The major plant nutrition concern identified in 1991 was a potential for potassium (K) deficiency. Sixty-eight percent of cotton leaf samples taken at early bloom were below the sufficiency level of 1.5% K. On the other hand, soil test K levels in the plow layer were all "medium" or higher. However, 90% of the subsoil samples were "medium" or "low" in extractable K. We speculated that low subsoil levels were influencing K in cotton leaves.

The objective of this study was to revisit the same fields that were surveyed in 1991 in order to assess any changes in land use patterns, tillage systems, and soil fertility status of cotton soils in Central Alabama. The 2001 survey was limited to Autauga and Elmore Counties.

Methods

The 1991 survey involved 36 randomly chosen fields in Autauga and Elmore Counties. These same fields were revisited during the winter of 2001. An additional 32 fields were included in the 2001 survey that were not part of the 1991 survey. In 1991, the survey was conducted during the summer and fall and included cotton leaf samples. The 2001 survey included soil samples at depths of 0-2 inches, 2-8 inches, and 12+ inches (subsoil sample). The reason for sampling at different depths was to assess the impact of tillage practices on soil nutrient stratification.

Random sub-samples were taken within a 1-acre area representative of the entire field. The entire field was not sampled. Detailed maps were made in 1991 so each site could be revisited. In 2001, GPS was used to identify each site for future surveys. The area sampled was the same area sampled in 1991. Each soil sample consisted of 15 to 20 sub-samples which were combined by depth. The samples were dried and analyzed by the Auburn University Soil Testing Laboratory for pH, estimated cation exchange capacity (soil group), and Mehlich-1 extractable P, K, Mg, and Ca. Some of the samples were tested for Mehlich-1 extractable micronutrients and metals. Some of the surface samples (0-2 inch) were also tested for total organic matter.

Tillage practices, previous crop, cover crop, depth to an argillic horizon (clay layer), and presence and depth of a traffic pan were recorded for each field.

Results

Land Use. Both Autauga and Elmore counties are experiencing population increases and urban sprawl associated with the Cities of Montgomery, Prattville, and Wetumpka, Alabama. However, of the 36 cotton fields surveyed in 1991, all but four were still being planted in cotton. One field had been converted to a subdivision, one was planted in pine trees, and two were planted in crops other than cotton.

Soil type (Table 1). Soils where cotton is planted in Autauga and Elmore Counties are very typical of Coastal Plain soils throughout Central and South Alabama. Half of the fields surveyed were in the Lucedale series which is described as a deep, well drained, moderately permeable soil of the Southern Coastal Plain Major Land Resource Area. Local farmers refer to Lucedale soils as "red land" because of the red surface color of these soils. Lucedale soils may be found on slopes of 0 to 15 percent but cotton is planted mainly on the more level sites. Surface soil textures of the soils in this survey were mostly fine sandy loams. Depth to argillic horizon is referred to as "depth to clay" by most farmers in this region. However the argillic horizon texture is usually sandy clay, sandy clay loam, loam, or silty clay loam rather than "clay". This depth is a reflection of the major soil series present (Table 1) but may also influence the formation and depth of traffic pans.

Table 1. Soil and cropping characteristics of 68 Central Alabama cotton fields.

Soil type		
Soil classification	Example of series	Percent of fields surveyed
Rhodic Paleudults	Lucedale fsl	50
Typic Paleudults	Bama fsl	3
Plinthic Paleudults	Bowie sl	6
Arenic Paleudults	Lucy ls	4
Typic Kandiudults	Norfolk sl	13
Typic Hapludults	Wickham fsl	22
Others	Roanoke fsl	2

Depth to argillic horizon (subsoil "clay")	
Depth to argillic horizon	Percent of fields surveyed
0-6 inches	13
7-12 inches	78
>12 inches	5
Not applicable	4

Presence of traffic pan (hardpan)	
Depth to traffic pan	Percent of fields surveyed
0-6 inches	36
7-12 inches	27
>12 inches	0
No traffic pan present	37

Tillage practices	
Practice	Percent of fields surveyed
Conventional tillage	44
Conservation tillage with subsoiling	51
Conservation tillage without subsoiling	5

Cover crops	
Cover crop planted?	Percent of fields surveyed
Yes	15
No	85

Traffic pans. Traffic pans or hard pans were found in 63 percent of the fields surveyed in 2001 (62% in 1991). This was a surprise considering that 51 percent of the farmers practiced some form of conservation tillage with subsoiling, usually paratilling or paraplowing. Traffic pans were identified using a soil penetrometer within the rows of cut cotton stalks. Since the survey was during the winter of 2001, soil moisture at the time of the survey was high. Many of the fields where traffic pans were found had no in-row subsoiling or paraplowing the previous season. However, some that had deep tillage prior to planting had recreated traffic pans within the row. Traffic pans are a known impediment to deep rooting and may be a major yield-limiting factor in drought years. The situation has not improved since 1991.

Tillage practices. The most dramatic change in the 10 years since 1991 has been in tillage practices. In 1991, all fields surveys were conventionally tilled. In 2001, 56 percent of the fields surveyed had some form of conservation tillage, usually strip tillage. However, only 15 percent of the fields had a winter cover crop planted, usually wheat or rye. This is reflected in the very low value for mean soil organic matter of 0.6 percent in the surface two inches of soil. Seventy-five percent of the fields surveyed had soil organic matter less than 0.8 percent in the surface two inches (Table 2). Based on soil organic matter data published from Alabama's Old Rotation experiment (Mitchell et al., 1996; Mitchell et al., 2000) this low level of soil organic matter results in poor soil quality and a very low cotton yield potential.

Soil test values

Soil pH. Central Alabama cotton farmers appear to be doing a very good job of maintaining an optimum soil pH (5.8 to 6.9) in the rooting zone. One of the thoughts behind taking a 0-2 inch sample and a 2-8 inch sample was to identify any stratification that may be developing as a result of the dramatic increase in conservation tillage practices over the past 10 years. Overall, there does not appear to be a dramatic pH stratification effect beyond what would be expected in these naturally acid, Coastal Plain soils. No differences due to tillage practice could be identified in this survey. However, there does appear to be a trend toward higher pH values in the surface soils due to liming. We may expect this tendency to become more pronounced as producers lime surface soils under conservation tillage practices.

Phosphorus. The 1991 survey found no evidence that phosphorus was a yield-limiting concern in Upper Coastal Plain cotton fields. The 2001 survey confirms this conclusion with 92% of the surface soils testing high or very high in extractable P. There does appear to be a trend toward stratification of P in the surface two inches of soil as would be expected with increasing conservation tillage and surface P application.

Potassium. Potassium also appears to be accumulating in surface soils with decreasing extractable K with depth. Soils testing high or very high in K were 86% in the surface two inches, 67% in the 2-8-inch layer, and 31% in the subsoil. As noted in the 1991 survey, low K in the subsoil could aggravate a K deficiency during a drought if roots are unable to get adequate K from the subsoil. However, research by Mullins et al. (1997, 1999) in Alabama concluded that broadcast K applications and high plow layer K is more efficient than trying to increase subsoil K for cotton production. Recent research from long-term potassium studies confirms that extractable plow-layer K is well correlated with cotton yield (Mitchell and Mullins, 1999).

Magnesium and calcium. Regardless of sampling depth, 97 to 98% of the fields had "high" levels of extractable soil Mg for cotton. Calcium is not rated for cotton in Alabama because maintaining an optimum soil pH through liming generally assures sufficient Ca for most Alabama cotton soils. This survey indicated that 95% of the fields had extractable Ca levels above 250 mg Ca per kg (500 pounds Ca per acre). Soil test values above 150 mg Ca per kg (300 pounds per acre) would be considered "high" for peanuts, one of the most calcium-sensitive crops that we grow in Alabama (Adams et al., 1994).

Table 2. Soil test value distribution in cotton fields in Autauga and Elmore Counties, 2001.

Analysis & rating*	Sample depth		
	0-2 inch	2-8 inch	12+ inch (subsoil)
	--------% of samples tested-------------		
Soil organic matter (n=44)			
0 to 0.4%	55	--	--
0.4 to 0.8%	20	--	--
0.8 to 1.2%	9	--	--
>1.2%	16	--	--
Cation exchange capacity (n=68)			
<4.6 cmol/kg	15	18	8
4.6-9.0 cmol/kg	81	78	85
>9.0 cmol/kg	4	4	7
Soil pH_w (n=49)			
<5.0	2	0	3
5.0-5.7	13	21	34
5.8-6.9	81	75	63
7.0+	4	4	0
Extractable P (n=68)			
Very low/low (<12 mg/kg)	4	13	69
Medium (13-25 mg/kg)	4	21	21
High (26-50 mg/kg)	37	50	6
Very high (>50 mg/kg)	55	16	4
Extractable K (n=68)			
Very low/low (<45 mg/kg)	1	3	23
Medium (46-90 mg/kg)	13	30	46
High (91-180 mg/kg)	62	63	31
Very high (>180 mg/kg)	24	4	0
Extractable Mg (n=68)			
Low (<25 mg/kg)	3	2	2
High (25+ mg/kg)	97	98	98
Extractable Ca (n=68)			
<250 mg/kg	5	4	6
250-500 mg/kg	38	47	61
501-750 mg/kg	38	38	30
750-1,000 mg/kg	16	9	3
>1,000 mg/kg	3	2	0
* n = number of samples analyzed			

Micronutrients and metals. Mehlich-1 (dilute double acid) is not the best extractant for estimating plant availability of micronutrients. In fact, there are few studies that show significant correlation between M1 extractable micronutrients and plant response to micronutrients over a range of soils. The same would be true of M1 extractable metals in soils. However, because of the convenience of analytical technology, the micronutrients and metals listed in Table 3 were analyzed using inductively coupled argon plasma (ICAP) spectroscopy on the soil extracts. The values serve as a broad benchmark. Very large and very low values for a particular micronutrient or metal may be reason for concern.

The only micronutrient routinely recommended for cotton is boron (B). In general, hot water extractable B values above 0.1 mg/kg are sufficient for cotton. This is near the detection limit for ICAP analyses using the M1 extract. Zinc values above 0.6 mg/kg are generally considered sufficient for most crops. Values above 10 mg Zn/kg may be toxic to sensitive crops such as peanuts. The mean values and ranges for extractable micronutrients and metals in these soils do not present any evidence that producers should be overly concerned about micronutrient or metal deficiencies or toxicities in cotton or any other crop.

Conclusion

In spite of a dramatic shift toward conservation tillage in the past decade, traffic pans remain a potential yield-limiting factor in cotton fields of Central Alabama. Increased use of paratilling and in-row subsoiling has not eliminated the presence of traffic pans within the surface 12 inches of soil. This situation is aggravated by poor overall soil quality as indicated by very low soil organic matter (mean=0.6%). The situation could be improved by using winter cover crops more extensively and allowing more biomass to accumulate on the soil surface. In general, soil fertility does not appear to be a limiting factor in cotton production. Most fields sampled had optimum soil pH and high P and K in the surface 8 inches of soil. While the extractant used for micronutrients and metals is not ideally correlated with plant availability, it does provide some indication that micronutrient availability and metal contamination of cotton fields is not a major concern at this time.

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Table 3. Mehlich-1 extractable soil micronutrients and metals from Autauga and Elmore County cotton fields, 2001.

Analysis	Mean	Std. Dev.	Minimum	Maximum
	----------------------mg/kg----------------------			
0-2 inch depth				
Cu	0.5	0.4	0	1.6
Mn	30.5	19.3	4.0	72.1
Zn	2.6	1.7	0.7	6.4
B	0.4	0.3	0.1	1.5
Ba	2.5	0.9	0.2	3.9
Co	0.2	0.1	0.1	0.5
Cr	0.6	0.5	0.2	2.3
Pb	0.8	0.3	0.5	1.5
Na	7.8	8.0	0	28.0
2-8 inch depth				
Cu	0.6	0.7	0	2.4
Mn	26.5	16.4	4.6	59.1
Zn	1.9	1.2	0.2	5.3
B	0.5	0.3	0	1.2
Ba	2.8	1.2	0.2	5.7
Co	0.2	0.1	0.1	0.5
Cr	0.7	0.5	0.2	2.4
Pb	0.9	0.3	0.5	1.6
Na	8.3	8.3	0	31
12+ inch depth (subsoil)				
Cu	0.6	0.6	0	1.9
Mn	18.7	11.1	1.4	42.1
Zn	1.4	1.7	0.2	6.5
B	0.4	0.2	0	0.8
Ba	2.6	0.7	0	3.5
Co	0.2	0.1	0	0.5
Cr	0.6	0.4	0.3	2.4
Pb	0.9	0.3	0.5	1.5
Na	11.2	9.9	0	34.9