ArcView. Table 2 provides a summary of the information obtained from the soil analyses for both the topsoil samples (0-6") and subsoil samples (6-12"). The table shows the extent of the range for all of the analyses including pH, extractable P and K, exchangeable cations (H, K, Ca, Mg, Na) and cation exchange capacity (CEC), organic matter content, an estimate of S based on organic matter, and Zn. When averaged across all 496 cells, it was quite interesting to see how close the topsoil and subsoil averages were to each other indicating a relatively uniform top 12 inches of soil. In general the range in soil test levels were smaller in the subsoil. For some nutrients, as much as a 3- to 4-fold difference was present in the field. Regression analysis was used to analyze the relationship between yields and the soil characteristics. Correlations were based on R-square analysis with the correlation coefficient calculated as the square root of the R^2. The results from this analysis has been included in Table 3 for comparisons of 1998 corn yield and the soil characteristic. When only one factor was included in the model, the highest correlations were with subsoil P ($r^2 = 0.246$) and topsoil P ($r^2 = 0.2396$). The field distribution of subsoil P is shown in Fig ST98-PS. TableCurve (Jandel Scientific) was used to examine the direction of the relationship and to determine the best equation to describe it. This analysis showed that as soil P increased, corn yields increased.. When two factors were considered at the same time in the model, the best combination was subsoil P + subsoil K. However, the combination of two factors did not greatly improve the correlation. When evaluating three factors in combinations, the best correlation occurred with subsoil P + subsoil Ca + subsoil Mg (Table 3).

In 2000, the research area was rotated back to corn following the cotton grown in 1999. Corn yields in 2000 ranged from 151 bu/A to a high of 222 bu/A and a field average of 182 bu/A (Table 1). The average yield in 2000 was 26 bu/A higher than the average in 1998. This translate to a 17% increase in grain yield. Part of the difference in yield could be reflected in the different corn varieties grown (Pioneer 32K61 in 1998 and Pioneer 3223 in 2000). Certain varieties do better on some soil types with much variation due to the environment, planting dates, and other factors. The range in yields in 2000 (71 bu/A, 47%) was greater than the range found in 1998 (53 bu/A, 40%). The field distribution of grain yield in shown in Figure 2000Y. Visual comparisons of the yield maps indicated an apparent difference between the two years. Where lower yields were observed in 1998 on the south side of the field, in 2000 the yields were much higher.

Regression analysis was again used to examine the relationship between the corn yields in 2000 and the soil samples collected in 1998. These soil samples were used to simulate what a producer might do in his commercial operation. Soil samples are usually taken on 3- to 4-year intervals and recommendations based on these over that time period. Subsoil P (Table 4) was again the factor most correlated with yield. However, the actual correlation was much less ($r^2 = 0.075$) than that observed in 1998. The relationship was still positive (increasing yields with increasing P levels). The second ranking independent variable in 2000 was topsoil pH. There was a slight increase in yield as soil pH increased.. As in 1998, the addition of a second factor in the model increased the correlation. In 2000, subsoil P + subsoil or topsoil pH gave the highest correlation. A field distribution of topsoil pH is shown in Figure ST98-pHT. The range in pH was 5.4 to 7.2 with and average for the field of 6.4 (Table 2).

Cotton Production - 1999

The 15-acre GPS/GIS field was rotated to cotton in 1999 following corn in the 1998 growing season. The summary data is given in Table 1. Lint yields ranged from 900 to 1439 lb lint/A at the first harvest with a field average of 1163 lb lint/A. Second harvest lint yields ranged from 33 to 208 lb/A with an average of 86 lb/A. Total lint yields ranged from a low of 949 lb/A to a high of 1508 lb/A with a field average of 1248 lb/A. The field distribution of lint yield is shown in Figure 1999LT. Lint yield distribution did not correspond to the corn yields from either 1998 or 2000 which would indicate that different factors are influencing the yield distribution.

Table 5 provides a summary of the regression analysis for total lint yields and soil parameters. The highest single-factor correlation occurred with topsoil acidity (H) ($r^2 = 0.0979$) as measured with a buffer pH technique. Using TableCurve to determine the direction of the relationship, it was found that lint yields actually increased as exchangeable acidity increased. This relationship is the reverse of what would normally be expected. As mentioned earlier, the correlations with single factors are not very good. The next most highly correlated factors were cation exchange capacity (CEC) and P. Lint yields were increasing as CEC increased but there was quite a bit of variability. Figure ST98-TCEC has been included to show the field distribution of CEC. The CEC can be used to estimate the boundaries of the different soil types in the area. Phosphorus showed up in both years of corn and has appeared again when cotton was grown. Unfortunately the relationship is quite different. While increasing corn yields were associated with increasing P levels, decreasing lint yields were associated with increasing P levels. This negative relationship between lint yields and increasing P levels has been observed in other research at the Delta Research and Extension Center.

Other factor which may be important but that has not appeared in most of the analysis is soil organic matter (Figure ST98-OM). Organic matter provides a natural buffer for rapid change in the field. From the maps generated, one may observe a similar distribution of OM and CEC in the field. Magnesium has appeared in several of the analysis (Figure ST98-TMg). An examination of the correlation between corn yields and lint yields has shown a negative relationship. Lower yields occur at the higher Mg levels. These soils are naturally high in exchangeable Mg (Table 2) and may account for more than 20% of the total exchangeable cations. These high Mg levels may actually be competing with K in the soil.

Conclusions

Basic observations and evaluations of the data collected so far shows how complicated the systems are. When looking at corn and cotton rotation systems, the factors which were most correlated for corn production were not correlated in the cotton production year. The most difficulty comes when factors such as P are correlated for both crops, but the responses appear to be opposites of each other. This is as P levels increase in corn production, yields increase, while in cotton production the yields tended to decrease. Different factors can and do influence growth characteristics of a particular crop. Using yield data from one year to plan the needs for future crops can lead to mis-applications of materials. Especially in rotation situations, it will be important to collect yield data for the different crops. The data collected also indicates the need for multiple years of yield information for the same crops grown under different environmental conditions. Additional years of data will be needed to obtain a better understanding of what is occurring in the field and thus this study will continue. The new technologies do provide helpful tools to explain some of the yield variation actually occurring in the field. While the technology is new and exciting, many details need to be addressed before an economic use of the technology can occur. There are many other factors which influence the spatial variability of yield.

Acknowledgments

Data presented in this manuscript has been collected and produced by the Delta Research and Extension Center Soil Fertility Department and the DREC-Weather/GIS Center at Stoneville, MS. The research has been funded in part through grants from Cotton Incorporated which are greatly appreciated.

Table 1. Summary of GIS information for corn and cotton component of corn-cotton rotation study. Field 12 GPS/GIS Study. Delta Research and Extension Center, Stoneville, MS. 1998 - 2000

Factor	Range Low	Range High	Difference	Mean
Corn Data - 1998				
Yield, bu/A	132.4	185.8	53.4	155.9
Moisture (%)	13.9	15.7	1.8	14.6
Test Wt., lb/bu	55.7	60.3	4.8	58.6
Corn Data - 2000				
Yield, bu/A	151	221.9	70.9	181.6
Moisture (%)	11.4	13.7	2.3	12.3
Test wt., lb/bu	56.3	59.8	3.5	58.2
Stand, plts/A	18327	28766	10439	23024
1999 Lint Data				
1st Harv., lb/A	899.8	1438.8	539.0	1163.0
2nd Harv., lb/A	33.2	208.5	175.2	85.5
Tot. Harv., lb/A	949.2	1508.2	562.0	1248.4
PFH, (%)	81.5	96.8	15.3	93.1

Data summary over 496 cells in 15-acre field

Table 2. Summary of GIS information for soils component of corn-cotton rotation study. Field 12 GPS/GIS Study. Delta Research and Extension Center, Stoneville, MS. 1998 Reference

Factor	Range Low	Range High	Difference	Mean
Topsoil, 0-6" samples				
pH	5.4	7.2	1.8	6.4
P, lb/A	57	171	114	94
K, lb/A	155	612	457	305
Exch. Cations, meq/100g				
H	0.00	3.20	3.20	1.56
K	0.20	0.78	0.58	0.39
Ca	5.47	16.11	10.64	9.00
Mg	1.47	5.21	3.74	2.68
Na	0.10	0.45	0.35	0.18
CEC, meq/100g	8.18	22.30	14.12	13.81
Org. Matter, %	0.40	2.11	1.71	0.97
S, lb/A	57.6	303.8	246.2	140.0
Zn, lb/A	1.8	9.0	7.2	3.0
Subsoil, 6-12" samples				
pH	5.4	7.2	1.8	6.4
P, lb/A	53	197	144	94
K, lb/A	166	555	389	306
Exch. Cations, meq/100g				
H	0.00	4.50	4.50	1.56
K	0.21	0.71	0.50	0.39
Ca	5.25	15.31	10.06	9.01
Mg	1.46	4.81	3.35	2.68
Na	0.10	0.36	0.26	0.18
CEC, meq/100g	7.79	22.20	14.41	13.82
Org. Matter, %	0.38	1.85	1.47	0.97
S, lb/A	54.7	266.4	211.7	139.2
Zn, lb/A	1.8	7.4	5.6	3.0

Data summary over 496 cells in 15-acre field.

Table 3. Summary of regression model values for the dependent variable grain yield for 1998. Field 12 GPS/GIS Study. Delta Research and Extension Center, Stoneville, MS.

Independent Variable(s) 1st Factor	2nd Factor	3rd Factor	R-Square Value	Correlation Coefficient
Sub P			0.2460	0.4961
Top P			0.2394	0.4893
Sub Mg			0.0869	0.2948
Top Mg			0.0820	0.2863
Top Na			0.0654	0.2558
Sub P	Sub K		0.2725	0.5220
Sub P	Sub Na		0.2698	0.5194
Sub P	Top K		0.2693	0.5189
Sub P	Sub Zn		0.2683	0.5180
Sub P	Top Mg		0.2667	0.5164
Sub P	Sub Ca	Sub Mg	0.3737	0.6113
Top P	Sub Ca	Sub Mg	0.3638	0.6032
Sub P	Top Ca	Top Mg	0.3473	0.5893
Top P	Top Ca	Top Mg	0.3434	0.5860
Sub P	Top Mg	Top CEC	0.3136	0.5600

N = 496 Observations

Table 4. Summary of regression model values for the dependent variable grain yield for 2000. Field 12 GPS/GIS Study. Delta Research and Extension Center, Stoneville, MS.

Independent Variable(s) 1st Factor	2nd Factor	3rd Factor	R-Square Value	Correlation Coefficient
Sub P			0.0751	0.2740
Top pH			0.0657	0.2563
Top P			0.0576	0.2400
Sub pH			0.0553	0.2352
Top H			0.0348	0.1865
Sub P	Sub pH		0.1344	0.3666
Sub P	Top pH		0.1331	0.3648
Top P	Top pH		0.1260	0.3550
Sub P	Top Ca		0.1111	0.3333
Top P	Sub pH		0.1095	0.3309
Sub P	Top Ca	Sub OM	0.1600	0.4000
Sub P	Top Ca	Sub S	0.1600	0.4000
Sub P	Top Ca	Sub pH	0.1552	0.3940
Top P	Top Ca	Sub OM	0.1552	0.3940
Top P	Top Ca	Sub S	0.1552	0.3940

N = 496 Observations

Table 5. Summary of regression model values for the dependent variable total lint yield for 1999. Field 12 GPS/GIS Study. Delta Research and Extension Center, Stoneville, MS.

Independent Variable(s) 1st Factor	2nd Factor	3rd Factor	R-Square Value	Correlation Coefficient
Top H			0.0979	0.3129
Sub CEC			0.0971	0.3116
Top CEC			0.0960	0.3098
Top P			0.0947	0.3077
Sub P			0.0899	0.2998
Top CEC	Top Mg		0.2181	0.4670
Sub CEC	Sub Mg		0.1957	0.4424
Top H	Top pH		0.1952	0.4418
Top H	Top Ca		0.1767	0.4204
Top H	Top CEC		0.1673	0.4090
Top P	Top CEC	Top Mg	0.2560	0.5060
Sub P	Top CEC	Top Mg	0.2555	0.5055
Top P	Sub CEC	Sub Mg	0.2389	0.4888
Sub P	Sub CEC	Sub Mg	0.2342	0.4839
Top pH	Top CEC	Top Mg	0.2300	0.4796

N = 496 Observations

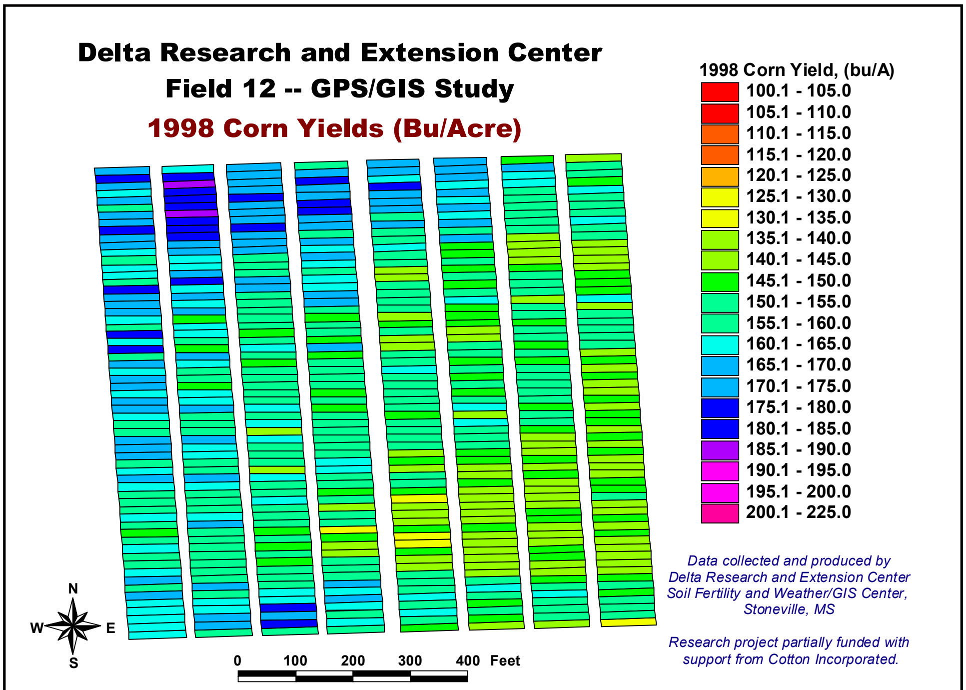

Figure 1998Y: Corn yield (adjusted to 15.5% moisture) GPS/GIS study. DREC Field 12 - 1998

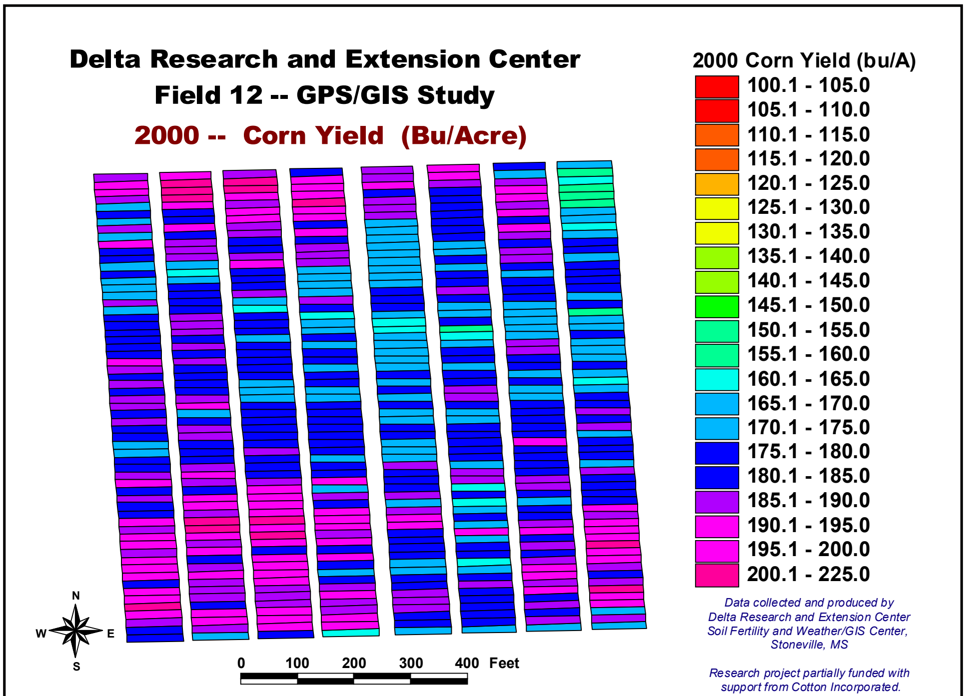

Figure 2000Y: Corn yield (adjusted to 15.5% moisture) GPS/GIS study. DREC Field 12 - 2000

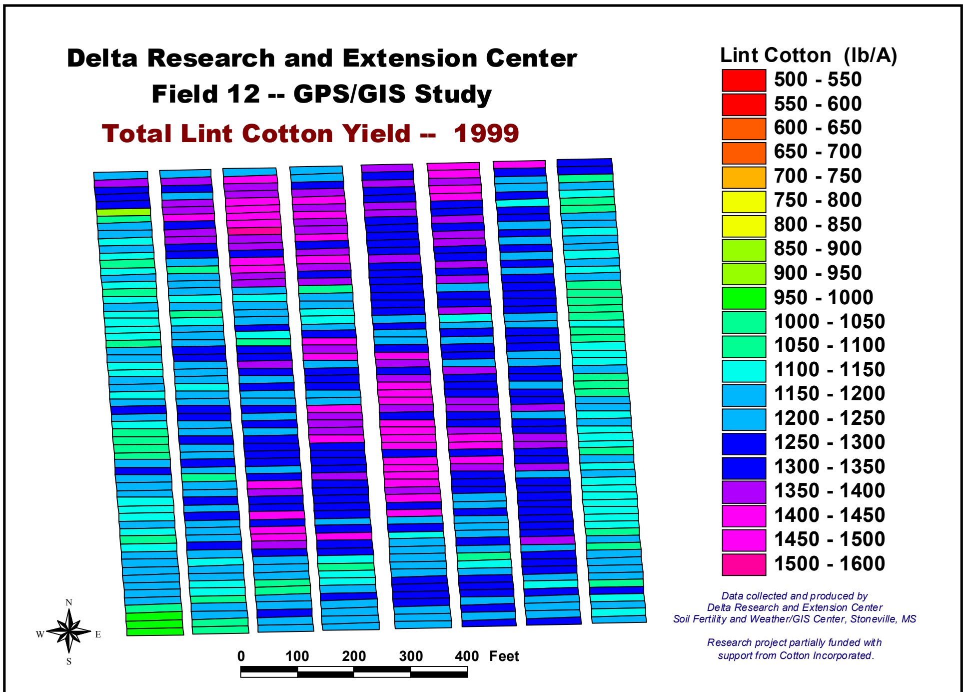

Figure 1999LT: Total Lint Cotton Yield from Two Harvests from GPS/GIS study. DREC Field 12. 1999

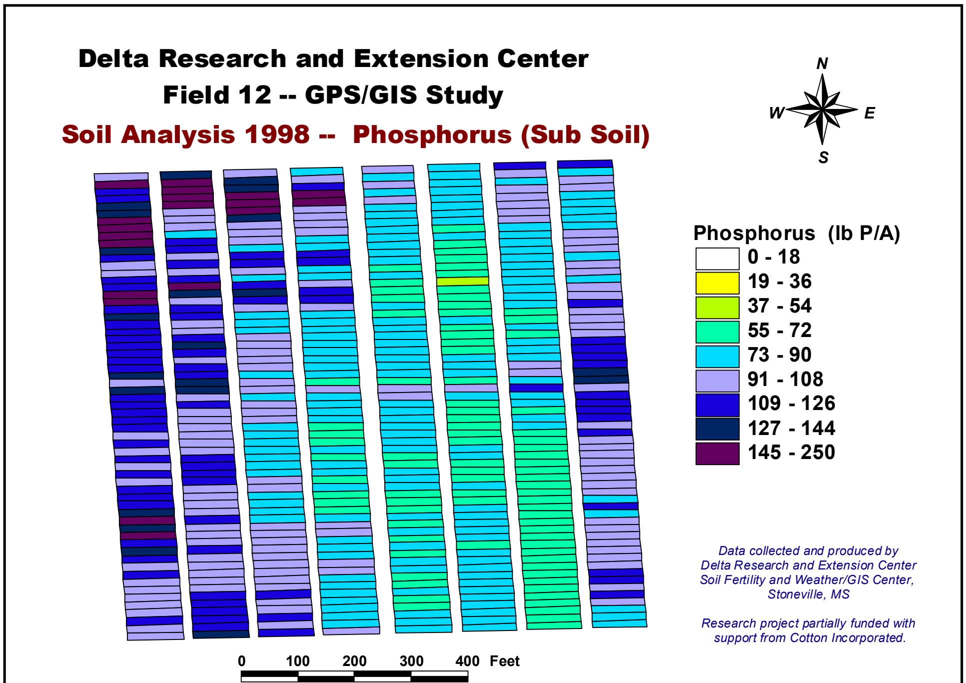

Figure ST98-PS: Soil Test Phosphorus (Sub soil level, 6-12") from GPS/GIS study. DREC Field 12 - 1998

Delta Research and Extension Center
Field 12 -- GPS/GIS Study
Soil Analysis 1998 -- Organic Matter (Top Soil)

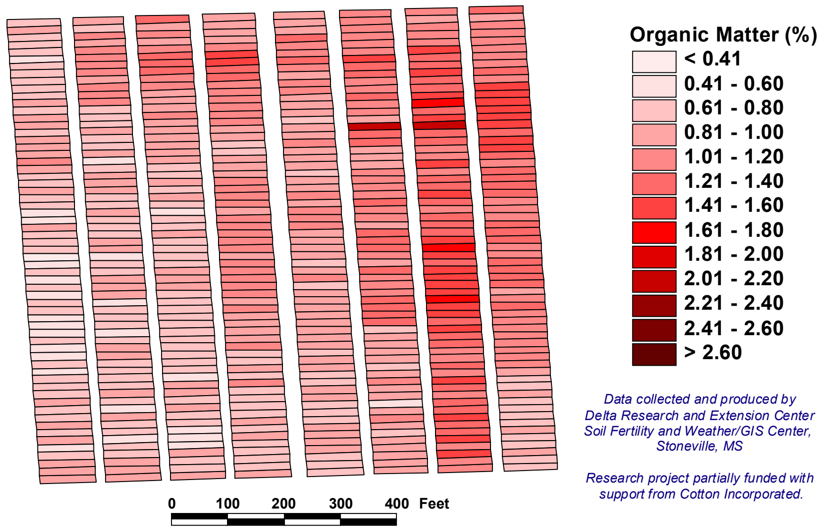

Figure ST98-TOM: Soil organic matter (Top soil level, 0-6") from GPS/GIS study. DREC Field 12 - 1998

Delta Research and Extension Center
Field 12 -- GPS/GIS Study
Soil Analysis 1998 -- Cation Exchange Capacity (Top Soil)

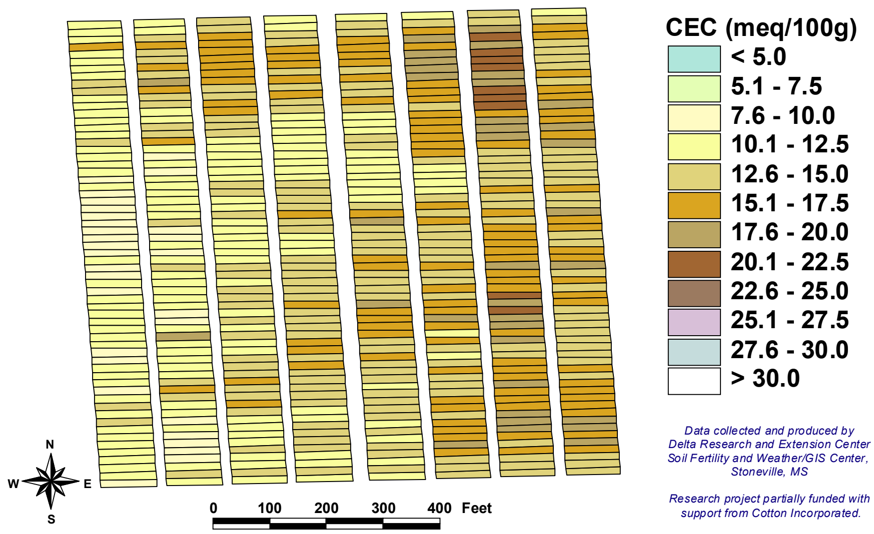

Figure ST98-TCEC: Cation Exchange Capacity (Top soil level, 0-6") from GPS/GIS study. DREC Field 12 - 1998

Delta Research and Extension Center
Field 12 -- GPS/GIS Study
Soil Analysis 1998 -- Magnesium (Top Soil)

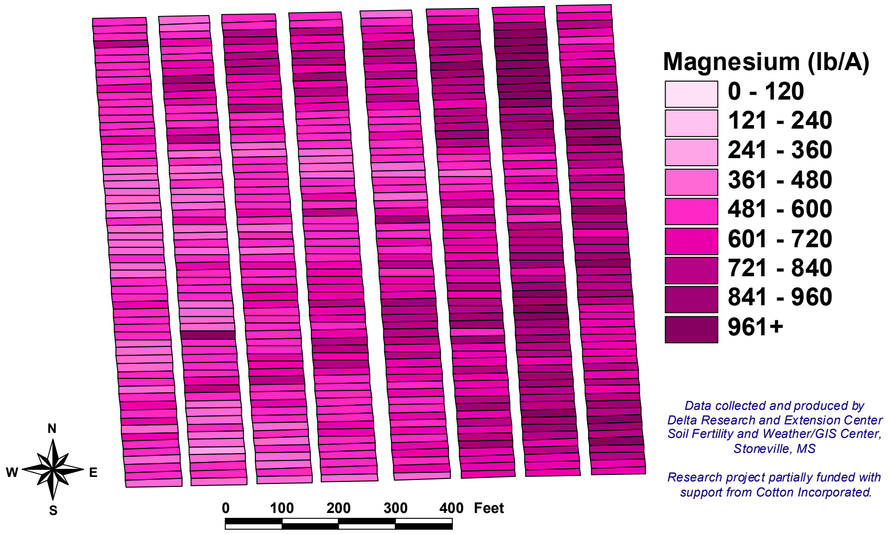

Figure ST98- TMG: Soil test magnesium (Top soil level, 0-6") from GPS/GIS study. DREC Field 12 - 1998

Delta Research and Extension Center
Field 12 -- GPS/GIS Study
Soil Analysis 1998 -- Soil pH (Top Soil)

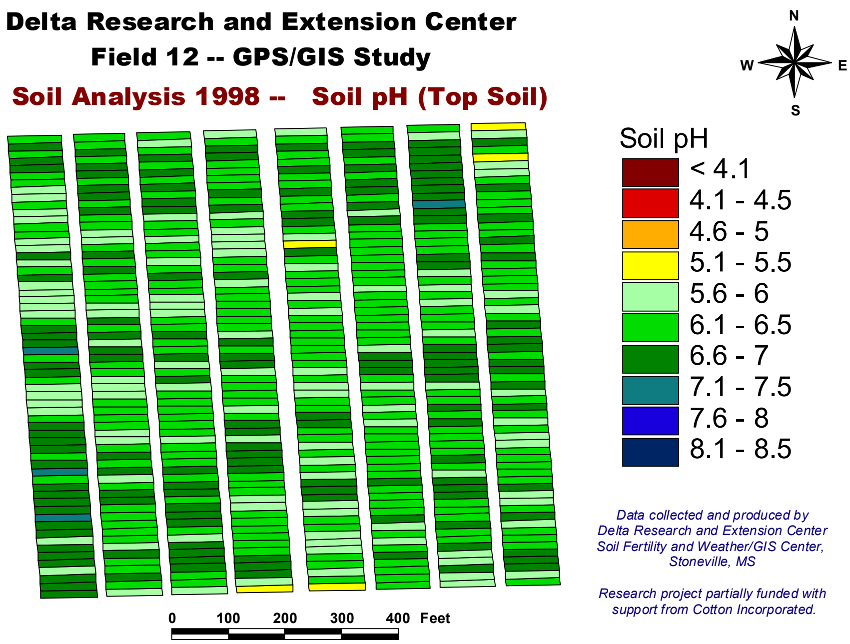

Figure ST98-pHT: Soil pH (top soil level, 0-6") from GPS/GIS study. DREC Field 12