Crop Yield Variation Associated with Coastal Plain Soil Map Units

D. L. Karlen,* E. J. Sadler, and W. J. Busscher

ABSTRACT

Variation among soil map units needs to be quantified so farmers can implement more economically and environmentally acceptable production practices. We conducted a 4-yr field study at an 8-ha research site near Florence, SC, to quantify yield variation for a southeastern Coastal Plain field. Nineteen soil map units, classified as Ultisols and representing seven soil series were identified by Soil Conservation Service cooperators. Corn (*Zea mays* L.) was grown in 1985, 1986, and 1988, while in 1987 wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] were double-cropped. All soils received conventional disk tillage, fertilization based on soil-test recommendations, and uniform planting rates. Crop yield was measured by harvesting transects throughout the field and subsequently identifying soil map units for each plot. Average corn yield among soil map units ranged from 3.7 to 8.0 Mg ha^{-1} in 1985, 0.1 to 2.8 Mg ha^{-1} in 1986, and 1.1 to 5.0 Mg ha^{-1} in 1988. Yields were lower in 1986 because of severe drought. Wheat yield ranged from 3.5 to 6.2 Mg ha^{-1}, while sorghum yield ranged from 1.7 to 5.2 Mg ha^{-1} in 1987. Extractable P, K, Ca, Mg, Mn, and Zn; soil organic matter and pH; and depth to an argillic horizon (Bt) were measured to identify causes for yield variation among soil map units. Depth to Bt had the best statistical relationship between crop yield and soil map unit, but yield variation within an individual map unit was almost as large as variation between map units. Our results demonstrate how measurements of crop yield by soil map unit can be determined and used to study soil variation. They also provide a data base that can be used to evaluate plant growth and soil management models for individual soil map units.

SOIL AND CROP MANAGEMENT PRACTICES are generally applied uniformly across entire fields. This occurs because fields are traditionally divided by physical or other arbitrary boundaries into management units that are treated independently without considering variation in soil series, phase, or potential productivity. As production costs increase, profit margins narrow, and public concern about agricultural practices increase, however, farmers may have to replace general fertilization and cultural practices used across entire fields with more precise management of smaller segments within each field.

Coastal Plain fields frequently have several soil map units within a single management unit, but differential fertilization and water management are not used because the magnitude and possible causes of yield variation among map units are not well documented.

We hypothesized that documenting yield variation among soil phases might improve fertilizer and water use efficiency by providing information needed to manage soils rather than fields. One example of this technology is the use of fine-tuned fertilization (Luellen, 1985). This would be a more intensive approach to fertilizer and crop management, but it may be more profitable and environmentally acceptable than current management practices.

Areas within fields that are subject to excessive leaching or runoff and may be nonpoint sources for

D.L. Karlen, USDA-ARS National Soil Tilth Lab. (NSTL), 2150 Pammel Dr., Ames, IA 50011; E.J. Sadler and W.J. Busscher, USDA-ARS Coastal Plains Research Center, P.O. Box 3039, Florence, SC 29501. Joint contribution of the NSTL and the USDA-ARS Coastal Plains Soil and Water Conservation Research Center in cooperation with the South Carolina Agric. Exp. Stn., Clemson, SC 29634. Received 31 July 1989. *Corresponding author.

Published in Soil Sci. Soc. Am. J. 54:859–865 (1990).

groundwater or surface water contamination could be fertilized and managed separately. Excessive nutrient applications could more easily be prevented than with current soil and crop management practices. However, before farmers can use intensive management practices such as differential fertilization within field units, yield variation within the field must be quantified and the factors responsible for that variation defined. Objectives of this research were to document crop yield variability within and among soil map units, and to develop a data base for a quantitative validation of plant growth and soil-management models as a function of soil map units in a southeastern Coastal Plain field.

MATERIALS AND METHODS

A detailed soil map was prepared for the USDA-ARS Coastal Plains Soil and Water Conservation Research Center by USDA-SCS soil scientists. Elevation measurements for a topographical map and initial soil borings were made at 15 by 15 m spacings across a 23-ha area. Additional borings were made, as necessary, between each of those points to accurately locate boundaries for each soil map unit. Two fields that had a total area of approximately 8 ha on the northeast side of the research center were used for this study. Within that area, seven soil series and 19 soil map units were identified.

Most of the experimental area had not been used for crop production for several years prior to the study. Procedures used to prepare the site were similar to those necessary to clear new areas or bring idled land back into production in the southeastern Coastal Plain. Volunteer trees were removed from each field during January 1985. The area was disked several times to a depth of approximately 0.1 m to incorporate accumulated weed and grass residues.

Approximately 25 randomly collected cores, 25 mm in diameter and 200 mm long, were composited and analyzed by the Clemson University Soil Testing Laboratory. Based on the analysis, 2.2 Mg ha^{-1} of dolomitic lime was broadcast and incorporated by disking on 11 Mar. 1985. On 15 April, 56–25–46 kg ha^{-1} of N–P–K fertilizer was broadcast and incorporated. A mixture of 3.4 kg ha^{-1} butylate (*S*-ethyl diisobutylthiocarbamate) and 2.0 kg ha^{-1} atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) was applied and incorporated, using a field cultivator for weed control. On 18 April, DeKalb-Pfizer[1] (DeKalb-Pfizer AgResearch, DeKalb, IL) hybrid corn (cv. 748) was planted at a seeding rate of 5.4 seed m^{-2} with in-row subsoiling using a Brown-Harden SuperSeeder (Brown Mfg. Corp., Ozark, AL) that had John Deere Flex-71 unit planters. On 15 May, the corn was sidedressed with 90 kg ha^{-1} N using liquid urea NH_4NO_3 (UAN) solution.

Measurements of grain yield were made on 16 September by harvesting 13 transects with an Almaco (G.W.C., Allan Machine Co., Nevada, IA) plot combine. The transects were selected with general knowledge of where various soil map units would be encountered, but without determining an exact number or distribution of plots. A baseline was established from fixed boundaries using a transit so that the exact location of every plot could subsequently be identified on the soil map. Soil map units for each plot were identified and merged with yield measurements in a data base. Within the 13 transects, 80 plots that were 1.5 m wide and had an average length of 14 m were identified as being representative of a single soil phase. Each transect had additional plots that were harvested, but they were dropped from the data set because they crossed two or more soil phases. Data were analyzed using PROC GLM, a general linear model available from SAS (SAS Institute, 1985).

Corn stover was incorporated by disking in November 1985. Both fields were moldboard plowed to a depth of approximately 0.2 m and disked in February 1986. Dolomitic lime was broadcast on 18 March at a rate of 2.2 Mg ha^{-1} and incorporated by disking. Fertilizer supplying 56–25–46–2 kg ha^{-1} N–P–K–B, respectively, was broadcast and incorporated on 27 March. On 4 April, 3.8 kg ha^{-1} butylate and 1.1 kg ha^{-1} atrazine were applied and incorporated using a field cultivator. Pioneer (Pioneer Hi-Bred Intl., Johnston, IA) Brand 3165 hybrid corn was planted at a seeding rate of 5.2 seed m^{-2} with in-row subsoiling on 4 April using the Brown-Harden SuperSeeder and John-Deere Flex-71 planters. On 19 May, the corn was sidedressed with 56 kg ha^{-1} N using anhydrous NH_3. Grain yield was measured by harvesting 15 transects on 25 August. The transects were in similar but not the exact locations as in 1985. Using the same approach as before, 93 single-soil-phase plots that were 1.5 m wide and averaged 14 m in length were identified and statistically analyzed.

Ten soil map units within the 15 harvested transects were identified and sampled at 0.0- to 0.15-, 0.15- to 0.30-, 0.30- to 0.45-, 0.45- to 0.60-, and 0.60- to 0.75-m depths during September of 1986. A composite sample for each depth within each map unit was obtained by randomly collecting 15 cores from preselected plots that were identified from the soil map as being within the boundaries of a single map unit. The samples were analyzed to determine water and buffer pH; Mehlich I extractable P, K, Ca, Mg, Mn, and Zn; organic matter; and NO_3–N.

Corn stover was incorporated by disking on 1 and 20 October. Fertilizer supplying 34–15–28 kg ha^{-1} N–P–K was broadcast on 4 November. Planting was delayed by rainfall so the area was disked a third time on 23 November. Coker (Coker's Pedigreed Seed Co., Hartsville, SC) var. 983 wheat was sown at a rate of 100 kg ha^{-1} (288 seed m^{-2}) with a John-Deere grain drill. On 18 Feb. 1987, fertilizer supplying 50 kg ha^{-1} N and 6 kg ha^{-1} S was applied. Grain yield for 195 single-soil-phase plots that were 1.4 m wide and 14 m long was measured by harvesting 29 transects on 8 June.

Substantial wheat straw remained after grain harvest, so the stubble was burned on 26 June. Grain sorghum was planted at a density of 17 seeds m^{-2} on 29 June. A KMC (Kelley Manufacturing CO., Tifton, GA) conservation-tillage planting system equipped with Case-IH (J.I. Case, Racine, WI) Series 800 planters was used for in-row subsoiling and planting. Starter fertilizer was banded beneath the row by spraying 45 kg N ha^{-1} of UAN solution through a nozzle attached to each subsoil shank (Karlen and Zublena, 1986). A mixture of 2.3 L ha^{-1} crop oil plus atrazine at a rate of 0.45 kg ha^{-1} was applied for weed control on 10 July when the sorghum was at growth stage V3 (third leaf). On 20 July, paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was applied through a KMC shielded sprayer at a rate of 0.7 kg ha^{-1} for additional weed control. Liquid fertilizer supplying 66 kg ha^{-1} N and 7 kg ha^{-1} S was applied on 28 July. Grain yield for 186 single-soil-phase plots was measured by harvesting 17 transects on 5 November. Each plot was 1.5 m wide, but length varied from 9 to 15 m because sampling sites were preselected by identifying and locating transects with a transit in positions where the soil map indicated that crop rows would be within a single map unit.

Sorghum stover was incorporated by disking in February 1988 after collecting composite soil samples for selected map units. Dolomitic lime was broadcast on 7 March at a rate of 2.2 Mg ha^{-1} and incorporated by disking. Fertilizer sup-

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

plying 56–25–46 kg ha^{-1} N–P–K, respectively, was broadcast and incorporated on 21 March. On 4 April, 3.8 kg ha^{-1} butylate and 1.1 kg ha^{-1} atrazine were applied and incorporated using a field cultivator. Pioneer Brand 3165 hybrid corn was planted at a seeding rate of 5.6 seed m^{-2} with in-row subsoiling on 24 March using the KMC planting system. Corn was fertilized on 19 May with 100 kg N ha^{-1} using UAN. Yield for 303 single-soil-phase plots that were 1.5 m wide and from 9 to 15 m long was measured by harvesting 21 transects on 27 September.

Depth to an argillic Bt horizon was hypothesized as one cause for yield variation among soil map units. Therefore, measurements collected at each 15 by 15 m grid point were entered into a data base that identified field position and depth to the Bt horizon. An algorithm weighting by inverse distance to nearest neighbors (Davis, 1973) was used to interpolate depth to clay from the grid points to the center of each yield plot. This technique utilized all grid points within 16 m of the plot center, generally providing two or three data points for each interpolation. Crop-yield relationships to Bt depth were determined using PROC REG, a least-squares regression procedure available from SAS (SAS Institute, 1985).

RESULTS AND DISCUSSION

The research site is located in Major Land Resource Area (MLRA) 133 (Austin, 1965), and soil series identified in the study area are classified as Ultisols (Table 1). Morphological characteristics of all these light-colored soils, which formed from marine and fluvial sediments under warm temperate forests, include a coarse-textured A horizon over a more clayey B with low (<35%) base saturation. Precipitation usually exceeds evapotranspiration for part of each year, which routinely causes leaching to occur. These soils also crust and compact easily because of their coarse texture and weak structure. Without liming, surface and subsurface horizons are very acid. Organic-matter content, cation-exchange capacity, and native fertility are low and topography is relatively flat. Maximum elevation differences across the study area are only 1.25 m. The low point (<41.0 m above mean sea level), where the large area of Coxville (Cx) soil is located, is a poorly drained, depressed area generally referred to as a "Carolina Bay," while the high point (>42.25 m above mean sea level) is where Norfolk sandy loam (NrA) is found (Fig. 1). Crop yield variation among soil map units is presumably caused by variation in chemical, physical, and biological properties (Long et al., 1963) rather than by differences in erosion, as shown for Piedmont soils (White et al., 1985).

The intensity of the SCS survey identified more soil map units than are shown in a standard soil survey for Florence and Sumter counties in South Carolina (Soil Conservation Service, 1979) and was much more intensive than a farmer would find useful. However, every crop showed considerable variation in this 305 by 427 m area ($x-y$ axis length in Fig. 1) suggesting this may be typical for a Coastal Plain field. The sampling pattern used to assess corn yield in 1988 as a function of soil map unit is also shown in Fig. 1. A similar pattern was used for the other samplings, but by the time the fifth crop was harvested, the soil map was completely digitized, and it was possible to pre-

Table 1. Proportionate distribution of soil map units within a 24-ha area where the 8-ha experimental field was located.

Map symbol	Soil classification†	Percent
BnA	Bonneau loamy fine sand, 0 to 2% slopes (loamy, siliceous, thermic Arenic Paleudult)	2.2
BoA	Bonneau loamy sand, 0 to 2% slopes, overwash (loamy, siliceous, thermic Arenic Paleudult)	0.2
Cx	Coxville loam (clayey, kaolinitic, thermic Typic Paleaquult)	4.5
Dn	Dunbar loamy fine sand (clayey, kaolinitic, thermic Aeric Paleaquult)	2.2
Do	Dunbar loamy fine sand, overwash (clayey, kaolinitic, thermic Aeric Paleaquult)	0.8
EmA	Emporia loamy fine sand, moderately thick surface, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	1.7
EpA	Emporia loamy fine sand, thick surface, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	2.5
EpB	Emporia loamy fine sand, thick surface, 2 to 4% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	0.2
ErA	Emporia fine sandy loam, 1 to 2% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	1.7
ErB	Emporia fine sandy loam, 2 to 4% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	6.0
ErD	Emporia fine sandy loam, 1 to 2% slopes (fine-loamy, siliceous, thermic Typic Hapludult)	1.5
GoA	Goldsboro loamy fine sand, 0 to 2% slopes (fine-loamy, siliceous, thermic Aquic Paleudult)	1.7
NbA	Noboco loamy fine sand, moderately thick surface, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	1.7
NcA	Noboco loamy fine sand, thick surface, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	7.9
NfA	Noboco fine sandy loam, 1 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	1.0
NkA	Norfolk loamy fine sand, moderately thick surface, deep water table, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	47.7
NnA	Norfolk loamy fine sand, moderately thick surface, very deep water table, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	6.0
NoA	Norfolk loamy fine sand, thick surface, 0 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	4.5
NrA	Norfolk fine sandy loam, 1 to 2% slopes (fine-loamy, siliceous, thermic Typic Paleudult)	5.2
W	Water	0.8

† Classification taken from Soil Conservation Service, 1979.

select sampling sites so that fewer plots with multiple soil map units were harvested.

Average corn, wheat, and sorghum yields are given in Table 2. Variation can be partially explained by differences in map unit, but managing individual soils rather than fields does not appear feasible with the current level of information. Perhaps by quantifying factors causing the variation, farmers will be able to block fields into low-, medium-, and high-yielding areas and thus make crop production more efficient and environmentally acceptable.

There were also large differences between average grain yield and the productivity ratings provided by the soil survey report. For example, in 1985 average corn yield exceeded the productivity rating for five soil map units, but yield for the other four map units was lower than expected. Seasonal rainfall in 1985 was

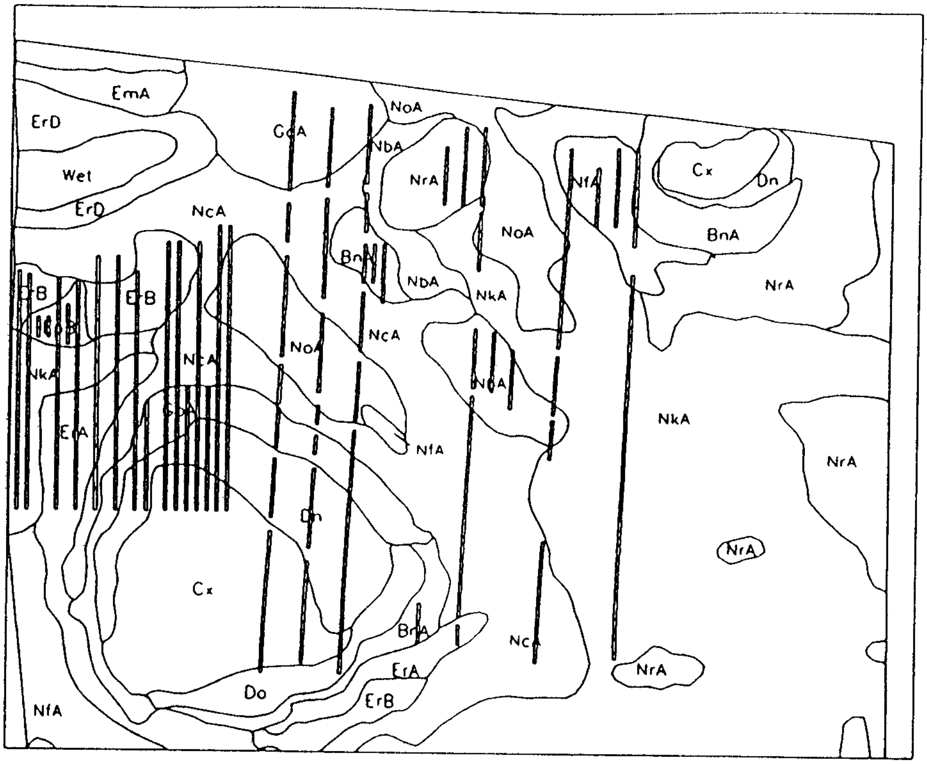

Fig. 1. Sampling scheme (transects) across soil map units used to measure corn yield variation within a Coastal Plain field in 1988.

very favorable for corn production at this location; therefore, lower average corn yield for Cx, Dn, GoA, and NcA map units probably reflects the effects of low soil pH that were found for those map units in a 1986 soil sampling (Table 3).

Drought caused severe water stress during critical plant growth stages in 1986 and 1988, so corn grain yields for all map units were well below the SCS productivity ratings (Table 2). Differences in yield among map units were still significant. Seasonal rainfall during the winter and spring of 1987 was very adequate and, therefore, wheat yields for all map units exceeded SCS productivity ratings. Variation in grain sorghum yields among soil map units was similar in magnitude to that for corn and wheat, but comparative productivity ratings for sorghum are not provided in the soil survey report (Soil Conservation Service, 1979).

Part of the yield variation can be explained by soil map unit (Table 2), but variability within individual soil map units was extremely high (Fig. 2). For all five crops grown during the 4-yr period, variance in yield among plots within a single soil map unit was nearly as large as the variance among soil map units. This indicates that developing management systems for individual soil map units may not be feasible, especially until factors that cause yield variations of this magnitude are better understood.

Soil-test parameters measured in 1986 and 1988 (Table 3) show that, as crop production continued on this previously idled land, gradual changes were occurring for several of the map units. Annual application of dolomitic lime was gradually increasing soil pH, Ca, and Mg concentrations even to a depth of 0.75 m. The NO_3–N concentrations were relatively low for both sampling dates, reflecting the low total N concentration that is found in many Coastal Plain soils (Matheny and Hunt, 1983). For five out of nine soil map units, NO_3–N was lower in 1988, but that probably reflected sampling date rather than a significant change due to management.

For six of ten map units, soil organic-matter contents decreased between sampling dates (Table 3). Sampling differences probably contributed to some of the change but, since conventional disk and moldboard plow tillage were used after several years of uncontrolled weed and grass growth and wheat straw produced in 1987 was burned, there probably was a slight decline in organic-C concentrations. Many

Table 2. Mean corn, wheat, and sorghum grain yields and productivity ratings for selected soil map units.

Soil map unit†	Corn				Wheat		Sorghum yield 1987
	Productivity rating‡	Yield 1985	Yield 1986	Yield 1988	Productivity rating	Yield 1987	
	Mg ha⁻¹						
BnA	5.8	–	–	5.2	–	3.8	2.4
Cx	6.9	3.6	0.7	1.4	3.4	3.5	2.6
Dn	7.2	3.9	0.2	1.2	3.7	3.7	1.6
Do	7.2	–	–	1.9	3.7	–	2.3
EpB	6.3	7.7	2.2	3.9	3.4	5.0	2.2
ErA	6.9	7.3	2.1	3.3	3.7	5.3	3.7
ErB	6.3	7.7	2.2	3.8	3.4	6.1	4.1
GoA	7.8	5.1	1.3	2.4	4.0	4.4	2.4
NbA	7.2	–	–	4.5	4.0	6.2	4.1
NcA	7.2	6.0	2.2	4.2	4.0	5.4	3.0
NfA	7.2	–	–	4.3	4.0	5.3	4.3
NkA	6.3	6.8	2.7	4.5	4.0	4.5	3.6
NoA	6.3	8.3	2.8	4.7	4.0	6.0	3.1
NrA	6.3	–	1.5	4.4	4.0	4.8	4.9
Mean	–	6.2	2.1	3.5	–	4.9	3.2
LSD(0.05)	–	1.4	0.8	0.8	–	0.9	1.0
CV(%)	–	17.3	27.9	24.6	–	16.4	27.2

† Soil map unit descriptions in Table 1.
‡ Productivity ratings provided by Soil Conservation Service.

Table 3. Soil-test characteristics in September 1986 and February 1988 at five sampling depths for soil located within the 8-ha experimental field.

Soil sample depth	Water pH		Mehlich I extractable: P		K		Ca		Mg		Mn		Zn		NO_3-N		Organic matter	
	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988
— m —			— mg kg⁻¹ —														— g kg⁻¹ —	
Coxville (Cx)																		
0.00–0.15	5.0	5.0	40	30	59	59	175	200	37	34	5.8	6.5	1.8	0.4	9.0	1.0	21.5	18.0
0.15–0.30	4.6	5.2	23	39	33	49	125	125	17	36	–	–	–	–	6.0	1.5	–	–
0.30–0.45	4.6	4.8	10	22	32	45	120	165	14	26	–	–	–	–	4.5	4.0	–	–
0.45–0.60	4.5	4.6	4	6	30	39	125	135	16	19	–	–	–	–	4.5	2.0	–	–
0.60–0.75	4.5	4.6	2	4	29	35	160	200	22	24	–	–	–	–	6.5	2.0	–	–
Dunbar (Dn)																		
0.00–0.15	5.1	5.4	32	35	54	48	125	150	22	20	3.2	6.0	0.3	0.3	3.0	1.0	14.0	12.0
0.15–0.30	5.2	5.4	38	24	42	37	135	135	20	21	–	–	–	–	1.0	1.0	–	–
0.30–0.45	4.8	4.9	18	32	48	43	85	110	12	18	–	–	–	–	1.5	1.0	–	–
0.45–0.60	4.5	4.6	2	3	61	48	85	125	17	19	–	–	–	–	3.0	1.5	–	–
0.60–0.75	4.4	5.0	1	2	44	50	100	200	17	36	–	–	–	–	4.0	1.0	–	–
Emporia (EpB)																		
0.00–0.15	5.7	6.0	42	47	62	50	250	300	47	65	2.5	2.5	0.4	0.7	1.0	–	15.0	12.0
0.15–0.30	4.9	5.4	17	33	50	42	150	200	37	38	–	–	–	–	1.0	1.0	–	–
0.30–0.45	4.8	5.0	2	6	65	48	150	150	44	36	–	–	–	–	2.0	1.0	–	–
0.45–0.60	4.8	5.0	1	1	61	52	150	200	31	34	–	–	–	–	3.0	2.0	–	–
0.60–0.75	5.0	5.2	1	2	52	45	140	250	34	38	–	–	–	–	2.0	3.0	–	–
Emporia (ErA)																		
0.00–0.15	6.0	6.3	33	22	80	93	300	400	70	90	3.0	3.0	0.3	0.2	3.0	1.0	15.0	15.0
0.15–0.30	5.3	5.5	9	6	63	80	220	280	55	75	–	–	–	–	3.0	1.0	–	–
0.30–0.45	5.1	5.3	1	3	54	51	250	300	60	65	–	–	–	–	6.0	2.0	–	–
0.45–0.60	5.3	5.6	1	2	38	42	300	320	55	65	–	–	–	–	3.0	2.0	–	–
0.60–0.75	5.3	5.2	1	4	27	36	280	350	65	60	–	–	–	–	3.0	4.0	–	–
Emporia (ErB)																		
0.00–0.15	6.0	6.1	25	18	75	80	275	280	58	65	3.0	3.0	1.2	0.4	1.0	1.0	13.0	13.0
0.15–0.30	5.3	5.2	5	8	59	78	260	300	55	85	–	–	–	–	1.0	1.0	–	–
0.30–0.45	5.2	5.1	1	2	48	65	205	280	55	75	–	–	–	–	3.5	–	–	–
0.45–0.60	5.0	5.2	0	2	36	44	225	350	53	75	–	–	–	–	2.5	–	–	–
0.60–0.75	5.0	5.2	0	1	25	32	215	300	70	90	–	–	–	–	1.5	–	–	–
Goldsboro (GoA)																		
0.00–0.15	5.4	5.6	40	36	52	45	165	167	38	32	3.5	4.7	0.3	0.2	2.5	1.0	14.0	15.3
0.15–0.30	5.1	5.6	36	31	35	36	150	153	23	28	–	–	–	–	2.5	1.0	–	–
0.30–0.45	4.9	5.2	21	23	31	42	100	110	19	22	–	–	–	–	2.5	1.0	–	–
0.45–0.60	4.8	4.9	6	6	34	51	140	167	26	38	–	–	–	–	3.0	1.3	–	–
0.60–0.75	4.7	4.9	2	6	38	52	175	200	36	52	–	–	–	–	3.5	2.0	–	–
Noboco (NcA)																		
0.00–0.15	5.5	5.9	40	44	55	47	176	265	33	44	3.5	5.2	0.4	0.2	1.3	1.0	12.7	11.5
0.15–0.30	5.6	5.6	30	28	42	39	203	260	37	39	–	–	–	–	2.0	2.5	–	–
0.30–0.45	4.9	5.2	4	4	72	63	150	215	40	54	–	–	–	–	4.0	3.5	–	–
0.45–0.60	4.9	5.0	1	2	69	68	250	290	51	68	–	–	–	–	5.7	3.5	–	–
0.60–0.75	5.0	5.2	1	1	41	51	260	265	52	62	–	–	–	–	3.3	4.5	–	–
Norfolk (NkA)																		
0.00–0.15	6.2	6.4	58	73	51	50	300	295	62	65	3.2	2.8	1.0	0.8	3.0	4.5	11.0	9.5
0.15–0.30	5.2	5.8	30	49	49	43	160	200	32	49	–	–	–	–	2.0	4.0	–	–
0.30–0.45	4.9	5.0	6	6	80	85	150	200	44	61	–	–	–	–	3.5	4.5	–	–
0.45–0.60	5.0	5.2	1	4	97	92	200	200	49	62	–	–	–	–	4.0	5.5	–	–
0.60–0.75	5.2	5.4	1	3	87	42	230	280	47	57	–	–	–	–	2.5	6.5	–	–
Norfolk (NoA)																		
0.00–0.15	5.3	6.2	12	54	44	56	150	350	22	61	3.5	7.5	0.2	0.8	1.0	4.0	11.0	12.0
0.15–0.30	5.5	6.1	13	25	32	39	150	265	30	45	–	–	–	–	2.0	4.0	–	–
0.30–0.45	5.0	5.8	2	13	57	48	150	210	32	49	–	–	–	–	1.0	4.0	–	–
0.45–0.60	5.0	5.4	0	2	54	73	250	355	55	68	–	–	–	–	1.0	4.0	–	–
0.60–0.75	5.1	5.6	0	2	28	53	260	325	55	72	–	–	–	–	2.0	7.5	–	–
Norfolk (NrA)																		
0.00–0.15	6.0	6.0	20	27	44	60	220	280	55	55	3.0	5.0	1.0	0.4	4.0	4.0	13.0	8.0
0.15–0.30	5.0	5.3	6	6	43	76	100	300	34	65	–	–	–	–	5.0	5.0	–	–
0.30–0.45	5.0	5.1	0	1	70	64	250	250	65	55	–	–	–	–	7.0	7.0	–	–
0.45–0.60	5.4	5.0	0	0	45	45	320	300	85	55	–	–	–	–	5.0	–	–	–
0.60–0.75	5.5	5.1	1	1	24	27	300	250	90	55	–	–	–	–	4.0	9.0	–	–

Coastal Plain soils have relatively low organic-matter contents and destroying or not returning potential soil C inputs can result in significant changes. However, by using conservation- or reduced-tillage practices, not burning crop residues, and producing good crop yields, organic-matter levels in these soils can be increased (Karlen et al., 1989).

Depth to a Bt horizon could explain some yield variances among map units, but relationships between this factor and crop yield were still relatively weak

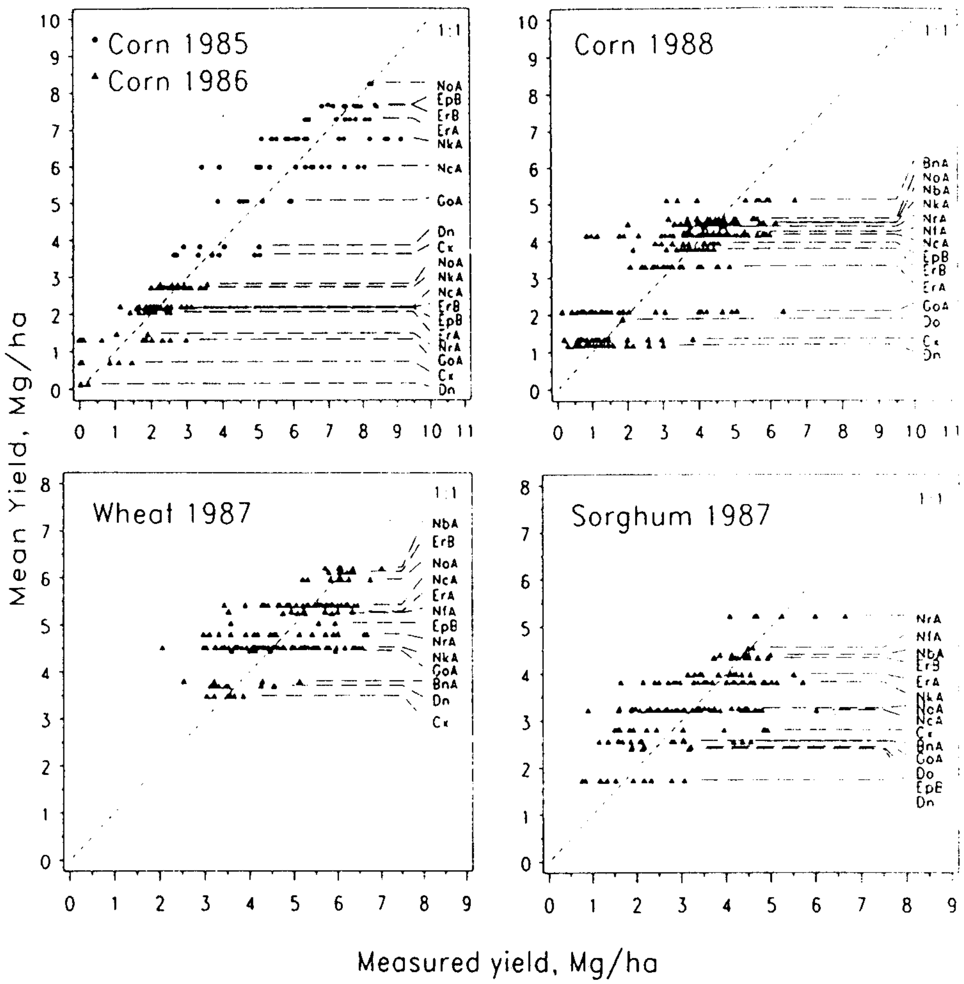

Fig. 2. Crop yield variation within and among Coastal Plain soil map units.

(Table 4). Grain yield generally declined as depth to Bt increased, but for sorghum in 1987 and corn in 1988 some map units showed a yield increase as depth to Bt increased. The relatively poor relationships between yield and Bt depth for individual map units suggests that other site-specific factors need to be measured and correlated with site-specific yield data unless soil-map-unit composition is more homogenous than we found for this Coastal Plain field. Another approach may be to use crop growth and de-

Table 4. Crop yield for selected soil map units showing a statistically significant relationship at $P \leq 0.20$ between yield and depth to the Bt horizon.

Year	Crop	Soil† map unit	$P > F$	r^2	Yield
					Mg ha^{-1}
1985	Corn	ErA	0.09	0.35	9.20 − (8.00·depth to Bt in meters)
1985	Corn	GoA	0.00	0.79	8.72 − (8.78·depth to Bt in meters)
1985	Corn	NkA	0.03	0.24	11.51 − (14.36·depth to Bt in meters)
1986	Corn	Cx	0.02	0.46	3.25 − (9.34·depth to Bt in meters)
1986	Corn	GoA	0.01	0.37	4.47 − (8.97·depth to Bt in meters)
1986	Corn	NkA	0.06	0.13	3.86 − (4.08·depth to Bt in meters)
1987	Wheat	Dn	0.01	0.64	8.24 − (12.86·depth to Bt in meters)
1987	Wheat	ErB	0.01	0.80	7.31 − (5.54·depth to Bt in meters)
1987	Sorghum	Dn	0.05	0.33	−1.08 + (7.74·depth to Bt in meters)
1987	Sorghum	EpB	0.07	0.99	6.85 − (13.33·depth to Bt in meters)
1987	Sorghum	GoA	0.00	0.56	6.35 − (10.45·depth to Bt in meters)
1987	Sorghum	NbA	0.12	0.41	2.41 + (6.73·depth to Bt in meters)
1988	Corn	Cx	0.10	0.12	4.28 − (9.73·depth to Bt in meters)
1988	Corn	GoA	0.00	0.24	6.41 − (10.62·depth to Bt in meters)
1988	Corn	NbA	0.00	0.76	0.74 + (11.99·depth to Bt in meters)
1988	Corn	NcA	0.11	0.04	2.57 + (4.45·depth to Bt in meters)
1988	Corn	NkA	0.05	0.08	3.27 + (3.71·depth to Bt in meters)

† Soil map unit descriptions in Table 1.

velopment models (Sadler et al., 1988) to identify interactive factors that cause yield variation within and between Coastal Plain map units.

SUMMARY AND CONCLUSIONS

A detailed soil survey map prepared by our SCS cooperators made it feasible to evaluate yield variation for corn, wheat, and grain sorghum as a function of soil map unit in a southeastern Coastal Plain field. Regression analysis suggested that depth to an argillic horizon (Bt) could explain some yield variation among soil map units. However, some relationships were positive, some were negative, but most were not significant. Seasonal crop yield variation within an individual map unit was almost as large as the variation among soil map units. This suggests that, although yield variation among soil map units can be determined, using that information to develop more profitable and environmentally safe soil and crop management practices may result in only crude adjustments to current farming practices. Further development of tailored management practices will require a more sophisticated approach to examine cause-and-effect relationships for crop yield on different soil map units.

ACKNOWLEDGMENTS

The authors would like to thank our USDA-SCS cooperators Mr. Bobby Ward, party leader; Mr. Ronald Morton, soil scientist; Mr. Leander Brown, soil scientist; Mr. Ellis Morrow, area conservationist; and Dr. Don Hallbick, state soil scientist. Their diligent efforts to prepare, classify, correlate, and publish a very detailed soil survey map for the USDA-ARS Coastal Plains Soil and Water Conservation Research Center made this study feasible.

REFERENCES

Austin, M.E. 1965. Land resource regions and major land resource areas. USDA Agric Handb 296. U.S. Gov. Print. Office, Washington, DC.

Davis, J.C. 1973. Statistics and data analysis in geology. John Wiley & Sons, New York.

Karlen, D.L., and J.P. Zublena. 1986. Fluid fertilization practices for corn in the Atlantic Coastal Plain. J. Fert. Issues 3:1-6.

Karlen, D.L., W.R. Berti, P.G. Hunt, and T.A. Matheny. 1989. Soil-test values after eight years of tillage research on a Norfolk loamy sand. Commun. Soil Sci. Plant Anal. 20:1413-1426.

Long, F.L., J.M. Daniels, F.T. Ritchie, Jr., and C.M. Ellerbe. 1963. Soil moisture characteristics of some lower Coastal Plain soils. USDA-ARS Publ. no. ARS 41-82. U.S. Gov. Print. Office, Washington, DC.

Luellen, W.R. 1985. Fine-tuned fertility. Tomorrow's technology here today. Crops and Soils 37(3):18-22.

Matheny, T.A., and P.G. Hunt. 1983. Effects of irrigation on accumulation of soil and symbiotically fixed N by soybean grown on a Norfolk loamy sand. Agron. J. 75:719-722.

Sadler, E.J., D.L. Karlen, and W.J. Busscher. 1988. Modeling of soil variability effects on corn, wheat, and sorghum for southeastern Coastal Plain soils. p. 284. *In* Agronomy abstracts. ASA, Madison, WI.

SAS Institute. 1985. SAS user's guide: Statistics. Vers. 5 ed. SAS Inst., Cary, NC.

Soil Conservation Service. 1979. Soil survey of Florence and Sumter Counties, South Carolina. USDA-SCS in cooperation with the South Carolina Agr. Exp. Stn., Clemson, SC.

White, A.W., Jr., R.R. Bruce, A.W. White, G.W. Langdale, and H.F. Perkins. 1985. Characterizing productivity of eroded soils in the southern Piedmont. *In* C.K. Mutchler (ed.) Proc. ASAE Natl. Symp. on Erosion and Soil Productivity, New Orleans, LA. 10-11 Dec. 1984. ASAE, St. Joseph, MI.