ABSTRACT

LOHMAN, MINDY. Evaluation of Realistic Yield Expectations in the North Carolina Piedmont and Coastal Plain. (Under the direction of Deanna Osmond and Jeffrey G. White.)

Realistic Yield Expectations (RYE) have been developed in North Carolina to assist in site-specific farming decisions that will improve N-use efficiency and reduce N contamination of ground- and surface water, especially in the Neuse River Basin. This study was conducted to determine whether correlations exist between soil chemical properties, actual yields, soil map units, transition zones at map unit boundaries, and RYEs. One site-year each of corn (*Zea mays* L.) and wheat (*Triticum aestivum* L.) yield data was collected in one Piedmont field; wheat was sampled for one year in a second Piedmont field, and corn (*Zea mays* L.) sampled for one year in a third Piedmont field. Two years of soybean and one year of wheat yield data were collected in one Coastal Plain field. Soil surveys of the fields were completed in 2002 at an approximate scale of 1:3500 (“remapped” soil map units) and compared to existing county soil surveys (“original” soil map units). Samples from equilateral triangle grid soil sampling were analyzed and used to map the spatial distribution of soil pH, P, K, and lime requirement. Interpolated maps were created to display the spatial distribution of the investigated soil chemical properties. To represent zones (transition zone or map unit interior), 20-m buffers centered on map unit boundaries were created in order to investigate these potentially variable areas. Interpolated nutrient maps showed visual correlations between soil map units and soil K values in the Coastal Plain, but no other relationships between soil chemical properties and soil map units or zones were visually apparent for either location. Yield maps showed visual relationships with soil map units in the Coastal Plain but not in the Piedmont. Remapped and original soil map units and zones were analyzed as fixed effects to determine their effectiveness in capturing the variability of soil chemical properties and crop yield. Analyses of variance with and without spatial covariance models included were utilized to analyze the data. The analyses incorporating spatial covariance models were determined to be more efficient than those presuming independent and identically distributed errors in capturing a significant proportion of the variability for tested soil chemical properties and crop yield in both locations. The remapped soil map units were more effective than the original soil map units in capturing this variability in most cases. Soil K was different among the remapped soil map units in the Field 7 in the Piedmont where the model r^2=0.82. In all locations, other investigated parameters also displayed differences, but none as highly significant as soil K in Field 7. Even though differences was discovered in other fields, management decisions would not likely be affected, as most differences were small and the means were usually classified in the same nutrient status category. In the Piedmont, RYEs were found to be less than actual yields, while in the Coastal Plain, RYEs were greater than actual yields, implying that the RYE database needs further study to determine if values are reasonable.

Evaluation of Realistic Yield Expectations in the North Carolina Piedmont and Coastal Plain

By

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Biography

Mindy Lohman was born in Greenville, IL and raised in Pocahontas, IL. She was involved in 4-H and various other agricultural activities while growing up and thus decided upon a career in agriculture. She received her B.S. in Plant and Soil Science from Southern Illinois University at Carbondale in May of 2001. The summer after graduation she interned with the USDA Forest Service in the Shawnee National Forest before attending North Carolina State University to pursue a Master's of Science degree in Soil Science in the fall of 2001.

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INTRODUCTION

Variability in soil chemical properties, crop yields, and yield potentials within and between fields can present management problems for producers. Traditional crop management systems are developed for managing fields uniformly and do not take into account the spatial variability within fields. This is due to fields being divided by physical or arbitrary boundaries into management units with little regard for variation in soils or potential productivity. The spatial variation of soil properties can contribute to uneven patterns of soil nutrients and crop growth, and can inhibit fertilizer efficiency for uniform applications (Miller et al. 1988). As environmental and economic considerations require reduced inputs and increased fertilizer efficiency, farmers must adapt to possible site-specific management of smaller units within each field as a potential solution to these problems (Karlen et al., 1990).

Association of Crop Yields with Soil Map Units

Several studies in the South Carolina Coastal Plain have indicated that it is not feasible to manage fields by individual soils due to the variation within soil map units (Karlen et al., 1990, Sadler et al., 1995, Sadler et al., 2000). They discovered that the variation within map units was as large as the variance between the map units and suggested that more research needs to be completed on the factors causing yield variation. Karlen et. al. (1990) discovered that the productivity rating for soil map units found in the soil survey was very different from the actual yield measured in the field.

A study in the Midwest (Iowa) opposed Karlen et al. (1990), indicating that yield interpretations found in county soil surveys can be used for field-scale management because there was no effect on expected crop yields even though the map units were taxonomically variable (Steinwand et al, 1996). The “farming soils, not fields” strategy has been demonstrated to be effective in various areas of the United States. Carr et al. (1991) suggested that producers should consider farming by soils to increase fertilizer profitability and indicated in a study field in Montana, individual soil map units produced significantly different grain yields ($P<0.05$). Other studies have found significant differences in crop yields among soils. Wibawa et al. (1993) found that barley yields in 1989 and 1990, and wheat yield in 1991 differed significantly among soil map units in North Dakota. In Iowa, yield variability patterns can be influenced by soil type (Bakhsh et al., 2000). In order to be profitable by managing fields by soils, yield goals for each map unit within a field must be determined. As a result, delineation of management zones within a field for site-specific farming is possible when appropriate yield classes are defined (Bakhsh et al., 2000).

There are problems however, associated with predicting the yield goal for individual soil map units. The relative productivities can vary from year to year and are dependent upon rainfall patterns and amounts, etc. (Wibawa et al., 1993). Spatial yield variation can also be controlled by soil properties and landscape features that may affect water holding capacity and aeration. (Jaynes and Colvin, 1997; Mulla and Schepers, 1997). Lark et al. (1998) found that over three growing seasons, soil physical properties and potential soil moisture deficits accounted for most of the differences in observed yield. They thought that this variation could be attributed to the difference in parent materials. Thus, research evaluating expected yield goals should be conducted as long-term studies in order to incorporate many of the possible explanations for spatial yield variability.

Association of Soil Chemical Properties with Soil Map Units

The correlation between soil properties and soil map units has not been well demonstrated. In the Midwest, hypotheses suggest that soil spatial variation may be controlled by inherent variations in soil characteristics (Rao and Wagenet, 1985; Cambardella et al., 1994). To test these hypotheses, Cambardella and Karlen (1999) completed a study in Iowa that examined the spatial patterns for soil chemical properties. The study found that strength of the spatial correlation varied for the various parameters evaluated and that management (conventional versus manure) also affects the strength of the spatial relationship.

Zone Management

Knowing the strength of correlation between soil chemical properties and yield with soil map units is important for zone management, one method of precision agriculture. Management zones are defined as a subset of the whole field with similar yield limiting factors where a uniform rate of a particular crop input is appropriate (Doerge, 1999a). These zones are useful to explore the spatial and temporal variations of yield and soil chemical properties. Management zones may be delineated based on quantitative, qualitative, and historical factors such as yield maps, soil chemical information, soil map units, aerial photographs, soil survey information, landscape positions, etc. (Doerge, 1999a). In order to assess the spatial patterns within management zones, soil samples may be taken following the zone or directed sampling method where soil samples are composited from regions of the field having similar fertility status or yield potential (Pocknee et al., 1996). Zone sampling reduces the number of soil samples taken compared to intensive grid sampling.

Management zones in Michigan based on soil map units have been shown to be less than ideal because they are indicative of productivity rather than fertility as past management can alter the variability of soil chemical properties (Mueller et al., 2001). However, Franzen and Kitchen (1999) found that soil N levels in North Dakota are sometimes related to soil map unit or landscape position, leading to using soil-based management zones to direct soil sampling and variable-rate nutrient application protocols. Similarly, spatial patterns in wheat yield and soil fertility in the Palouse region of Washington have been correlated to patterns in soil organic matter (SOM), and management zones have been created based on varying levels of SOM. Higher yields were associated with higher SOM and the yield differences between each management zone were statistically significant (Mulla, 1993).

There have been several studies evaluating the use of yield maps to delineate management zones. Kitchen et al. (1996) based potential management zones on yield maps from the previous years' crops in North Dakota, and noted that the availability of multiple years of yield maps is much more useful for recognizing response patterns and thus delineating management zones. Khakural et al. (1996) determined that using management zone groupings based on three different productivity levels in Minnesota maximized differences in yield. This method, however, did not maximize the differences in soil properties, as the yield variability seemed to be controlled by inherent soil characteristics such as depth to free $CaCO_3$ rather than soil fertility variation. Management units based on high and low productivity levels in wheat have been shown to be effective zones for fertilizer management (Bhatti et al., 1999).

Statistical Approaches

Soil properties and yield tend to be spatially correlated. Geostatistics provides a method to evaluate spatial correlation by determining the semivariance. Semivariance is defined as the average variance between all possible points spaced a constant distance apart. Theoretically, pairs of sampling points closer together should show smaller semivariance, while points farther apart should display larger semivariance.

Spatial variations with interdependence are quantified with semivariograms, a standard statistical assessment of spatial variability as a function of the distance between observations (Littell et al.,1996). Semivariograms consist of three parameters; the range, sill, and nugget. The range is the distance over which sample pairs are correlated; at distances greater than the range, sample pairs cease to be correlated. At separation distances greater than the range, the semivariance remains constant at a quantity known as the sill. The sill corresponds to the variance of the sample, i.e., it is an estimate of the population variance. In theory, samples taken where the separation distance is zero should show no variance, but this is not always true as some soil properties can show large variation at very small separation distances (McBratney and Pringle, 1997). The nugget effect describes this micro-scale variation as well as incorporating any measurement error.

North Carolina Nutrient Index System

In North Carolina, the soil test reports the levels of P and K as indices (Tucker et al. 1997). The scale of index values ranges from 0 to greater than 100 where the critical quantitative value for each nutrient is 25. If a specific nutrient has an index value of 25 or below, this is an indication of low soil fertility, high nutrient requirement, and a crop yield response would occur with the addition of fertilizer. Index values between 26 and 50 specify medium fertility and need nutrient additions for optimum crop production. Soils testing above 50 have high nutrient status and rarely will respond to additional nutrients. Values greater than 100 are considered excessive and there would be no crop yield response to a fertilizer application. The conversion between index values and metric units are presented in Table 1.

Realistic Yield Expectations

Realistic yield expectations (RYEs) have been developed in North Carolina to assist in field-specific farming decisions that will improve N-use efficiency and reduce N contamination of ground and surface water. Realistic yield expectations are utilized in North Carolina to calculate N fertilizer recommendations. The RYE for the crop in question for a specific soil mapping unit is multiplied by a given N factor, which is based on soil type, to result in the N fertilizer recommendation. The N factor has a range of values for each crop as the value of the factor is affected by soil characteristics. Using corn as an example, the N factor (Table 2) values range from 1.0 to 1.25 lb N bu^{-1}. If the corn crop was grown on a sandy soil, an N factor at the upper end of the range should be used as the sandy soil has a higher N leaching potential. Specific N factors have been determined for each crop and soil mapping unit combination. The RYE values are scaled so that they can be achieved by a high level of management, which is essentially the top 20% of growers. Producers can either calculate their own RYEs by taking the average of the best 3 out of 5 growing seasons for harvested crops on each map unit in their fields or they can used the value in the state RYE data base (North Carolina Nutrient Management Workgroup. 2003).

Objectives

The objectives of this research were to: 1) examine the spatial relationships between yield (corn, soybean, and wheat) and soil mapping units, 2) assess the relationships between soil chemical properties and soil map units, 3) study the correlations between soil chemical properties and crop yields, and 4) evaluate the hypothesis that map unit boundaries (transition zones) may be highly variable areas that require different management protocols. The information gained from these objectives will then be utilized to evaluate the (RYE) database in North Carolina where yield goals are based on soil map units.

MATERIALS AND METHODS

Study Locations and Background

Two locations were selected in central and eastern North Carolina to represent typical grain farms. The study sites were selected for the high amount of spatial variability as indicated by multiple map units within each field. Corn (*Zea mays* L.), wheat (*Triticum aestivum* L.) and soybean *(Glycine max* [L.] Merr.) were grown at both locations.

The Piedmont location in Franklin County, NC (36° 4' 12" N, 78° 23' 24" W) consists of three fields (Fields 3, 5, and 7) of areas 9.5, 14.4, and 7.7 ha, respectively (Fig. 1). Field 3 was reduced to 5.6 ha in 2003 because the producer planted additional corn in the remainder of Field 3 in 2003 for economic reasons. Fields 3 and 5 in the Piedmont were irrigated with effluent from a bioprocessing manufacturing plant. The effluent provided water to these fields, increasing yields in the droughty growing seasons.

The Coastal Plain location in Wayne County, NC (35° 17' 24" N, 78° 5' 24" W) is comprised of two adjacent fields of total area equal to 14.7 ha (Fig. 2). These fields are named and managed as two separate fields, but harvested as one unit. Table 3 describes the original soil map units for each site that were determined using the USDA NRCS SSURGO Certified Soil Survey for the respective county (1:24,000; Fig. 3A, 4A, 5A, 6A, 7A) (SSURGO, 2000). The rainfall varied between the locations as the Piedmont received more rainfall than the field in the Coastal Plain. The monthly rainfall is presented in Fig. 8 and 9 for the Piedmont and Coastal Plain, respectively.

Intensive Soil Survey

Because previous research (Sadler et al., 2000) indicated that soil surveys at a scale of 1:20,000 were not adequate for management zone delineation when attempting to correlate grain yield variation with soil map units, an intensive soil survey was completed in 2002 for both locations (Table 4). The scale of the survey was approximately 1:3500. The new map unit boundaries were georeferenced using a differentially corrected global positioning system (DGPS) (Fig. 3B, 4B, 5B, 6B, 7B).

Grid Soil Sampling

Georeferenced soil sampling was conducted in the fall of 2000 for the Piedmont and fall 2001 in the Coastal Plain using a DGPS. Eight cores to a depth of 0.2 meters were taken at each grid location and mixed to ensure that a representative sample was collected. In the Piedmont, the samples were collected on a 23 m equilateral triangle grid, while in the Coastal Plain the equilateral triangle grid spacing was 21.3 m (Fig. 10). The samples were air dried and sent to the NC Department of Agriculture and Consumer Services (NCDA&CS) Soil Testing Laboratory (Raleigh, NC) for analysis of pH (1:1 H_2O), P and K (Mehlich, 1984) and lime requirement (Mehlich, 1976). Interpolated maps of pH, P, K, and lime requirement were created using the inverse distance-squared weighting method of interpolating where the default cell size was chosen. The soil pH maps were classified using the quantile method, where each class contains the same number of cells. The P and K soil chemical property maps were classified using the NCDA Index system while the yield maps were classified based on equal intervals.

Transition Zone Establishment

Transition zones were established around the map unit polygons in order to identify the areas around soil map units that may be highly variable and pose unique management problems. Figure 11 depicts the transition zones where 20 m buffers centered on map unit boundaries were created in ArcView 3.2 (Environmental Systems Research Institute [ESRI], 380 New York Street, Redlands, CA) and geoprocessing techniques were then utilized to assign soil sampling points to transition or map unit interior zones. The map unit interior was defined as all area that did not fall within the transition zone.

Crop Yield

In order to assess the spatial variability of crop yields at each location, each producer's combine was equipped with an AgLeader PF 3000 yield monitor (AgLeader, 2202 S. Riverside Dr., Ames, IA) and a DGPS. After installation, the yield monitors were calibrated following AgLeader protocol for each new crop that was harvested. Yield data was collected every 1 s in the Coastal Plain and every 2 s in the Piedmont. These data were then used to produce non-interpolated yield maps for each crop using ArcView 3.2. During harvest, the producers were allowed to harvest as normal and drove at approximately 7.2 km hr^{-1} and 5 km hr^{-1} in the Piedmont for wheat and corn respectively, while the speeds in the Coastal Plain were 5.6 km^{-1} hr for soybeans and 6 km hr^{-1} for wheat. Using the guidelines described by Doerge (1999b) and Blackmore and Moore (1999), the yield data were corrected to remove possible errors. Two header widths at field boundaries were discarded from the data to exclude combine passes made to clean the field edges.

This resulted in removing 10 m of yield data from field edges in the Piedmont and 11 m of yield data from field edges in the Coastal Plain, due to different header widths. Yield data connected with passes with incomplete swaths in the header were also removed, which accounted for an additional 10 m of data removed from the field edges for Fields 3 and 5 in the Piedmont and 15 m in the Coastal Plain.

The missing yield data for Field 7 in the Piedmont was due to that portion of the field being inundated at the time of harvest. The missing yield data in the Coastal Plain was due to a misunderstanding with the producer. The fields were harvested with two combines only one of which was equipped with a yield monitor. Corn was grown in the Coastal Plain in 2001, but due to problems with the yield monitor, this site-year of data was lost.

The yield data sets were normally very large and caused problems in SAS when computing the PROC MIXED algorithm (SAS Institute, 2001). To alleviate this problem, for yield data sets with greater than 3000 data points, 35 m X 35 m square grids were created on the field using ArcView 3.2. The grid square average yields and geographical centers were then used for the PROC MIXED analyses. In circumstances when the data would not converge in PROC MIXED, a no-nugget model was utilized to allow the data to converge.

Statistical Procedures

In order to complete the statistical analysis, the data was classified with two attributes, soil map units and location within zones. Geostatistical software (GS+, Gamma Design Software, St. Plainwell, MI) was used to evaluate the spatial dependence of yield by calculating semivariograms based on the raw yield and soil chemical property data. This data would serve as the standard for characterizing the spatial structure of the data. The GS+ maximum default lag distance was reduced by half to calculate the semivariograms. Selection of the isotropic models for semivariograms was made based on the highest r^2 values for the regression. It should be noted that in some cases, using the semivariograms with the highest r^2 values resulted in semivariogram models with parameters extrapolated well beyond the range of the data, thus rendering the data suspect. The semivariograms were examined by evaluation of the range, sill, and nugget as well as the model type and model r^2 value. This model r^2 parameter illustrated the goodness of fit of the semivariogram models. Semivariograms were then generated in GS+ using the residuals of the basic fixed effect models for comparison with the semivariograms of the original data. The same parameters (range, sill, nugget, model type, and ANOVA r^2 value) were reported for comparison. Soil chemical property differences associated with map unit variability and location zones were tested using traditional analysis of variance (ANOVA) in PROC GLM (SAS Institute, 2001). When means were significantly different in ANOVA, Tukey's Multiple Comparison Test was used to determine which means among the set of means differed from the rest (Tukey, 1977). Significant differences were determined at the 0.05 confidence level. Tukey's procedure was chosen to evaluate the differences between means because it was considered to be conservative. Soil map units and zones were treated as class variables. The ANOVA r^2 values from this analysis were used to describe the proportion of soil chemical property variability that was accounted for by the *iid* (independently and identically distributed) models. The same *iid* model was analyzed using PROC MIXED and LSMEANS were generated with this analysis. LSMEANS were calculated to compare soil chemical properties within soil map units, zones, and their interaction.

In order to evaluate the spatial components of this data, soil chemical property differences associated with map units and zones were tested using ANOVA in PROC MIXED with map units and zones again treated as class variables. The MIXED procedure was used because the spatial autocorrelation of the soil test data could be accounted for in this spatial covariance model. The range, sill, and nugget parameters from the GS+ raw data semivariograms were supplied as the starting parameters in the PARMS statement for the PROC MIXED spatial model program in SAS. LSMEANS were also calculated and were used to characterize all means in the discussion.

In order to determine if the full spatial model was necessary to explain the observed soil chemical property variation, the Akaike's Information Criterion (AIC) values in the PROC MIXED output were compared between the *iid* models (reduced model) and the spatial covariance models (full model). The smaller the AIC value in the comparison, the more efficient the respective model at capturing a significant proportion of the variability. In all cases, the full model, with spatial parameters described the variance better than the reduced model and was used for further explanations of spatial variability. Since the full model was chosen for all cases, it was concluded that these data contain significant spatial variability.

All procedures described above were conducted on the remapped and original soil information. The same procedures also evaluated the differences in yield for each location. The F-test results from the PROC GLM will be described, but differences will only be discussed if significant in PROC MIXED because the full model was selected in all cases.

In order to analyze the simple correlations between yield and soil chemical properties PROC GLM was utilized. A 35 X 35 m grid was established on each field where the average soil chemical properties and average yield from each grid cell were used for the comparison. The resultant r^2 value was noted to determine the significance of the relationship between these parameters. This analysis was completed for both the original and remapped soil data.

RESULTS AND DISCUSSION

Piedmont

Field 3 Soil Chemical Properties

There was no visual relationship among remapped or original soil map units with respect to soil pH on the interpolated nutrient maps of Field 3 (Fig. 12). There were differences in pH among remapped soil map units (Tables 5 and A1). In Field 3, the average soil pH was pH 5.9 (Table 5). The ANOVA r^2 for the remapped statistical model was 0.33 indicating that a proportion of the spatial variability of soil pH was explained by the *iid* model (Table 5). The target pH for wheat and corn in the Piedmont was pH 6.0.

There were no differences in soil pH among the original soil map units (Tables 5 and A2). The ANOVA r^2 was only 0.06 meaning that this model did not capture much of the soil pH variability among the original soil map units in Field 3 (Table 5). The remapped soil map unit model was more effective in capturing the spatial variability of soil pH as the ANOVA r^2 was greater for the remapped soil map unit model. There were no soil samples taken in the original Wake-Saw-Wedowee Complex.

In Proc MIXED, there were no differences in soil pH among the remapped or original soil map units or zones (Tables 6, 7, and 8).

In Field 3, there were differences in soil pH among the remapped map units in Proc GLM, but not with the spatial covariance model in Proc MIXED. This indicated that most of the variability that the map units captured in Proc GLM was the result of the spatial correlation accounted for in the Proc MIXED model. The range of spatial dependence of soil pH was 127 m (Table 9). The sill parameter calculated from the raw observations (Table 9) was less than the sill generated from the residuals in the original soil map unit *iid* model (Table 10). Because the raw observation sill was less than the soil map unit residuals sill, the variability in soil pH was not accounted for by the fixed effects in the original map unit *iid* model. Among the remapped soil map units, the opposite was true where a proportion of the variability was captured by the fixed effects as the sill of the raw observation semivariogram was greater than the sill of the remapped soil map unit *iid* model (Table 11).

No visual relationship was apparent between soil P and remapped or original soil map units on the interpolated nutrient maps (Fig. 13). There were no differences in soil P among the remapped soil map units or remapped zones (Tables 5 and A1). The ANOVA r^2 for soil P in Field 3 was very low, where r^2=0.09, indicating that very little of the variability in soil P was captured by this statistical model (Table 5). The mean soil P in Field 3 was 73 kg ha^{-1} (Table 5). The soil P in Field 3 was classified as having medium nutrient status indicating that there would be a slight yield response to the application of P fertilizer.

There were differences in soil P levels among the original soil map units in Proc GLM (Tables 5 and A2). Although there were differences in soil P levels among the original soil map units, the ANOVA r^2 was 0.04 indicating that the statistical model explained very little of the soil P variability. Neither model was effective in capturing the spatial variability of soil P in Field 3 as the ANOVA r^2 values were similar (Table 5).

There were no significant differences in soil P among the remapped or original soil map units or zones when modeled with the spatial covariance model in Proc MIXED (Tables 6, 7, and 8).

Proc GLM indicated that there were differences in soil P among the original map units, but these same factors were not significant in Proc MIXED (Table 8). Soil P was spatially dependent to a range of 81 m, larger than the grid soil sample spacing (Table 9). A small proportion of the variability in soil P among the remapped and original map units was accounted for by the fixed effects in the remapped and original *iid* model because the sill of the raw observation semivariogram (Table 9) was slightly greater than the sill from the remapped and original map unit residual model semivariograms (Table 11 and 10, respectively).

There was no observable relationship among the remapped or original soil map units and soil K on the interpolated soil K map of Field 3 (Fig. 14). There were differences in soil K among both the remapped and original soil map units (Tables 5 and A1). The average soil K in Field 3 was 120 kg ha^{-1}, indicating that the average soil K was classified as having a medium nutrient status. Soils with medium soil K nutrient status may have a low yield response to the application of soil K fertilizer. The remapped soil information was more effective in capturing a proportion of the soil K variability as the ANOVA r^2 was 0.51 for the remapped soil map units and 0.09 for the original soil map units (Tables 5 and A2). The remapped soil map unit model captured approximately one-half of the variability in soil K.

There were no differences in soil K among the remapped or original soil map units or zones in Proc MIXED (Tables 6, 7, and 8).

Soil K was different among remapped and original soil map units in Proc GLM, but not in Proc MIXED. The variability that was captured in Proc GLM was the result of the spatial correlation accounted for in the covariance model in Proc MIXED, thus rendering the factors to be non-significant in Proc MIXED. All other factors were non-significant in both statistical models. The range of spatial dependence of soil K was 151 m (Table 9). The sill calculated from the raw soil K observations (Table 9) was greater than the sill calculated from the remapped soil map unit residuals in the *iid* model (Table 11) indicating that the fixed effects accounted for a proportion of the variability in soil K among the remapped map units. Among the original map units, the sill of the raw soil K observations was less than the sill of the original map unit residual model, meaning that the variability was not accounted for by the fixed effects (Table 10).

There was no visual relationship among remapped or original soil map units and lime requirements on the Field 3 interpolated map for lime requirement (Fig 15). There were differences in lime requirement among both remapped and original soil map units in Proc GLM (Tables 5 and A1). The average lime requirement in Field 3 was 0.2 Mg ha^{-1} (Table 5). The remapped soil map unit ANOVA r^2 was 0.20 meaning that 20% of the variability in lime requirement was captured by this statistical model (Table 5). The original soil map unit ANOVA r^2 was 0.12 indicating that the remapped soil information may have been slightly more effective in capturing the variability in lime requirement for Field 3 (Tables 5 and A2). There were also significant differences in lime requirement among original zones (Tables 5 and A2).

In Proc MIXED, there were no differences in lime requirement among the remapped soil map units in Field 3 (Tables 6 and 7). There was a significant difference in lime requirement among the original map units where the lime requirement was slightly greater for the original Wedowee_B map unit than for the original Wedowee_C map unit (Table 8).

There were differences in lime requirement among original soil map units for both Proc GLM and Proc MIXED models. In Proc GLM, there were differences in lime requirement among the remapped map units and the original zones, but these same factors were not significant in Proc MIXED indicating that the variability that was captured in the GLM model was the result of spatial correlation accounted for in the spatial covariance model in Proc MIXED. In Field 3, lime requirement was spatially correlated to a distance of 156 m (Table 9). The sill of the raw lime requirement semivariogram (Table 9) was very similar to the sill of the semivariogram calculated from the residuals of the *iid* remapped and original soil map unit models (Table 11 and 10, respectively), signifying that the fixed effects did not effectively account for variability in lime requirement among the remapped and original soil map units.

For the investigated soil chemical properties in Field 3 except soil K, neither *iid* model (remapped or original) explained the extent of the variability of these parameters as the ANOVA r^2 values were fairly small. The ANOVA r^2 for soil K in Field 3 was 0.51 indicating that 51% of the variability in soil K was captured by the basic fixed effects model in Proc GLM (Table 5). However, the remapped map unit model ANOVA r^2 values were greater than the original map unit model values. The spatial correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED *iid* model for all of the investigated soil chemical properties in Field 3.

Field 3 2002 Corn Yield

The yield map for corn in 2002 showed no visual relationship between yield and the remapped or original soil map units (Fig. 16). There were differences in corn yield among remapped soil map units in Field 3 in Proc GLM (Tables 5 and A1). Field-wide average yield was 8.7 Mg ha^{-1} (Table 5). The remapped soil map unit ANOVA r^2 was 0.13 indicating that little of the variability in corn yield was captured by this statistical model (Table 5).

There were no differences in corn yield among the original map units, but there were differences in corn yield among the original zones (Tables 5 and A2). The ANOVA r^2 for the original soil data was 0.07 (Table 5). The remapped soil map units were more effective in capturing the corn yield variability as the ANOVA r^2 was greater for the remapped map units.

In Proc MIXED, there were no differences in corn yield among the remapped or original map units or within their associated zones (Tables 6, 7, and 8).

There were differences in corn yield among the remapped soil map units and original zones in Proc GLM, but not in Proc MIXED. The corn yield variability that was captured in Proc GLM was the result of the spatial correlation accounted for in the spatial covariance model in Proc MIXED. All other factors were non-significant in both statistical models. The range of spatial correlation of corn yield was 699 m

(Table 9). The sill of the raw corn yield observations (Table 9) was slightly greater than the sill of the residual remapped and original soil map unit semivariograms (Tables 11 and 10, respectively), indicating that the fixed effects did not account for much of the yield variability among the remapped soil map units.

Field 3 2003 Wheat Yield

The yield map for wheat in 2003 showed no visual relationship between yield and the remapped or original soil map units (Fig. 17). In 2003, the interaction between remapped map units and remapped zones was significant in the iid model in Proc GLM (Tables 5 and A1). The average wheat yield in Field 3 was 2.3 Mg ha^{-1} (Table 5). The remapped soil map unit ANOVA r^2 was 0.02 indicating that the statistical model did not capture the variability in wheat yield (Table 5).

For the original soil map units, there were slight differences in wheat yield (Tables 5 and A2). There were no differences in wheat yield among original zones for Field 3 in 2003. The original soil map unit ANOVA r^2 was 0.01, indicating that only 1% of the variability was captured by this statistical model (Table 5). Neither model, remapped or original effectively captured the variability of wheat yield in Field 3.

In Proc MIXED with the spatial covariance model, there were differences in wheat yield among the remapped zones where wheat yield was greater in the transition zones (Tables 6 and 7). Wedowee was the only original map unit where yield data was recorded in 2003 (Fig 17B).

All factors that were significant in Proc GLM became non-significant in Proc MIXED except the remapped zones indicating that the wheat yield variability captured in Proc GLM was the result of the spatial correlation accounted for in the spatial covariance model in Proc MIXED except for the remapped zones. The range of spatial correlation of wheat yield was 70 m (Table 9). The sill of the raw wheat yield observations (Table 9) was the same as the sill of the remapped and original soil map unit residual semivariograms (Tables 11 and 10, respectively) indicating that the fixed effects did not capture the wheat yield variability in Field 3.

For the crop yield in Field 3, both corn and wheat, neither model (remapped or original) explained the extent of the variability of these parameters as the ANOVA r^2 values were fairly small. The ANOVA r^2 values were greater for all remapped map unit models than for the original map unit models. The spatially correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED *iid* model for all site years of yield information in Field 3. The statistical model in Proc MIXED provided more realistic estimates of the crop yield by accounting for the spatial covariance in the error structure for corn and wheat yield factors.

Field 5 Soil Chemical Properties

There was no visual relationship between remapped or original soil map units with respect to soil pH on the interpolated nutrient maps of Field 5 (Fig. 18). There were no differences in soil pH among remapped or original soil map units and location within zones for Field 5 (Tables 12, A3, and A4). The interaction between map units or transition zone was also not significant for both the remapped and original soil map units. The mean soil pH in Field 5 was pH 5.9 (Table 12). The

ANOVA r^2 was very low at 0.04 indicating that the spatial variability of soil pH among the remapped soil map units was not captured by this statistical model (Table 12). The original soil map unit model ANOVA r^2 was 0.03, slightly lower than the ANOVA r^2 for the remapped soil map units indicating that neither model was effective in capturing the variability of soil pH in Field 5 (Table 12).

There were no differences in soil pH among the remapped or original soil map units or zones in Proc MIXED where the spatial covariance was modeled (Tables 13, 14, and 15). The interaction between both remapped and original map units and zones was also not significant.

In Field 5, there was no difference in significance in soil pH for either statistical model (Proc GLM or Proc MIXED) indicating that adding the spatial components to the statistical model did not make the model more effective in capturing the spatial variability of soil pH in Field 5. The range of spatial dependence of soil pH was infinite to some point beyond the largest separation distance sampled (Table 16). The sill parameter calculated from the raw observations (Table 16) was the same as the sill generated from the remapped and original map unit residuals in the *iid* model in Proc GLM indicating that the fixed effects did not effectively capture the variability in soil pH (Tables 17 and 18, respectively).

In Field 5, there was no visual relationship between remapped or original soil map units with respect to soil P on the interpolated nutrient maps (Fig. 19). There were no differences in soil P among remapped or original soil map units or zones (Tables 12, A3, and A4). The interaction was also not significant for the remapped and original soil data. The average P level in Field 5 was 50 kg ha^{-1} (Table 12). The remapped soil map unit ANOVA r^2 was 0.05, meaning that this statistical model did not capture the spatial variability of soil P within the remapped soil map units. The original soil map unit ANOVA r^2 was very low at 0.02, again indicating that this statistical model was not effective in capturing the variability of soil P in Field 5 (Table 12). The average soil P was classified as having a low nutrient status. The yield in Field 5 would benefit greatly from an addition of P fertilizer.

In Proc MIXED where the spatial covariance was modeled, there were no differences in soil P among the remapped or original map units in Field 5 (Tables 13, 14, and 15). There were differences in soil P among the original zones where the soil P was greater within the transition zone for all original map units (Table 15).

There were no differences in soil P among the remapped and original map units in both statistical models, but there were differences in soil P among the original zones in Proc MIXED only. By being significant in Proc MIXED and not Proc GLM, the spatial covariance was accounted for in the error structure and a more true approximation of the variance was calculated. Differences that were not apparent in Proc GLM were then detected in Proc MIXED. The range of spatial dependence of soil P was 576 m in Field 5 (Table 16). Over half of the maximum lag distance, there was little spatial covariance structure meaning that there was relatively little increase in semivariance as lag distance increased. The sill parameter calculated from the raw observations (Table 16) was slightly greater than the sill generated from the remapped and original soil map unit residuals in the *iid* model in Proc GLM (Tables

17 and 18, respectively) indicating that a small portion of the variability in soil P was accounted for by the fixed effects in the *iid* model.

In Field 5, there was no visual relationship between remapped or original soil map units with respect to soil K on the interpolated nutrient maps of Field 5 (Fig. 20). There were differences in soil K among the remapped soil map units (Tables 12 and A3). The mean soil K level in Field 5 was 268 kg ha^{-1} and was classified as having a very high nutrient status with respect to soil K (Table 12). The remapped soil map unit ANOVA r^2 was 0.20 indicating that 20% of the variability in soil K was explained by this statistical model (Table 12).

There were also differences in soil K among the original map units and zones for Field 5 (Tables 12 and A4). The original soil map unit ANOVA r^2 was 0.17 indicating that the remapped soil map unit model was slightly more effective in capturing the spatial variability of soil K in Field 5 (Table 12).

There were no differences in soil K among the remapped or original map units or zones in Proc MIXED (Tables 13, 14, and 15). The interaction between original map units and zones was significant indicating that soil K was greater in the map unit interior for the original Wedowee_B map unit and Wake-Wateree-Wedowee complex and was lower in the map unit interior for the remaining original map units (Table 19).

There were differences in soil K among the remapped and original map units and the original zones in Proc GLM, but not with the spatial covariance model in Proc MIXED indicating that the variability that was captured in Proc GLM was resultant of the spatial correlation accounted for in the Proc MIXED model. Thus the factors were rendered non-significant in Proc MIXED. Conversely, the original interaction was significant in Proc MIXED, but not Proc GLM meaning that the spatial covariance was accounted for by the error structure in the spatial covariance model and the true variance was approximated, thus detecting differences that would normally not be apparent. The range of spatial dependence of soil K was 159 m (Table 16). The sill parameter calculated from the raw observations (Table 16 was greater than the sill generated from the remapped and original soil map units residuals in the *iid* model in Proc GLM (Tables 17 and 18, respectively) indicating that a proportion of the variability in soil K was accounted for by the fixed effects.

There was no visual relationship between remapped or original soil map units with respect to lime requirement on the interpolated nutrient maps of Field 5 (Fig. 21). There were differences in lime requirement among the remapped soil map units (Tables 12 and A3). There were no differences in lime requirement among remapped zones and no interaction between remapped map units and zones (Table 13). The average lime requirement for Field 5 was 0.1 Mg ha^{-1} (Table 12). The remapped soil map units ANOVA r^2 was 0.16 signifying that a small proportion of the variability was captured in this statistical model (Table 12).

There were no differences in lime requirement among the original soil map units, original zones, and no interaction between original map units and zones (Tables 12 and A4). The original soil map unit ANOVA r^2 was 0.04 indicating that the remapped statistical model was more effective in capturing the variability of the lime requirement for Field 5 (Table 12).

In Proc MIXED, there were no differences in lime requirement among the remapped or original soil map units or zones (Tables 13, 14, and 15). The interaction between soil map unit and zone was also not significant for both the remapped and original data.

There were significant differences in lime requirement among the remapped map units in Proc GLM but the same factor was not significant in Proc MIXED signifying that the variability that was captured in Proc GLM was the result of the spatial correlation accounted for in the spatial covariance model in Proc MIXED. Thus, when modeled in Proc MIXED, the map unit factor became non-significant. All other factors were non-significant in both statistical models. Lime requirement was spatially correlated to a range of 1731 m (Table 16). The sill parameter calculated from the raw observations (Table 16) was slightly greater than the sill generated from the remapped and original residuals in the *iid* model in Proc GLM (Tables 17 and 18, respectively) indicating that a proportion of the variability in lime requirement was accounted for by the fixed effects in the *iid* model for both the remapped and original soil map units.

For the investigated soil chemical properties in Field 5, neither of the *iid* models (remapped or original) explained much of the variability of these parameters as the ANOVA r^2 values were fairly small. The remapped soil map unit model ANOVA r^2 values were greater than the original soil map unit models. The disparity between ANOVA r^2 values was greatest for the lime requirement where the remapped ANOVA r^2 was greater than the original soil map units ANOVA r^2. The spatially correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED iid model.

Field 5 2002 Wheat Yield

The yield map for wheat in 2002 showed no visual relationship between yield and remapped or original soil map units (Fig. 22). The interaction between remapped soil map units and remapped zones was significant meaning that wheat yield was not necessarily greater in the transition zone for all remapped soil map (Tables 12, A3, and A5). The average wheat yield in Field 5 was 4.0 Mg ha^{-1} (Table 12) and the remapped soil map unit ANOVA r^2 was 0.05 (Table 12). The small remapped ANOVA r^2 indicated that only 5% of the variability in wheat yield was captured by this statistical model for Field 5.

There were differences in wheat yield among the original zones as the wheat yield was slightly greater within the transition zone (Tables 12 and A4). The original soil map unit ANOVA r^2 was 0.01 (Table 12). The remapped soil map unit model was slightly more effective than the original map unit model in capturing the spatial variability in wheat yield for Field 5, but in both cases the r^2 values were very low.

There were no differences in wheat yield among the remapped or original map units or zones in Proc MIXED (Tables 13, 14, and 15). Their interaction was also non-significant.

All factors that were significant in Proc GLM became non-significant in Proc MIXED indicating that the wheat yield variability captured in Proc GLM was resultant of the spatial correlation accounted for in the spatial covariance model in Proc MIXED. The range of spatial correlation of wheat yield was 1833 m (Table 16). The sill of the raw wheat yield observations (Table 16) was slightly greater than the sill of the residual *iid* model remapped soil map unit semivariogram indicating that the remapped fixed effects accounted for only a slight proportion of the variability (Table 17). Among the original soil map units, the sill of the original residual iid model (Table 18) was approximately the same as the raw observation sill indicating that the variability was not captured by the original fixed effects.

In Field 5 neither model (remapped or original) explained the extent of the variability of the wheat yield as the ANOVA r^2 values were fairly small. The ANOVA r^2 values were greater for the remapped map unit models than for the original map unit models. The spatial correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED *iid* model.

Field 7 Soil Chemical Properties

There was no visual relationship between remapped or original soil map units with respect to soil pH on the interpolated nutrient maps of Field 7 (Fig. 23). There were differences in pH among remapped map units, but not among the original soil map units (Tables 20, A6, and A7). The interaction between original soil map units and zones was also significant (Table A8). The remapped soil map unit ANOVA r^2 was 0.48 indicating that this model was fairly effective in capturing the variability of soil pH (Table 20). The interaction between original soil map units and transition zones was also significant (Table 20). The ANOVA r^2 was 0.47 for the original soil map unit model, signifying that both models, remapped and original, were somewhat effective in capturing the soil pH variability.

In the Proc MIXED covariance model there were no differences in pH among remapped nor original map units or zones, and no interaction between them (Tables 21, 22, and 23). In Field 7, there were differences in soil pH among the remapped and original map units in Proc GLM, but not with the spatial covariance model in Proc MIXED. Remapped and original map units as well as the interaction between the original map units and original zones became non-significant in Proc MIXED, thus indicating that most of the variability that these factors captured in Proc GLM was the result of the spatial correlation accounted for in the Proc MIXED model. When Proc MIXED modeled this spatial correlation and adjusted the analysis of the factors tested for spatial correlation, the remapped and original map units and original interaction became non-significant. The range of spatial dependence of soil pH was 150 m (Table 24). The sill parameter calculated from the raw observations (Table 24) was greater than the sills generated from the remapped and original residuals in the *iid* model in Proc GLM (Tables 25 and 26, respectively). Since the raw observation sill was larger than the residuals sill, a significant proportion of the variability in soil pH was accounted for by the fixed effects in the *iid* residual models.

In Field 7, there was no visual relationship between remapped or original soil map units with respect to soil P on the interpolated nutrient maps of Field 7 (Fig. 24). There were differences in soil P among the remapped and original soil map units in Field 7 (Tables 20, A6, and A7). The mean soil P level was 99 kg ha^{-1} in Field 7 (Table 20). The remapped soil map unit ANOVA r^2 was 0.15 indicating that this model was not very effective in capturing the variability in soil P (Table 20). The average soil P among the remapped map units was classified as having medium nutrient status meaning there would be some yield response to the addition of P fertilizer. Among the original map units and original zones, there were differences in soil P (Table 20 and A7). The original map units ANOVA r^2 was 0.19, which was slightly greater than the ANOVA r^2 for the remapped soil map units (Table 20).

Table 21 illustrates that there were no differences in soil P among remapped or original map units when spatial covariance was modeled in Proc MIXED (Tables 21, 22, and 23). The interaction was not significant for both the remapped and original data. Proc MIXED indicated that there were differences in soil P among the original and remapped zones with the soil P levels higher in the interior map unit areas (Table 21).

Proc GLM indicated that there were differences in soil P among remapped and original map units, but these same factors were not significant in Proc MIXED. Conversely, there were differences in soil P between zones in Proc MIXED, but not in Proc GLM for the remapped map units. In Proc MIXED, the spatial correlation was accounted for in the error structure, enabling the true differences to be detected that were not seen in Proc GLM. In both Proc GLM and MIXED, there were differences in soil P between the original zones. Where soil P was different among the factors in Proc GLM and were non-significant in Proc MIXED, the spatial covariance model adjusted the level of these factors to make the factors non-significant. Soil P was spatially dependent to a range of 111 m (Table 24). A significant proportion of the variability in soil P was not accounted for by the fixed effects in the *iid* model because the sill of the raw observation semivariogram (Table 24) was less than the sill from the residual model semivariogram for both remapped and original soil map units (Tables 25 and 26, respectively).

There was no visual relationship between remapped soil map units with respect to soil K on the interpolated nutrient maps of Field 7 (Fig. 25). It does appear visually that the original map units somewhat captured the areas of varying K levels as the high, medium, and low values correspond to the original soil map units. It should be noted however, that the distinct line of higher soil K levels for Field 7 correspond directly to the previous management of the field. The southern portion of the field where the soil K levels were noticeably higher corresponds to an area that was previously forested and cleared for use as agricultural land in the early 1990's. This distinct region of higher soil K values may have been a result of the difference in nutrient cycling between forested and agricultural systems. It was also possible that the northern portion of the field that has been in production for a longer time period was not supplied with sufficient K fertilizer. The Piedmont soils are inherently high in K due to high mica content in the soil and the producer may not have added the appropriate amount of fertilizer K leading to lower values in the northern part of Field 7. In Proc GLM there were differences in soil K levels among the remapped and original soil map units (Tables 20 and A6), but no differences between zones and no interactions. The mean soil K level for the remapped soil map units in Field 7 was 476 kg ha^{-1} and was classified as having very high nutrient status meaning that there would not be a yield response to the addition of soil K (Table 20). The remapped ANOVA r^2 was 0.82 indicating that this statistical model explained most of the variability of soil K among the remapped soil map units (Table 20). This ANOVA r^2 values was the greatest among all parameters tested in all locations. Proc GLM also reported that there were differences in soil K among the original soil map units (Tables 20 and A6). The original ANOVA r^2 was 0.77; again indicating that most of the variability of soil K among the original map units was captured in this statistical model, but the remapped soil map unit model was slightly more effective in describing the soil K variability (Table 20).

There were no differences in soil K among the remapped soil map units or between the remapped zones in Proc MIXED (Tables 21 and 22). Their interaction was also not significant. Table 23 shows Proc MIXED results indicating that there were differences in soil K levels among original map units and original zones. Soil K was greater in the Wedowee_B map unit and was greater within the original transition zones. Even though there were differences between the original map units with respect to soil K levels, the soil K levels were classified as high or very high, indicating that there would not be a yield response to the addition of K fertilizer.

Soil K was different among remapped soil map units in Proc GLM, but not in Proc MIXED. Among the original soil map units, differences in soil K among map units were apparent in both statistical models. Soil K was also different within the original zones in Proc MIXED, but not in Proc GLM. This signified that by accounting for the spatial covariance in the error structure, the true variance was approximated and original zones then became significant. The range of spatial dependence of soil K was infinite to a point beyond the largest separation distance sampled (Table 24). The sill calculated from the raw soil K observations (Table 24) was undefined and was therefore unable to be compared to the sill calculated from the remapped and original residuals in the *iid* models (Tables 25 and 26, respectively)

There was no visual relationship between remapped or original soil map units with respect to lime requirement on the interpolated nutrient maps of Field 7 (Fig. 26). There were differences in lime requirement among remapped soil map units in Proc GLM (Tables 20, A6). The interaction between original soil map units and original zones was significant in Proc GLM (Tables 20, A7, and A8). The average lime requirement in Field 7 was 0.2 Mg ha^{-1} (Table 20). The remapped ANOVA r^2 was 0.40 meaning that 40% of the variability in lime requirement was captured by this model (Table 20).

The original soil map unit ANOVA r^2 was 0.23 (Table 20). The remapped soil map unit model was more effective at capturing the variability of lime requirement in Field 7.

There were differences in lime requirement among the remapped soil map units in Proc MIXED (Tables 21 and 22). The lime requirement for the Chewacla_V map unit was statistically greater than the amounts of lime needed for the other map units in Field 7 (Table 22). The lime amount required in the remapped Chewacla_V map unit was 1.0 Mg ha^{-1}. There were no differences in lime requirement among the remapped or original zones and the interaction was also not significant for both the remapped and original soils data (Tables 21, 22, and 23). There were differences in lime requirement among remapped soil map units for both Proc GLM and Proc MIXED models. In Proc GLM, the interaction between original soil map units and original zones was significant, but this interaction was non-significant in Proc MIXED. Proc MIXED modeled for spatial correlation and adjusted the factors involved in the interaction for spatial autocorrelation, thus rendering the interaction non-significant. In Field 7 lime requirement was spatially correlated to a distance of 125 m (Table 24). The sill of the raw data lime requirement semivariogram (Table 24) was greater than the sill of the semivariogram calculated from the remapped and original map unit residuals of the iid model (Tables 25 and 26, respectively), signifying that the fixed effects in the model accounted for a significant proportion of the variability in lime requirement. Among the original map unit zones, there were differences in various soil chemical properties for each field. Even though there were significant differences for the soil chemical properties among the original map units, in most cases soil management would not be affected as the differences were small and/or occurred at soil test levels that would not likely respond to inputs.

The statistical model in Proc MIXED provided more realistic estimates of the Piedmont soil chemical properties by accounting for the spatial covariance in the error structure. The ANOVA r^2 for the remapped soil K model was the greatest among all soil chemical properties tested in all locations. The ANOVA r^2 was greater for the remapped soil map unit models except for soil P where the original soil map unit model had a slightly greater ANOVA r^2 value. The spatial correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED iid model for all of the investigated soil chemical properties.

Field 7 2002 Corn Yield

The yield map for corn in 2002 showed no visual relationship between yield and the original soil map units (Fig. 27). There was a slight visual relationship between yield and the remapped soil map units where the higher corn yields appear to be associated with the remapped Wedowee_B soil map unit. In Proc GLM, the interaction between remapped soil map units and transition zone was significant (Tables 20, A6, and A9). The average corn yield in Field 7 was 5.8 Mg ha^{-1} (Table 21). The remapped soil map unit ANOVA r^2 was 0.40 indicating that some of the variability in corn yield was captured in this statistical model (Table 20). The interactions between soil map units and zones were also significant for the original and remapped map units for corn yield in Field 7 (Tables 20, A7, and A8). The original soil map unit ANOVA r^2 was 0.31 indicating that about one-third of the variability in corn yield was captured by this statistical model (Table 20). The remapped statistical model was more effective in capturing the corn yield variability as the ANOVA r^2 value was greater.

There were no differences in corn yield among the remapped or original soil map units in Proc MIXED (Tables 21, 22, and 23). The interaction between map unit and transition zone was also not significant for either the remapped or original soil data. There were differences in corn yield among the remapped zones where the corn yield was lower within the transition zone for all remapped soil map units (Table 22). There was no yield data collected in the remapped Chewacla_A, Chewacla_V, or Wehadkee_A map units (Fig 27B). No yield data was collected for the original Chewacla map unit.

There were differences in corn yield among the remapped and original soil map units in Proc GLM, but not in Proc MIXED where the model included spatial correlation. In Proc GLM the interaction was also significant at the 0.05 probability level for both the remapped and original soils data. Both of these factors were significant in Proc GLM, but were non-significant in Proc MIXED indicating that the variability in corn yield that was captured by the Proc GLM model was resultant of spatial correlation accounted for in the Proc MIXED model. There were significant differences in corn yield among the remapped zones in both Proc GLM and Proc MIXED. The sill parameter of the semivariogram was greater for the raw yield observations (Table 24) than for the remapped and original soil map unit residuals calculated by the *iid* model (Tables 25 and 26, respectively). This indicated that a significant proportion of the variability of corn yield was accounted for by the fixed effects in the statistical model.

In Field 7, both models explained some proportion (30-40%) of the variability of the corn yield. The remapped map unit model ANOVA r^2 values were greater than the original map unit model values. The ANOVA r^2 values for the yield in Field 7 were greater than any ANOVA r^2 values among the Piedmont fields for both the remapped and original soil map units. The spatial correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED *iid* model.

For all fields in the Piedmont, the remapped soil information was slightly more effective than the original soils data at predicting the yield within each respective field, as the ANOVA r^2 was greater for the remapped soil map units than for the original map units. The strength of this correlation was quite weak in Fields 3 and 5, but stronger in Field 7, indicating that the Field 3 and 5 models did not effectively capture the yield variability within those fields. In Field 7 some of the variability was captured within the statistical models for both the remapped and original soil map units. The improvement in correlation in remapped soil map units might be due in part to the increased number of map units. The yield among the original zones in Fields 3 and 5 was different, but the yield was not different among the original zones in Field 7 or among the remapped zones in all Piedmont fields.

Coastal Plain

Soil Chemical Properties

In the Coastal Plain, a visual relationship existed between soil pH and the remapped soil map units as the soil pH within some of the smaller map units appeared to be relatively uniform (Fig. 28). There was no relationship between soil pH and the original map units on the interpolated nutrient maps (Fig. 28). There were differences in pH among remapped soil map units (Tables 27 and A10). The average soil pH in the Coastal Plain for the remapped soil map units was pH 5.4 (Table 27). Even though there were differences in soil pH among the remapped soil map units in the Coastal Plain, the ANOVA r^2 was 0.05 indicating that this model explained only a very small proportion of the variability of the soil pH within this field (Table 27). The target pH for the investigated crops (soybean and wheat) in the Coastal Plain was pH 6.0. There were no differences in pH among original map units or between zones (Tables 27 and A11) and the ANOVA r^2 values were very low indicating that these statistical models were not effecting in accounting for the variability in soil pH.

There were differences in pH among remapped soil map units as calculated by the spatial covariance model in Proc MIXED (Table 28). The highest soil pH (5.5) was associated with the remapped Noboco soil map unit, while the lowest soil pH in the Coastal Plain was associated with the remapped Norfolk_A soil map unit (Table 29). There was no difference in soil pH among the original soil map units or zones in Proc MIXED (Tables 28 and 30). The LSMEANS from Proc MIXED were the same as the LSMEANS generated from Proc GLM indicating that adding the spatial parameters to the statistical model was not necessary to evaluate the differences in soil pH among the remapped soil map units.

In the Coastal Plain, there were differences in soil pH among the remapped and original map units in both Proc GLM and Proc MIXED. All other factors were non-significant in both statistical models. The range of spatial dependence of soil pH was very large at 1533 m in the Coastal Plain (Table 31). Visual interpretation indicated a nugget of approximately 0.09 and a sill of approximately 0.11 attained over a spatial correlation range of approximately 104 m. The sill of the raw observation semivariogram (Table 31) were the same as the sills generated from the remapped and original *iid* residual models meaning that the fixed effects did not explain the variability of soil pH (Tables 32 and 33, respectively).

There was no visual relationship between soil P levels and remapped or original map units for the interpolated P nutrient maps (Fig. 29). There were differences in soil P levels among the original and remapped soil map units (Tables

27, 28, A10, and A11). The average soil P in the Coastal Plain was 108 kg ha^{-1} (Table 27) and was classified as having medium nutrient status indicating that there would be a small yield response to the addition of P fertilizer. The remapped soil map unit ANOVA r^2 was only 0.11, signifying that only a small proportion of the variability was accounted for by the factors present in the model (Table 27). The original map unit ANOVA r^2 was 0.24 and while this was a low r^2 value, the original map unit model was more effective than the remapped map unit model in accounting for soil P variability (Table 27).

In the Coastal Plain the interaction between remapped soil map units and zones was significant at the 0.05 probability level in Proc MIXED (Tables 28 and 29). Soil P was lower in the transition zone for the Wagram_B soil map unit while it was higher in the transition zones of the other remapped soil map units (Table 34). The highest soil P was associated with the remapped Wagram_B soil map unit interior (127 kg ha^{-1}) and the lowest was associated with the remapped Goldsboro map unit interior (47 kg ha^{-1}) (Table 29). There were differences in soil P among the original soil map units as determined by the spatial covariance model (Table 28). Among the original soil map units, the highest soil P was associated with the Ruston_B soil map unit (129 kg ha^{-1}) and the lowest was associated with the Norfolk_C soil map unit (101 ka ha^{-1}) (Table 30).

Proc GLM indicated that there was a significant difference in soil P among remapped and original map units at the 0.05 probability level. The interaction between remapped soil map units and remapped zone was significant in Proc MIXED and was non-significant in Proc GLM. The range of spatial dependence was

144 m for soil P in the Coastal Plain (Table 31). The sill of the raw observation semivariogram (Table 31) was greater than the sills of the *iid* residual model for both remapped and original soil map units (Tables 32 and 33, respectively). This signified that the fixed effects accounted for a proportion of the variability of soil P in the Coastal Plain.

Among the remapped soil map units, there was a visual relationship where the soil K was fairly uniform in all remapped soil map units except the remapped Wagram_B map unit. Soil K levels within the Wagram_B were variable, ranging from 0 to 98 kg ha^{-1} (Fig. 30). There was no apparent visual relationship between soil K and original map units in the Coastal Plain (Fig. 30). There were significant statistical differences in soil K among remapped soil map units (Tables 27 and A10). The mean soil K level in the Coastal Plain was 44 kg ha^{-1} (Table 27) and was classified as having medium nutrient status. Soils with medium nutrient status would exhibit a crop response to the addition of K fertilizer. The ANOVA r^2 for the remapped soil map unit model was 0.31 indicating that this model was fairly effective at capturing the variability of soil K (Table 27). This ANOVA r^2 was the greatest among all parameters tested in the Coastal Plain.

The relationship between soil K and original map units was not significant, and the statistical model did not explain the extent of the spatial relationship, as the original soil map unit ANOVA r^2 was 0.12 (Tables 27 and A11). The interaction between the original map units and zone was significant implying that soil K levels were not necessarily higher within the transition zone for all map units (Table A12).

There were differences in soil K among the remapped soil map units in the spatial covariance model (Table 28). The soil K was lower in the remapped Wagram_B soil map unit than the other remapped soil map units (Table 29). For some map units, this difference was only 3 kg ha^{-1}, and the declaration of significant differences may have been due to the high number of Wagram_B observations, allowing that mean to be more powerfully estimated. The highest soil K was associated with the remapped Norfolk_A soil map unit (77 kg ha^{-1}). The interaction between the original soil map units and the zones was significant indicating that the soil K levels were not necessarily greater within the transition zone for all of the original soil map units. The soil K in the interior of the Ruston_A and _B soil map units was lower than the soil K in the transition zone, while the opposite was true for the remaining original soil map units (Table 35).

Soil K was different among remapped soil map unit in both Proc GLM and Proc MIXED using the *iid* and spatial covariance models, respectively. Among the original soil map units, the interaction was significant in both statistical models. The range of spatial dependence of soil K was 534 m (Table 31). The sill of the raw observation semivariogram (Table 31) was slightly greater that the sill from the remapped and original *iid* residual semivariograms (Tables 32 and 33, respectively) indicating that the fixed effects were somewhat effective in capturing a proportion of the variability of soil K.

There was not an apparent visual relationship between remapped or original soil mapping units and lime requirement on the interpolated map of the Coastal Plain location (Fig. 31). There were no differences in lime requirement among remapped soil map units in Proc GLM (Tables 27 and A10). The statistical model explained very little of the lime requirement variability as the remapped soil map unit ANOVA r^2 was 0.06 (Table 27). The average lime requirement in the Coastal Plain was 0.4 Mg ha^{-1} (Table 27). The original soil map unit ANOVA r^2 was 0.05, signifying that the original soil map unit model was not effective in capturing the variability of lime requirement (Tables 27 and A11). There were no differences in the lime requirement among the original soil map units and the original zones (Table 27).

With the Proc MIXED spatial covariance model, there were no differences in lime requirement among the remapped or original soil map units and zones (Tables 28, 29 and 30). The interaction was also not significant for the remapped and original soils data (Table 28).

The remapped and original soil map units and zones were non-significant in both statistical models (Proc GLM and Proc MIXED). Lime requirement was spatially dependent to a range of 1305 m (Table 31). Visual interpretation indicated a nugget of approximately 0.7, a sill of approximately 0.10, attained over a spatial correlation range of approximately 104m. The fixed effects did not account for the variability in lime requirement as the sill of the raw observation semivariogram (Table 31) was the same as the sill for the remapped and original *iid* residual model semivariograms for lime requirement in the Coastal Plain (Tables 32 and 33, respectively).

In the Coastal Plain, neither model (remapped or original) explained the variability of the soil chemical properties as the ANOVA r^2 values were fairly small. Generally, the remapped soil map units better captured the variability of the soil chemical properties, except soil P, within the field as the portions of the field that varied in elevation or clay content were mapped due to the scale of the intensive 2002 soil survey. These parameters could affect the distributions of nutrients within the field by providing the necessary environment for nutrient leaching or accumulation. The scale of the original soil survey was too large to encompass these areas of changing topography or clay content. The spatial correlated error models were determined to better capture a significant proportion of the variability, as the AIC values were smaller than the AIC value generated from the Proc MIXED *iid* models for all of the investigated soil chemical properties.

2000 Soybean Yield

The yield map for soybean in 2000 showed an apparent visual relationship between yield and the remapped soil map in the Coastal Plain (Fig. 32). The interaction between the remapped map units and zones was significant implying that soybean yield was not necessarily higher in the transition zone for all map units (Tables 27 and A10). Field-wide average soybean yield in 2000 was 1.0 Mg ha^{-1} (Table 27). These measured yield values in 2000 were approximately 40% low due to a calibration error with the yield monitor.

No visual relationship was observed between the original map units and 2000 soybean yield (Fig. 32). There were differences in 2000 soybean yield among the original soil map units (Tables 27 and A11). The remapped data better predicted soybean yield in 2000 than the original soils data because the ANOVA r^2 for the remapped soil data was 0.35 and only 0.09 for the original soil map units (Table 27). No yield data was collected in the original Bibb or Rains map units.

There was no difference in soybean yield among the remapped or original soil map units or within the zones associated with those mapping units in Proc MIXED (Tables 28, 29, and 30). The interaction was also non-significant for both the remapped and original soil data when modeled with spatial correlation factors.

There were differences in soybean yield among the remapped and original soil map units in Proc GLM, but not in Proc MIXED. All other factors were non-significant in both statistical models. The range of spatial dependence for soybean yield was 103 m (Table 31). The sill generated from the raw observations (Table 31) was approximately the same as the sill generated from the *iid* model residuals (Tables 32 and 33, respectively) signifying that the soybean yield variability was not accounted for by the fixed effects in the model due to the close proximity of these sill values.

2002 Wheat Yield

The 2002 wheat yield map exhibited a visual relationship between remapped soil map units and yield, but not with the original map units (Fig. 33). The interaction between the remapped map units and zones was significant (Tables 27 and A10). In 2002, the average wheat yield in the Coastal Plain was 2.6 Mg ha^{-1} (Table 27). The remapped soil map unit ANOVA r^2 was 0.19 indicating that the spatial model did not capture a large amount of the yield variability for the remapped soil information. The original soil information was even less effective in capturing the yield variability as the ANOVA r^2 was 0.05 (Tables 27 and A11). There was a difference in wheat yield among original soil map units (Table 27). There was no yield data collected in the original Bibb or Rains map units.

There were no differences in wheat yield among the remapped or original soil map units and zones in Proc MIXED. The interactions were also not significant for both the remapped and original data (Tables 28, 29, and 30).

The interaction between remapped soil map units and zone was significant in Proc GLM, but not in Proc MIXED. There were also differences in wheat yield among original soil map units in Proc GLM indicating that the variability in wheat yield that was captured by the Proc GLM model was resultant of spatial correlation accounted for by the factors in the Proc MIXED model. The range of spatial correlation was 1209 m (Table 31). Over half of the maximum lag distance, there was little spatial correlation structure meaning that there was relatively little increase in the semivariance above the nugget as the lag distance increased. The sill of the semivariogram with the raw observation data (Table 31) was greater than the sill of the semivariogram calculated from the remapped map unit residuals of the *iid* model in Proc GLM meaning that the fixed effects accounted for a proportion of the wheat yield variability (Table 32). Among the original map units however, the raw observation sill was the same as the original *iid* model semivariogram sill signifying that the original soil map units did not account for the variability in wheat yield (Table 33).

2002 Soybean Yield

A visual relationship was apparent between the remapped soil map units and 2002 soybean yield on the yield map, but not for the original map units (Fig 34). There were differences in soybean yield among remapped soil map units (Tables 27 and A10). The lower yields in the Wagram_B map unit can be attributed to the low water holding capacity (WHC) of the Wagram soil, where an arenic horizon is present. The remapped Wagram_B map unit was also among the lowest yielding map units in the 2000 soybean and 2002 wheat crops. Average soybean yield in 2002 (1.7 Mg ha^{-1}) was greater than the soybean yield in 2000 in the Coastal Plain (Table 27). This was most likely due to more yield data being collected in the higher yielding portions of the field than in 2000 and a properly calibrated yield monitor. Even though there was a significant difference in the soybean yield among the remapped soil map units, the model did not explain the variability of the yield as the remapped soil map unit ANOVA r^2 was only 0.03 (Table 27).

There were differences in soybean yield among original soil map units as well as among zones (Tables 27 and A11). No yield information was collected from the Bibb or Rains original map units. The original soil map units were slightly more efficient than the remapped soil map units for predicting 2002 soybean yield as the original soil map unit ANOVA r^2 was 0.10 for the statistical model (Table 27).

In the Coastal Plain, there was no difference among the remapped or original soil map units in the Proc MIXED spatial correlation model (Tables 28, 29, and 30). The interaction between original soil map units and original transition zones was significant (Table 28) indicating that soybean yield was lower within the transition zone for the original Norfolk_C map unit and was higher for the other original soil map units except the Lumbee which was the same (Table 35).

For the 2002 soybean yield in the Coastal Plain, there were differences among both remapped and original soil map units and original zones in Proc GLM. The interaction between original soil map units and original zones was significant at the 0.05 confidence level in Proc MIXED where the spatial covariance was modeled. By modeling this spatial covariance, the true variance of the soybean yield was approximated and the interaction became significant. 2002 soybean yield was spatially dependent to a range of 96 m (Table 31), much less than the range of the 2000 soybean yield.

For both soybean and wheat yield in the Coastal Plain, neither model (remapped or original) explained the extent of the variability of these parameters as the ANOVA r^2 values were fairly small. The spatial correlated error model was determined to better capture a significant proportion of the variability, as the AIC value was smaller than the AIC value generated from the Proc MIXED *iid* model for all site years of yield information in the Coastal Plain. The remapped soils information was more efficient for predicting the crop yield for 2000 soybean yield and 2002 wheat yield, while the original soil map units were slightly better predictors of 2002 soybean yield based on the ANOVA r^2 values.

Soil Chemical Properties vs. Yield

There were few significant relationships between any soil chemical property and crop yield in both locations. In the Piedmont, soil pH was significantly related to the 2002 wheat yield in Field 5 ($p=0.002$) (Table 36). When the interpolated soil pH map (Fig. 16) was compared with the wheat yield map (Fig. 30), there was an apparent visual relationship between the two parameters. The areas of higher soil pH were somewhat associated with the areas of higher wheat yield in the field. In the Coastal Plain, soil K was significantly related to the 2000 soybean ($p=0.0001$) and 2002 wheat ($p=0.001$) yields (Table 36). Soil K was not visually associated with areas of higher yield on the maps for the Coastal Plain.

Realistic Yield Expectations

Piedmont

The standard errors for measured yields were determined from SAS Proc MIXED and used for the comparison with RYEs. For this comparison, differences were declared if the disparity between RYEs and measured yields exceeded the standard error of the measured yield. For the 2002 corn harvest in Field 3, the remapped Wedowee_D map unit was greater than the corn RYE (Table 37). There were no other differences between measured yield values or RYEs for the remaining remapped soil map units or among the original soil map units. In 2003, the wheat RYE was greater than the actual measured yield for the remapped and original map units (Tables 37 and 38, respectively). In most cases for Field 3, the RYE was greater than the measured yield. This could have been due poor growing conditions for both of these crops in 2002 and 2003, as it was very dry during the growing season in the Piedmont. Field 3 was irrigated with effluent to prevent yield loss, but the addition of water did not increase the crop yield in Field 3 enough to match the RYEs of the remapped or original soil map units. The measured yields for the remapped soil map units were greater than the RYE value for the wheat crop in Field 5, except in the State_A and State_B soil map units where the yield and RYEs were not different (Tables 39). Among the original soil map units in Field 5, the measured yields were greater than the RYEs (Table 40). In Field 7, the measured corn yields were not different than the RYE values for the remapped soil map units, except in the remapped Wake_C map unit where the measured yield was greater than the corn RYE (Tables 41). The measured yield in the original Wedowee_C map unit was not different than the RYE for corn, but among remaining original map units, the measured corn yield was greater than the RYE (Table 42). Overall in the Piedmont, the difference between the RYE values and the measured yields could be a result of these fields having been irrigated. The current RYE database does not include yield values for irrigated crops.

Coastal Plain

The comparison of measured soybean and wheat yield with the respective RYE values in the Coastal Plain showed that for all of the site-years of yield information, the RYE database values were greater than the actual yield for both the remapped and original soil information (Tables 43 and 44, respectively). The low yield values could be attributed to the insufficient amount of moisture during the growing season for the crops grown in the Coastal Plain. This problem was accentuated by the low WHC of the Coastal Plain soils. Also, in 2000 there was a calibration error with the combine where the recorded yield values were approximately 40% lower than the actual yield. When the reported yields were adjusted for the 40 % difference, they were still lower than the RYE in most cases. The amount of yield information collected for each site-year was not optimal, as there was never yield data for the entire field. The disparity between RYE and actual yields may also have been due to this lack of adequate information.

CONCLUSIONS

In the Piedmont, the complexity of the soils (i.e. impure soil map units) made it difficult to distinguish statistically significant differences in soil chemical properties and yield with respect to soil map units and zones with the Proc MIXED spatial covariance model. The spatial covariance models for soil chemical properties and crop yield were more effective in capturing the spatial variability than the *iid* models, which modeled spatial correlation only by map units and zones. The remapped soil information was usually more effective in predicting soil chemical properties and yield, although the strength of the correlation of soil map units with soil chemical properties and crop yield was weak in the Piedmont. There were no differences in yield among the remapped and original soil map units for all Piedmont fields. Among the zones in the Piedmont, patterns of higher or lower values of soil chemical properties and yield were not detected, although there were some individual differences among the various soil chemical properties and yield in the Piedmont fields. The differences in soil chemical properties and yield that were detected among the zones would not greatly affect management, as the differences between the transition zone and map unit interior were usually small, and the map unit means were usually classified in the same nutrient status category.

The high soil K levels in the Piedmont are most likely due to the inherent amount of K in the soil as well as the management within the fields. The soils within these fields have high mica content, a 2:1 secondary mineral that contains K ions within the interlayer mineral sites. In acidic conditions, the removal of K is enhanced by the effect of high concentrations of H^+ protons exchanging for K ions on the exchange complex. The crops grown in a corn-wheat-soybean rotation do not have high K removal rates, and the amount of clay in the soils of the Piedmont limits K from leaching.

Overall, the fields in the Piedmont were not good candidates for zone management based on mapunits or zones, as the soils within these fields were inherently complex and significant differences in yield and soil chemical properties were difficult to distinguish. The ANOVA r^2 values were very low for most parameters indicating that the statistical model did not effectively capture the extent of the variability of that parameter. It would not be economically feasible for this producer to spend resources on variable rate application of any nutrients or lime within these Piedmont fields.

In the Coastal Plain there were no differences in yield among the remapped or original soil map units. There were differences in soil chemical properties among the soil map units in the Coastal Plain, but the differences would cause very few changes among nutrient management schemes. Where differences were observed, the ANOVA r^2 values in the Coastal Plain were very low, signifying that the statistical model was not effective in capturing the variability in the investigated parameters. The Coastal Plain was not suited for zone management based on map units or zones, as indicated by the low ANOVA r^2 values even though there were fewer map units within the Coastal Plain fields than in the Piedmont fields.

Because the soil pH was below the target pH of 6.0 for the investigated crops in the Coastal Plain, micronutrient deficiencies and aluminum (Al) toxicity can become problematic and lead to decreased yields. Also, low pH can cause problems with calcium availability and P uptake, as Al^{3+} complexes with P at the surface of the root, thus limiting P uptake. However, the lime requirements were still quite low, ranging from 0.3 to 0.7 Mg ha^{-1} for the Coastal Plain.

Soil P was different among the original soil map units and phosphorus management would change as the low end of the soil P range was classified as having medium nutrient status and the high end was classified as having high nutrient status. The yield in the Coastal Plain would benefit from an addition of P fertilizer on those soils classified as having medium nutrient status, but there would likely be no yield response to P for those soils classified as having high nutrient status. The fairly high P levels within the field are possibly a result of the management of the field. Crops in a corn-wheat-soybean rotation remove relatively small amounts of soil P and the producer has been applying turkey litter as a form of fertilizer. Turkey litter is known to contain very high levels of P and provides an inexpensive form of fertilizer for the producer. The crop yield in the Coastal Plain would likely have a yield response to the addition of K fertilizer as the average soil K levels were classified as having low nutrient status. The producer applied turkey litter and inorganic fertilizer to meet the K needs in the Coastal Plain field. Also, K is known to leach from the sandy soils of the Coastal Plain, thus leading to the less than adequate levels of soil K in this field.

Overall, the soils were not as inherently variable in the Coastal Plain as in the Piedmont, and the remapped soil information was more effective in capturing the variability in soil chemical properties and crop yield within the soil map units. The remapped soil map units were smaller in size than the original soil map units where the intensive soil survey better captured differences in soil texture and clay content that were included within the larger Wagram_B soil map unit. The Wagram_B soil map unit has a thick sandy surface horizon where the coarser the soil, the lower the water holding capacity, and the lower the grain yield. Yield was expected to be different between the Wagram_B map unit and the other map units in the Coastal Plain. The other remapped soil map units had a greater WHC than the Wagram_B map unit that would lead to increased yields. On the yield maps, there is an apparent visual correlation between the remapped soil map units and the 2000 soybean and 2002 wheat yields, but these visual relationships were not statistically different when the underlying spatial correlation was included in the statistical model. The lack of differences in yield may be because there were not enough yield data points within each map unit to accurately predict the mean yield and detect statistical differences within the soil map unit. The zones in the Coastal Plain were too variable for patterns in nutrient levels or yield to be statistically identified. There were individual differences between zones for some soil chemical properties, but these differences would not usually affect nutrient or crop management. Again the spatial covariance models were more effective in capturing the spatial variability of soil chemical properties and crop yield than the *iid* models.

The RYE database of yield goals based on soil map units needs further testing to determine if the established RYE values are adequate or excessive. With the current data, the established RYE values in the Coastal Plain appear to be generous, as the actual measured yield values in this study were lower than the RYE value even when harvesting problems were taken into account. The lower actual yields are not unexpected since the RYE was estimated from the average of multiple years of yield data as well as expert opinions of the value of the map unit RYEs. This study only evaluated two site-years of yield data and in most cases, the expert opinions were thought to be generous. In the Piedmont, actual yields were sometimes higher than the RYE values. These may have been due to the irrigation with the bioprocessing plant effluent. Yield variability involves factors other than the influence of soil type or nutrient status, such as weather and pest pressure. As a result, more site-years of yield data are needed to better characterize soil yield potentials. Additional locations would also be useful to be able to investigate more soil map units.

Table 1. Conversions for North Carolina soil test index system.

Index Range	Nutrient Status	Nutrient Range P	Nutrient Range K
		kg ha^{-1}	
0 - 10	Very Low	0 - 24	0 - 39
11 - 25	Low	25 - 60	40 - 98
26 - 50	Medium	61 - 120	99 - 195
51 - 100	High	121 - 240	196 - 390
100+	Very High	241+	390+

Table 2. N factor (lbs N bu^{-1}) for the investigated crops. N factor for soybean was developed for waste applications

Crop	lbs N bu^{-1}
Corn	1.0 - 1.25
Soybean	3.5 - 4.0
Wheat	1.7 - 2.4

Table 3. Original soil classification from USDA NRCS SSURGO Certified Soil Survey. The surveys were completed for the Piedmont and Coastal Plain in 1998 and 1974, respectively.

Map Unit	Map Symbol	Soil Classification
Piedmont		
Chawacla	ChA	Fine-loamy, mixed, active, thermic Fluvaquentic Dystrudepts
Wake-Saw-Wedowee Complex	WaB	
Wake		Mixed, thermic Lithic Udipsamments
Saw		Fine, kaolinitic, thermic Typic Kanhapludults
Wedowee		Fine, kaolinitic, thermic Typic Kanhapludults
Wake-Wateree-Wedowee Complex	WbD	
Wake		Mixed, thermic Lithic Udipsamments
Wateree		Coarse-loamy, mixed, semiactive, thermic Typic Dystrudepts
Wedowee		Fine, kaolinitic, thermic Typic Kanhapludults
Wedowee	WeB, WeC	Fine, kaolinitic, thermic Typic Kanhapludults
Coastal Plain		
Bibb	Bb	Coarse-loamy, siliceous, active, acid, thermic Typic Fluvaquents
Lumbee	Lu	Fine-loamy over sandy or sandy-skeletal, siliceous, subactive, thermic Typic Endoaquults
Norfolk	NoC	Fine-loamy, kaolinitic, thermic Typic Kandiudults
Rains	Ra	Fine-loamy, siliceous, semiactive, thermic Typic Paleaquults
Ruston	RuA, RuB	Fine-loamy, siliceous, semiactive, thermic Typic Paleudults
Wagram	Wa	Loamy, kaolinitic, thermic Arenic Kandiudults

Table 4. Soil classification from the intensive soil survey completed in 2002.

Map Unit	Map Symbol	Soil Classification
Piedmont		
Chewacla	ChA, ChV	Fine-loamy, mixed, active, thermic Fluvaquentic Dystrudepts
Durham	Du, DuB	Fine-loamy, siliceous, semiactive, thermic Typic Hapludults
Helena	HeB, HeC, HeD	Fine, mixed, semiactive, thermic Aquic Hapludults
Pacolet	PaB, PaC, PaD	Fine, kaolinitic, thermic Typic Kanhapludults
State	StA, StB	Fine-loamy, mixed, semiactive, thermic Typic Hapludults
Vance	VaC	Fine, mixed, semiactive, thermic Typic Hapludults
Wake	WkB, WkC, WkD, WkE	Mixed, thermic Lithic Udipsamments
Wateree	WaB, WaD	Coarse-loamy, mixed, semiactive, thermic Typic Dystrudepts
Wedowee	WeB, WeC, WeD	Fine, kaolinitic, thermic Typic Kanhapludults
Wehadkee	WhA	Fine-loamy, mixed, active, nonacid, thermic Fluvaquentic Endoaquepts
Coastal Plain		
Goldsboro	Go	Fine-loamy, siliceous, subactive, thermic Aquic Paleudults
Noboco	Nb	Fine-loamy, siliceous, subactive, thermic Oxyaquic Paleudults
Norfolk	NoA, NoB	Fine-loamy, kaolinitic, thermic Typic Kandiudults
Wagram	WaB, WaC	Loamy, kaolinitic, thermic Arenic Kandiudults

Table 5. ANOVA results from PROC GLM for corn and wheat yield and soil chemical properties for Field 3 in the Piedmont. Overall mean is mathematical average of the raw data.

	Crop Yield		Soil Chemical Properties			
Source of Variation	2002 Corn	2003 Wheat	pH	P	K	Lime
Remapped						
Map unit	*	*	*	NS	*	*
Zone	NS	*	NS	NS	NS	NS
Map unit X Zone	NS	*	NS	NS	NS	NS
Remapped ANOVA r^2	0.13	0.02	0.33	0.09	0.51	0.20
Original						
Map unit	NS	*	NS	*	*	*
Zone	*	NS	NS	NS	NS	*
Map unit x Zone	NS	NS	NS	NS	NS	NS
Original ANOVA r^2	0.07	0.01	0.06	0.04	0.09	0.12
	---Mg ha^{-1}---			---kg ha^{-1}---		Mg ha^{-1}
Overall Mean	8.7	2.3	5.9	73	120	0.20

* Significant at the 0.05 probability level.

Table 6. ANOVA results from PROC MIXED for corn and wheat yield and soil chemical properties for Field 3 in the Piedmont.

	Crop Yield		Soil Chemical Properties			
Source of Variation	2002 Corn	2003 Wheat	pH	P	K	Lime
Remapped						
Map unit	NS	NS	NS	NS	NS	NS
Zone	NS	*	NS	NS	NS	NS
Map unit X Zone	NS	NS	NS	NS	NS	NS
Original						
Map unit	NS	NS	NS	NS	NS	*
Zone	NS	NS	NS	NS	NS	NS
Map unit x Zone	NS	NS	NS	NS	NS	NS

* Significant at the 0.05 probability level.

Table 7. Average corn and wheat yield and soil chemical properties by remapped soil map unit and location within a zone for Field 3 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield		Soil Chemical Properties			
Map unit	2002 Corn†	2003 Wheat	pH	P	K	Lime
	---Mg ha^{-1}---			---kg ha^{-1}---		Mg ha^{-1}
Durham	N/A	2.2	N/A	N/A	N/A	N/A
Durham_B	5.9	2.3	5.9	63	128	0.3
Helena_B	N/A	N/A	N/A	N/A	N/A	N/A
Helena_D	6.4	N/A	5.9	43	81	0.2
Pacolet_B	5.8	N/A	6.1	36	137	0.2
Wateree_D	5.4	N/A	6.2	45	159	0.2
Wedowee_B	6.9	N/A	5.8	88	129	0.2
Wedowee_C	6.3	N/A	5.7	44	109	0.4
Wedowee_D	8.4	N/A	5.8	30	111	0.2
Transition Zone Mean	6.2	2.5a	5.9	52	127	0.2
Interior Mean	6.6	2.1b	5.9	48	117	0.2

† N/A, No data collected within this map unit.

Table 8. Average corn and wheat yield and soil chemical properties by original soil map unit and location within a zone for Field 3 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield		Soil Chemical Properties			
Map unit	2002 Corn†	2003 Wheat	pH	P	K	Lime
	---Mg ha^{-1}---			---kg ha^{-1}---		Mg ha^{-1}
Wake-Saw-Wedowee complex	N/A	N/A	N/A	N/A	N/A	N/A
Wedowee_B	7.2	2.3	5.9	68	134	0.4a‡
Wedowee_C	7.0	2.2	5.9	74	117	0.3b
Transition Zone Mean	7.2	2.3a	5.9	68	126	0.3
Interior Mean	7.0	2.2b	5.8	74	126	0.3

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 9. Summary of spatial statistics for raw observations for Field 3 in the Piedmont. The model r^2 is from the GS+ semivariogram analysis.

Variable	Range (m)	Sill	Nugget†	Model‡	Model r^2
Crop Yield					
2002 Corn	699	7	1.9	E	0.96
2003 Wheat	70	0.23	0.07	S	0.89
Soil Property					
pH	127	0.12	0.03	S	0.99
P	81	5555	60	E	0.90
K	151	2393	119	S	0.99
Lime	156	0.07	0.03	E	0.99

† NN, No-nugget model.
‡ E, exponential model; S, spherical model.

Table 10. Summary of spatial statistics for original map units for Field 3 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	ANOVA r^2	Model[†]	Model r^2
Crop Yield						
2002 Corn	726	6.9	2.0	0.01	E	0.97
2003 Wheat	70	0.23	0.07	0.01	S	0.90
Soil Property						
pH	1101	0.3	0.04	0.06	E	0.97
P	81	5488	260	0.04	E	0.89
K	150	2454	83	0.08	S	0.99
Lime	147	0.06	0.03	0.12	E	0.99

[†] E, exponential model; S, spherical model.

Table 11. Summary of spatial statistics for remapped map units for Field 3 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	ANOVA r^2	Model†	Model r^2
Crop Yield						
2002 Corn	666	5.6	2.1	0.01	E	0.96
2003 Wheat	70	0.23	0.07	0.01	S	0.89
Soil Property						
pH	130	0.09	0.04	0.33	S	0.98
P	98	5349	1910	0.10	S	0.96
K	78	1240	68	0.51	E	0.99
Lime	879	0.08	0.04	0.20	E	0.80

† E, exponential model; S, spherical model.

Table 12. ANOVA results from PROC GLM for wheat yield and soil chemical properties for Field 5 in the Piedmont. Overall mean is mathematical average of the raw data.

	Crop Yield	Soil Chemical Properties			
Source of Variation	2002 Wheat	pH	P	K	Lime
Remapped					
Map unit	*	NS	NS	*	*
Zone	NS	NS	NS	NS	NS
Map unit X Zone	*	NS	NS	NS	NS
Remapped ANOVA r^2	0.05	0.04	0.05	0.20	0.16
Original					
Map unit	NS	NS	NS	*	NS
Zone	*	NS	NS	*	NS
Map unit x Zone	NS	NS	NS	NS	NS
Original ANOVA r^2	0.01	0.03	0.02	0.17	0.04
	---Mg ha^{-1}---		---kg ha^{-1}---		Mg ha^{-1}
Overall Mean	4.0	5.9	50	268	0.1

* Significant at the 0.05 probability level.

Table 13. ANOVA results from PROC MIXED for wheat yield and soil chemical properties for Field 5 in the Piedmont.

	Crop Yield	Soil Chemical Properties			
Source of Variation	2002 Wheat	pH	P	K	Lime
Remapped					
Map unit	NS	NS	NS	NS	NS
Zone	NS	NS	NS	NS	NS
Map unit X Zone	NS	NS	NS	NS	NS
Original					
Map unit	NS	NS	NS	NS	NS
Zone	NS	NS	*	NS	NS
Map unit x Zone	NS	NS	NS	*	NS

* Significant at the 0.05 probability level.

Table 14. Average wheat yield and soil chemical properties by remapped soil map unit and location within a zone for Field 5 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Wheat†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Durham_B	N/A	N/A	N/A	N/A	N/A
Helena_B	3.9	N/A	N/A	N/A	N/A
Helena_C	N/A	N/A	N/A	N/A	N/A
Pacolet_B	3.9	6.0	67	211	0.3
Pacolet_C	3.9	5.9	71	205	0.3
Pacolet_D	3.9	5.8	63	217	0.4
State_A	4.0	5.9	83	182	0.3
State_B	4.1	N/A	N/A	N/A	N/A
Vance_C	N/A	N/A	N/A	N/A	N/A
Wake_B	3.9	N/A	N/A	N/A	N/A
Wake_D	N/A	N/A	N/A	N/A	N/A
Wake_E	3.9	6.1	112	171	0.5
Wateree_B	N/A	N/A	N/A	N/A	N/A
Wedowee_B	3.6	N/A	N/A	N/A	N/A
Transition Zone Mean	3.9	5.9	101	212	0.4
Interior Mean	3.9	5.9	57	189	0.4

† N/A, No data collected within this map unit.

Table 15. Average wheat yield and soil chemical properties by original soil map unit and location within a zone for Field 5 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Wheat†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla_A	N/A	N/A	N/A	N/A	N/A
Wake-Saw- Wedowee complex	3.9	5.9	44	231	0.3
Wake-Wateree-Wedowee complex	3.8	6.0	52	260	0.3
Wedowee_B	3.9	5.7	61	236	0.3
Transition Zone Mean	3.9	5.9	63a‡	270	0.4
Interior Mean	3.9	5.9	41b	214	0.2

† N/A, No data collected within this map unit.

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 16. Summary of spatial statistics for raw observations for Field 5 in the Piedmont. The model r^2 is from the GS+ semivariogram analysis.

Variable	Range (m) †	Sill†	Nugget	Model‡	Model r^2
Crop Yield					
2002 Wheat	1833	5.3E+05	2.7E+05	E	0.78
Soil Property					
pH	∞	∞	0.67	L	0.76
P	576	5715	2190	S	0.96
K	159	8811	130	E	0.99
Lime	1731	0.10	0.03	E	0.99

† ∞, Parameters infinite in Linear model.
‡ E, exponential model; L, linear model; S, spherical model.

Table 17. Summary of spatial statistics for remapped map units for Field 5 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m) †	Sill†	Nugget	ANOVA r^2	Model‡	Model r^2
Crop Yield						
2002 Wheat	1833	5.1E+05	2.5E+05	0.05	E	0.76
Soil Property						
pH	∞	∞	0.65	0.04	L	0.78
P	611	5579	2120	0.05	S	0.96
K	147	7299	860	0.20	E	0.99
Lime	554	0.06	0.04	0.15	S	0.98

† ∞, Parameters infinite in Linear model.
‡ E, exponential model; L, linear model; S, spherical model.

Table 18. Summary of spatial statistics for original map units for Field 5 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m) †	Sill†	Nugget‡	ANOVA r^2	Model§	Model r^2
Crop Yield						
2002 Wheat	1833	5.3E+05	2.6E+05	0.001	E	0.78
Soil Property						
pH	∞	∞	0.66	0.03	L	0.78
P	584	5690	2130	0.02	S	0.97
K	120	7156	2180	0.17	S	0.99
Lime	1704	0.09	0.03	0.04	E	0.99

† ∞, Parameters infinite in Linear model.
‡ NN, No-nugget model.
§E, exponential model; L, linear model; S, spherical model.

Table 19. Soil K simple effect means from interaction between original soil map units and zones for Field 5 in the Piedmont. Means reported are LSMEANS from the Proc MIXED spatial covariance model

Map Unit	Transition Zone	Map Unit Interior
	--------kg ha^{-1}--------	
Chewacla_A	144	N/E†
Wateree_B	241	220
Wedowee_B	217	254
Wake-Wateree-Wedowee complex	253	268

†N/E, non-estimable in SAS.

Table 20. ANOVA results from PROC GLM for corn yield and soil chemical properties for Field 7 in the Piedmont. Overall mean is mathematical average of the raw data.

	Crop Yield	Soil Chemical Properties			
Source of Variation	2002 Corn	pH	P	K	Lime
Remapped					
Map unit	*	*	*	*	*
Zone	*	NS	NS	NS	NS
Map unit X Zone	*	NS	NS	NS	NS
Remapped ANOVA r^2	0.40	0.48	0.15	0.82	0.40
Original					
Map unit	*	*	*	*	*
Zone	NS	NS	*	NS	NS
Map unit x Zone	*	*	NS	NS	*
Original ANOVA r^2	0.31	0.47	0.19	0.77	0.23
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Overall Mean	5.8	6.1	99	476	0.2

* Significant at the 0.05 probability level.

Table 21. ANOVA results from PROC MIXED for corn yield and soil chemical properties for Field 7 in the Piedmont.

	Crop Yield	Soil Chemical Properties			
Source of Variation	2002 Corn	pH	P	K	Lime
Remapped					
Map unit	NS	NS	NS	NS	*
Zone	*	NS	*	NS	NS
Map unit X Zone	NS	NS	NS	NS	NS
Original					
Map unit	NS	NS	NS	*	NS
Zone	NS	NS	*	*	NS
Map unit x Zone	NS	NS	NS	NS	NS

* Significant at the 0.05 probability level.

Table 22. Average corn yield and soil chemical properties by remapped soil map unit and location within a zone for Field 7 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Corn†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla_A	N/A	6.2	80	434	0.3b‡
Chewacla_V	N/A	5.7	122	447	1.0a
Wake_C	4.8	6.2	110	545	0.2b
Wateree_D	5.2	6.1	128	345	0.1b
Wedowee_B	5.2	5.9	95	399	0.2b
Wedowee_D	4.7	5.9	80	415	0.2b
Wehadkee_A	N/A	6.2	138	602	0.1b
Transition Zone Mean	4.8b	6.0	94b	461	0.3
Interior Mean	5.2a	6.0	122a	449	0.3

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 23. Average corn yield and soil chemical properties by original soil map unit and location within a zone for Field 7 in the Piedmont. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Corn†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla	N/A	6.0	63	333b‡	0.2
Wake-Wateree-Wedowee complex	5.4	5.9	92	423b	0.2
Wedowee_B	5.4	6.7	137	808a	0.1
Wedowee_C	5.4	N\A	N\A	N\A	N/A
Transition Zone Mean	5.3	6	96b	552a	0.3
Interior Mean	5.5	6	120a	358b	0.3

† N/A, No data collected within this map unit.

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 24. Summary of spatial statistics for raw observations for Field 7 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis.

Variable	Range (m) †	Sill†	Nugget	Model‡	Model r^2
Crop Yield					
2002 Corn	91	4.4E+06	6.9E+05	S	0.99
Soil Property					
pH	150	0.20	0.03	S	0.99
P	111	2464	884	E	0.98
K	∞	∞	100	L	0.97
Lime	125	0.26	0.04	S	0.99

† ∞, Parameters infinite in Linear model.
‡E, exponential model; L, linear model; S, spherical model.

Table 25. Summary of spatial statistics for remapped map units for Field 7 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	Model†	Model r^2
Crop Yield					
2002 Corn	525	3.0E+06	1.5E+06	E	0.64
Soil Property					
pH	144	0.12	0.05	E	0.97
P	179	4399	1466	E	0.95
K	756	3.6E+04	1.8E+04	E	0.76
Lime	177	0.16	0.07	E	0.96

†E, exponential model.

Table 26. Summary of spatial statistics for original map units for Field 7 in the Piedmont. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	Model†	Model r^2
Crop Yield					
2002 Corn	45	2.6E+06	1000	E	0.97
Soil Property					
pH	93	0.13	0.03	E	0.98
P	993	3193	1596	E	0.93
K	117	3.8E+04	4800	S	0.99
Lime	106	0.20	0.07	S	0.99

† E, exponential model; L, linear model; S, spherical model.

Table 27. ANOVA results from PROC GLM for crop yield and soil chemical properties in the Coastal Plain. Overall mean is mathematical average of the raw data.

	Crop Yield			Soil Chemical Property			
Source of Variation	2000 Soybean	2002 Wheat	2002 Soybean	pH	P	K	Lime
Remapped							
Map unit	*	*	*	*	*	*	NS
Zone	NS	NS	NS	NS	NS	NS	NS
Map unit X Zone	*	*	NS	NS	NS	NS†	NS
Remapped ANOVA r^2	0.35	0.19	0.03	0.05	0.11	0.31	0.06
Original							
Map unit	*	*	*	NS	*	NS	NS
Zone	NS	NS	*	NS	NS	NS	NS
Map unit x Zone	NS	NS	NS	NS	NS	*	NS
Original ANOVA r^2	0.09	0.05	0.10	0.05	0.24	0.12	0.05
	------------Mg ha^{-1}------------				---kg ha^{-1}---		Mg ha^{-1}
Overall Mean	1.0	2.6	1.7	5.4	108	44	0.4

* Significant at the 0.05 probability level.

Table 28. ANOVA results from PROC MIXED for crop yield and soil chemical properties in the Coastal Plain.

	Crop Yield			Soil Chemical Property			
Source of Variation	2000 Soybean	2002 Wheat	2002 Soybean	pH	P	K	Lime
Remapped							
Map unit	NS	NS	NS	*	*	*	NS
Zone	NS	NS	NS†	NS	*	NS	NS
Map unit X Zone	NS	NS	NS	NS	*	NS	NS
Original							
Map unit	NS	NS	NS	NS	*	NS	NS
Zone	NS	NS	*	NS	NS	NS	NS
Map unit x Zone	NS	NS	*	NS	NS	*	NS

* Significant at the 0.05 probability level.

Table 29. Average crop yield and soil chemical properties for remapped soil map units and location within a zone for the Coastal Plain. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield			Soil Chemical Properties			
Map unit	2000 Soybean	2002 Wheat	2002 Soybean	pH	P	K	Lime
	------------Mg ha^{-1}------------				---kg ha^{-1}---		Mg ha^{-1}
Goldsboro	1.9	2.5	2.0	5.2b‡	63	71a	0.5
Noboco	1.6	2.7	1.9	5.5a	96	55a	0.5
Norfolk_A	1.8	2.6	1.8	5.0b	101	77a	0.7
Norfolk_B	0.6	2.5	1.9	5.4ab	90	53a	0.4
Wagram_B	1.0	2.4	1.7	5.4ab	121	50b	0.4
Transition Zone Mean	1.3	2.5	1.8	5.3	102	63	0.6
Interior Mean	1.4	2.6	1.9	5.3	85	60	0.5

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 30. Average crop yield and soil chemical properties by original soil map unit and location within a zone for the Coastal Plain. Means reported are LSMEANS from Proc Mixed in SAS.

	Crop Yield			Soil Chemical Properties†			
Map unit	2000 Soybean	2002 Wheat	2002 Soybean	pH	P	K	Lime
	------------Mg ha^{-1}------------				---kg ha^{-1}---		Mg ha^{-1}
Bibb	N/A†	N/A	N/A	N/A	N/A	N/A	N/A
Lumbee	0.8	N/A	1.7	5.5	122ab‡	50	0.5
Norfolk_C	0.8	2.5	1.9	5.4	101b	48	0.4
Rains	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ruston_A	0.8	2.5	1.7	5.4	124ab	41	0.4
Ruston_B	0.9	N/A	1.7	5.4	129a	47	0.5
Wagram_B	0.8	2.4	1.7	5.4	120ab	45	0.4
Transition Zone Mean	0.8	2.5	1.8	5.4	120	46	0.5
Interior Mean	0.8	2.5	1.7	5.4	118	47	0.4

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table 31. Summary of spatial statistics for raw observations in the Coastal Plain. The parameters were generated from the GS+ semivariogram analysis.

Variable	Range (m)	Sill	Nugget	Model†	Model r^2
Crop Yield					
2000 Soybean	103	0.20	0.05	S	0.99
2002 Wheat	1209	0.76	0.38	E	0.45
2002 Soybean	96	0.26	0.07	S	0.93
Soil Property					
pH	1533	0.17	0.09	E	0.83
P	144	1942	315	S	0.99
K	534	388	152	E	0.97
Lime	1305	0.14	0.07	E	0.84

† E, exponential model; S, spherical model.

Table 32. Summary of spatial statistics for remapped map units in the Coastal Plain. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	ANOVA r^2	Model†	Model r^2
Crop Yield						
2000 Soybean	594	0.19	0.09	0.35	E	0.92
2002 Wheat	411	0.64	0.32	0.03	E	0.59
2002 Soybean	100	0.26	0.07	0.20	S	0.95
Soil Property						
pH	1533	0.17	0.09	0.06	E	0.87
P	130	1778	294	0.11	S	0.99
K	1533	307	153	0.31	E	0.99
Lime	1503	0.14	0.07	0.06	E	0.81

† E, exponential model; S, spherical model.

Table 33. Summary of spatial statistics for original map units in the Coastal Plain. The parameters were generated from the GS+ semivariogram analysis of the residual *iid* model.

Variable	Range (m)	Sill	Nugget	ANOVA r^2	Model†	Model r^2
Crop Yield						
2000 Soybean	84	0.18	0.01	0.09	E	0.98
2002 Wheat	1233	0.76	0.37	0.05	E	0.41
2002 Soybean	81	0.24	0.01	0.10	E	0.82
Soil Property						
pH	1533	0.17	0.09	0.05	E	0.75
P	117	1399	378	0.24	S	0.99
K	261	279	139	0.12	E	0.97
Lime	1533	0.14	0.07	0.05	E	0.86

† E, exponential model; S, spherical model.

Table 34. Soil P simple effect means from interaction of remapped soil map units and zones in the Coastal Plain. Means reported are LSMEANS from the Proc MIXED spatial covariance model

Map Unit	Transition Zone	Map Unit Interior
	------------kg ha^{-1}------------	
Goldsboro	80	47
Noboco	112	80
Norfolk_A	105	96
Norfolk_B	101	80
Wagram_B	116	127

Table 35. Soil K and 2002 soybean yield simple effect means from interaction of original soil map units and zones in the Coastal Plain. Means reported are LSMEANS from the Proc MIXED spatial covariance model

	Soil K		2002 Soybean Yield	
Map Unit	Transition Zone	Map Unit Interior	Transition Zone	Map Unit Interior
	-----kg ha^{-1}-----		-----Mg ha^{-1}-----	
Bibb	N/A†	N/A	N/A	N/A
Lumbee	49	51	1.7	1.7
Norfolk_C	44	51	1.8	1.9
Rains	N/A	N/A	N/A	N/A
Ruston_A	43	39	1.8	1.7
Ruston_B	52	43	1.8	1.6
Wagram_B	41	49	1.8	1.6

†N/A, no data collected within this map unit

Table 36. Correlations between soil chemical properties and crop yield in the Piedmont and Coastal Plain.

	Piedmont Yields				Coastal Plain Yields		
Soil Chemical Property	Field 3 2002 Corn	Field 3 2003 Wheat	Field 5	Field 7	2000 Soybean	2002 Wheat	2002 Soybean
pH	NS	NS	0.002†	NS	NS	NS	NS
P	NS	NS	NS	NS	NS	NS	NS
K	NS	NS	NS	NS	0.0001†	0.003†	NS

† P-value from Proc MIXED output indicating significance at the 0.05 confidence level.

Table 37. Comparison of actual measured corn and wheat yield to RYE for remapped map units in Field 3.

Map Unit	2002 Corn Yield †	Standard Error	Corn RYE	2003 Wheat Yield†	Standard Error	Wheat RYE
	-------------------------------		Mg ha^{-1}		-------------------------------	
Durham	N/A	N/A	5.6	2.2	0.1	3.0
Durham_B	5.9	1.7	5.3	2.3	0.1	2.9
Helena_B	N/A	N/A	5.8	N/A	N/A	3.3
Helena_D	6.4	1.7	4.7	N/A	N/A	3.0
Pacolet_B	5.8	1.8	6.8	N/A	N/A	3.3
Wateree_D	5.4	1.7	4.2	N/A	N/A	3.1
Wedowee_B	6.9	1.7	6.8	N/A	N/A	3.3
Wedowee_C	6.3	1.7	6.3	N/A	N/A	3.2
Wedowee_D	8.4	1.8	5.5	N/A	N/A	3.0

† N/A, No yield data collected within map unit.

Table 38. Comparison of actual measured corn yield to RYE for original map units in Field 3.

Map Unit	2002 Corn Yield†	Standard Error	Corn RYE	2003 Wheat Yield†	Standard Error	Wheat RYE
		------------------------	------------	Mg ha^{-1}	------------	------------------------
Wake-Saw-Wedowee Complex	N/A	N/A	4.6	N/A	N/A	2.1
Wedowee_B	7.2	0.8	6.8	2.3	0.2	3.2
Wedowee_C	7.0	0.8	6.3	2.2	0.2	3.1

† N/A, No yield data collected within map unit.

Table 39. Comparison of actual measured wheat yield to RYE for remapped map units in Field 5.

Map Unit	Actual Yield†	Standard Error	RYE
	---------------Mg ha^{-1}---------------		
Durham_B	N/A	N/A	2.9
Helena_B	3.9	0.3	3.3
Helena_C	N/A	N/A	3.2
Pacolet_B	3.9	0.1	3.3
Pacolet_C	3.9	0.1	3.1
Pacolet_D	3.9	0.1	2.7
State_A	4.0	0.2	4.0
State_B	4.1	0.2	3.9
Vance_C	N/A	N/A	3.1
Wake_B	3.9	0.2	1.3
Wake_D	N/A	N/A	1.0
Wake_E	3.9	0.2	1.0
Wateree_B	N/A	N/A	3.5
Wedowee_B	3.6	0.1	3.3

† N/A, No yield data collected within map unit.

Table 40. Comparison of actual measured wheat yield to RYE for original map units in Field 5.

Map Unit	Actual Yield†	Standard Error	RYE
	----------Mg ha^{-1}----------		
Chewacla_A	N/A	N/A	4.4
Wake-Saw- Wedowee complex	3.9	0.1	2.1
Wake-Wateree-Wedowee complex	3.8	0.1	2.3
Wedowee_B	3.9	0.1	3.3

† N/A, No yield data collected within map unit.

Table 41. Comparison of actual measured corn yield to RYE for remapped map units in Field 7.

Map Unit	Actual Yield†	Standard Error	RYE
	----------Mg ha^{-1}----------		
Chewacla_A	N/A	N/A	9.4
Chewacla_V	N/A	N/A	9.4
Wake_C	4.8	1.7	2.7
Wateree_D	5.2	1.6	4.2
Wedowee_B	5.2	1.6	6.8
Wedowee_D	4.7	1.6	5.5
Wehadkee	N/A	N/A	5.3

† N/A, No yield data collected within map unit.

Table 42. Comparison of actual measured corn yield to RYE for original map units in Field 7.

Map Unit	Actual Yield†	Standard Error	RYE
	----------Mg ha^{-1}----------		
Chewacla	N/A	N/A	9.4
Wake-Wateree-Wedowee complex	5.4	0.7	4.0
Wedowee_B	5.4	0.6	6.8
Wedowee_C	5.4	0.9	6.3

† N/A, No yield data collected within map unit.

Table 43. Comparison of actual measured yields to RYEs for remapped map units in the Coastal Plain.

Map Unit	2000 Soybean Yield	Standard Error	2002 Soybean Yield	Standard Error	Soybean RYE	2002 Wheat Yield	Standard Error	Wheat RYE
	--		Mg ha^{-1}				--	
Goldsboro	1.9	0.04	2.0	0.26	3.0	2.5	0.34	4.4
Noboco	1.6	0.03	1.9	0.16	2.9	2.7	0.27	3.9
Norfolk_A	1.8	0.03	1.8	0.17	2.8	2.6	0.25	4.0
Norfolk_B	0.6	0.23	1.9	0.17	2.7	2.5	0.25	3.9
Wagram_B	1.0	0.01	1.7	0.11	1.9	2.4	0.19	2.6

Table 44. Comparison of actual measured yields to RYEs for original map units in the Coastal Plain.

Map Unit	2000 Soybean Yield	Standard Error	2002 Soybean Yield	Standard Error	Soybean RYE	2002 Wheat Yield	Standard Error	Wheat RYE
	--Mg ha^{-1}--							
Bibb	N/A	N/A	N/A	N/A	2.6	N/A	N/A	3.0
Lumbee	0.8	0.16	1.7	0.14	3.0	N/A	N/A	3.4
Norfolk_C	0.8	0.16	1.9	0.11	3.5	2.5	0.29	3.7
Rains	N/A	N/A	N/A	N/A	3.0	N/A	N/A	3.7
Ruston_A	0.8	0.15	1.7	0.10	2.7	2.5	0.29	3.7
Ruston_B	0.9	0.13	1.7	0.09	2.6	N/A	N/A	3.6
Wagram_B	0.8	0.15	1.7	0.10	1.9	2.4	0.29	2.6

† N/A, No yield data collected within map unit.

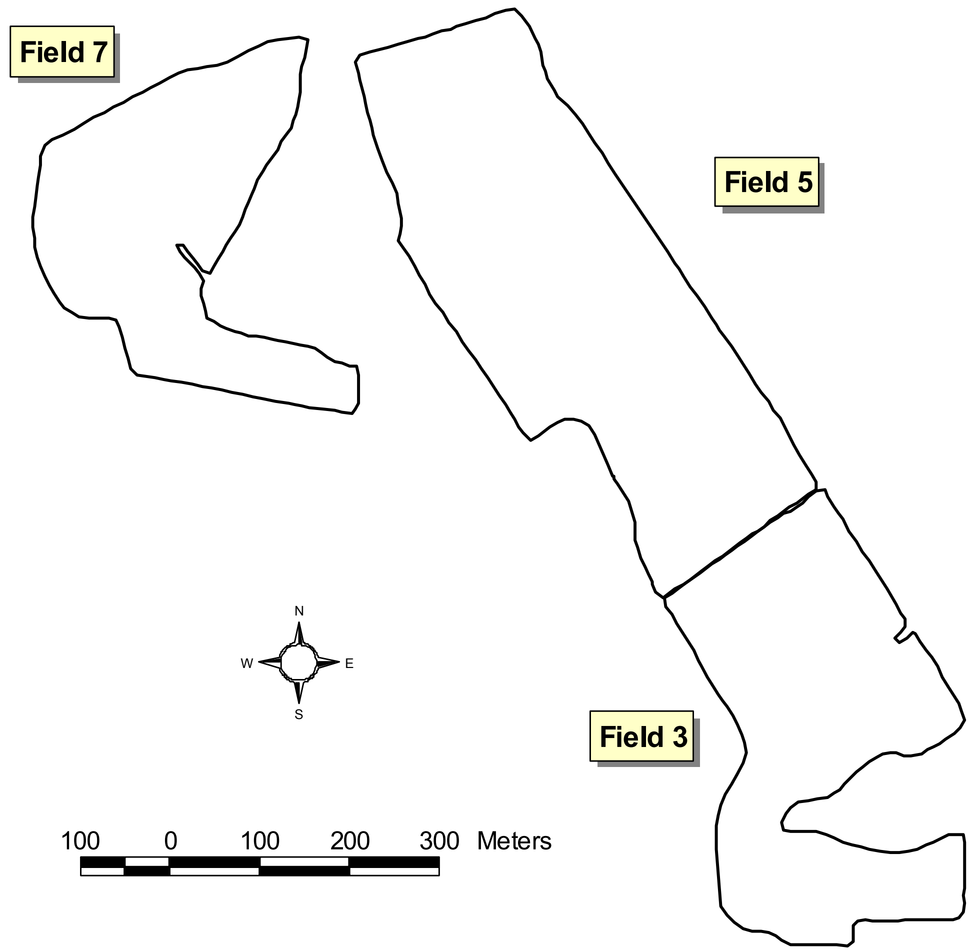


Figure 1. Spatial relationship of Piedmont fields labeled Field 3, 5, and 7.

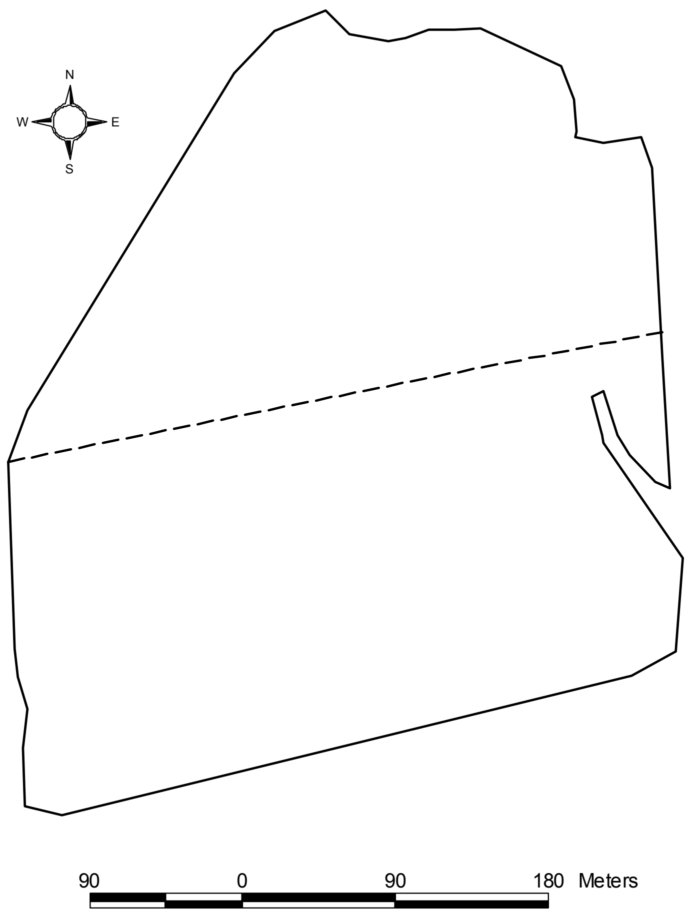


Figure 2. Coastal Plain fields where the dashed line delineates the field subdivision line.

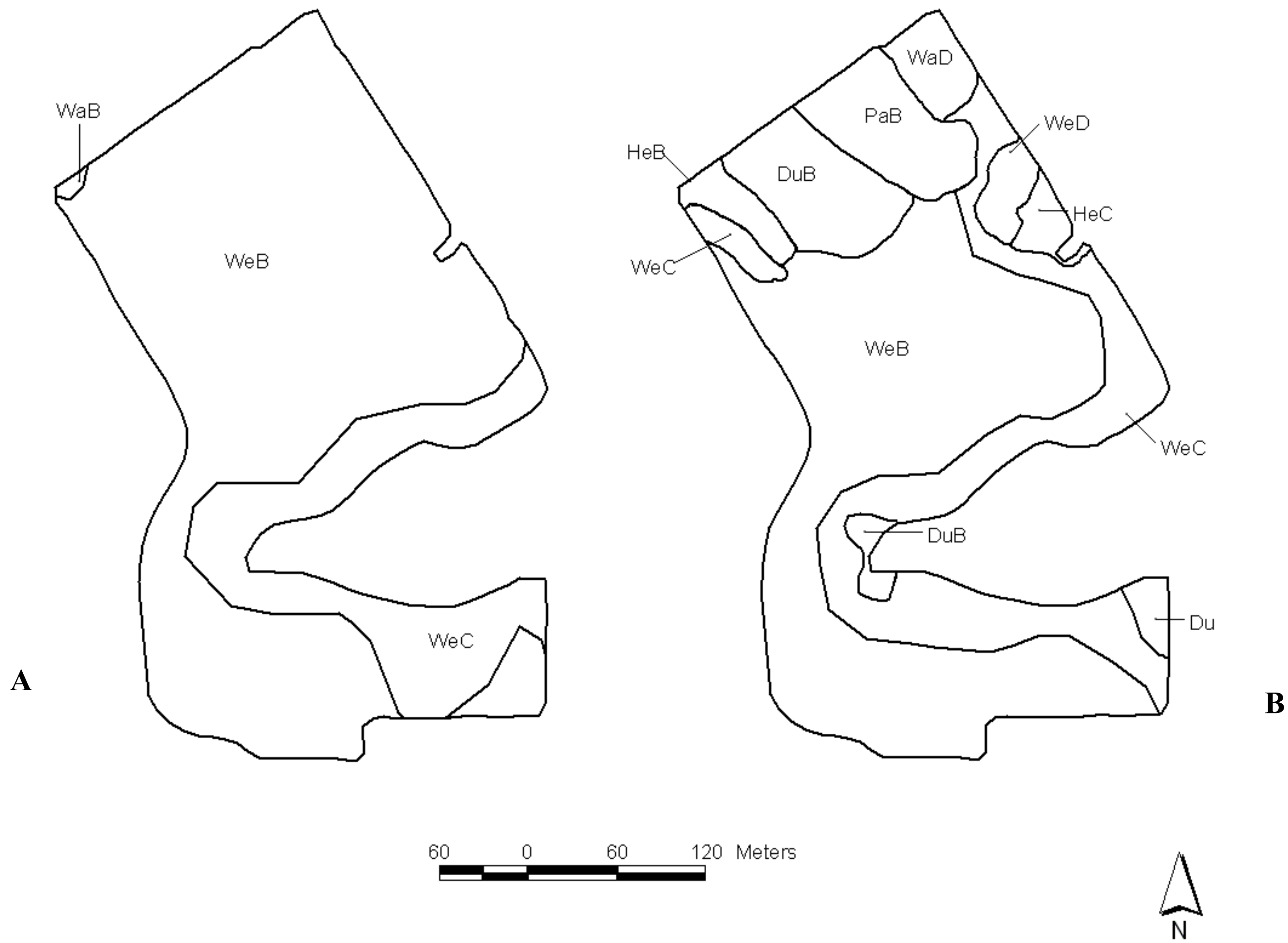


Figure 3. Soil map units for Field 3 in the Piedmont. (A) original map units from soil survey and (B) map units resulting from intensive soil survey in 2002.

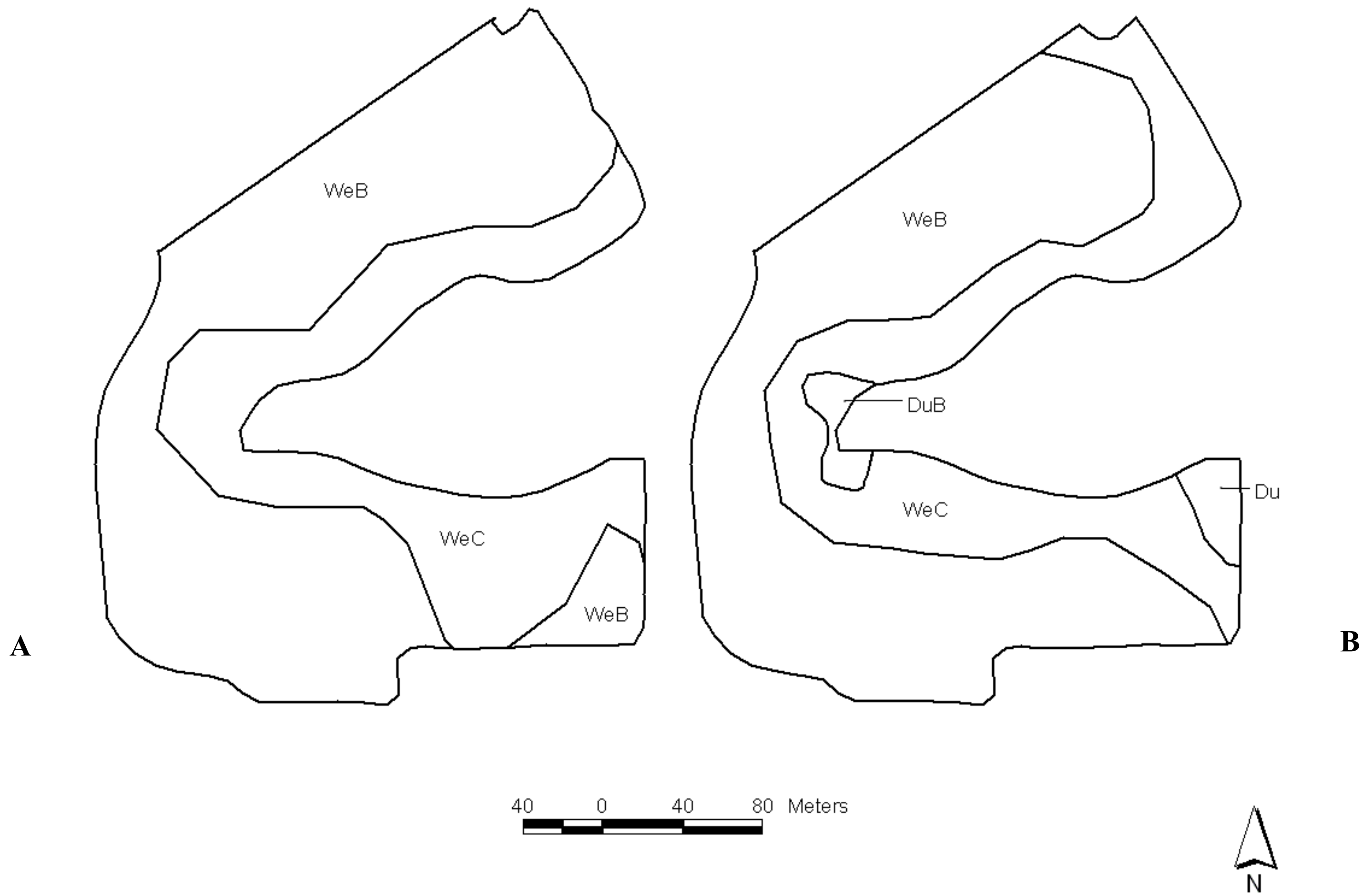


Figure 4. Soil map units for the reduced Field 3 in the Piedmont. (A) original map units from soil survey and (B) map units resulting from intensive soil survey in 2002. The producer only planted a portion of the original Field 3 in 2003.

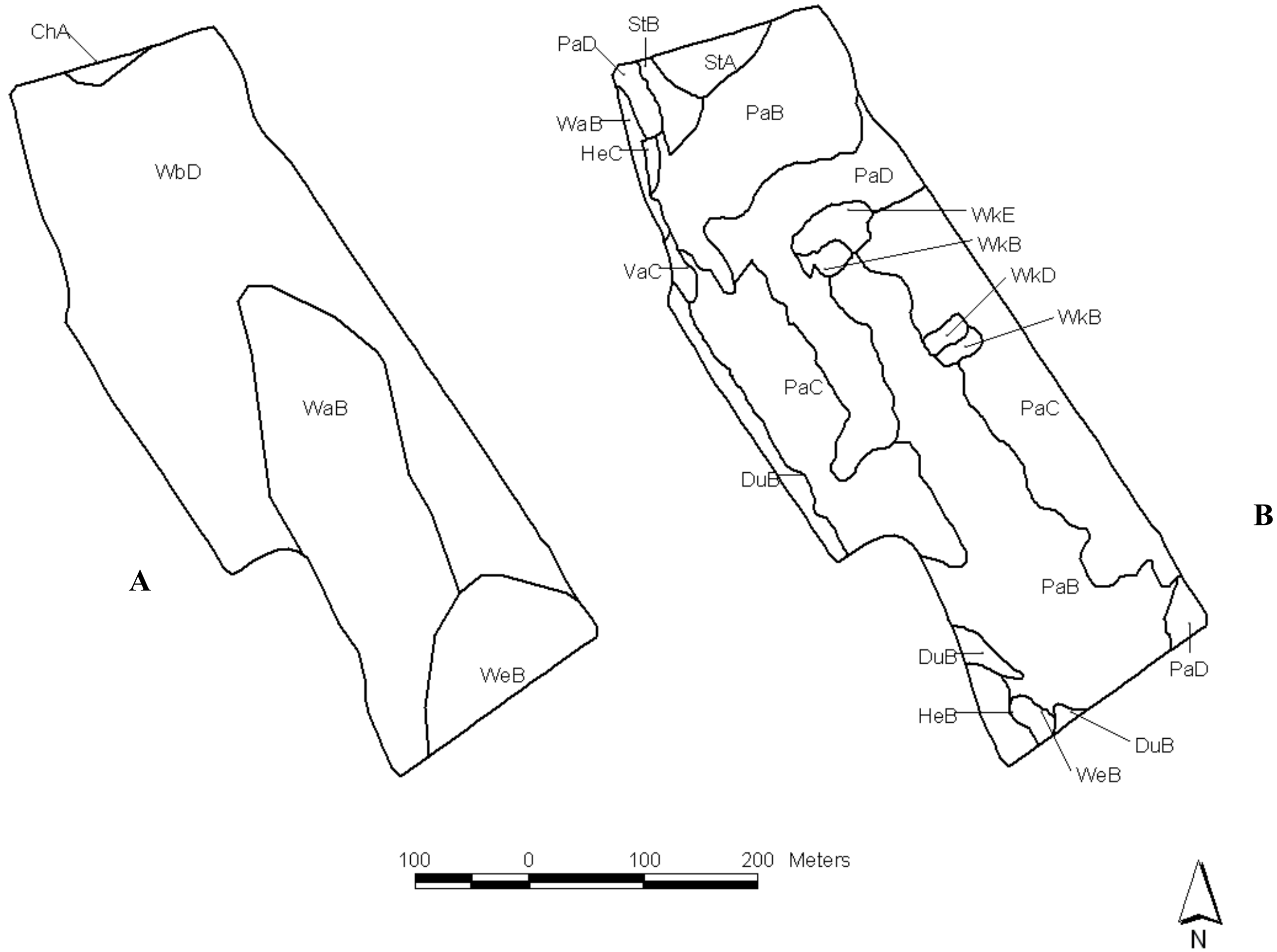


Figure 5. Soil map units for Field 5 in the Piedmont. (A) original map units from soil survey and (B) map units resulting from intensive soil survey in 2002.

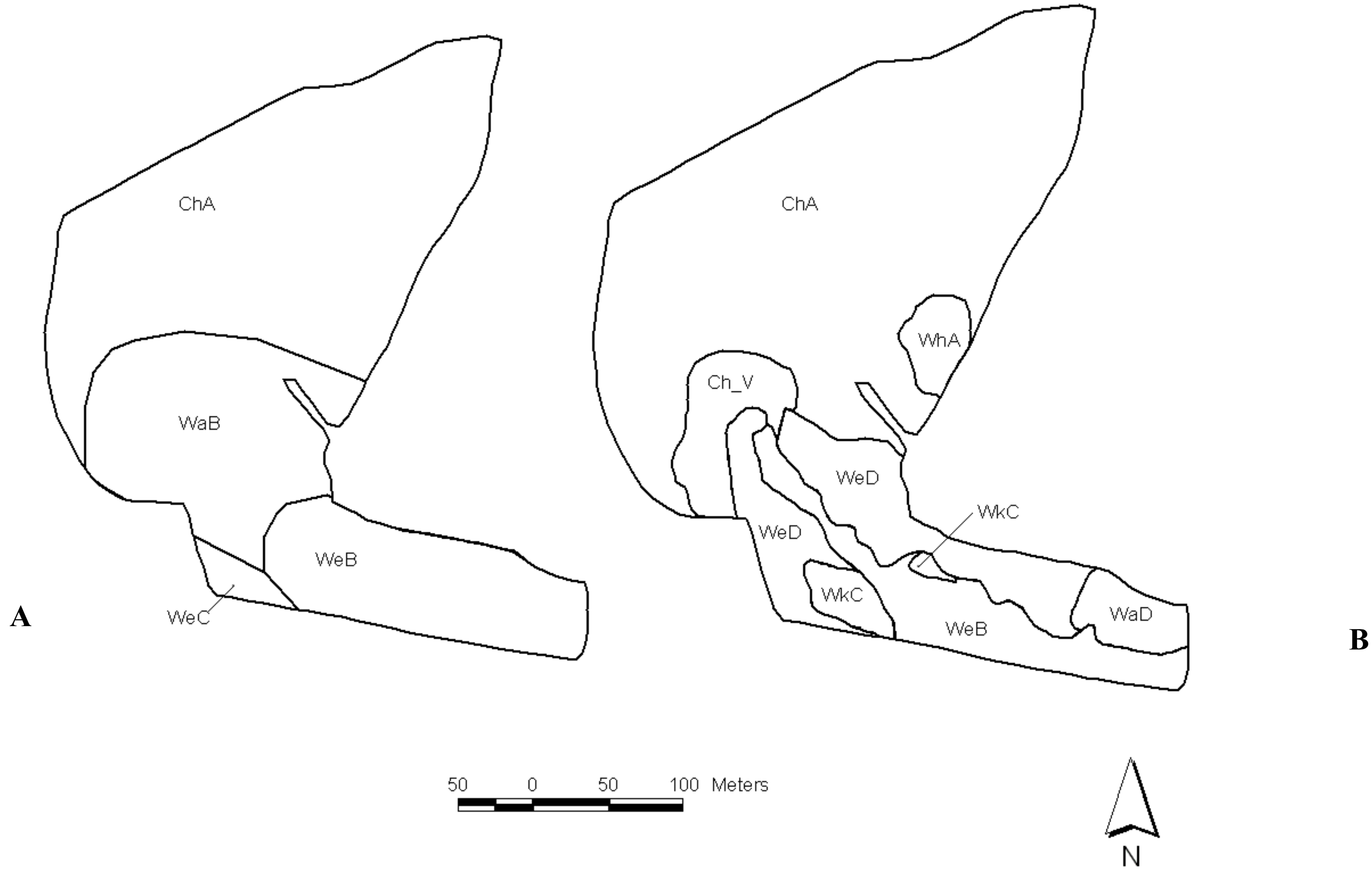


Figure 6. Soil map units for Field 7 in the Piedmont. (A) original map units from soil survey and (B) map units resulting from intensive soil survey in 2002.

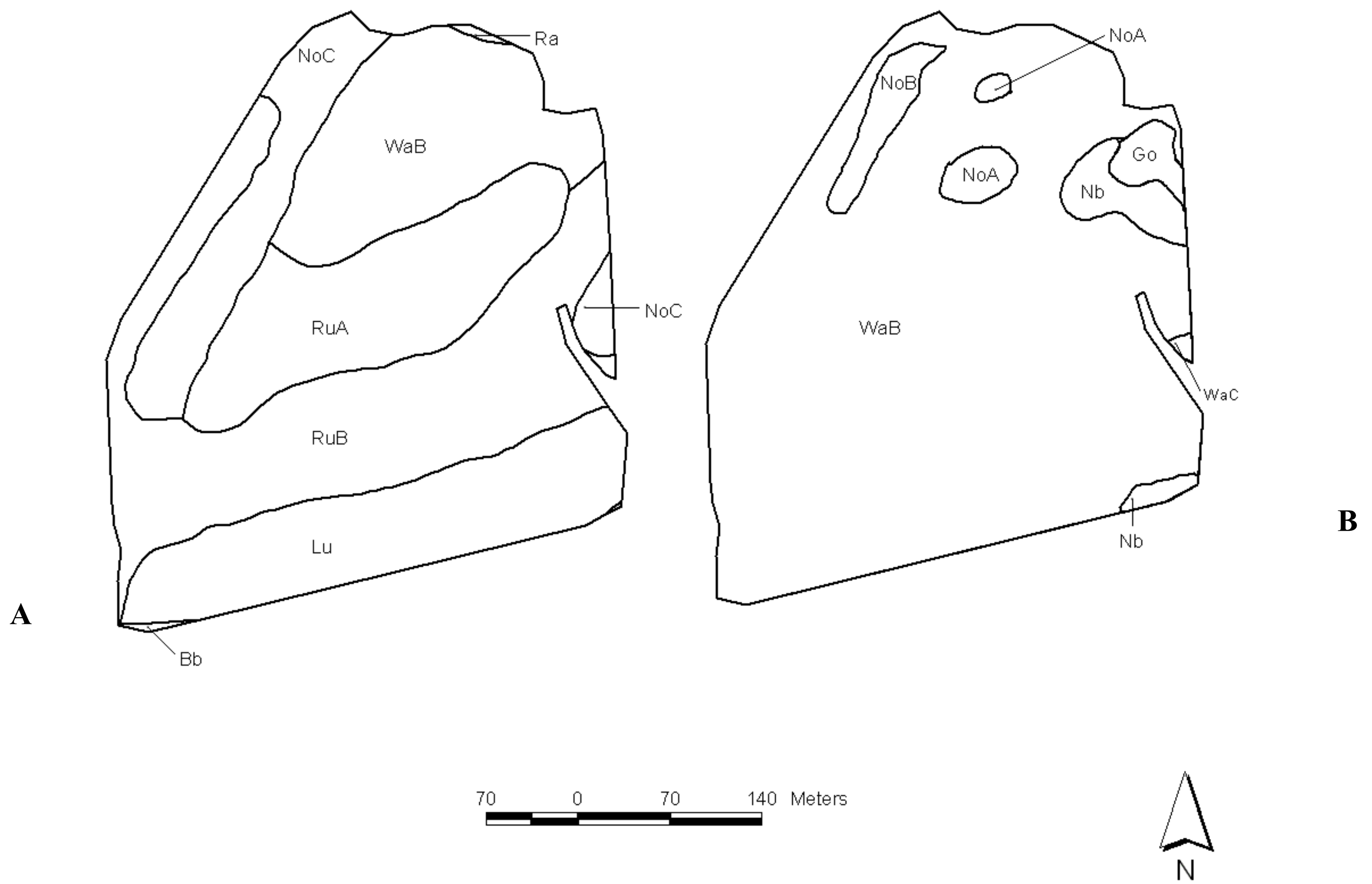


Figure 7. Soil map units for the Coastal Plain. (A) original map units from soil survey and (B) map units resulting from intensive soil survey in 2002.

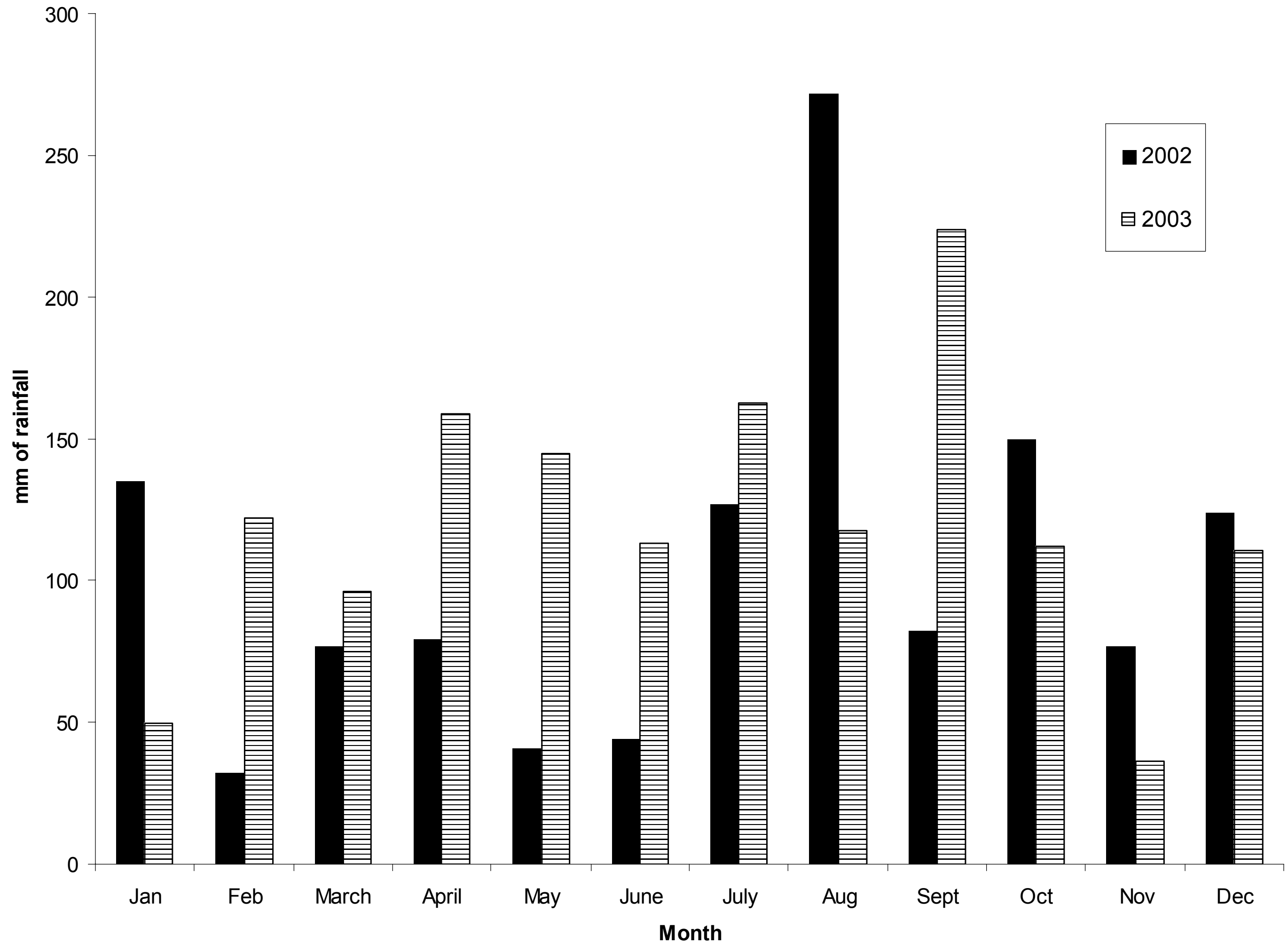


Figure 8. Monthly rainfall in the Piedmont for the 2002 and 2003 growing seasons.

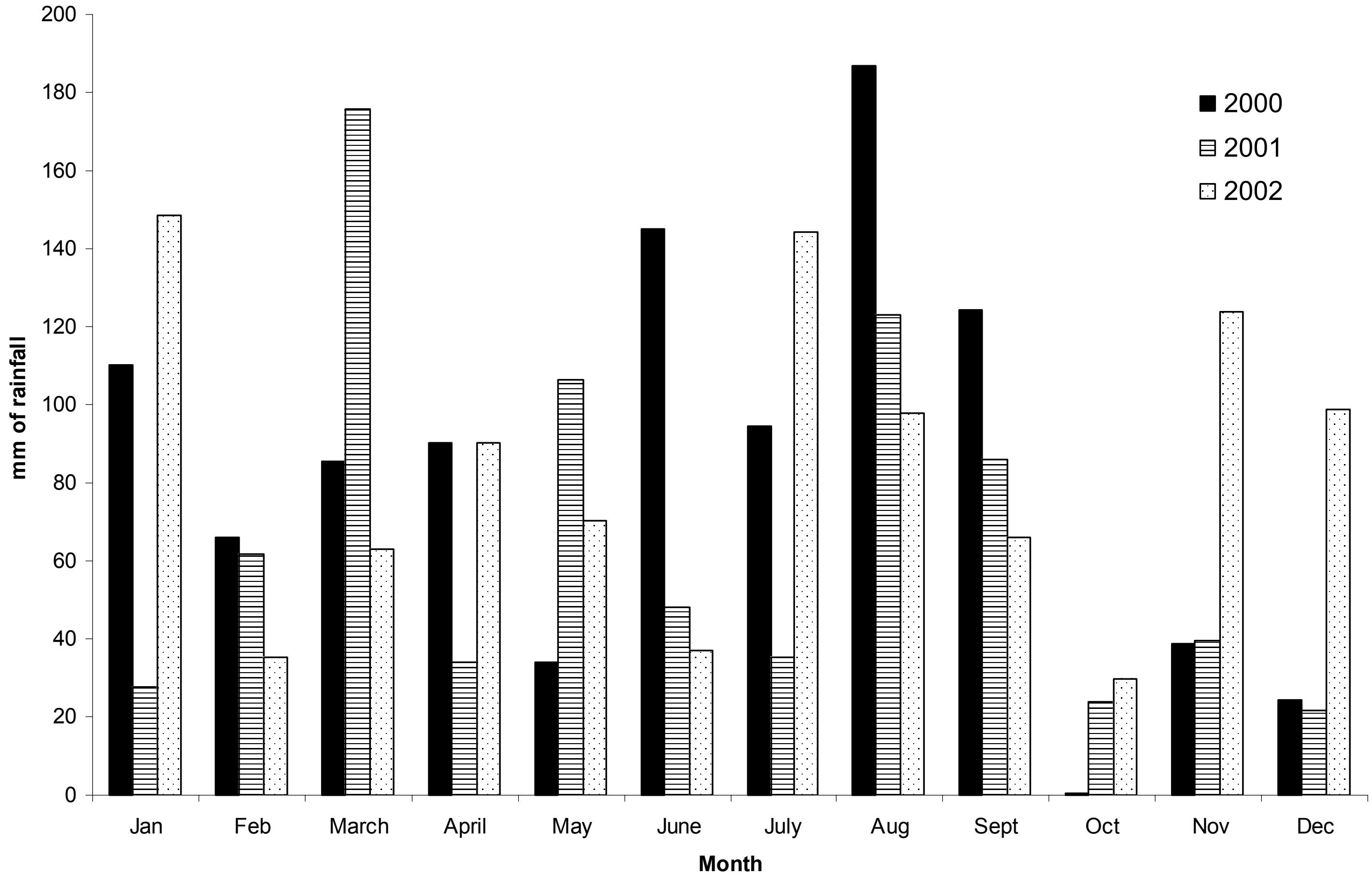


Figure 9. Monthly rainfall in the Coastal Plain for the 2000, 2001, and 2002 growing seasons.

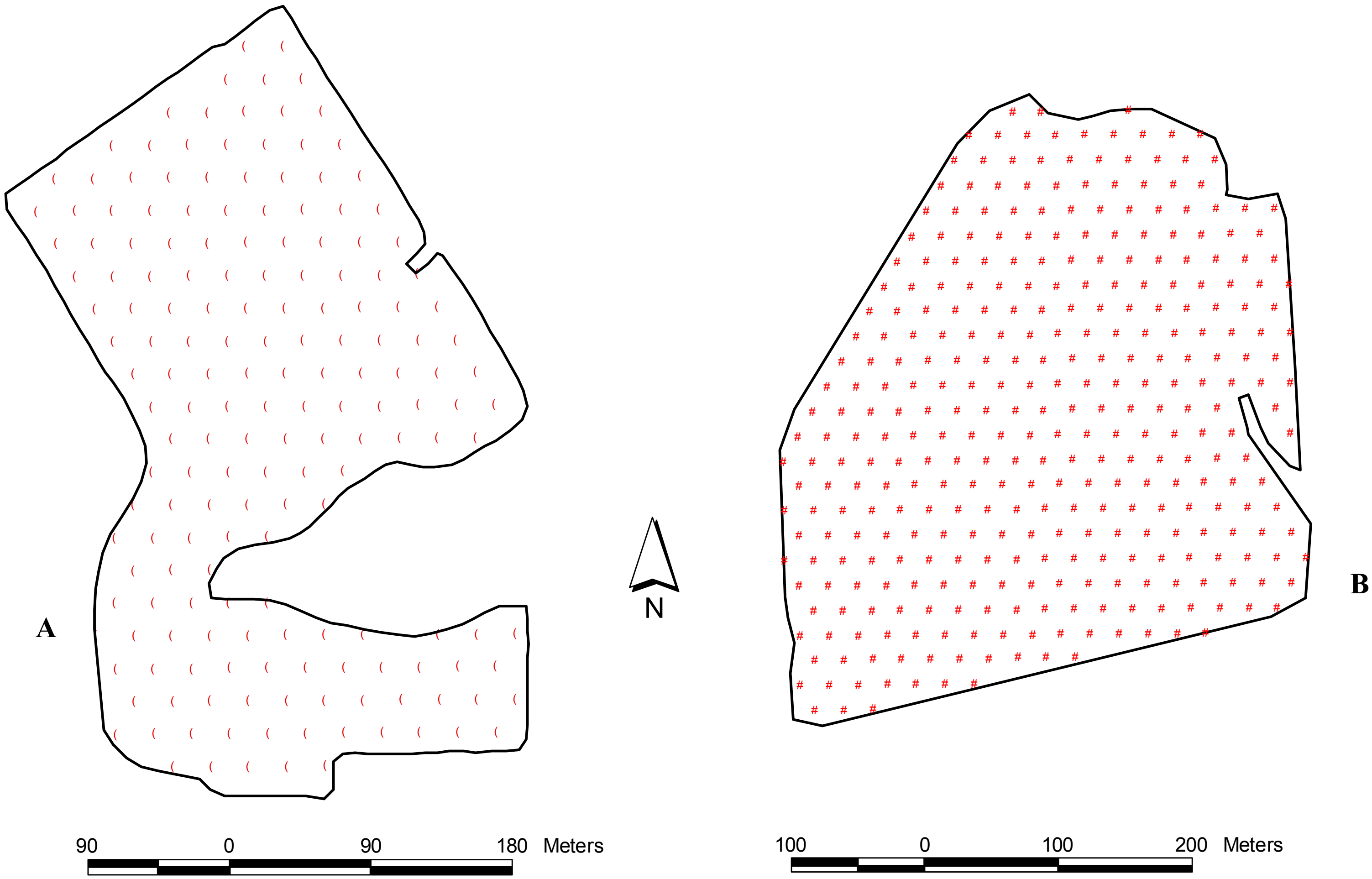


Figure 10. Examples of equilateral triangle grid patterns used for soil sampling. (A) Piedmont spacing (23 m) and (B) Coastal Plain spacing (21.3 m).

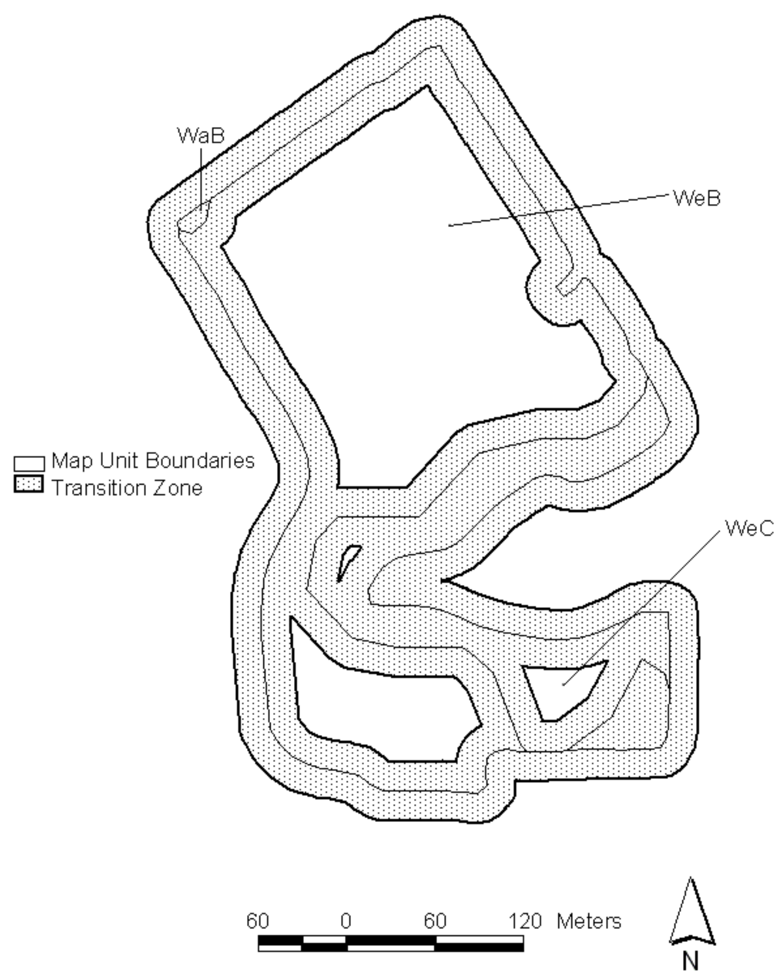


Figure 11. Depiction of 20 m transition zones centered on map unit boundaries.

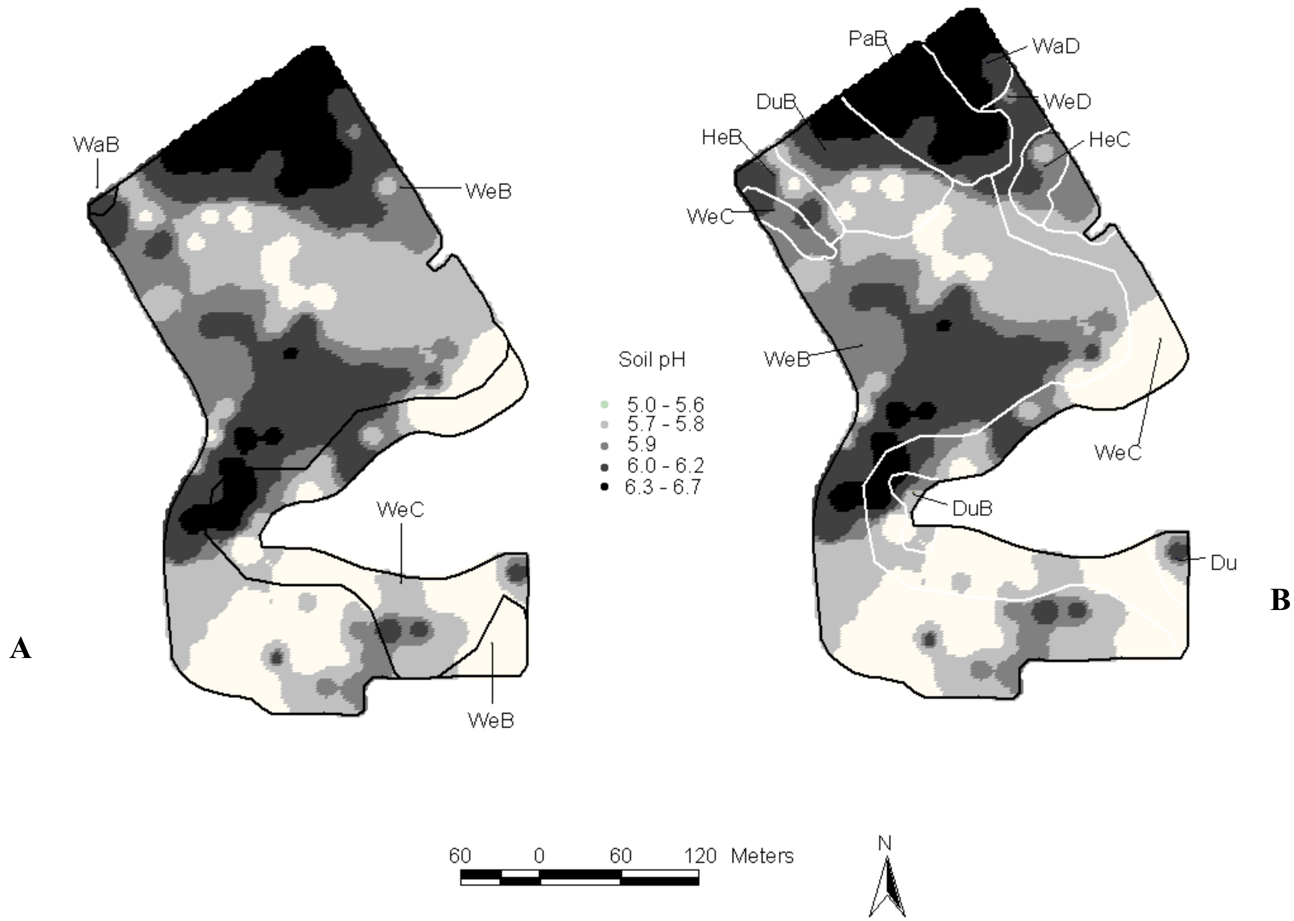


Figure 12. Soil pH for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the quantile approach.

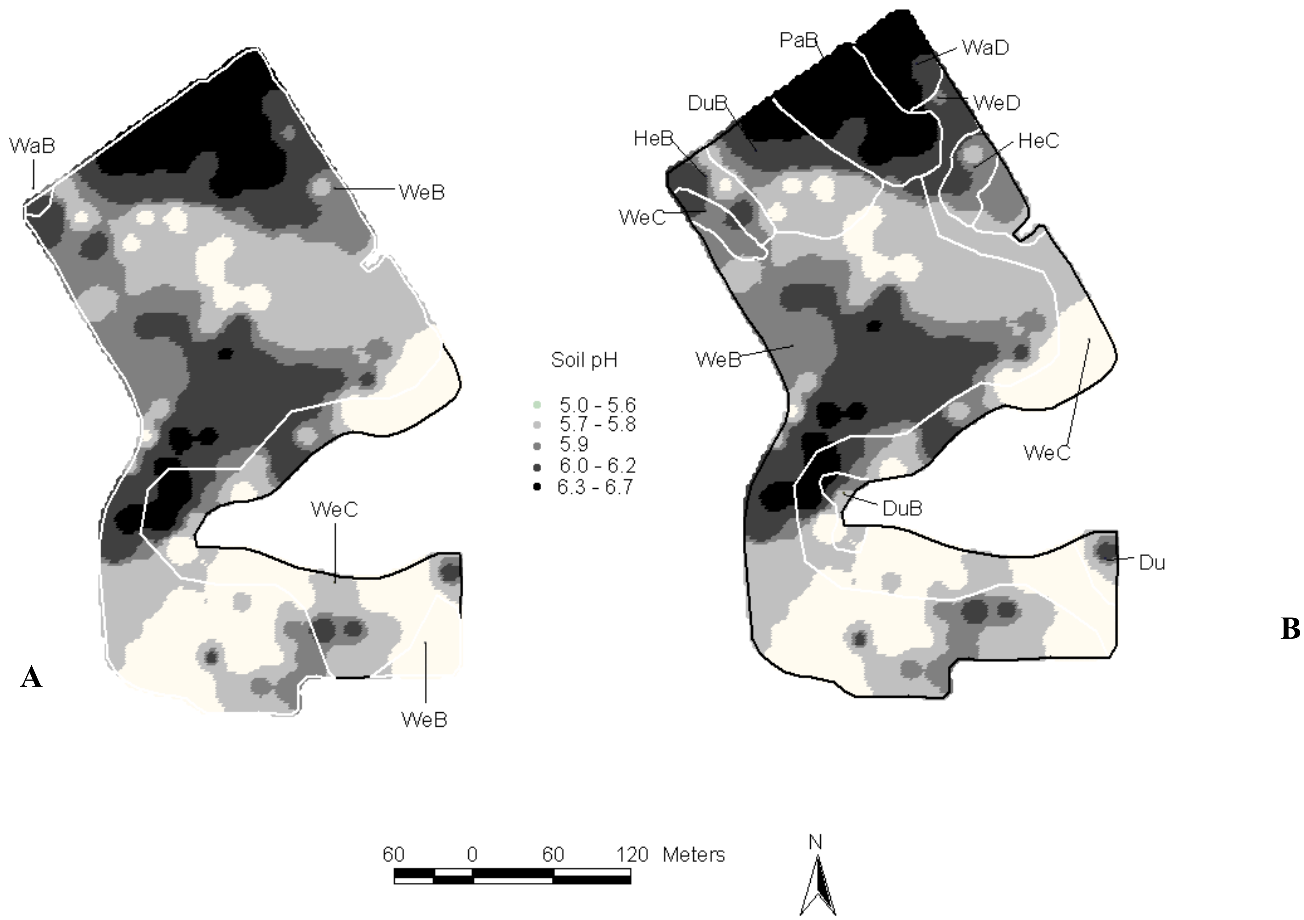


Figure 13. Soil P for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

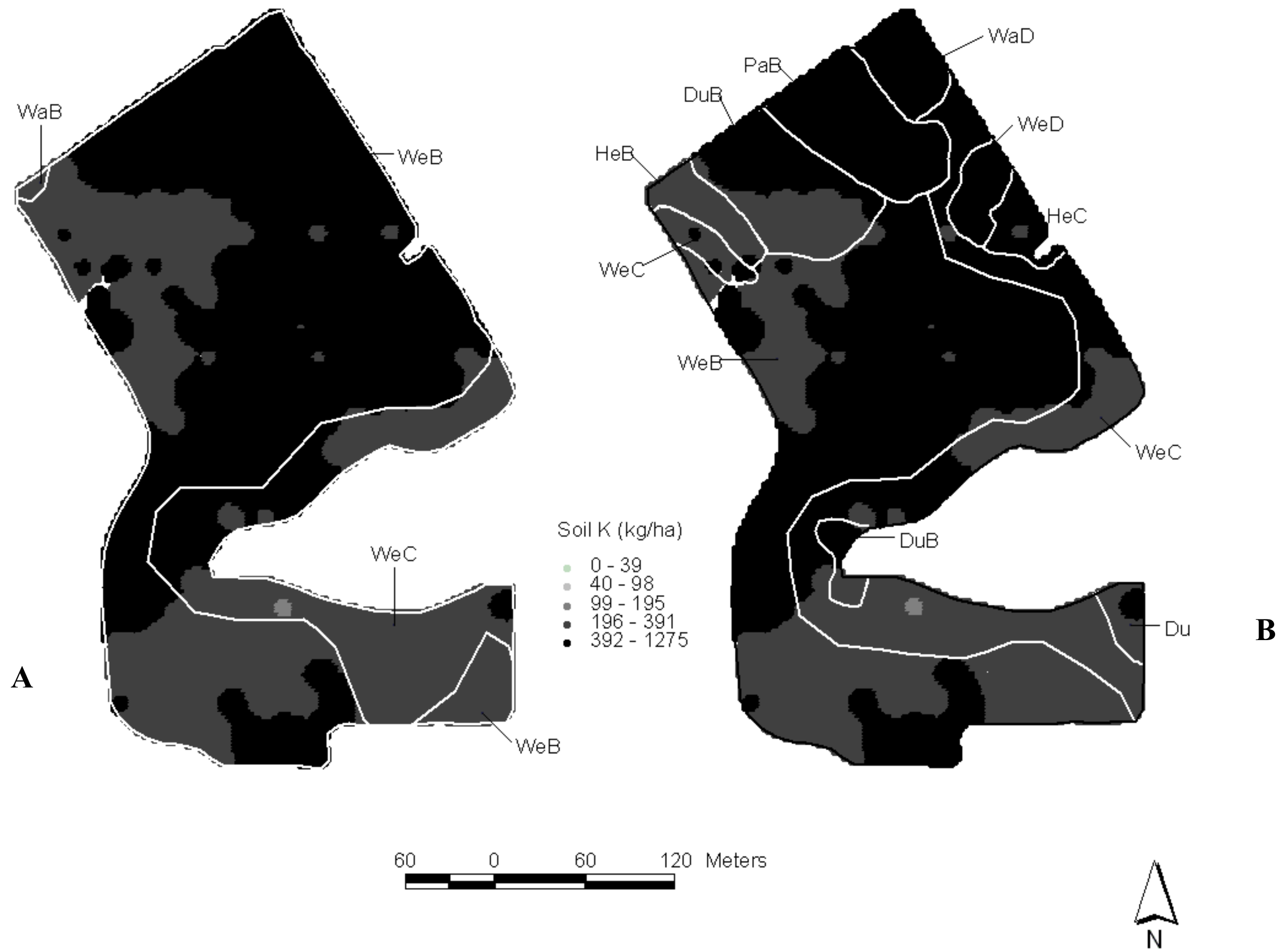


Figure 14. Soil K for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

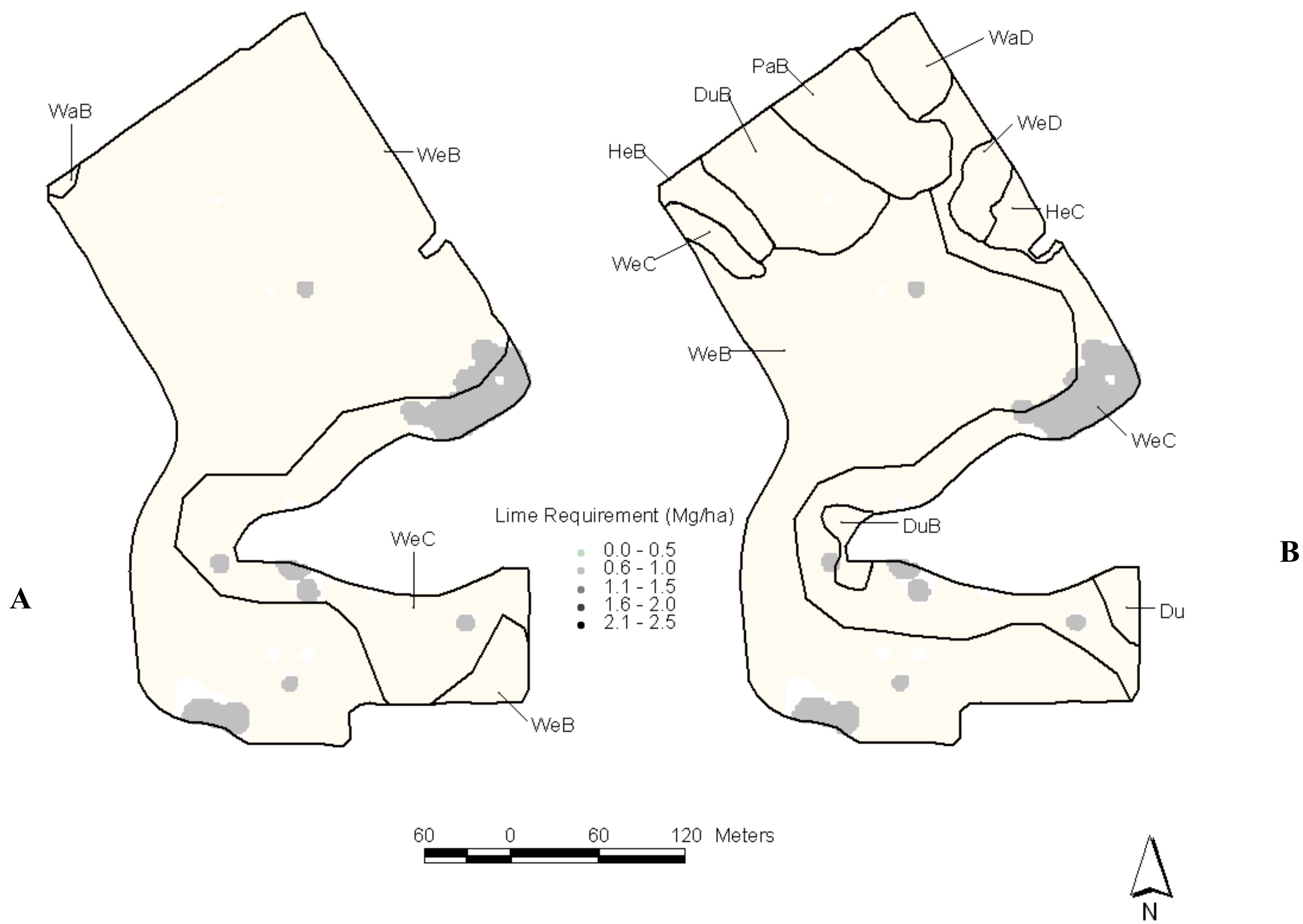


Figure 15. Lime requirement for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units.

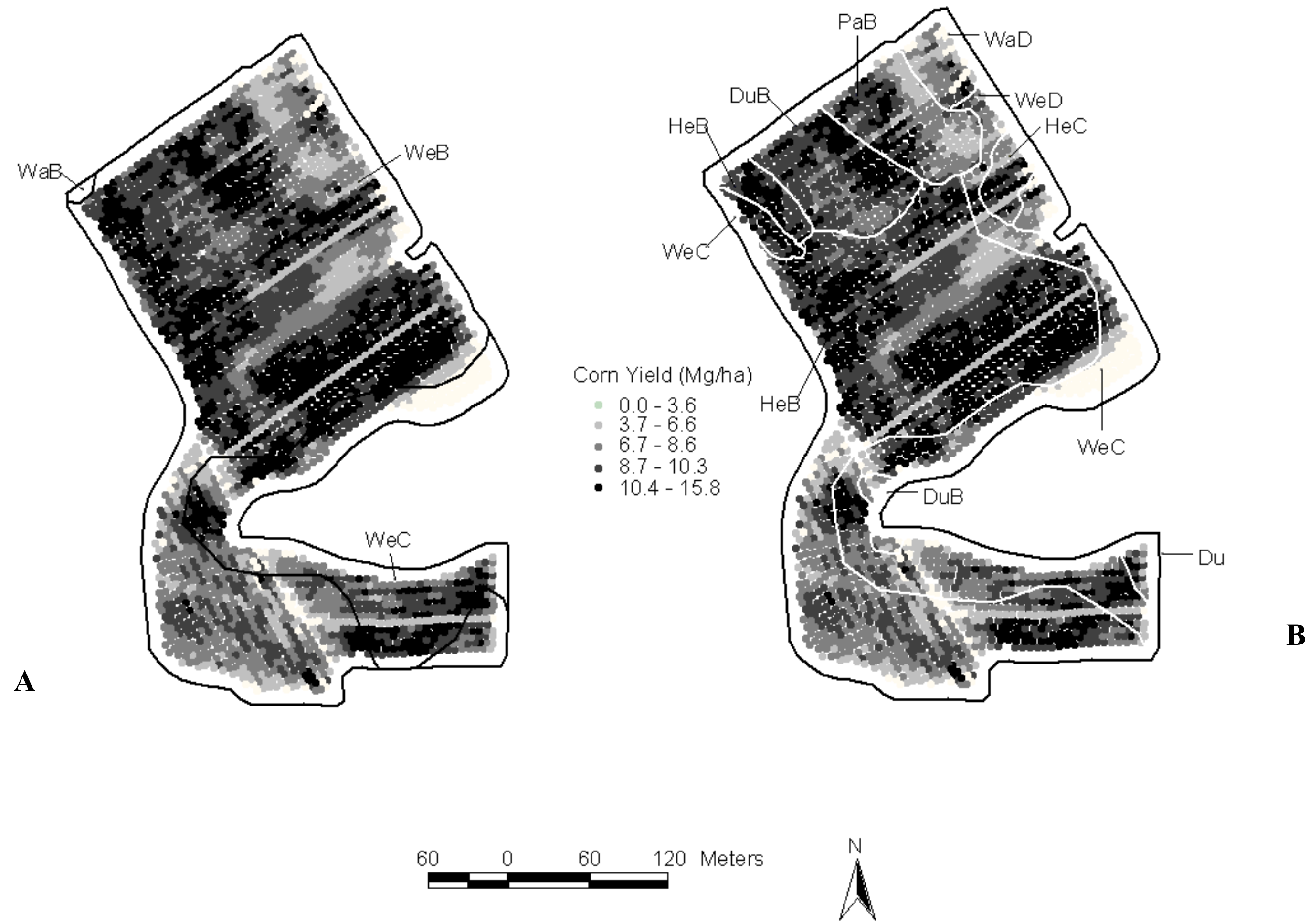


Figure 16. 2002 corn yield for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units.

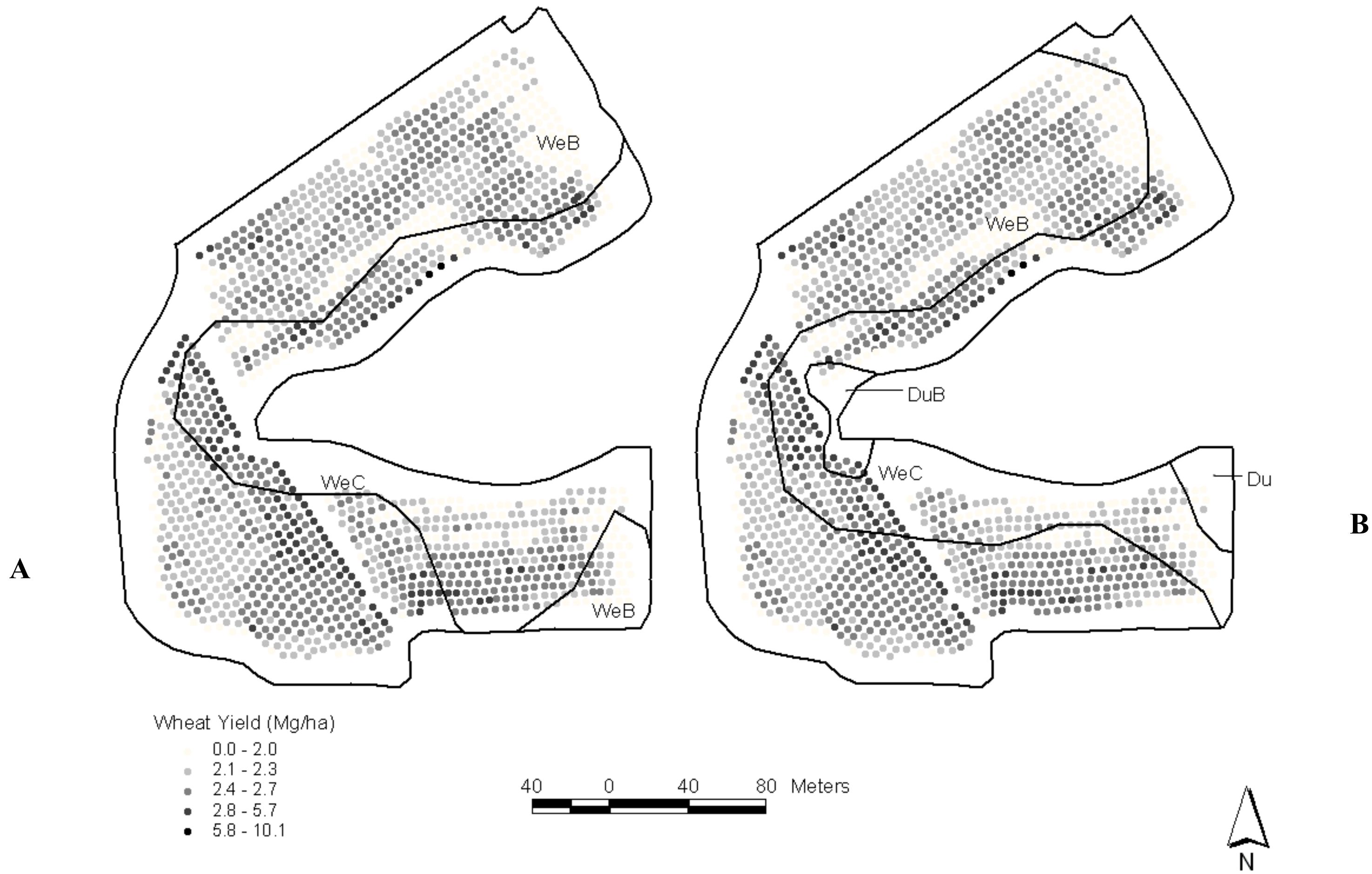


Figure 17. 2003 wheat yield for Field 3 in the Piedmont. (A) original map units and (B) remapped soil map units.

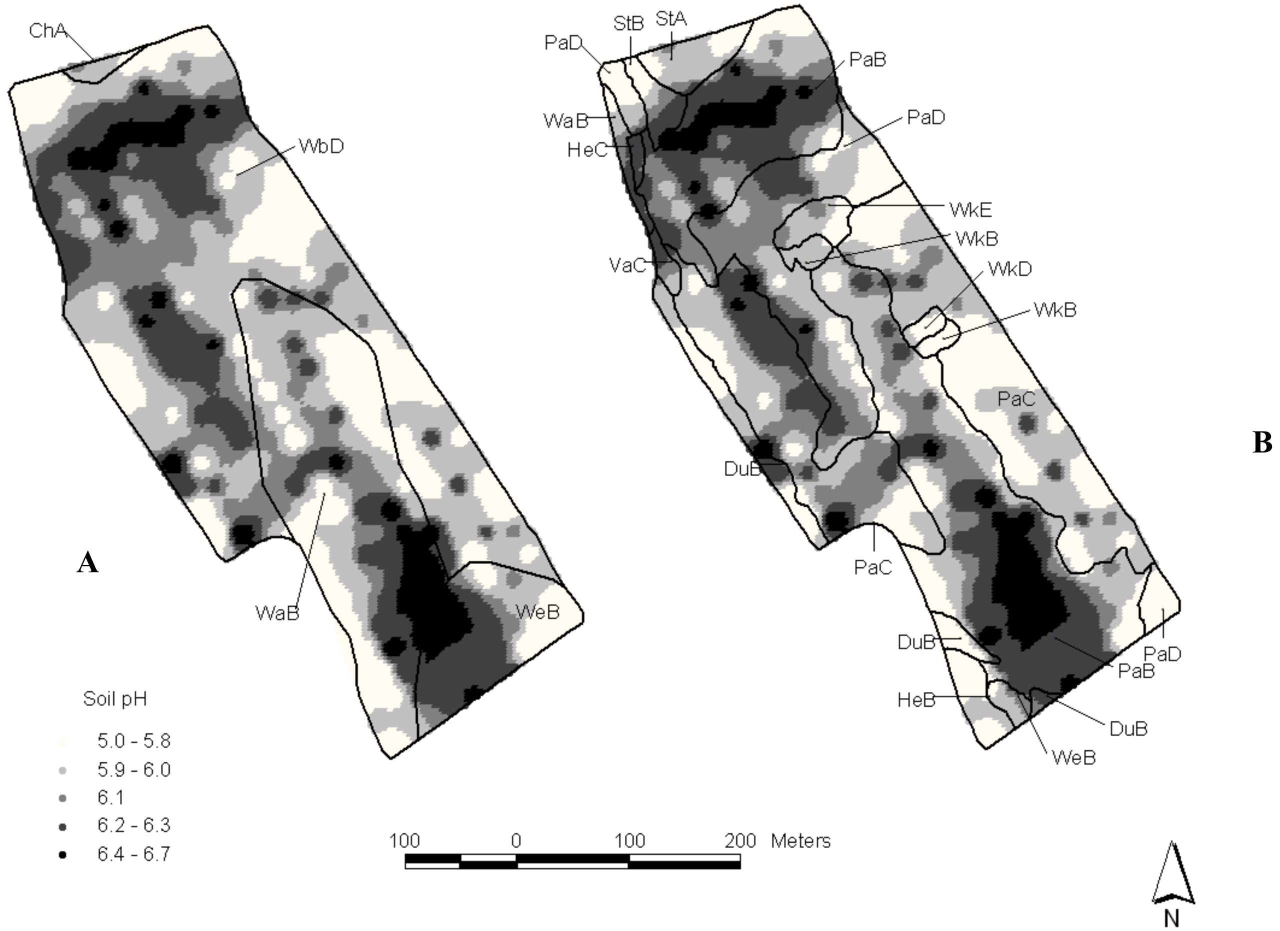


Figure 18. Soil pH for Field 5 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the quantile approach.

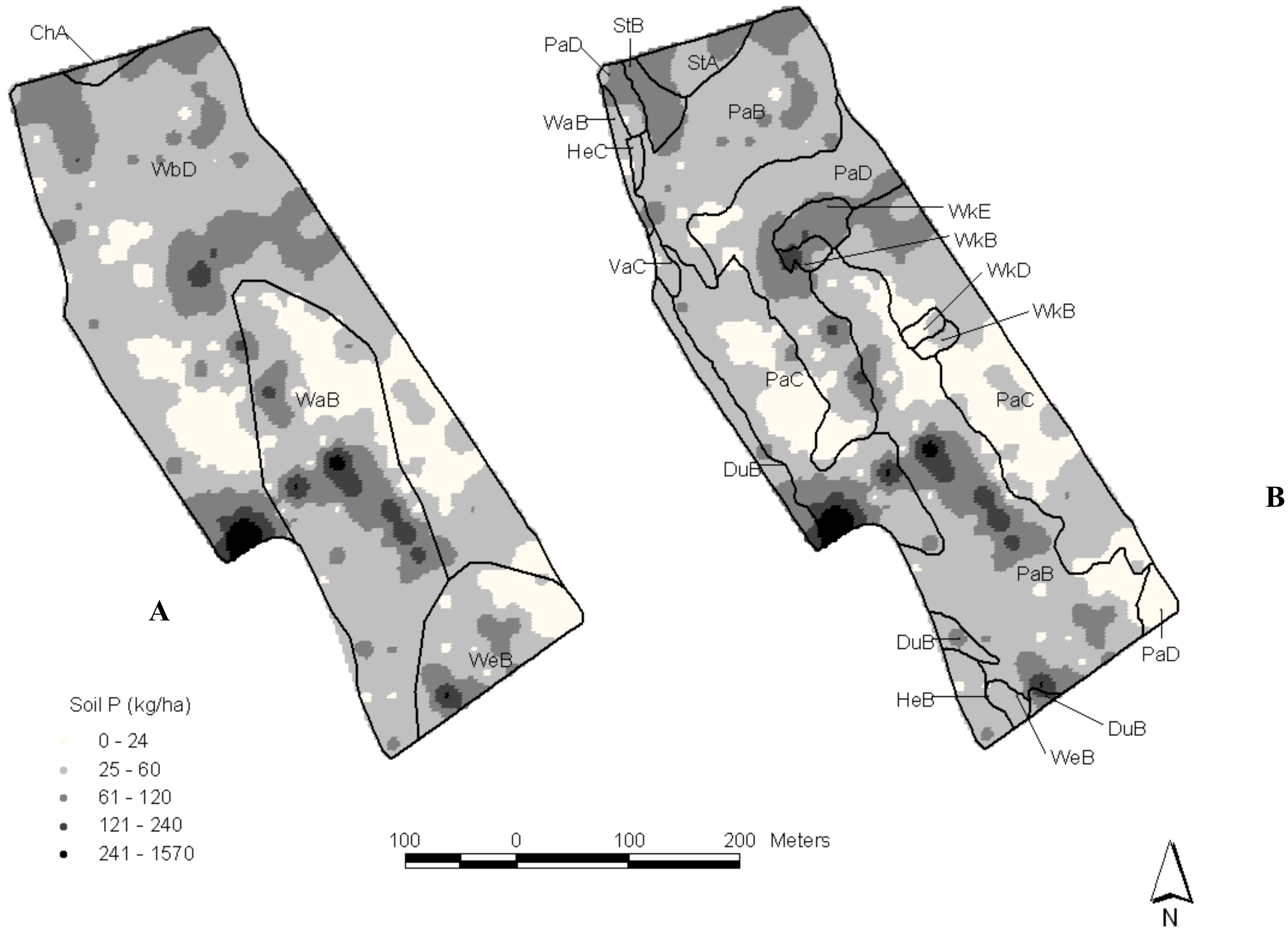


Figure 19. Soil P for Field 5 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

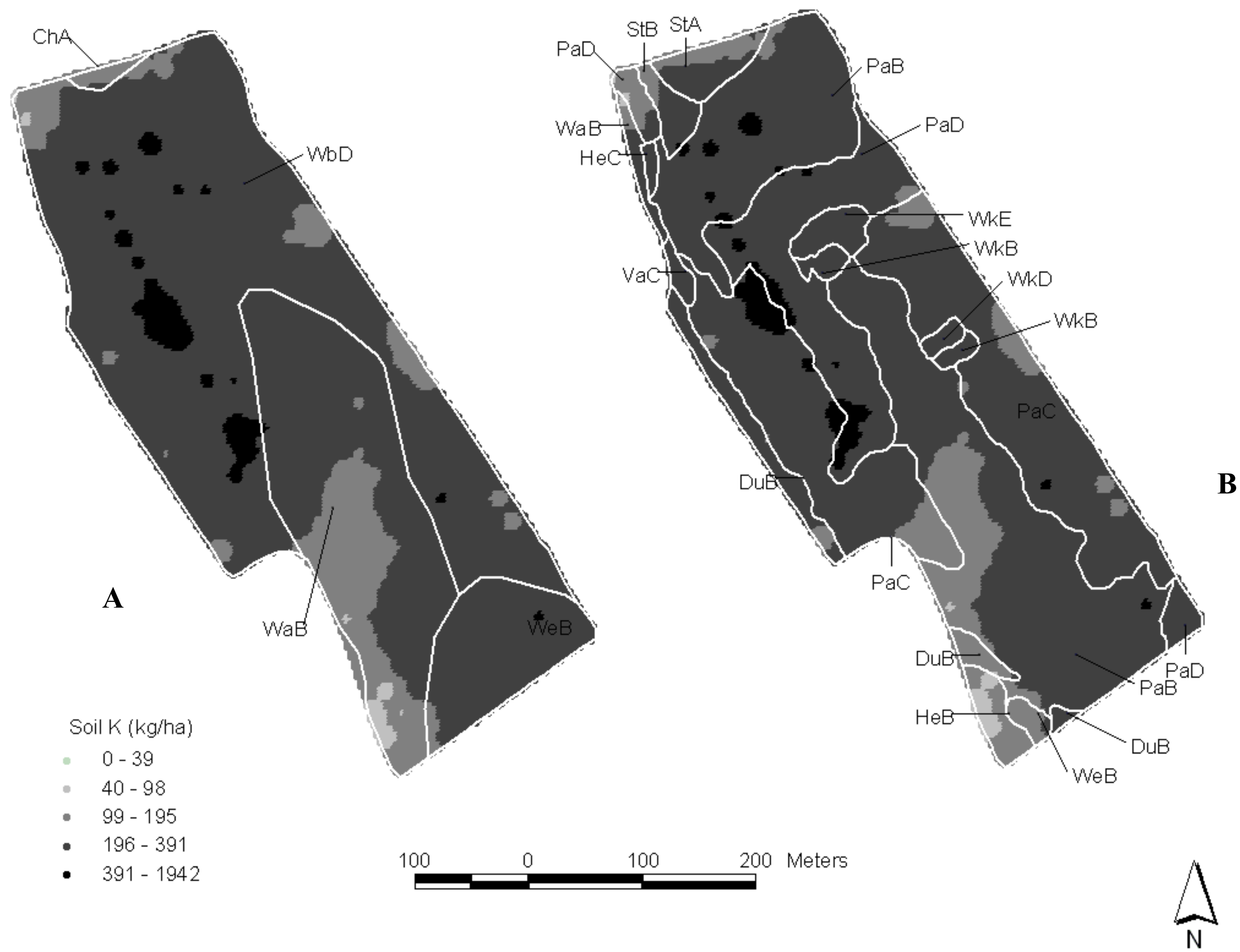


Figure 20. Soil K for Field 5 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

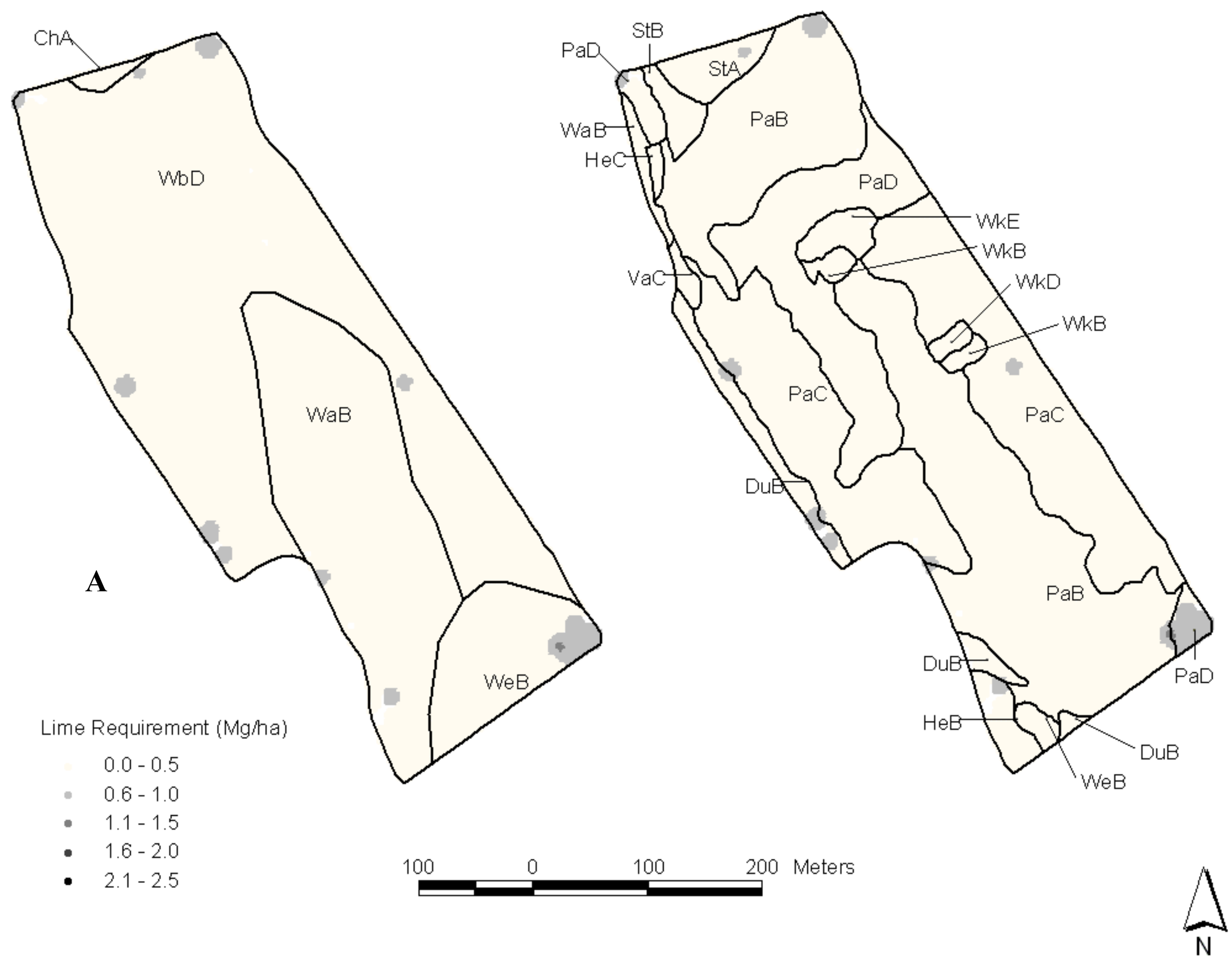


Figure 21. Lime Requirement for Field 5 in the Piedmont. (A) original map units and (B) remapped soil map units.

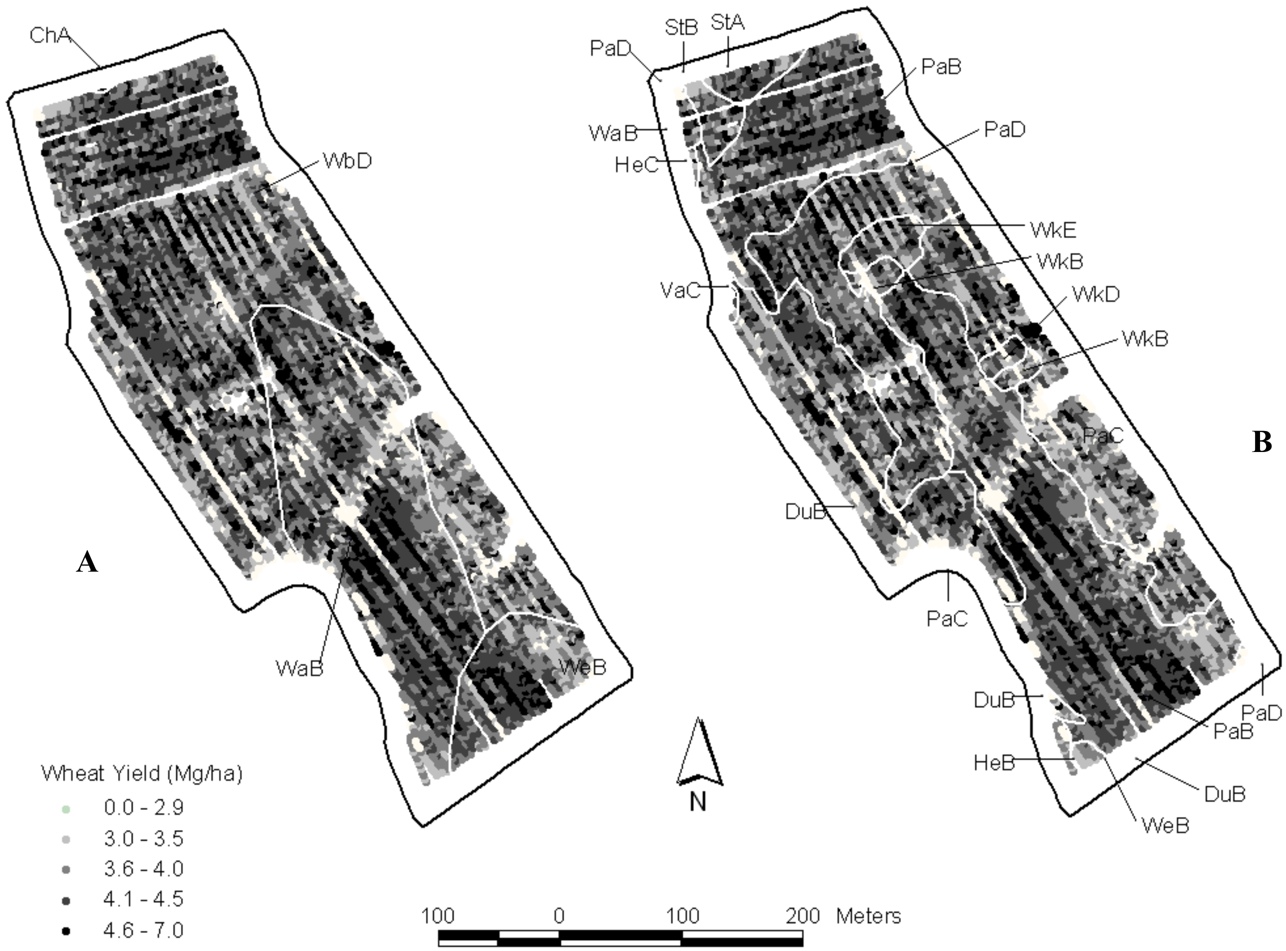


Figure 22. 2002 wheat yield for Field 5 in the Piedmont. (A) original map units and (B) remapped soil map units.

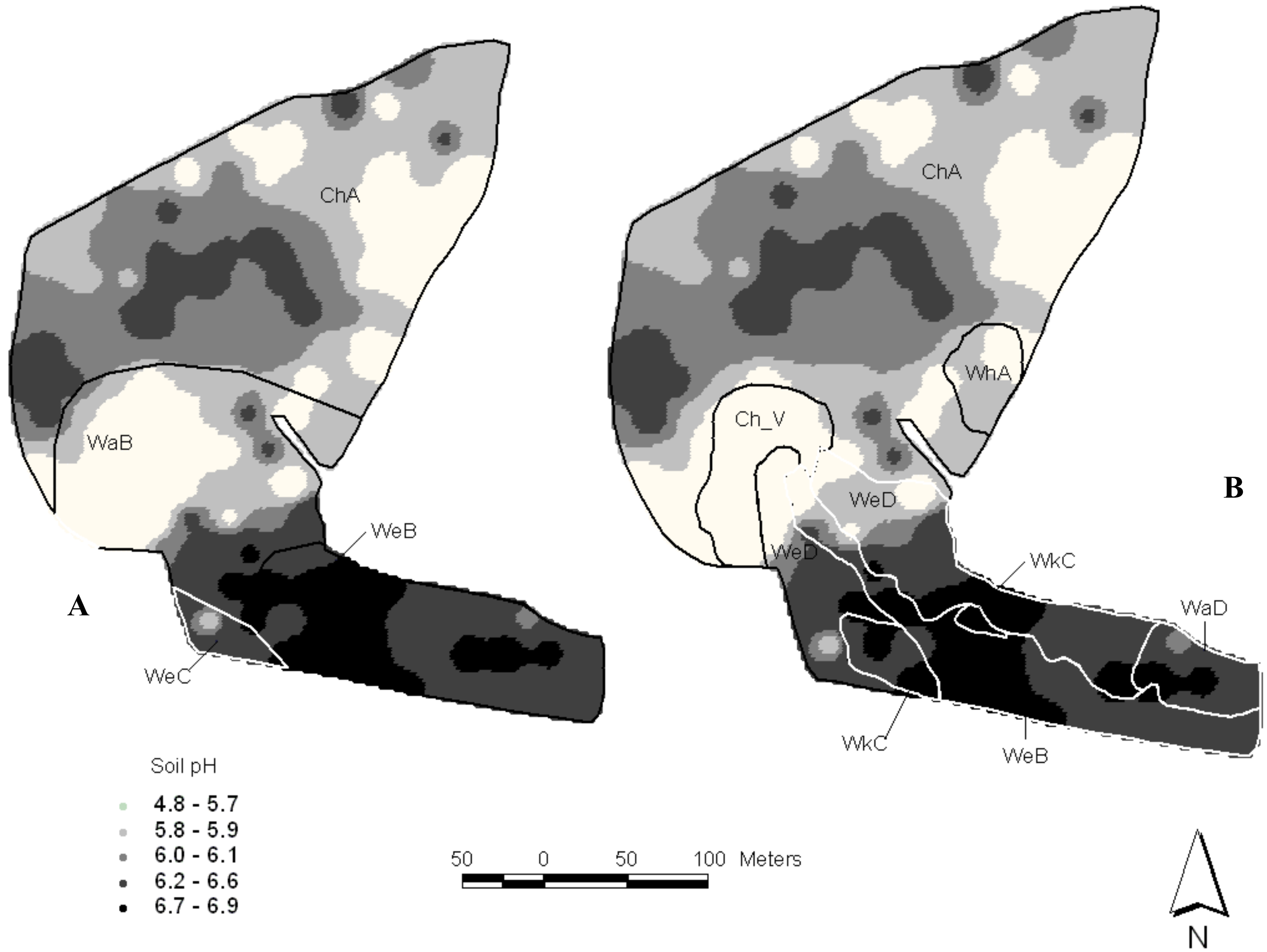


Figure 23. Soil pH for Field 7 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the quantile approach.

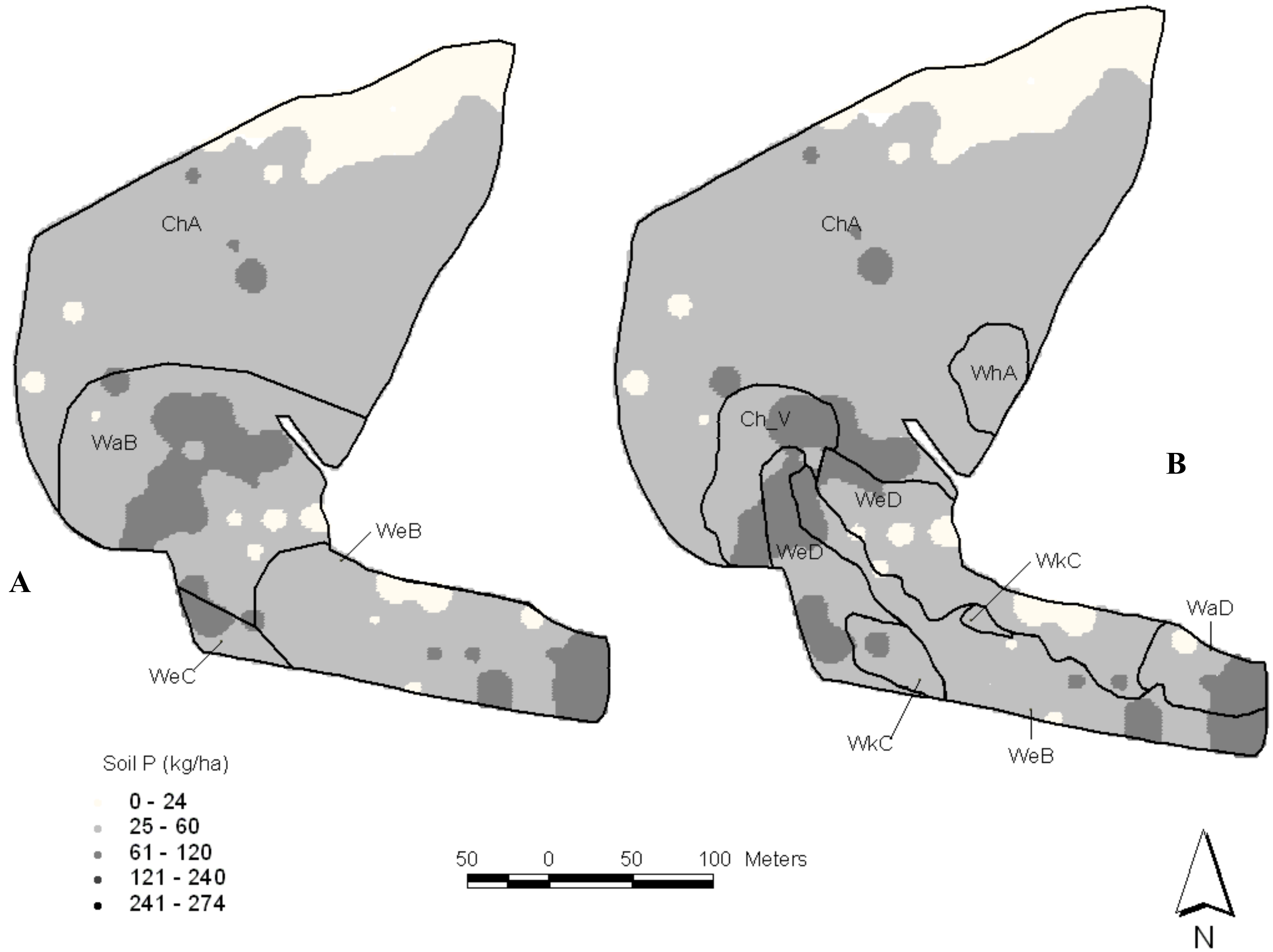


Figure 24. Soil P for Field 7 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

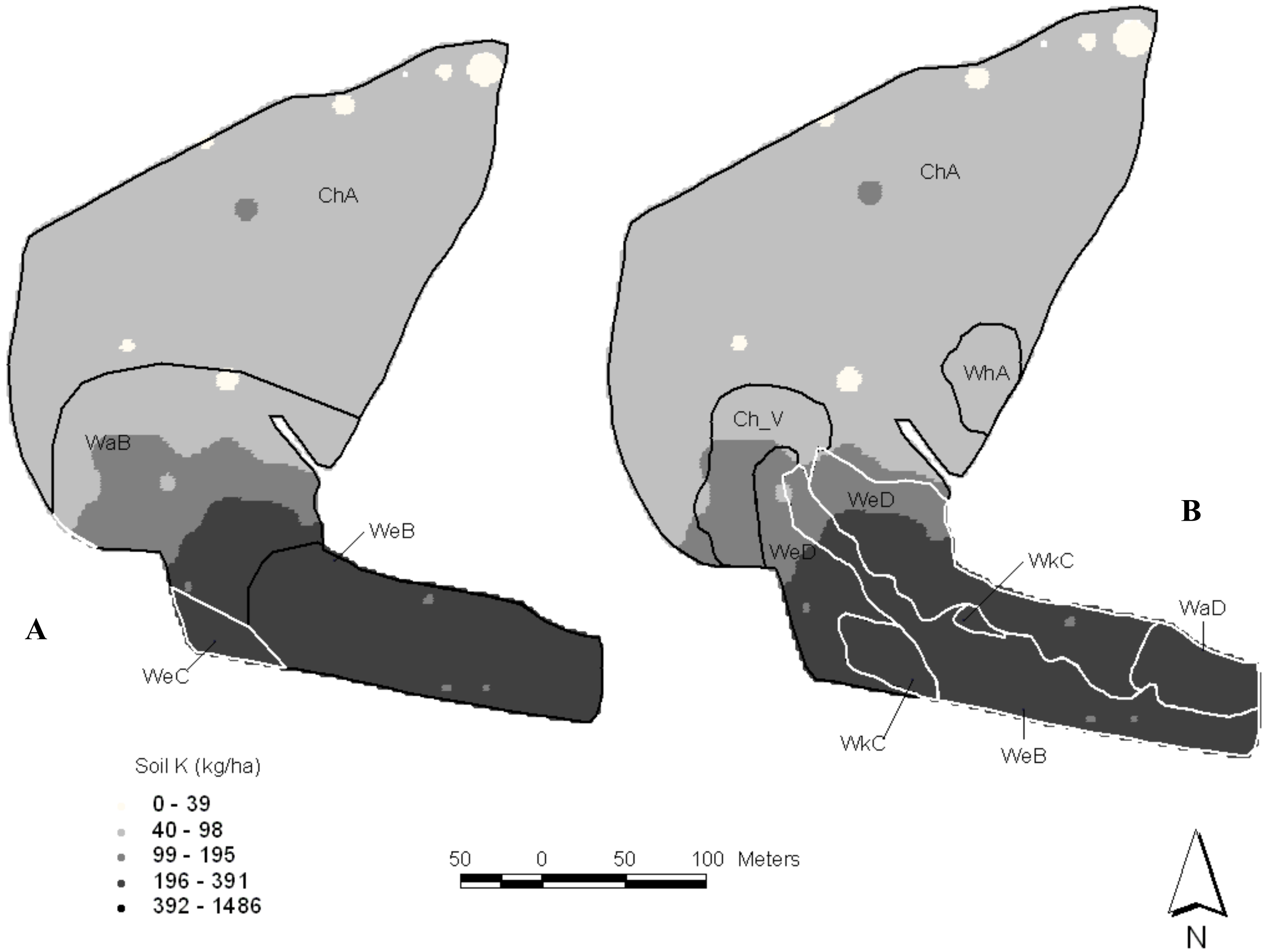


Figure 25. Soil K for Field 7 in the Piedmont. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

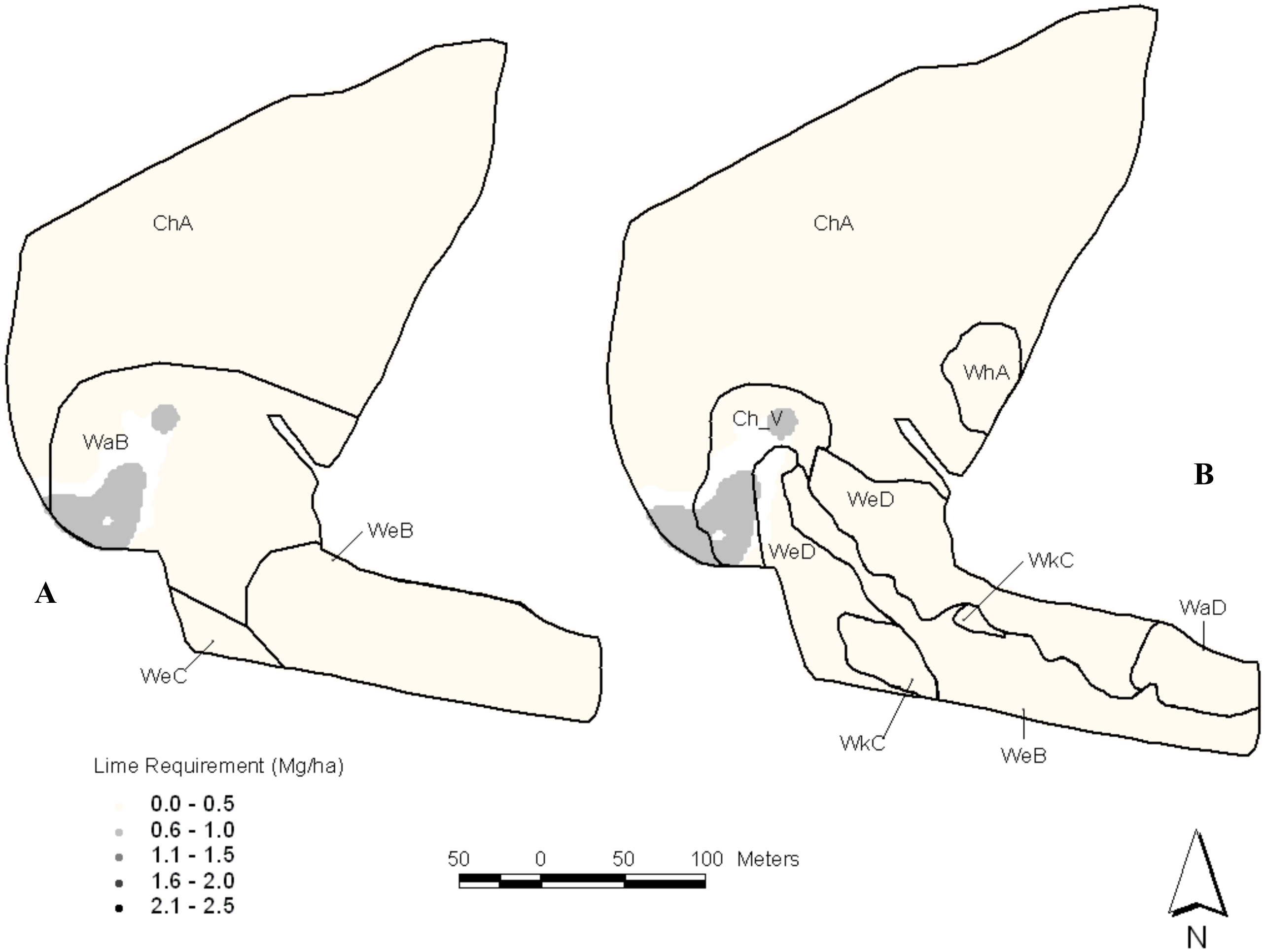


Figure 26. Lime Requirement for Field 7 in the Piedmont. (A) original map units and (B) remapped soil map units.

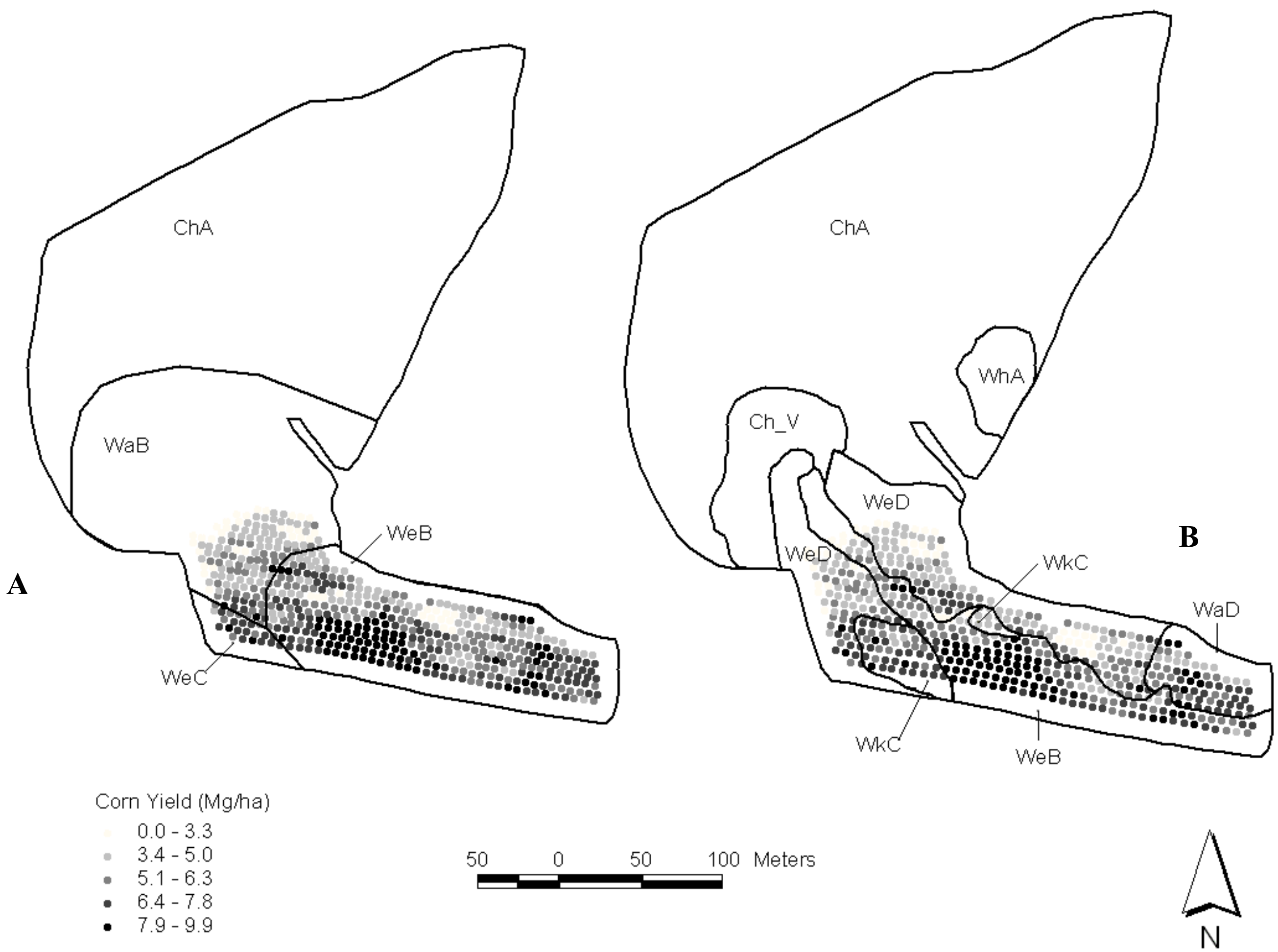


Figure 27. 2002 corn yield for Field 7 in the Piedmont. (A) original map units and (B) remapped soil map units.

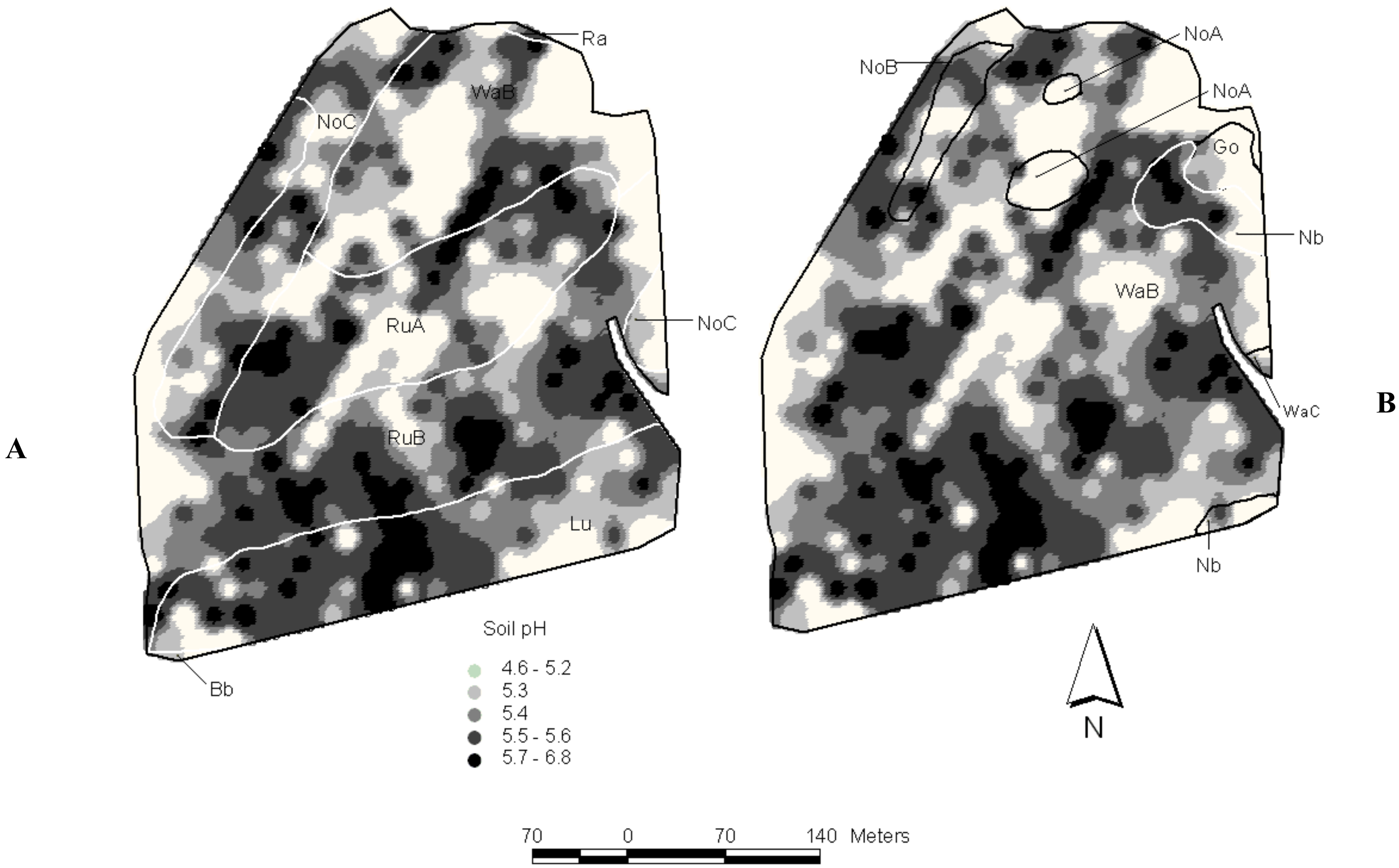
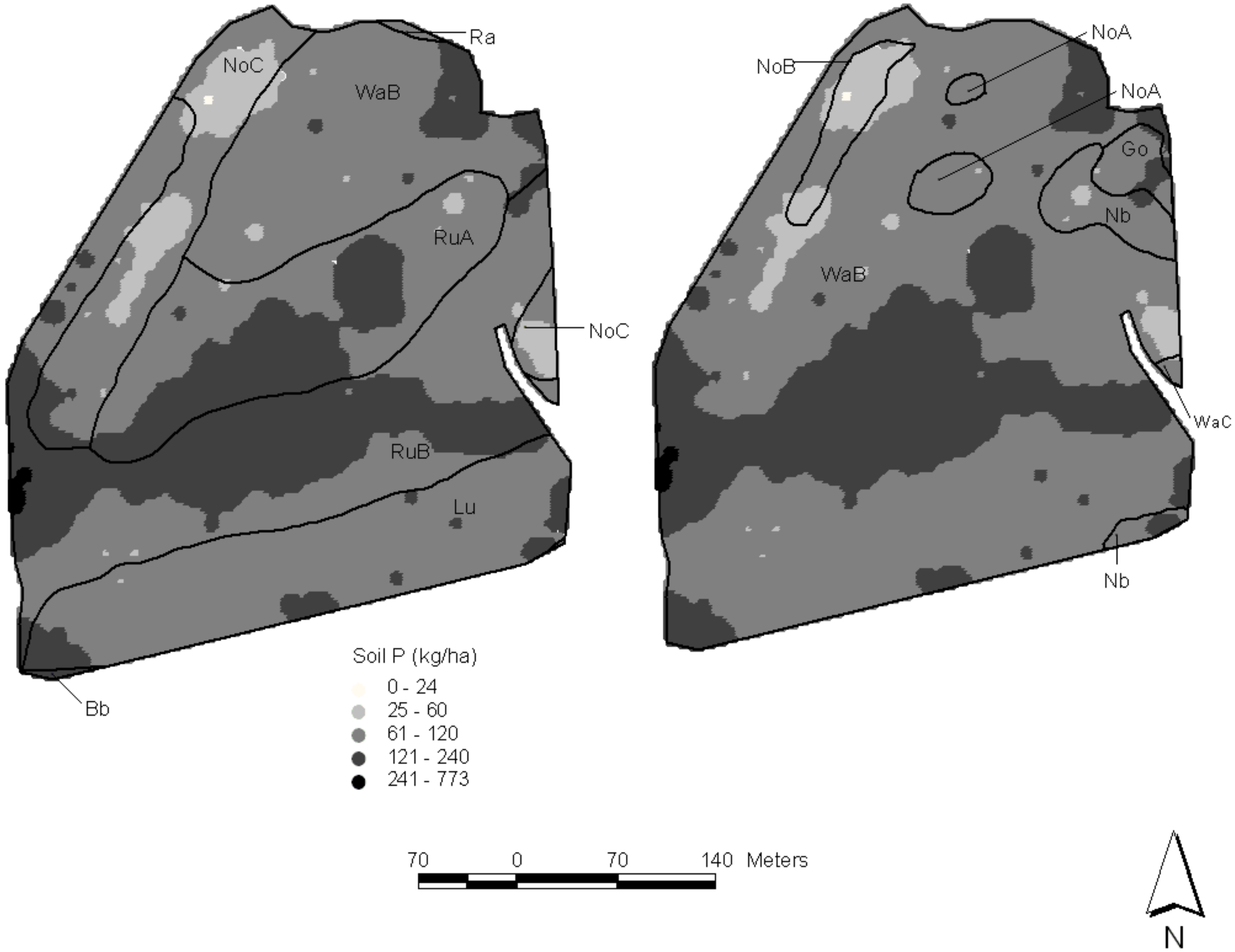


Figure 28. Soil pH in the Coastal Plain. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the quantile approach.

A



B

Figure 29. Soil P in the Coastal Plain. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

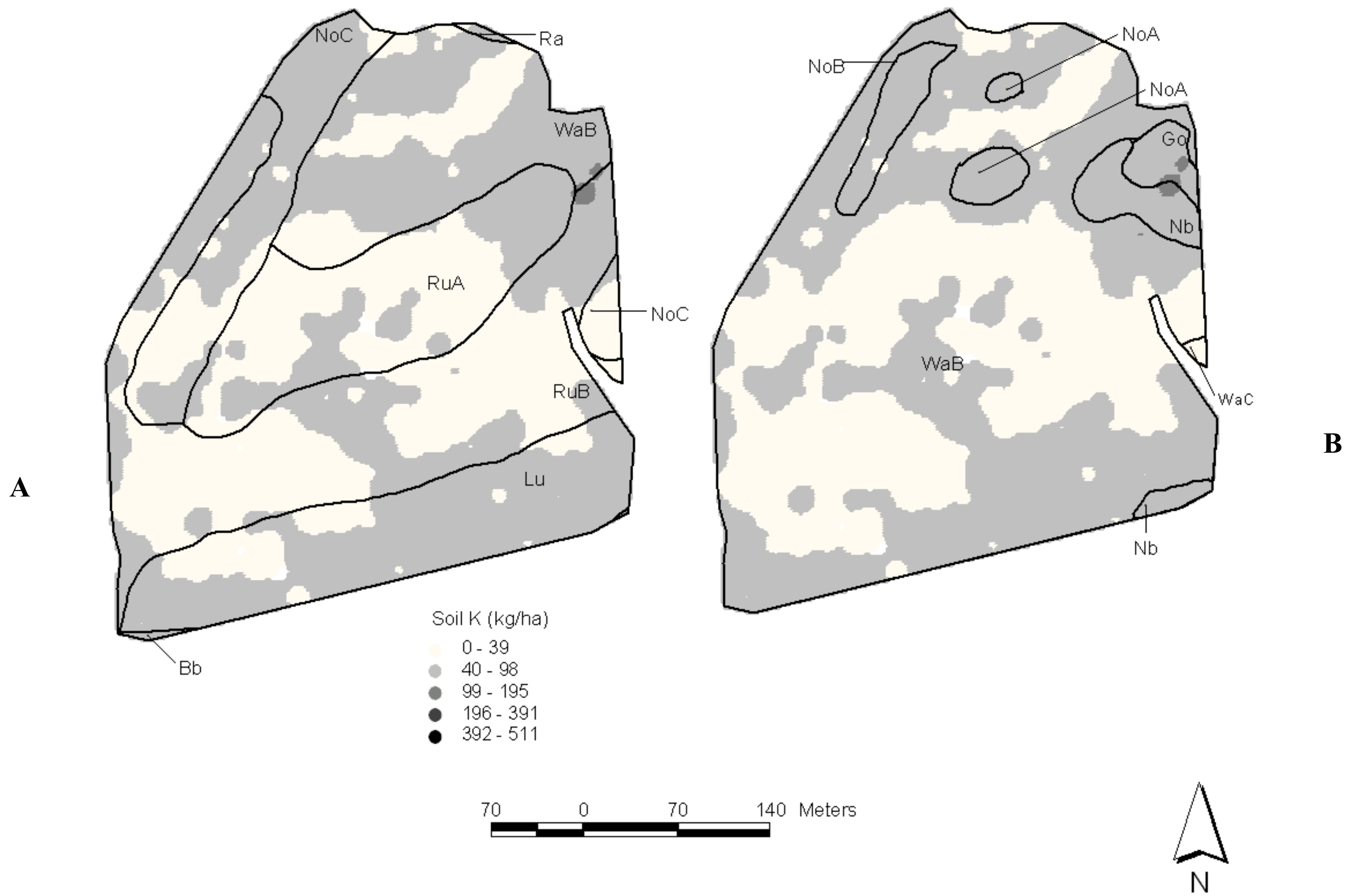


Figure 30. Soil K in the Coastal Plain. (A) original map units and (B) remapped soil map units. The interpolated maps were classified using the NCDA Nutrient Index System for the assigned classes.

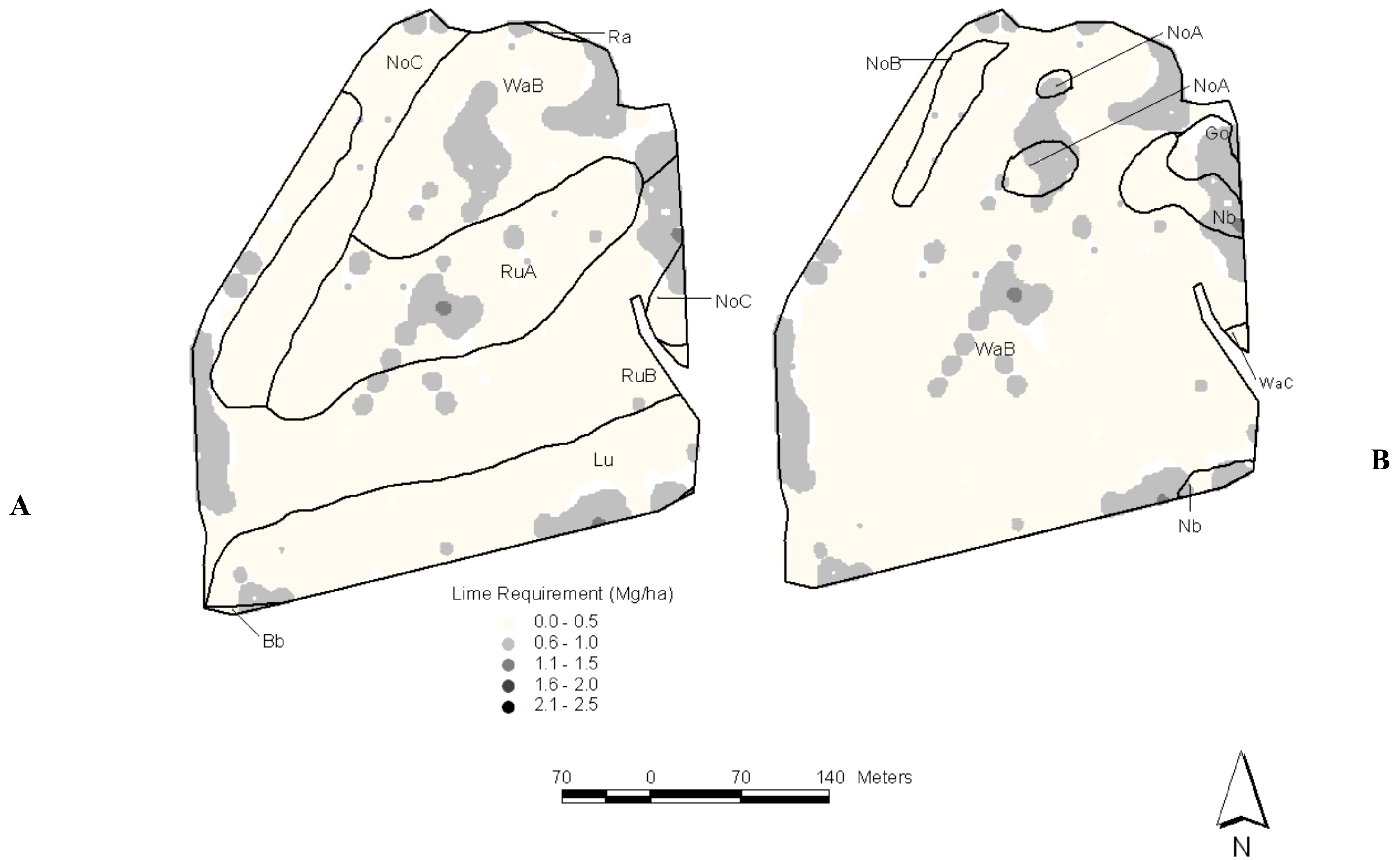


Figure 31. Lime Requirement for the Coastal Plain. (A) original map units and (B) remapped soil map units.

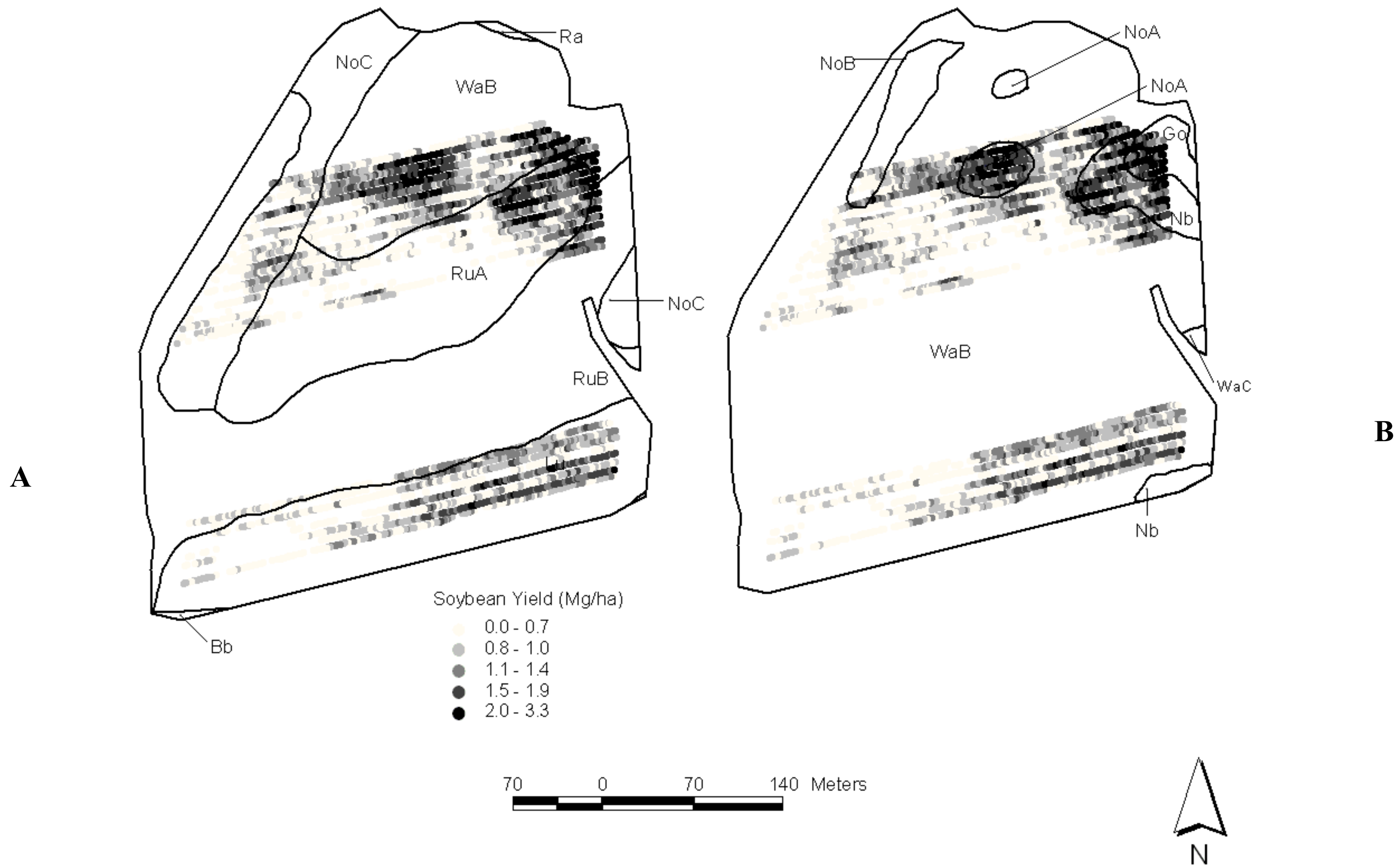


Figure 32. 2000 soybean yield in the Coastal Plain. (A) original map units and (B) remapped soil map units.

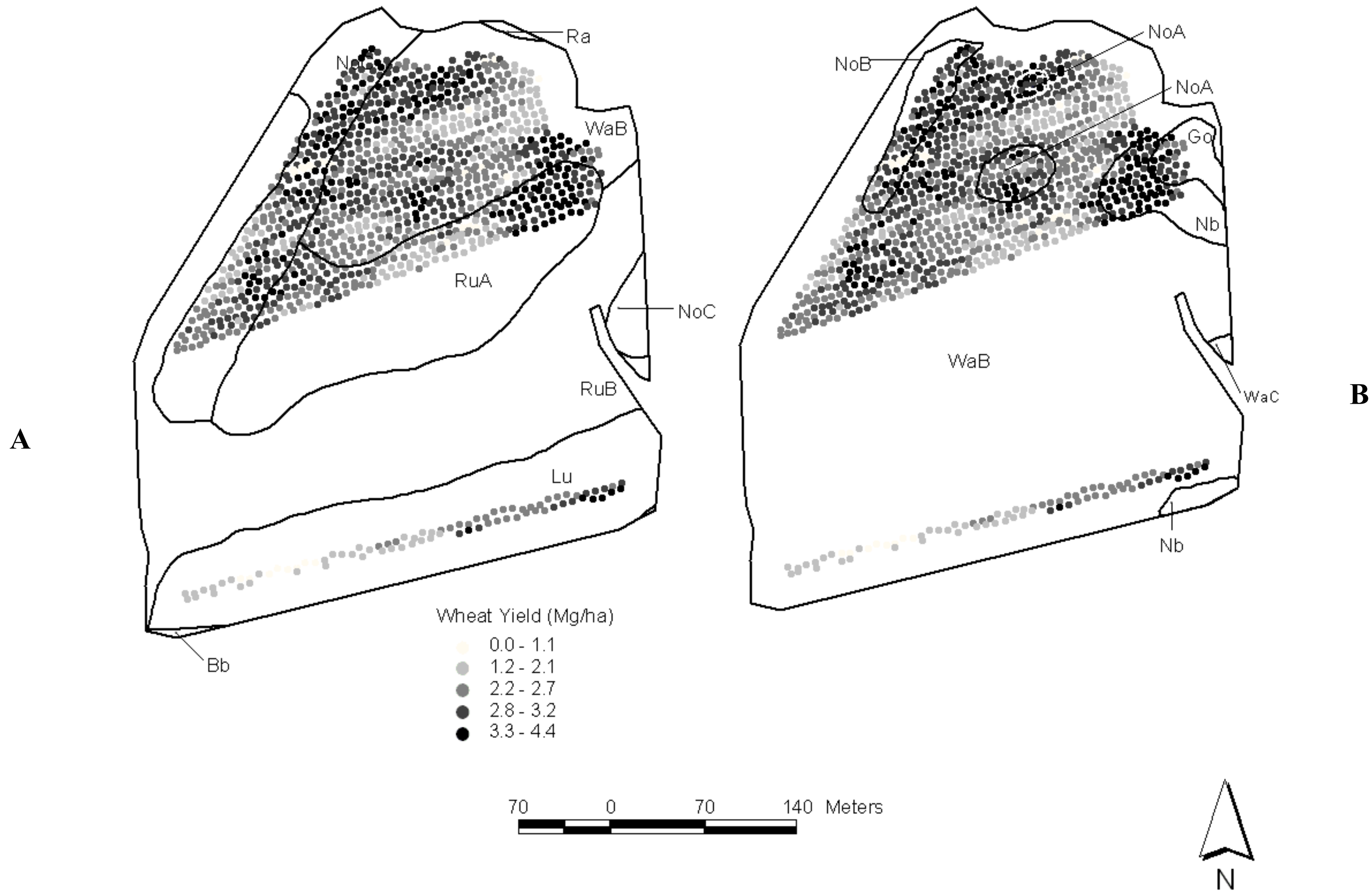


Figure 33. 2002 wheat yield in the Coastal Plain. (A) original map units and (B) remapped soil map units.

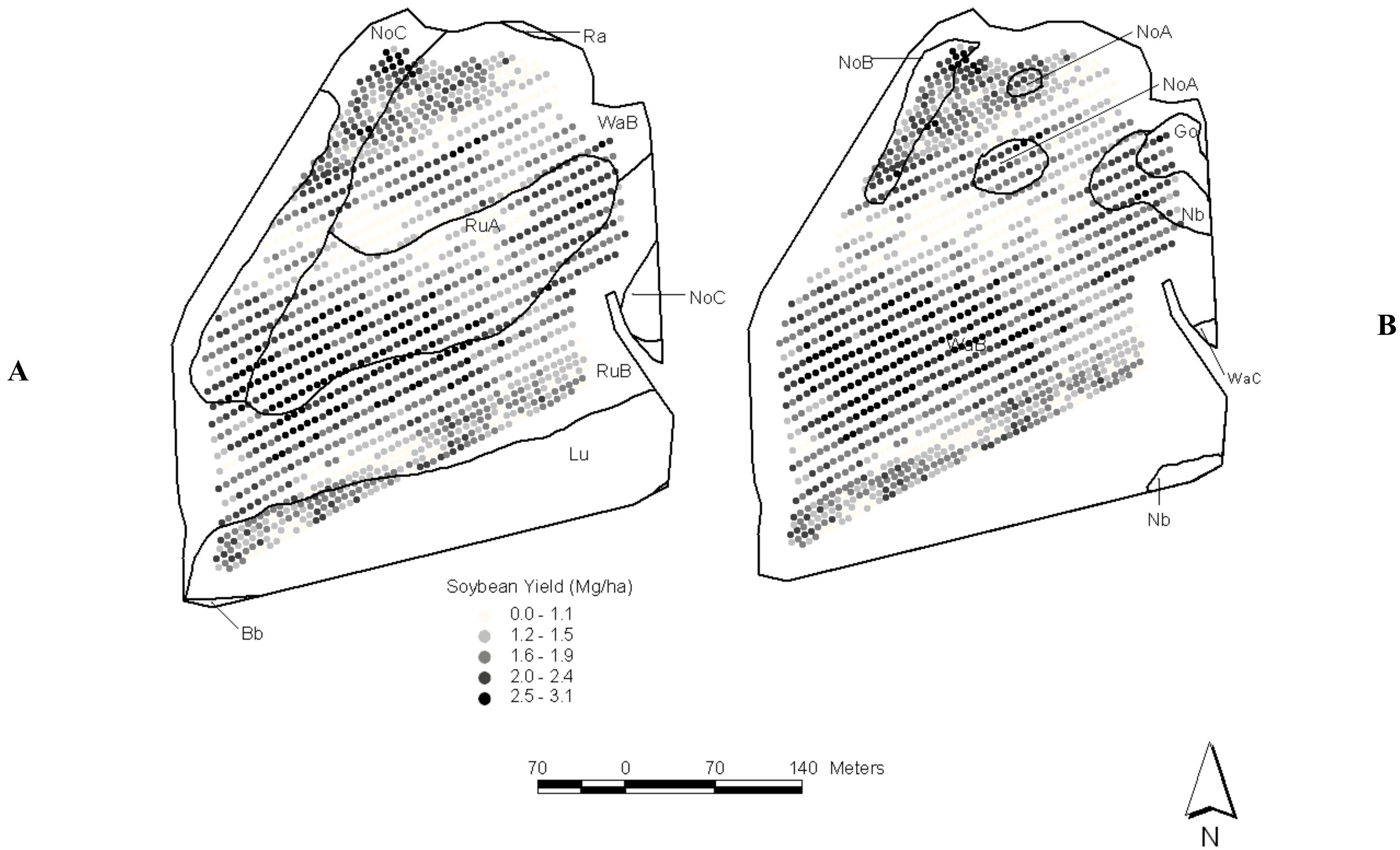


Figure 34. 2002 soybean yield for the Coastal Plain. (A) original map units and (B) remapped soil map units.

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APPENDIX A

LSMEANS FROM PROC GLM

Table A1. Average corn yield and soil chemical properties by remapped soil map unit and location within a zone for Field 3 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield		Soil Chemical Properties			
Map unit	2002 Corn[†]	2003 Wheat	pH	P	K	Lime
	-----Mg ha^{-1}-----			---kg ha^{-1}---		Mg ha^{-1}
Durham	N/A	2.3	N/A	N/A	N/A	N/A
Durham_B	9.1a[‡]	2.4	5.9b	63	122b	0.2b
Helena_B	N/A	N/A	N/A	N/A	N/A	N/A
Helena_D	7.4ab	N/A	5.9b	43	108b	0.1b
Pacolet_B	8.4ab	N/A	6.5a	36	217a	0.0b
Wateree_D	6.5b	N/A	6.4a	45	272a	0.0b
Wedowee_B	8.9a	N/A	5.9b	88	112b	0.2b
Wedowee_C	7.2b	N/A	5.6c	44	87b	0.5a
Wedowee_D	9.6a	N/A	5.9b	30	131b	0.1b
Transition Zone Mean	8.2	2.3	6.0	52	142	0.1
Interior Mean	8.2	2.4	6.0	48	158	0.2

[†] N/A, No data collected within this map unit.
[‡] Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A2. Average corn yield and soil chemical properties by original soil map unit and location within a zone for Field 3 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield		Soil Chemical Properties			
Map unit	2002 Corn[†]	2003 Wheat	pH	P	K	Lime
	-----Mg ha^{-1}-----			---kg ha^{-1}---		Mg ha^{-1}
Wake-Saw-Wedowee complex	N/A	N/A	N/A	N/A	N/A	N/A
Wedowee_B	8.6	2.3b[‡]	5.9	71b	125a	0.2b
Wedowee_C	8.3	2.4a	5.9	104a	89b	0.3a
Transition Zone Mean	7.8b	2.3	5.9	78	105	0.3a
Interior Mean	9.0a	2.4	5.8	98	108	0.2b

[†] N/A, No data collected within this map unit.
[‡] Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A3. Average wheat yield and soil chemical properties by remapped soil map unit and location within a zone for Field 5 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Wheat†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Durham_B	N/A	N/A	N/A	N/A	N/A
Helena_B	N/A	N/A	N/A	N/A	N/A
Helena_C	N/A	N/A	N/A	N/A	N/A
Pacolet_B	4.0	6.0	67	272b‡	0.1b
Pacolet_C	3.9	5.9	71	266b	0.1b
Pacolet_D	4.0	5.8	63	319a	0.2a
State_A	4.2	5.9	83	189b	0.1b
State_B	4.0	N/A	N/A	N/A	N/A
Vance_C	N/A	N/A	N/A	N/A	N/A
Wake_B	3.9	N/A	N/A	N/A	N/A
Wake_D	N/A	N/A	N/A	N/A	N/A
Wake_E	3.9	6.1	112	261b	0.1b
Wateree_B	N/A	N/A	N/A	N/A	N/A
Wedowee_B	3.7	N/A	N/A	N/A	N/A
Transition Zone Mean	4.2	5.9	101	286	0.2
Interior Mean	3.9	5.9	57	236	0.1

† N/A, No data collected within this map unit.

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A4. Average wheat yield and soil chemical properties by original soil map unit and location within a zone for Field 5 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Wheat†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla_A	N/A	N/A	N/A	N/A	N/A
Wake-Saw- Wedowee complex	3.9	5.9	44	224b	0.3
Wake-Wateree-Wedowee complex	3.8	6.0	52	283a	0.3
Wedowee_B	3.9	5.7	61	262a	0.3
Transition Zone Mean	4.0b‡	5.9	63	260a	0.4
Interior Mean	3.9a	5.9	41	252b	0.2

† N/A, No data collected within this map unit.

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A5. Wheat yield simple effect means from interaction between remapped soil map units and zones for Field 5 in the Piedmont. Means reported are LSMEANS from the Proc GLM statistical model.

Map Unit	Transition Zone	Map Unit Interior
	----------------kg ha^{-1}----------------------	
Durham_B	N/E†	3.6
Helena_B	N/E†	3.5
Helena_C	N/E†	3.7
Pacolet_B	4.1	4.0
Pacolet_C	3.8	3.9
Pacolet_D	4.0	4.0
State_A	4.2	4.1
State_B	4.1	4.0
Vance_C	N/E†	3.9
Wake_B	4.2	3.6
Wake_D	N/E†	3.8
Wake_E	3.9	3.9
Wateree_B	N/A	N/A
Wedowee_B	3.7	3.6

†N/E, non-estimable in SAS.

‡N/A, no data collected within this soil map unit.

Table A6. Average corn yield and soil chemical properties by remapped soil map unit and location within a zone for Field 7 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Corn†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla_A	N/A	5.9b‡	88b	242b	0.2b
Chewacla_V	N/A	5.3c	160a	363b	1.4a
Wake_C	6.4	6.8a	138ab	1332a	0.0b
Wateree_D	6.4	6.7a	131ab	957a	0.0b
Wedowee_B	7.2	6.7a	125ab	1031a	0.0b
Wedowee_D	4.6	6.3a	99ab	922a	0.2b
Wehadkee_A	N/A	5.8bc	100ab	247b	0.2b
Transition Zone Mean	6.3	6.2	108	742	0.3
Interior Mean	6.9	6.2	132	714	0.2

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A7. Average corn yield and soil chemical properties by original soil map unit and location within a zone for Field 7 in the Piedmont. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield	Soil Chemical Properties			
Map unit	2002 Corn†	pH	P	K	Lime
	Mg ha^{-1}		---kg ha^{-1}---		Mg ha^{-1}
Chewacla	N/A	6.0	76b‡	229c	0.1
Wake-Wateree-Wedowee complex	4.7	5.9	115a	500b	0.5
Wedowee_B	5.9	6.7	109a	1080a	0.0
Wedowee_C	6.8	N\A	N\A	N\A	N/A
Transition Zone	5.7	6.3	95b	500	0.2
Interior Mean	5.8	6.1	105a	716	0.2

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A8. Soil pH, lime requirement and corn yield simple effect means from interaction of original soil map units and zones for Field 7 in the Piedmont. Means reported are LSMEANS from the Proc GLM statistical model.

	Soil pH		Lime Requirement		Corn Yield	
Map Unit	Transition Zone	Map Unit Interior	Transition Zone	Map Unit Interior	Transition Zone	Map Unit Interior
			---------------Mg ha^{-1}------------------			
Chewacla	6.0	6.0	0.1	0.2	N/A[†]	N/A
Wake-Wateree-Wedowee Complex	5.7	6.1	0.7	0.2	3.9	5.4
Wedowee_B	6.8	6.6	0.0	0.0	6.5	5.2
Wedowee_C	N/E[‡]	6.3	N/E	0.3	7.1	6.5

[†]N/A, no data collected within this soil map unit.

[‡]N/E, non-estimable in SAS.

Table A9. Corn yield simple effect means from interaction between remapped soil map units and zones for Field 7 in the Piedmont. Means reported are LSMEANS from the Proc GLM statistical model.

Map Unit	Transition Zone	Map Unit Interior
	---------------kg ha^{-1}---------------	
Chewacla_A	6.0	5.8
Chewacla_V	5.1	5.4
Wake_C	6.8	6.7
Wateree_D	6.8	6.5
Wedowee_B	6.8	6.7
Wedowee_D	6.3	6.3
Wehadkee_A	5.8	5.7

†N/A, no data collected within this soil map unit.

Table A10. Average crop yield and soil chemical properties for remapped soil map units and location within a zone for the Coastal Plain. Means reported are LSMEANS from Proc GLM in SAS.

Map unit	Crop Yield: 2000 Soybean	Crop Yield: 2002 Wheat	Crop Yield: 2002 Soybean	Soil Chemical Properties: pH	Soil Chemical Properties: P	Soil Chemical Properties: K	Soil Chemical Properties: Lime
	----------Mg ha^{-1}----------				---kg ha^{-1}---		Mg ha^{-1}
Goldsboro	1.9	3.0	2.1a‡	5.2b	87a	88a	0.6a
Noboco	1.6	3.4	2.0a	5.5a	86a	65bc	0.5a
Norfolk_A	1.8	2.8	1.9a	5.0b	78a	70ac	0.7a
Norfolk_B	0.6	2.9	1.9a	5.4ab	40b	58bce	0.5a
Wagram_B	1.0	2.6	1.7b	5.4ab	102a	48de	0.4b
Transition Zone Mean	1.3	3.0	1.9	5.3	84	67	0.6
Interior Mean	1.4	2.9	1.9	5.3	72	65	0.5

‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A11. Average crop yield and soil chemical properties by original soil map unit and location within a zone for the Coastal Plain. Means reported are LSMEANS from Proc GLM in SAS.

	Crop Yield			Soil Chemical Properties†			
Map unit	2000 Soybean	2002 Wheat	2002 Soybean	pH	P	K	Lime
	----------Mg ha^{-1}----------				---kg ha^{-1}---		Mg ha^{-1}
Bibb	N/A†	N/A	N/A	N/A	N/A	N/A	N/A
Lumbee	0.7bc‡	N/A	1.6c	5.5	102bc	48	0.4
Norfolk_C	0.6c	2.7a	1.8ab	5.4	66d	45	0.4
Rains	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ruston_A	0.9b	2.7a	1.9a	5.4	116ab	40	0.3
Ruston_B	1.0a	N/A	1.8b	5.4	127a	45	0.4
Wagram_B	1.2a	2.6b	1.6c	5.4	93c	48	0.5
Transition Zone							
Mean	1.0	2.7	1.8a	5.4	101	46	0.4
Interior Mean	1.0	2.7	1.7b	5.4	101	44	0.4

† N/A, No data collected within this map unit.
‡ Within columns, means followed by the same letter are not significantly different by Tukey's multiple pairwise comparison procedure (p=0.05).

Table A12. Soil K simple effect means from interaction between original soil map units and zones in the Coastal Plain. Means reported are LSMEANS from the Proc GLM statistical model.

Map Unit	Transition Zone	Map Unit Interior
	------------kg ha^{-1}------------	
Bibb	N/A[†]	N/A
Lumbee	87	90
Norfolk_C	69	72
Rains	N/A	N/A
Ruston_A	64	53
Ruston_B	65	64
Wagram_B	40	57

[†]N/A, no data collected within this soil map unit.

APPENDIX B

SEMIVARIOGRAMS

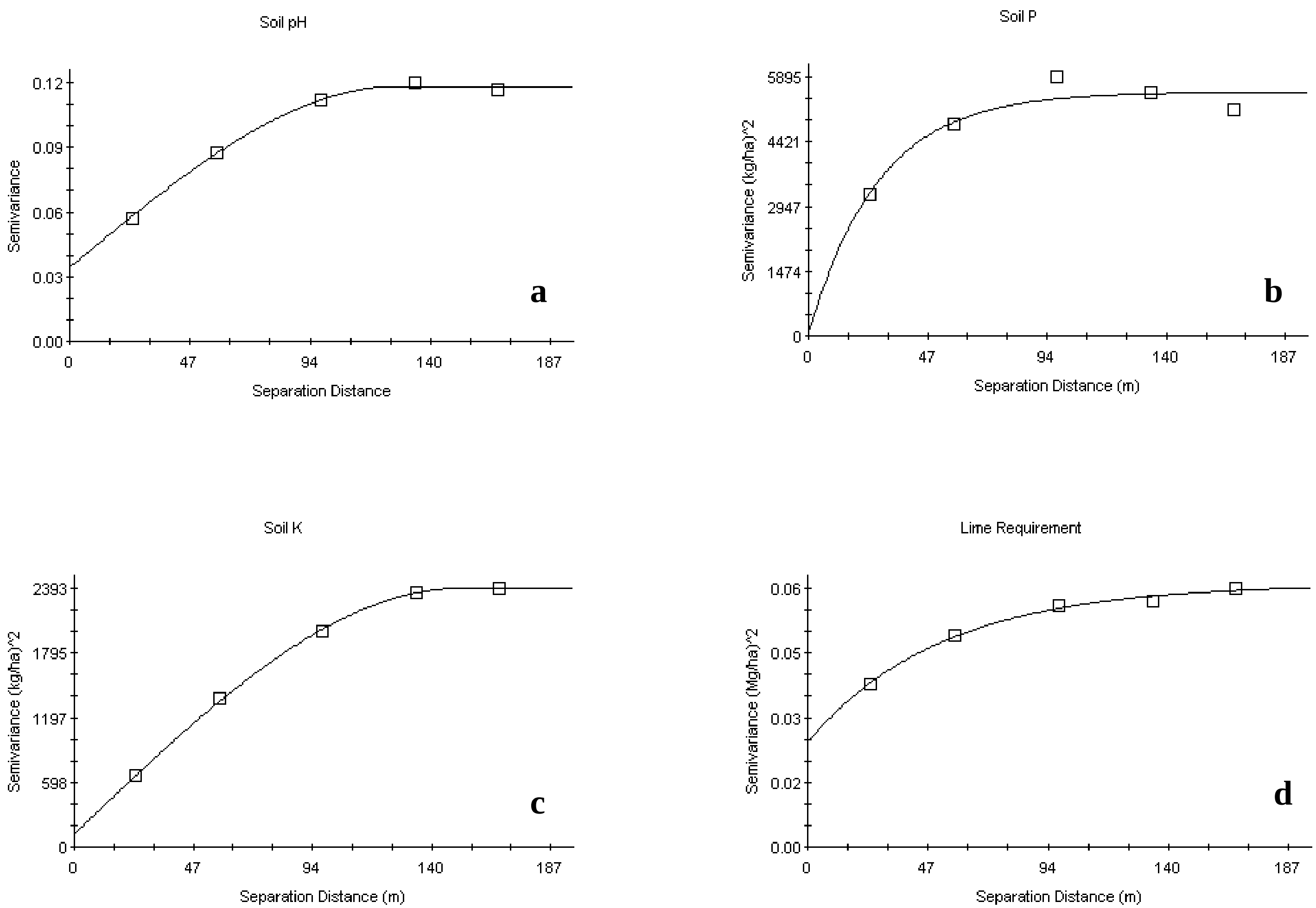

Fig. B1. Field 3 semivariograms of raw data for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

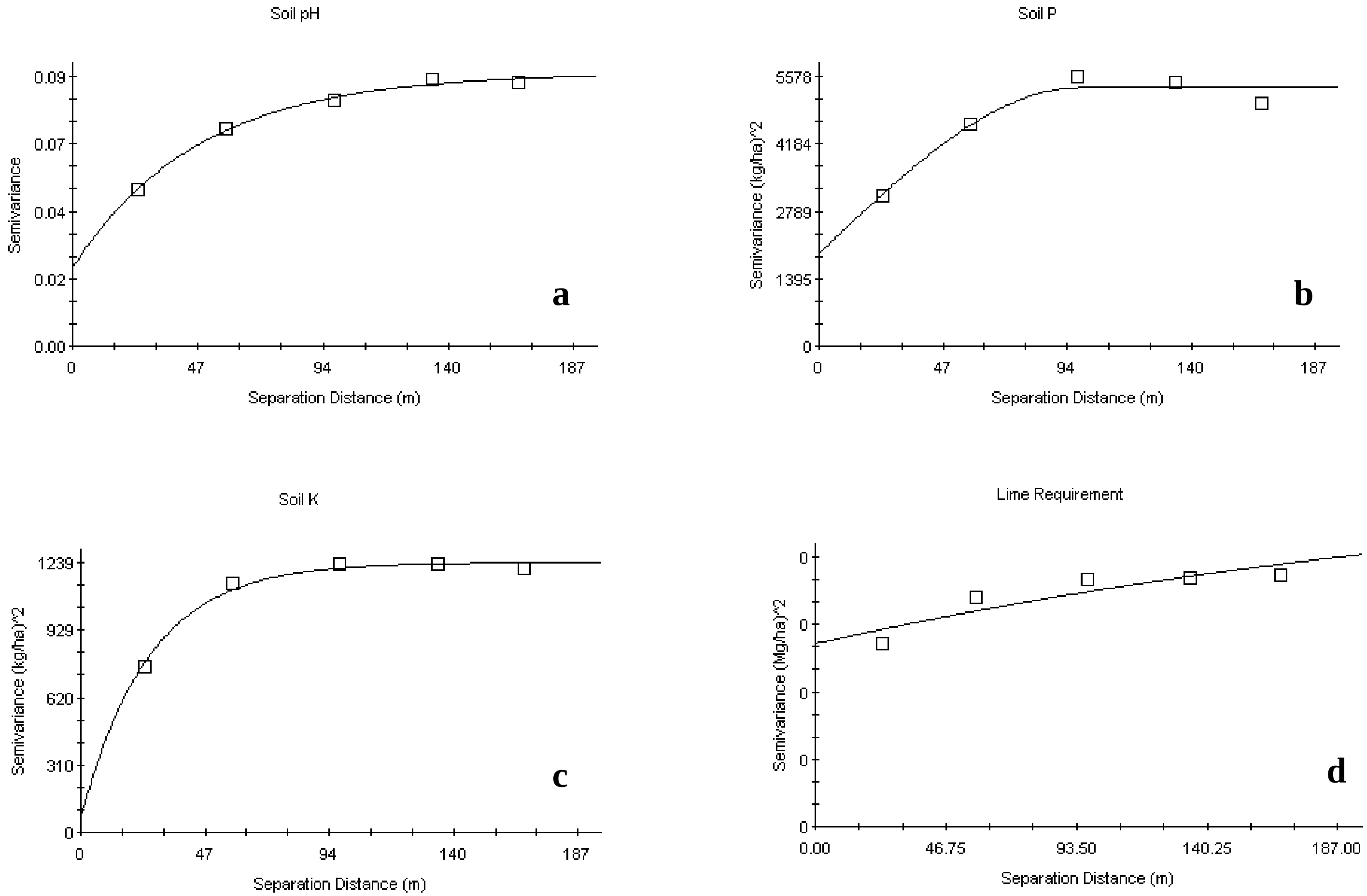

Fig. B2. Field 3 semivariograms of remapped soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

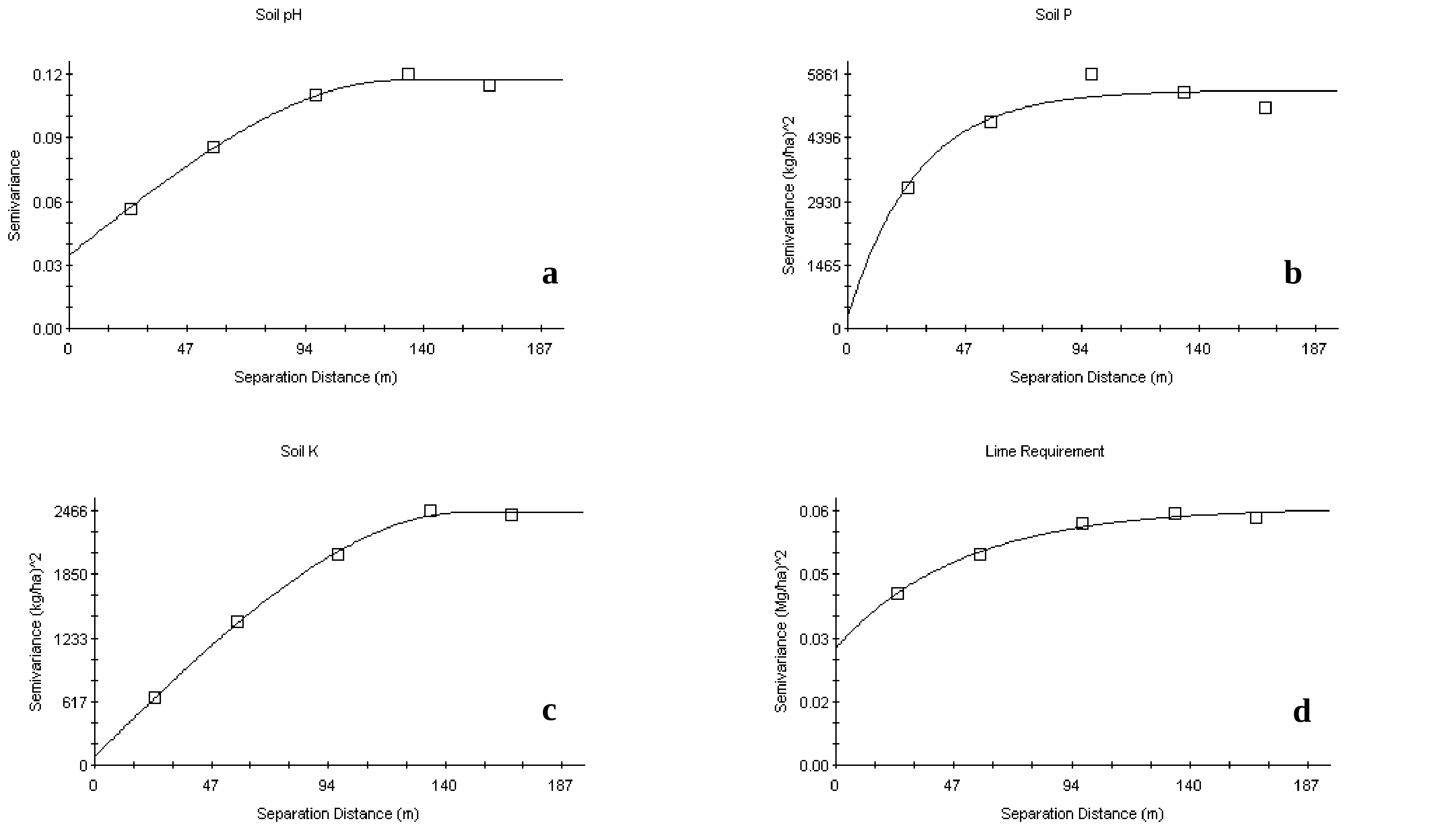

Fig. B3. Field 3 semivariograms of original soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

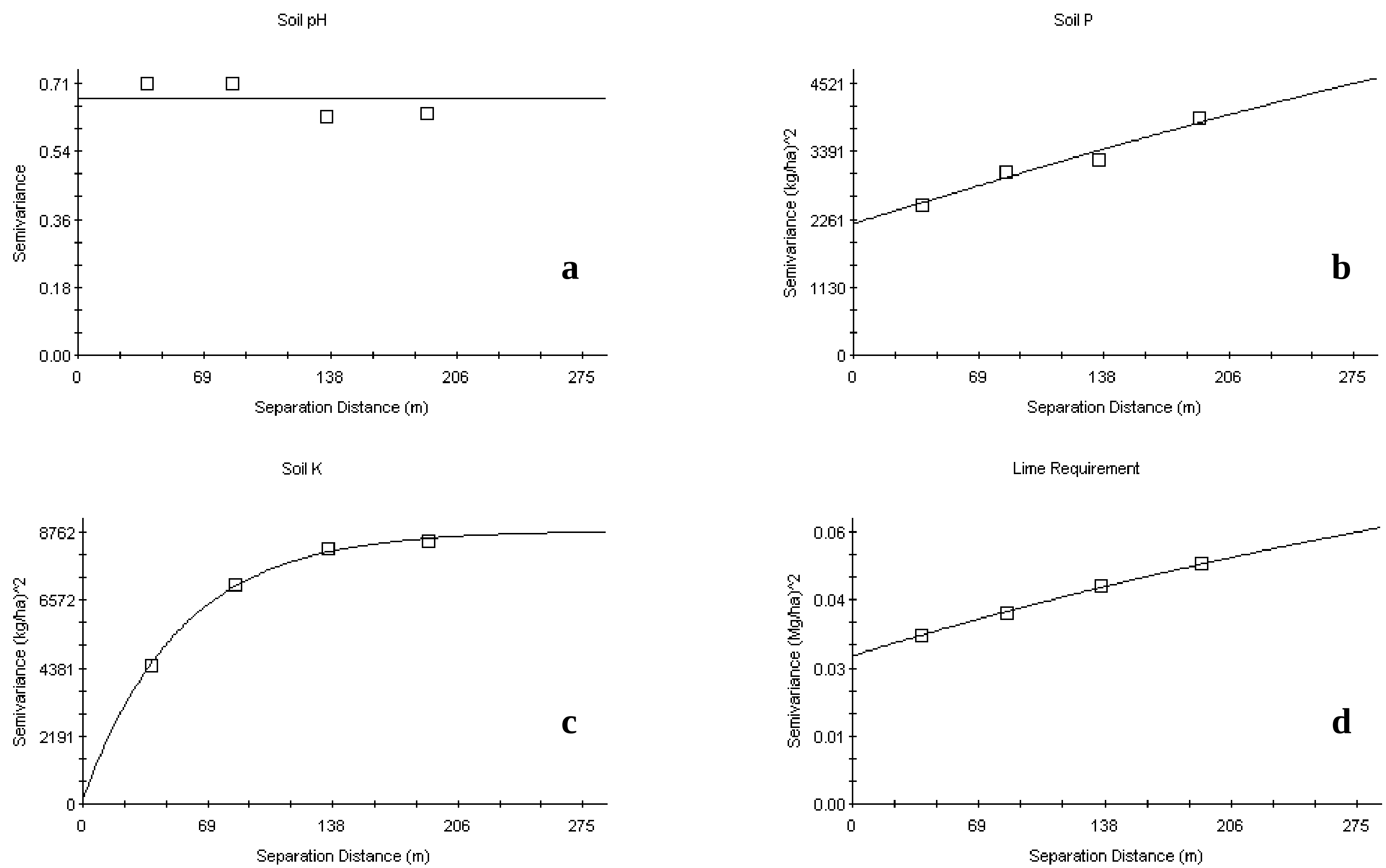

Fig. B4. Field 5 semivariograms of raw data for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

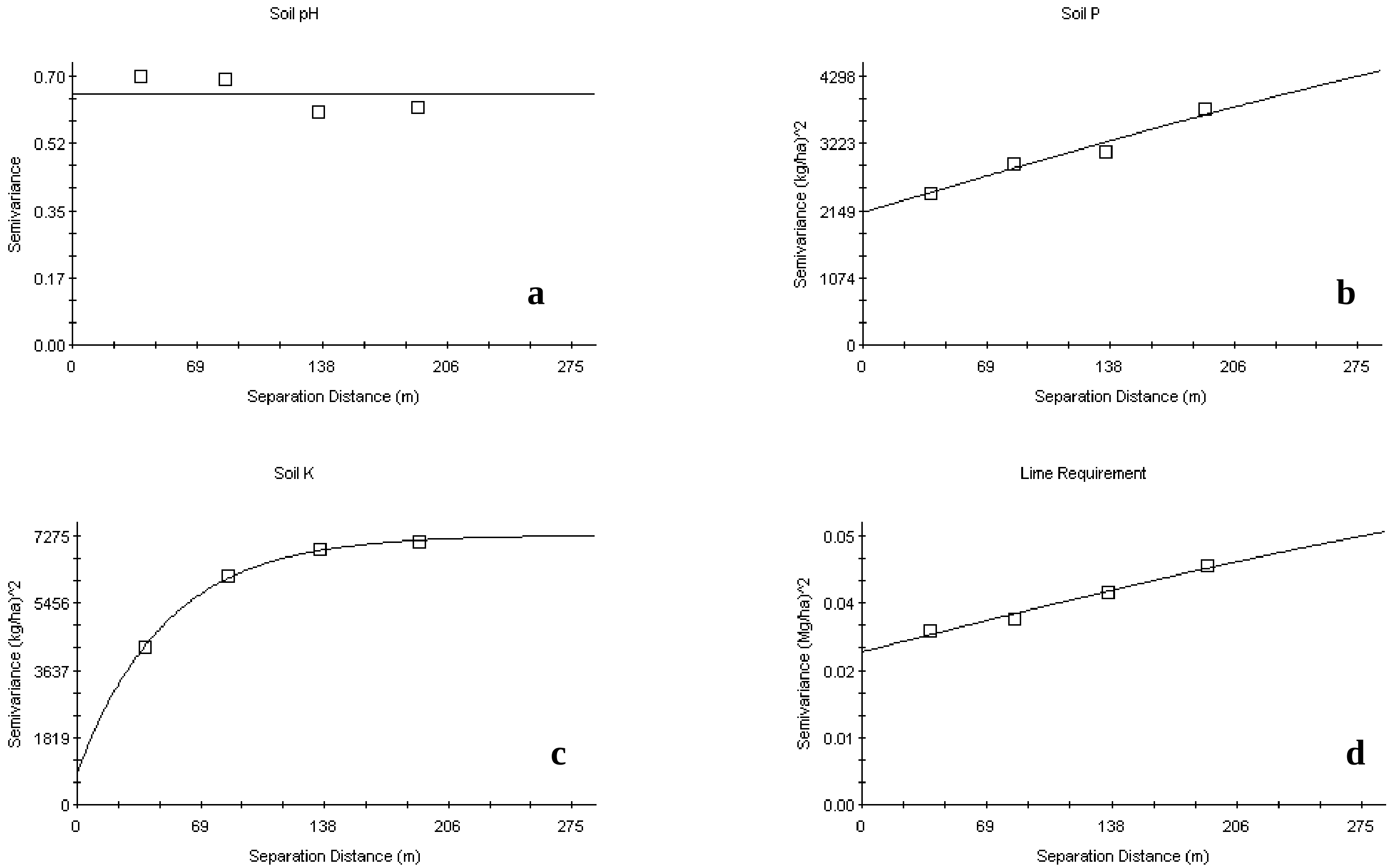

Fig. B5. Field 5 semivariograms of remapped soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

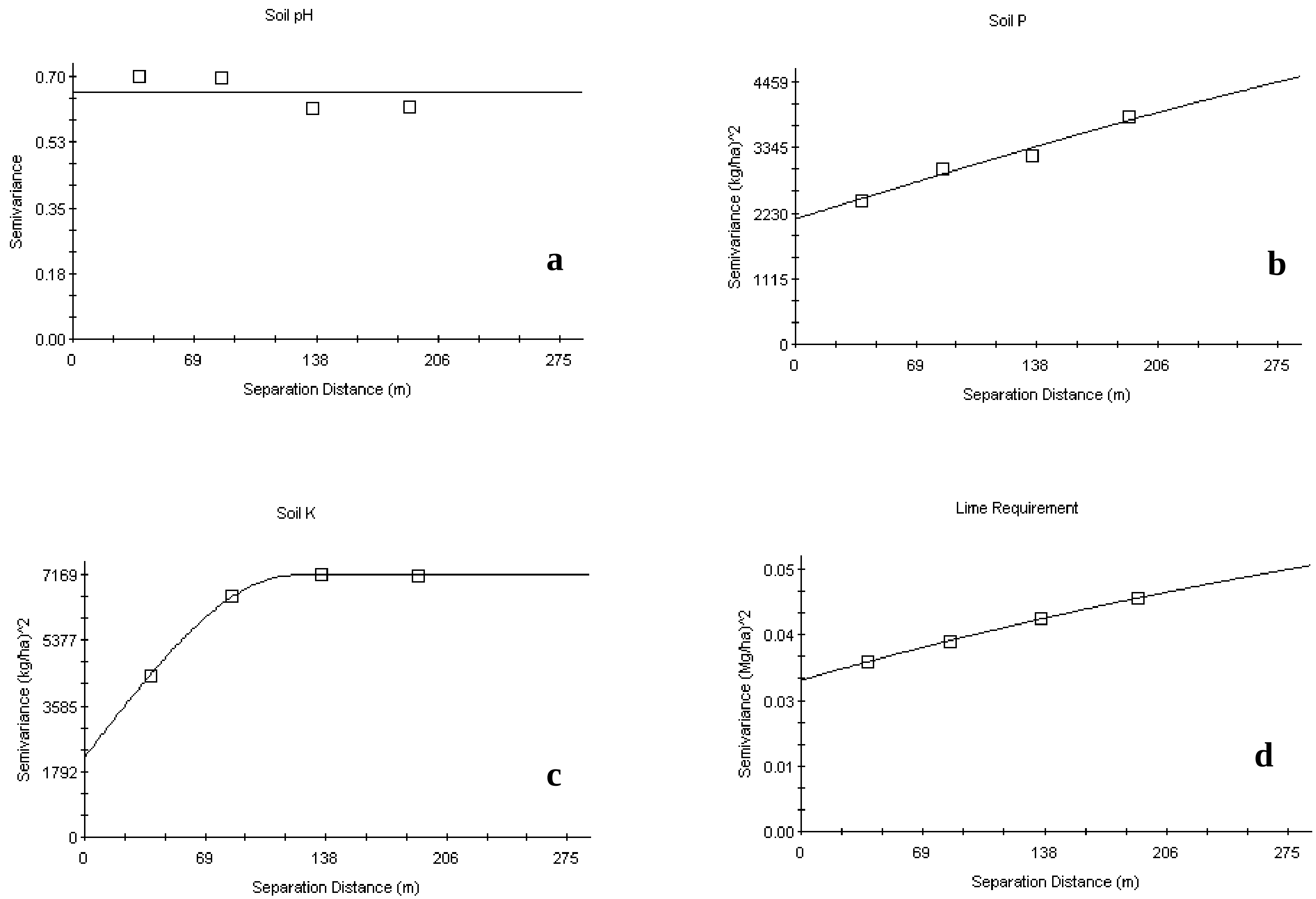

Fig. B6. Field 5 semivariograms of original soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

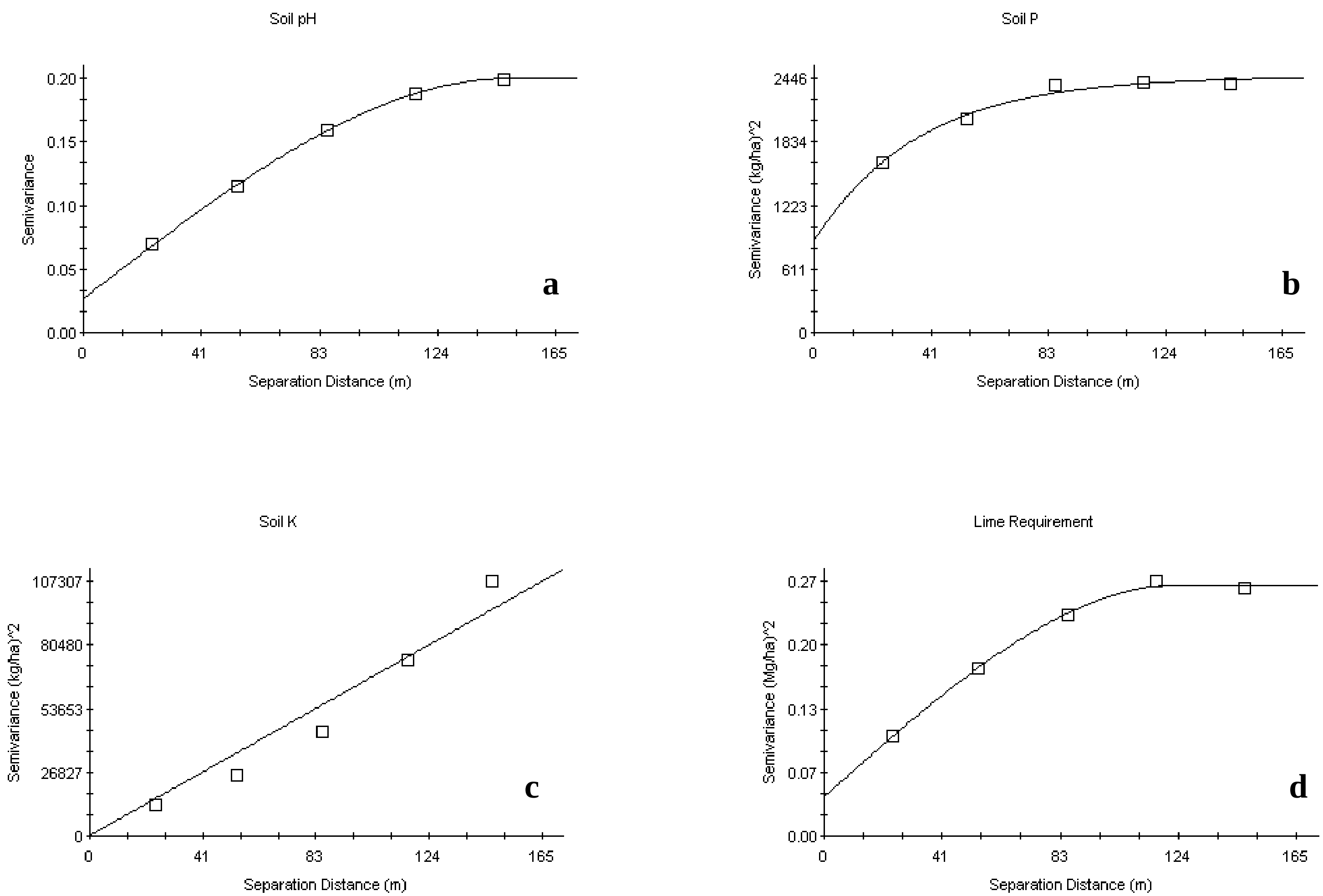

Fig. B7. Field 7 semivariograms of raw data for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

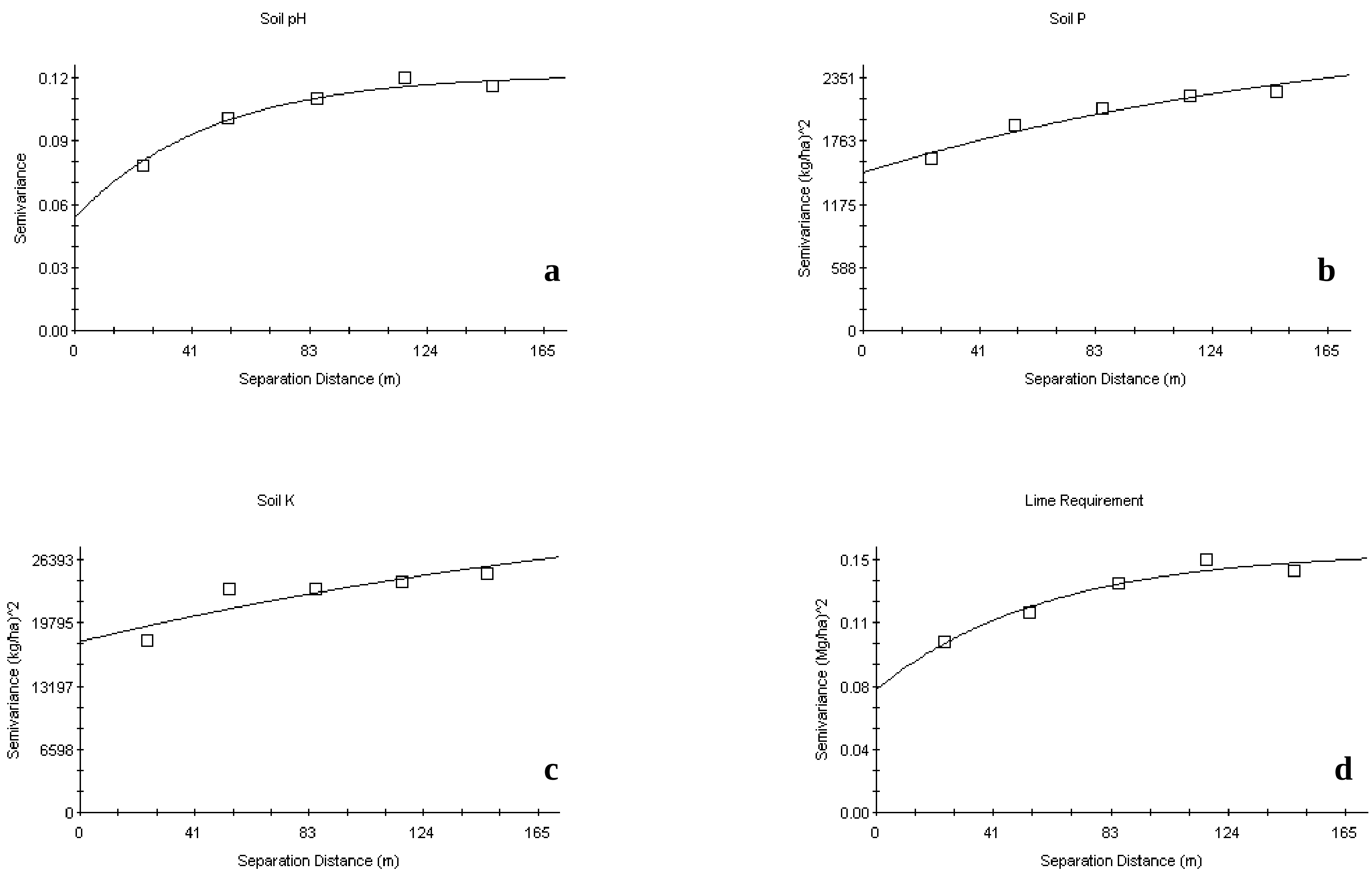

Fig. B8. Field 7 semivariograms of remapped soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

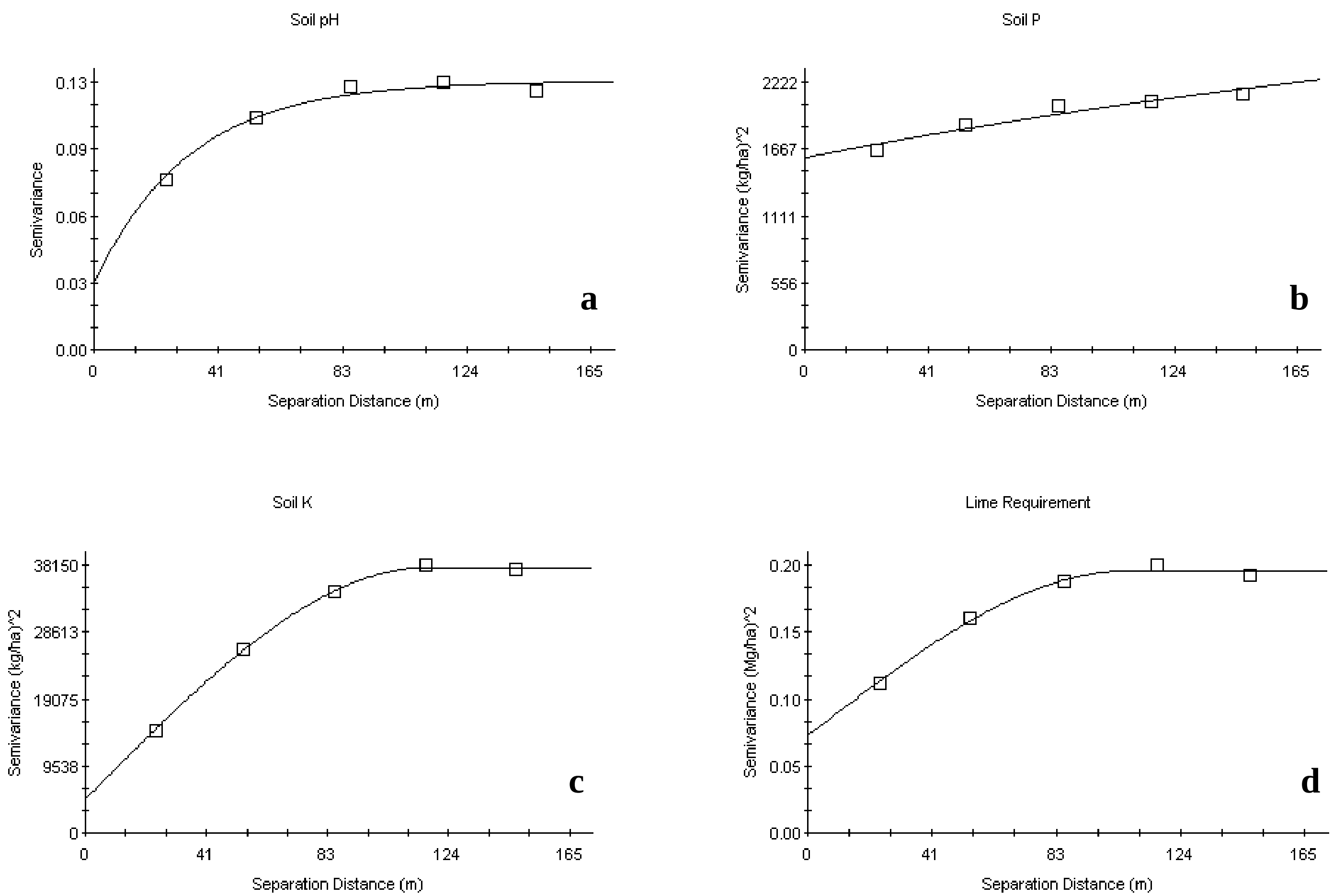

Fig. B9. Field 7 semivariograms of original soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

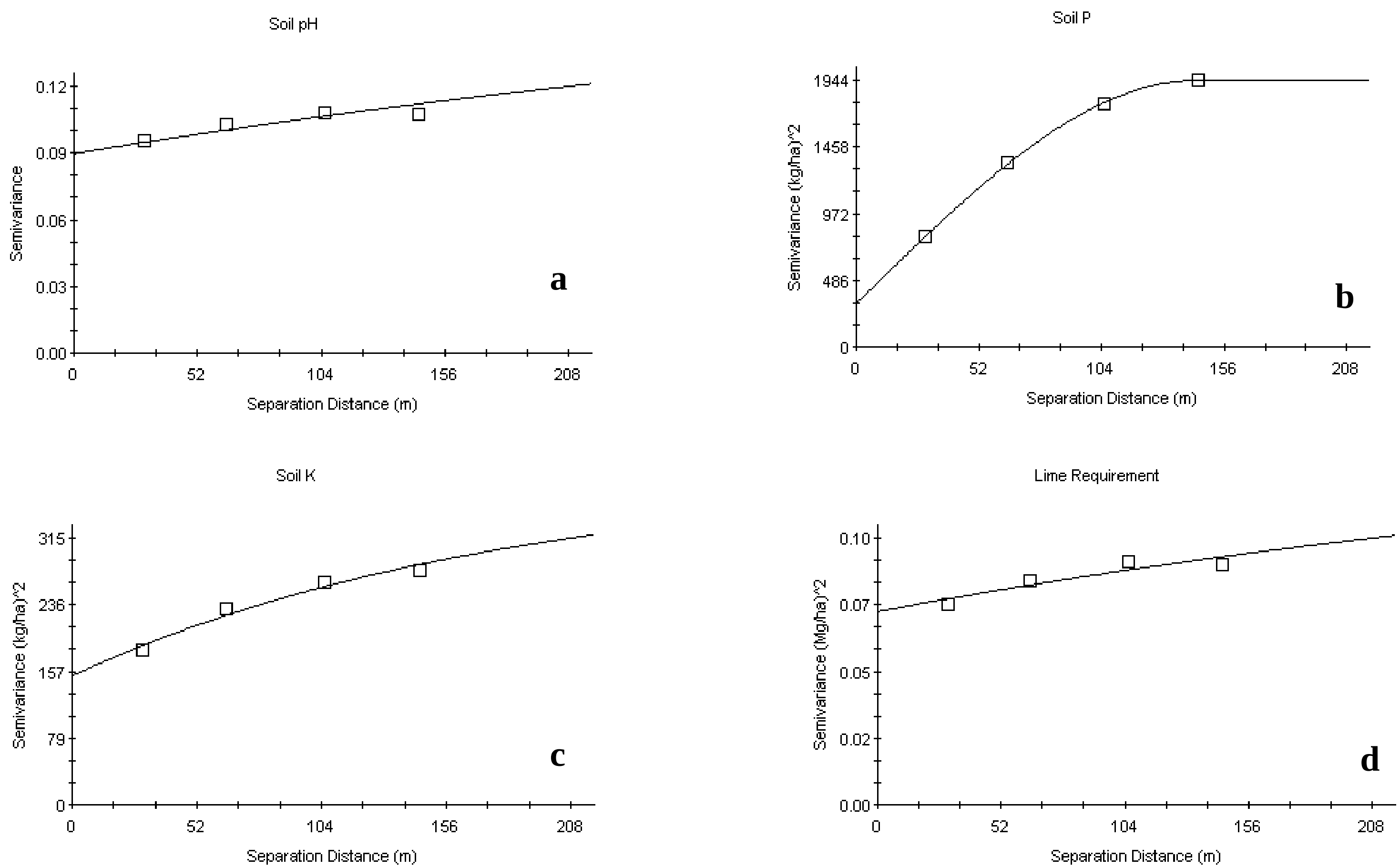

Fig. B10. Coastal Plain semivariograms of raw data for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

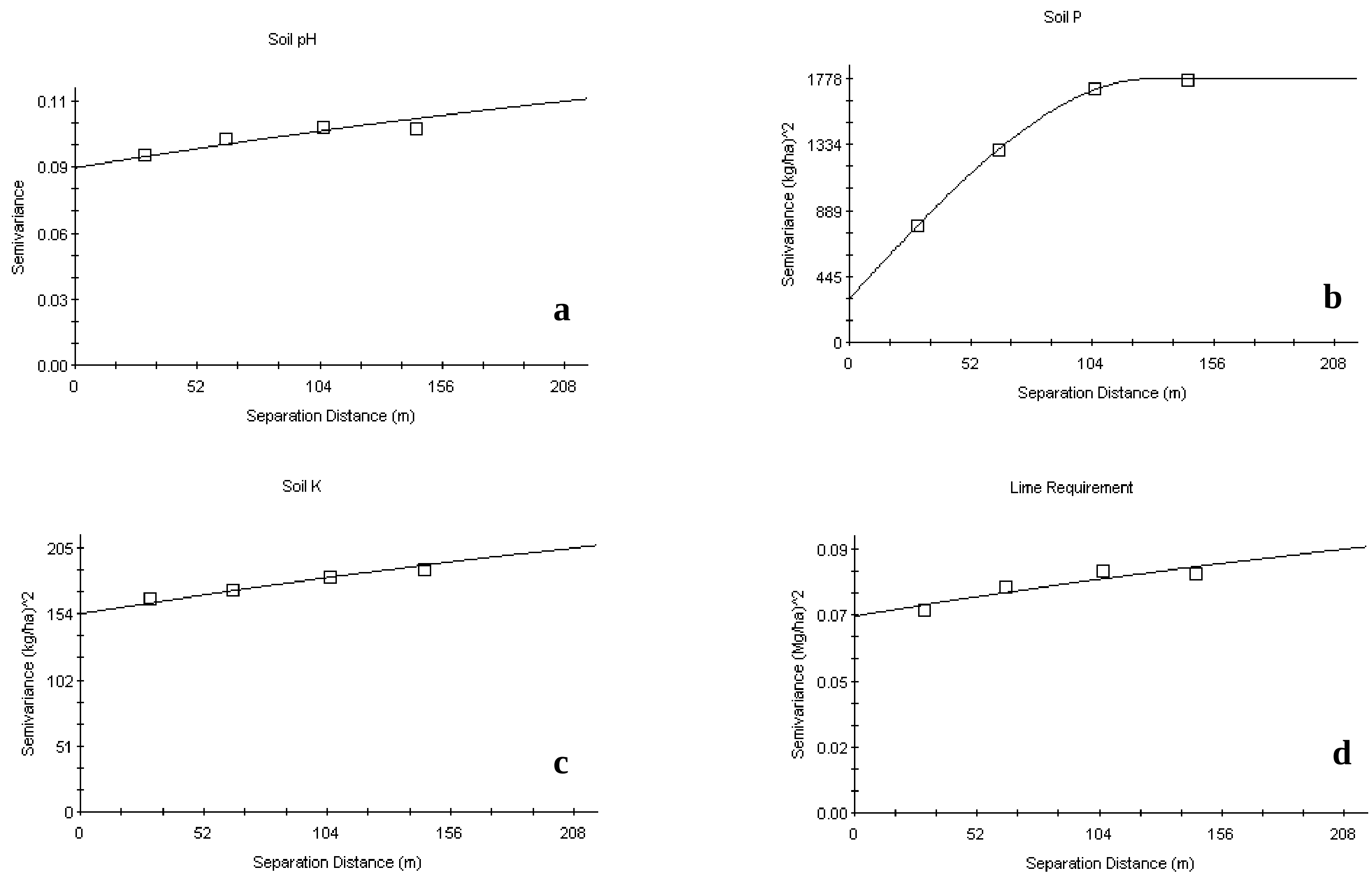

Fig. B11. Coastal Plain semivariograms of remapped soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

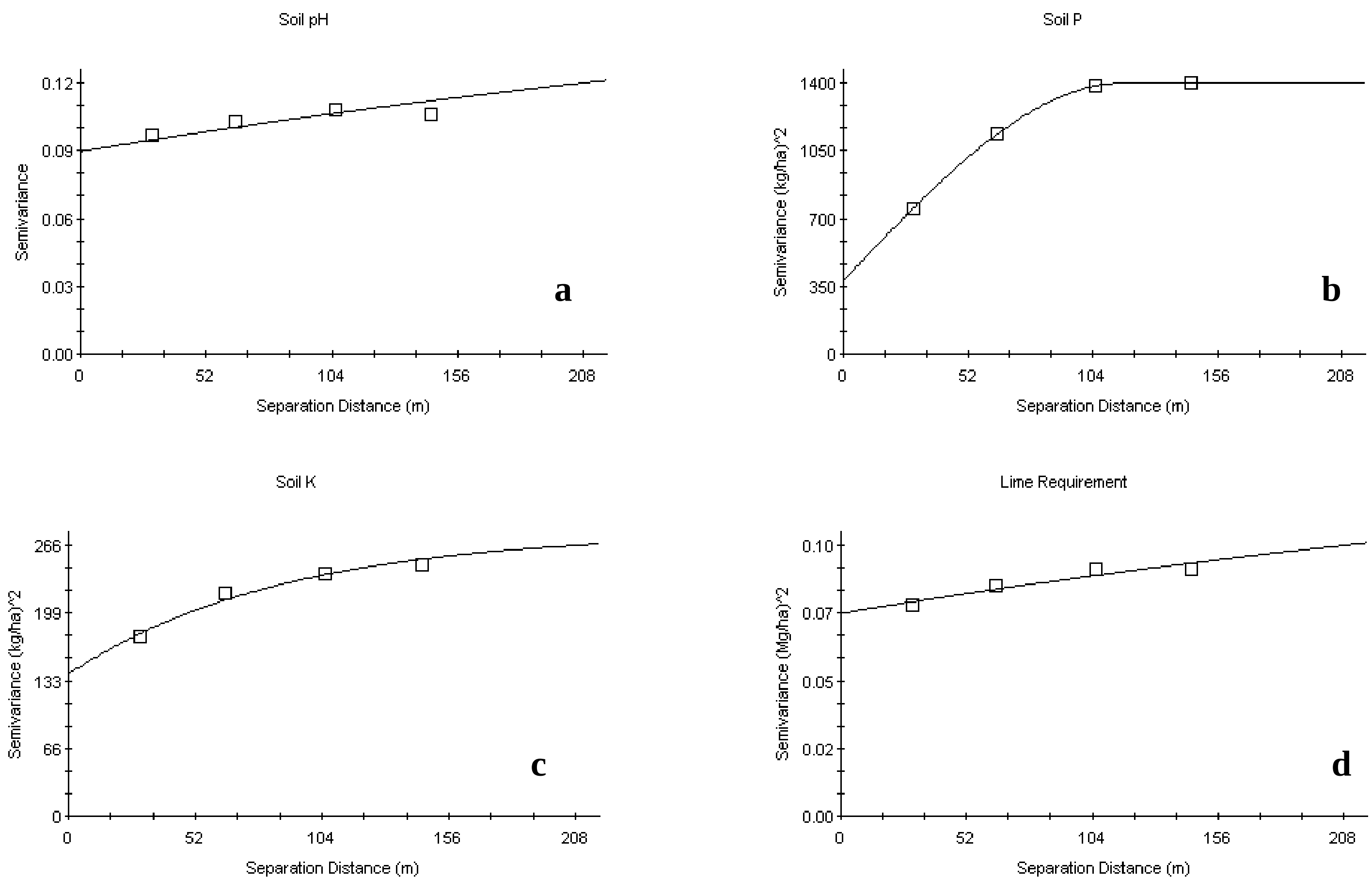

Fig. B12. Coastal Plain semivariograms of original soil map unit residuals for soil chemical properties including (a) soil pH, (b) soil P, (c) soil K, and (d) lime requirement.

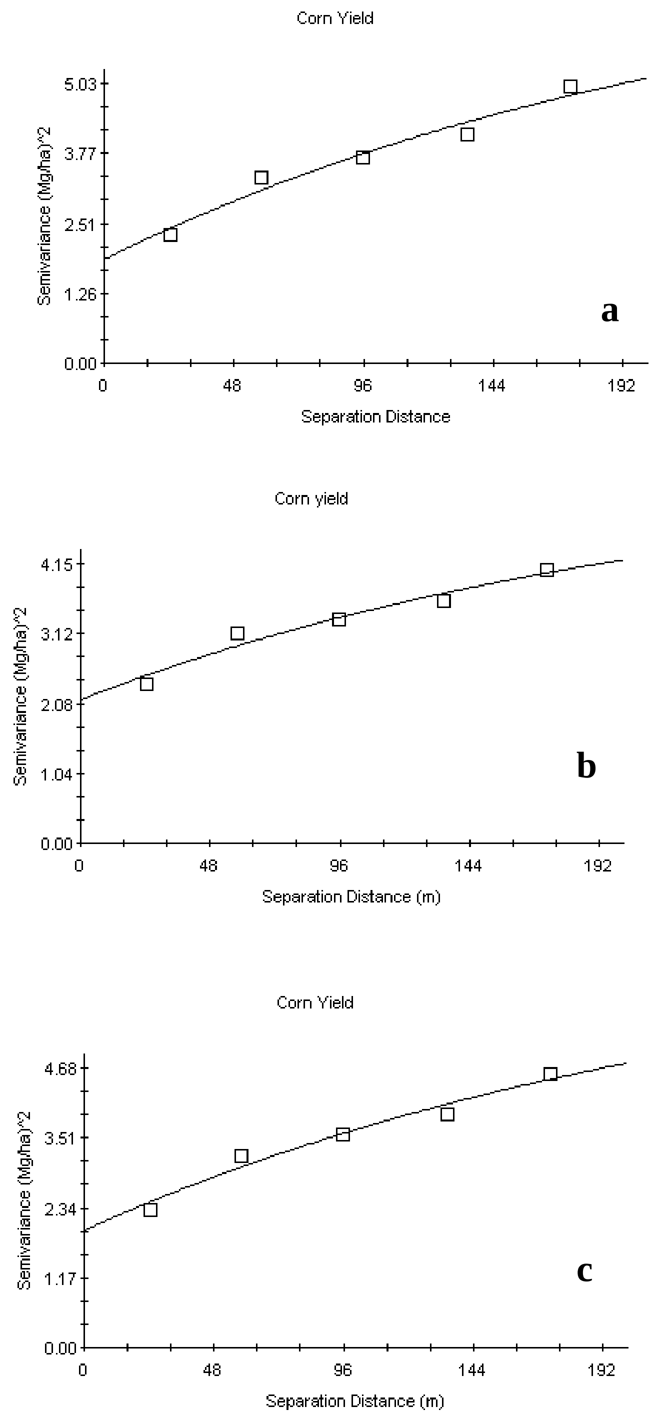

Fig. B13. Semivariograms of 2002 corn yield for Field 3 in the Piedmont for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

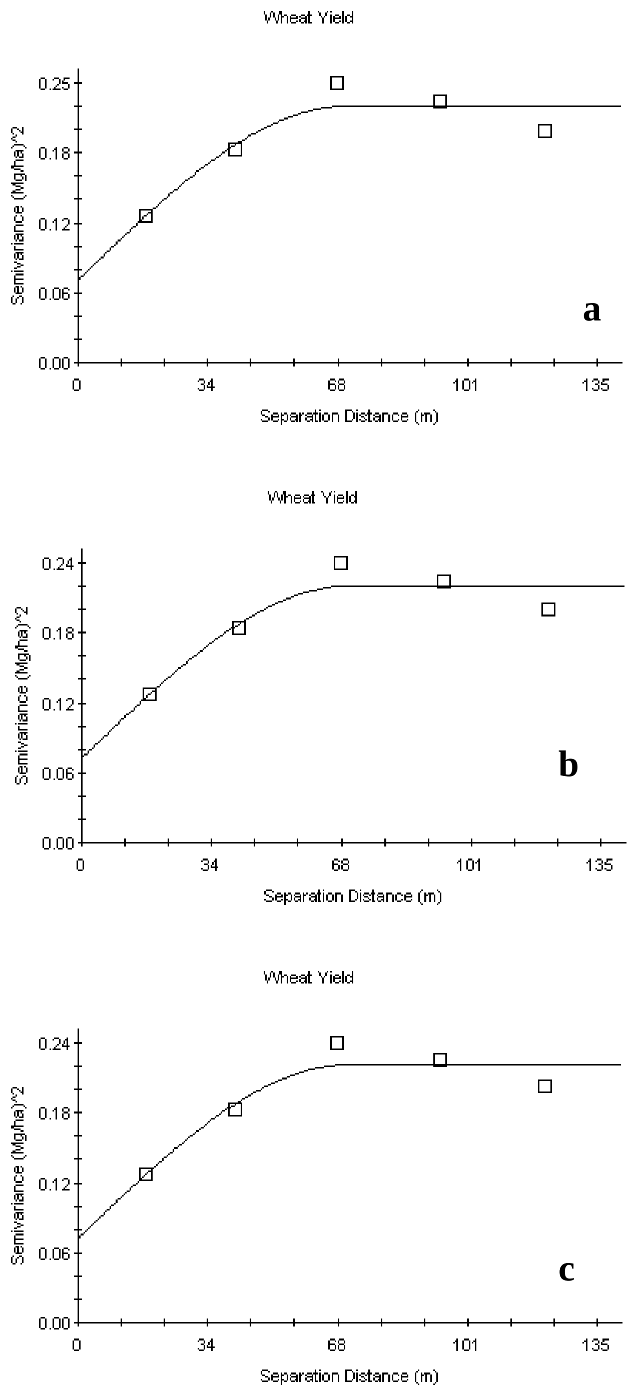

Fig. B14. Semivariograms of 2003 wheat yield for Field 3 in the Piedmont for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

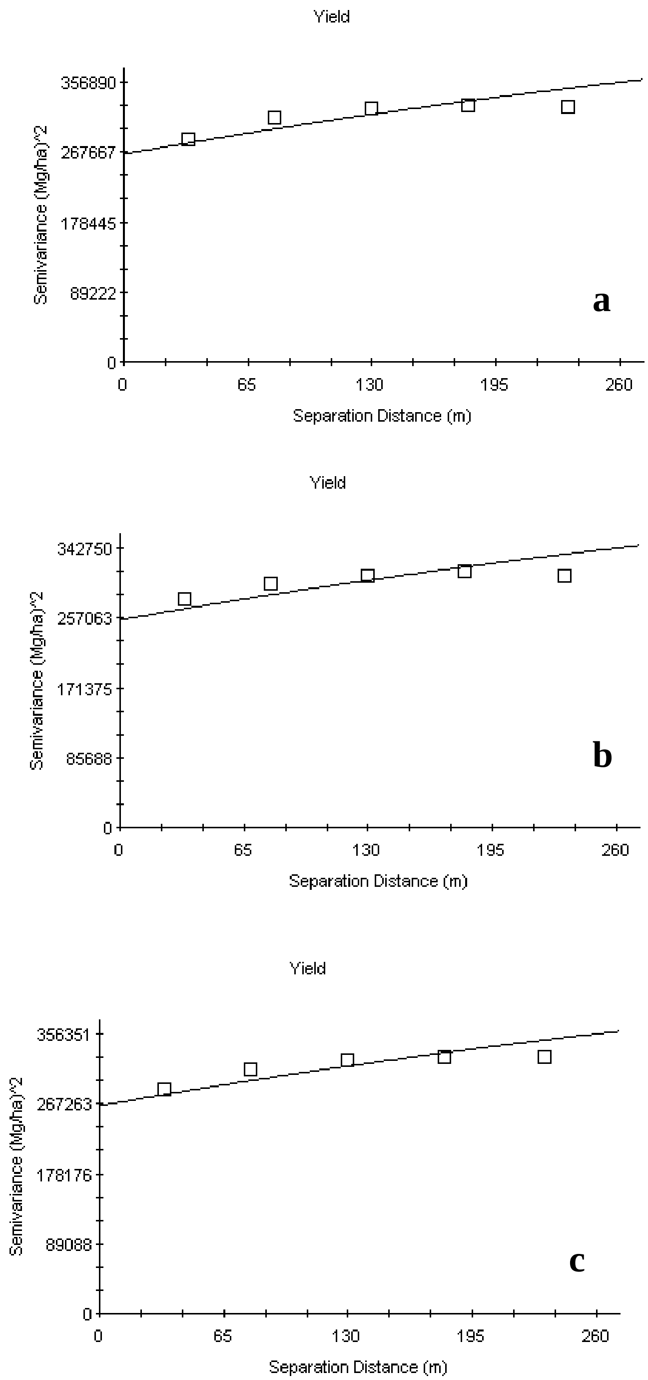

Fig. B15. Semivariograms of 2002 wheat yield for Field 5 in the Piedmont for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

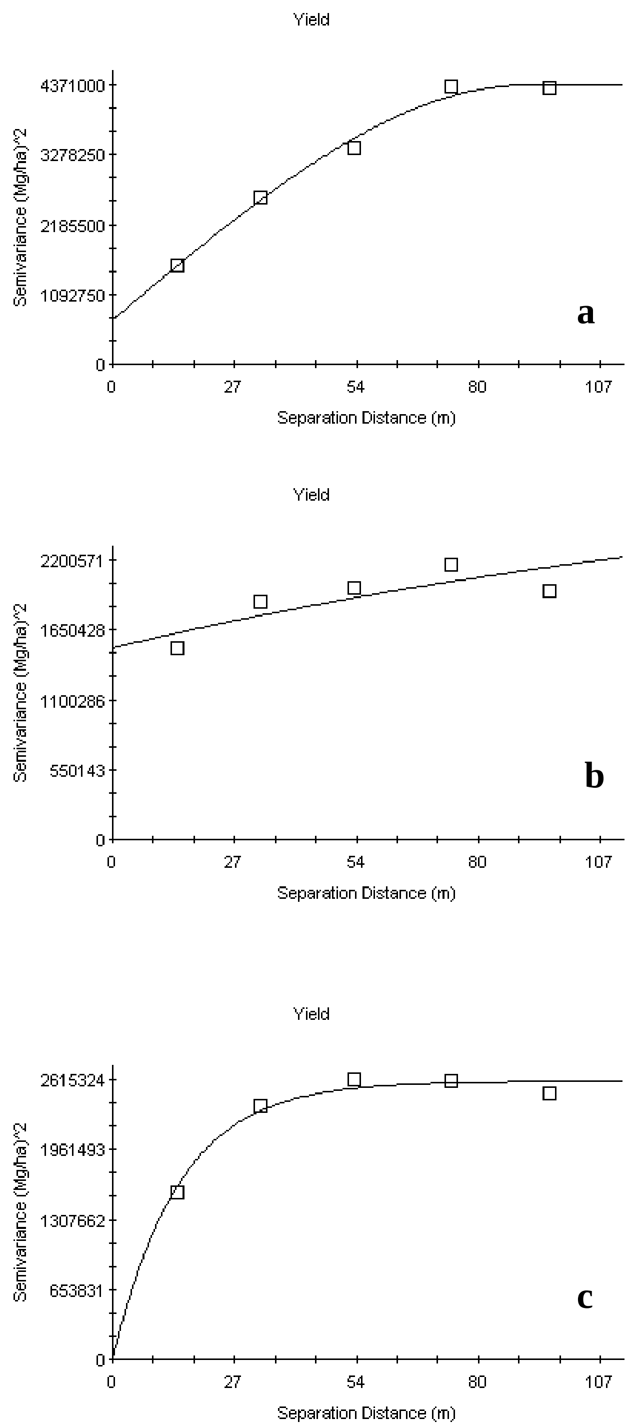

Fig. B16. Semivariograms of 2002 corn yield for Field 7 in the Piedmont for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

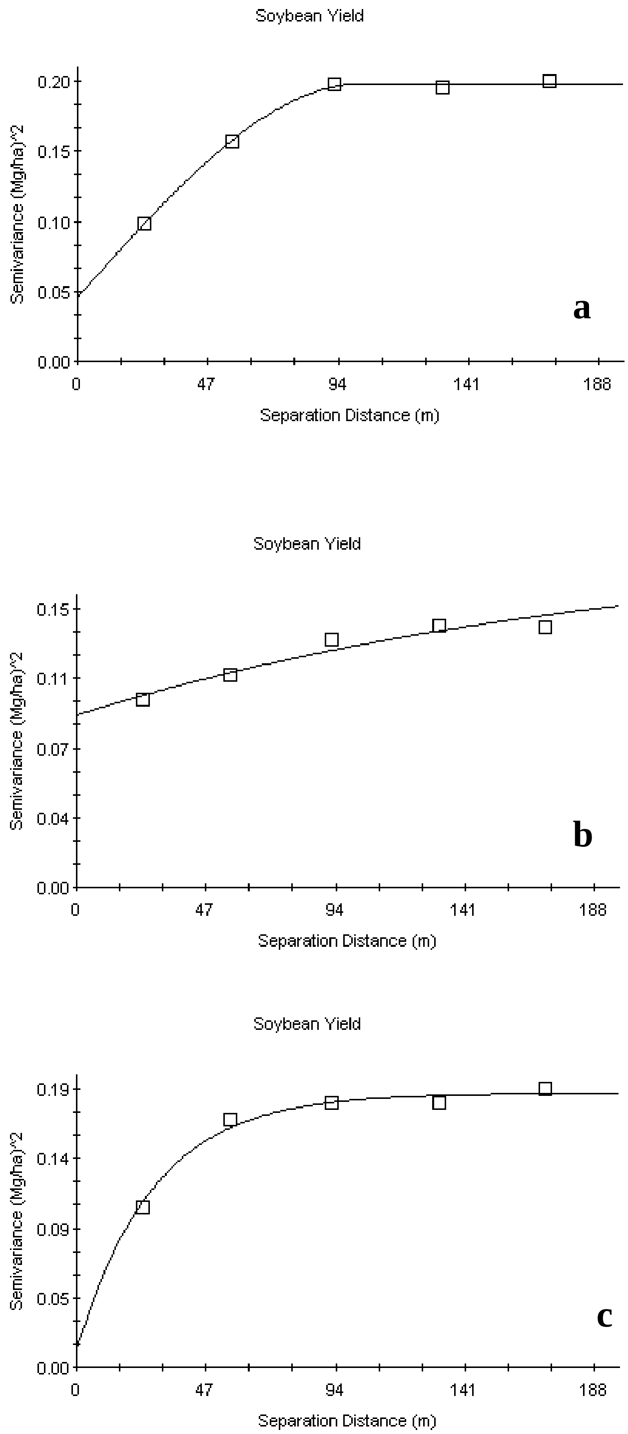

Fig. B17. Semivariograms of 2000 soybean yield for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

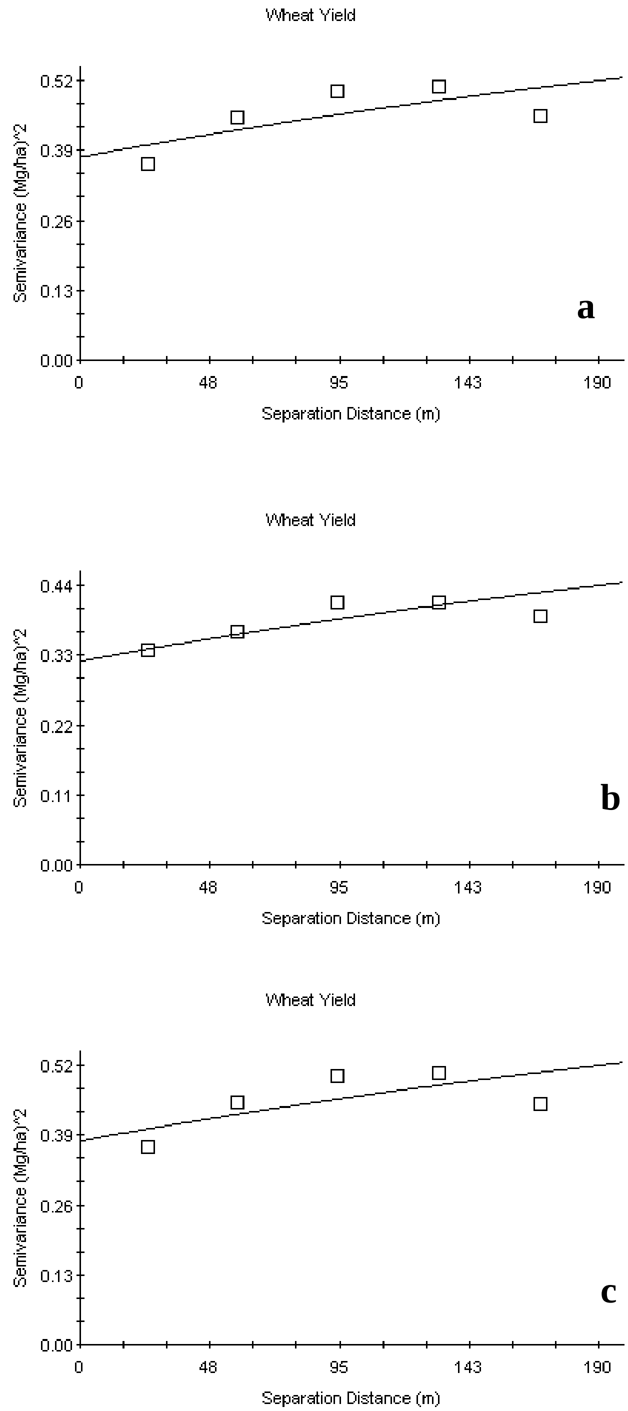

Fig. B18. Semivariograms of 2002 wheat yield for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

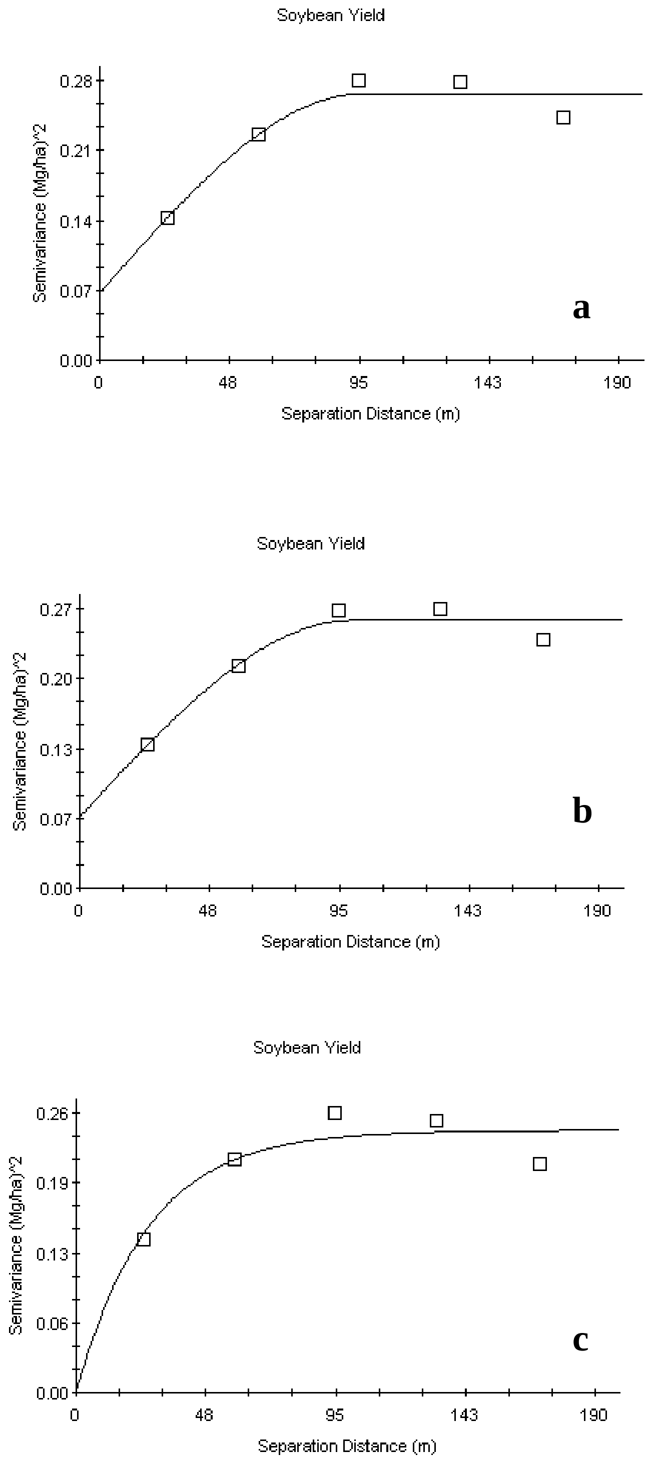

Fig. B19. Semivariograms of 2002 soybean yield for (a) raw yield data, (b) yield residuals for the remapped soil map units, and (c) yield residuals for the original soil map units.

APPENDIX C
SPATIAL PARAMETERS AND AIC STATISTICS FROM PROC MIXED

Table C1. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among remapped map units for Field 3 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002 Corn	117	13	NN	2360.6	14840.0	E
2003 Wheat	70	0.59	0.04	1055.8	1840.8	S
Soil Property						
pH	146	0.14	0.03	48.0	92.3	S
P	36	7007	375	1857.5	1906.1	E
K	152	2758	53	1580.2	1647.1	S
Lime	86	0.08	0.03	1.0	28.7	E

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C2. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among original map units for Field 3 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002 Corn	61	7.2	NN	2381.1	2384.0	E
2003 Wheat	70	0.60	0.03	1086.2	1849.3	S
Soil Property						
pH	153	0.17	0.02	47.4	131.6	S
P	45	7189	854	1978.9	2335.9	E
K	185	3399	39	1683.8	1882.1	S
Lime	42	0.07	0.02	13.6	21.3	E

† NN, No-nugget model.
‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.
§E, exponential model; S, spherical model.

Table C3. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among remapped map units for Field 5 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002 Wheat	17	0.18	NN	645.8	12782.0	E
Soil Property						
pH	190	1.30	0.65	701.2	707.2	E
P	418	7423	2223	2908.5	2912.7	S
K	119	1.1E+04	1477	2979.0	3119.3	E
Lime	465	0.15	0.02	36.8	59.3	S

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C4. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among original map units for Field 5 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002						
Wheat	18	0.19	NN	630.9	13150.0	E
Soil Property						
pH	0	0.00	0.70	709.8	715.7	E
P	414	7174	2126	3016.8	3028.8	S
K	113	7647	1384	3094.8	3247.5	S
Lime	98	0.10	0.02	26.4	68.0	E

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C5. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among remapped map units for Field 7 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002						
Corn	72	7.9E+06	3.5E+05	8809.7	9133.8	E
Soil Property						
pH	204	0.34	0.03	73.9	116.8	E
P	300	2864	1327	1407.1	1427.0	E
K	677	3.6E+05	NN	1675.0	1757.3	E
Lime	83	0.26	0.05	121.3	145.1	E

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C6. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among original map units for Field 7 in the Piedmont.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2002 Corn	23	5.0E+06	2.6E+05	8848.1	9237.2	E
Soil Property						
pH	154	0.29	0.03	78.8	116.6	E
P	112	2847	1227	1468.3	1485.6	E
K	117	3.8E+04	NN	1745.1	1878.7	S
Lime	133	0.29	0.04	138.5	178.3	S

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C8. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among remapped map units in the Coastal Plain.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
2000 Soybean	112	0.38	0.01	4681.3	4979.3	S
2002 Wheat	83	0.39	0.04	1689.9	2124.4	E
2002 Soybean	45	0.61	0.20	782.1	1885.5	S
Soil Property						
pH	36	0.10	NN	210.5	215.1	E
P	124	2467	NN	3144.3	3424.4	S
K	46	246	100	2702.4	2737.2	E
Lime	18	0.09	0.02	124.9	148.6	E

† NN, No-nugget model.

‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.

§E, exponential model; S, spherical model.

Table C9. Summary of spatial statistics generated from Proc MIXED covariance models and AIC statistics from Proc MIXED models with and without spatial covariance parameters among original map units in the Coastal Plain.

				AIC Statistic		
Variable	Range (m)	Sill	Nugget†	With‡	Without‡	Model§
Crop Yield						
Soybean '00	41	0.22	NN	6185.9	6322.1	E
Wheat '02	150	0.67	0.17	1694.5	2289.1	E
Soybean '02	24	0.24	0.02	775.7	1793.6	E
Soil Property						
pH	36	0.11	NN	226.2	229.7	E
P	123	2563	NN	3168.9	3386.3	S
K	31	293	19	2727.1	2833.5	E
Lime	53	0.10	0.05	141.1	166.3	E

† NN, No-nugget model.
‡With, Proc MIXED model including spatial covariance parameters; Without, Proc MIXED model without spatial covariance parameters.
§E, exponential model; S, spherical model.

APPENDIX D
SCATTERPLOTS
OF
RYE vs ACTUAL YIELD

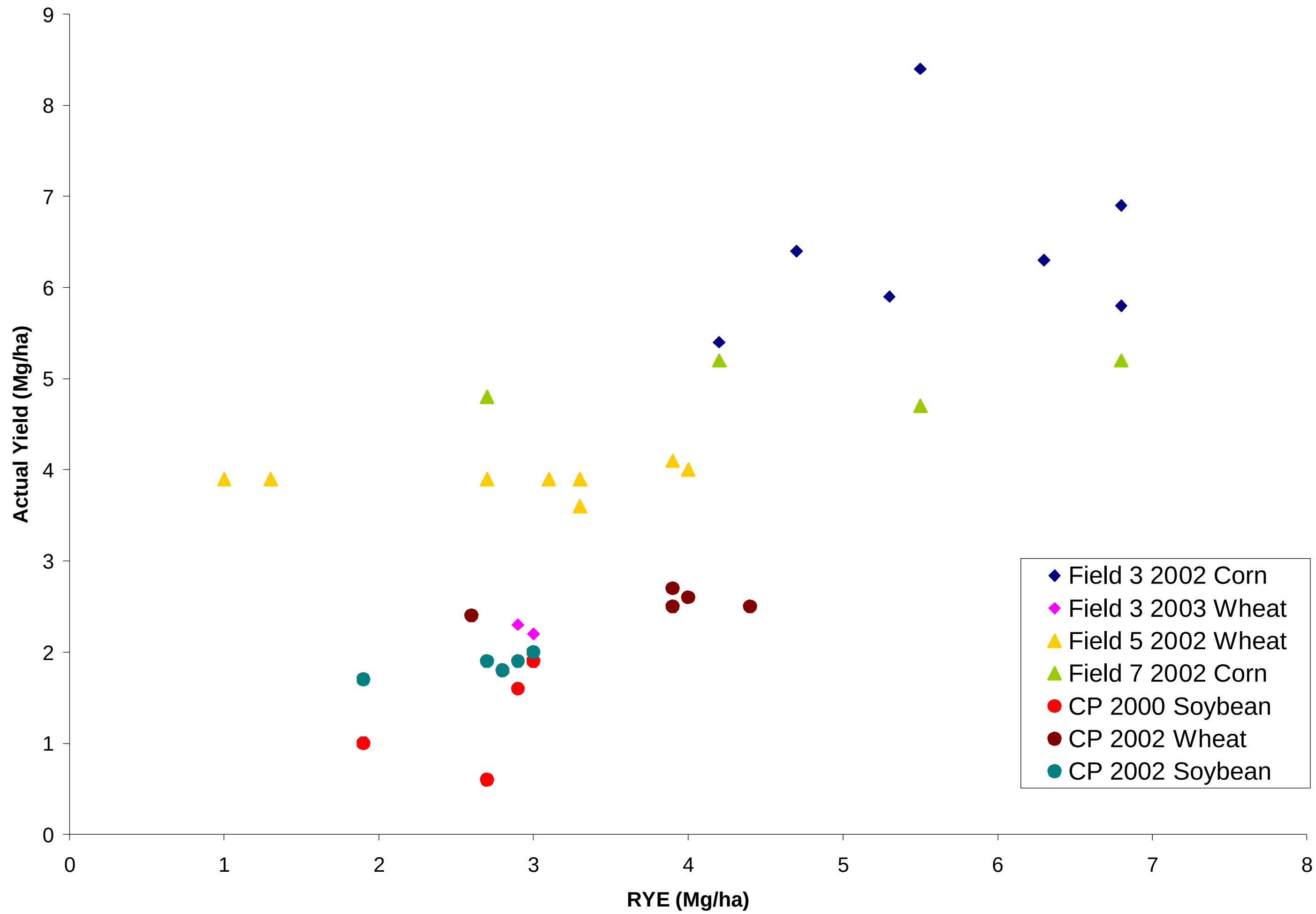

Fig. D1. Scatterplot comparing the RYE values with the actual yield from each field among the remapped soil map units. Each site-year of data was differentiated by a different color and fields were differentiated by unique symbols.

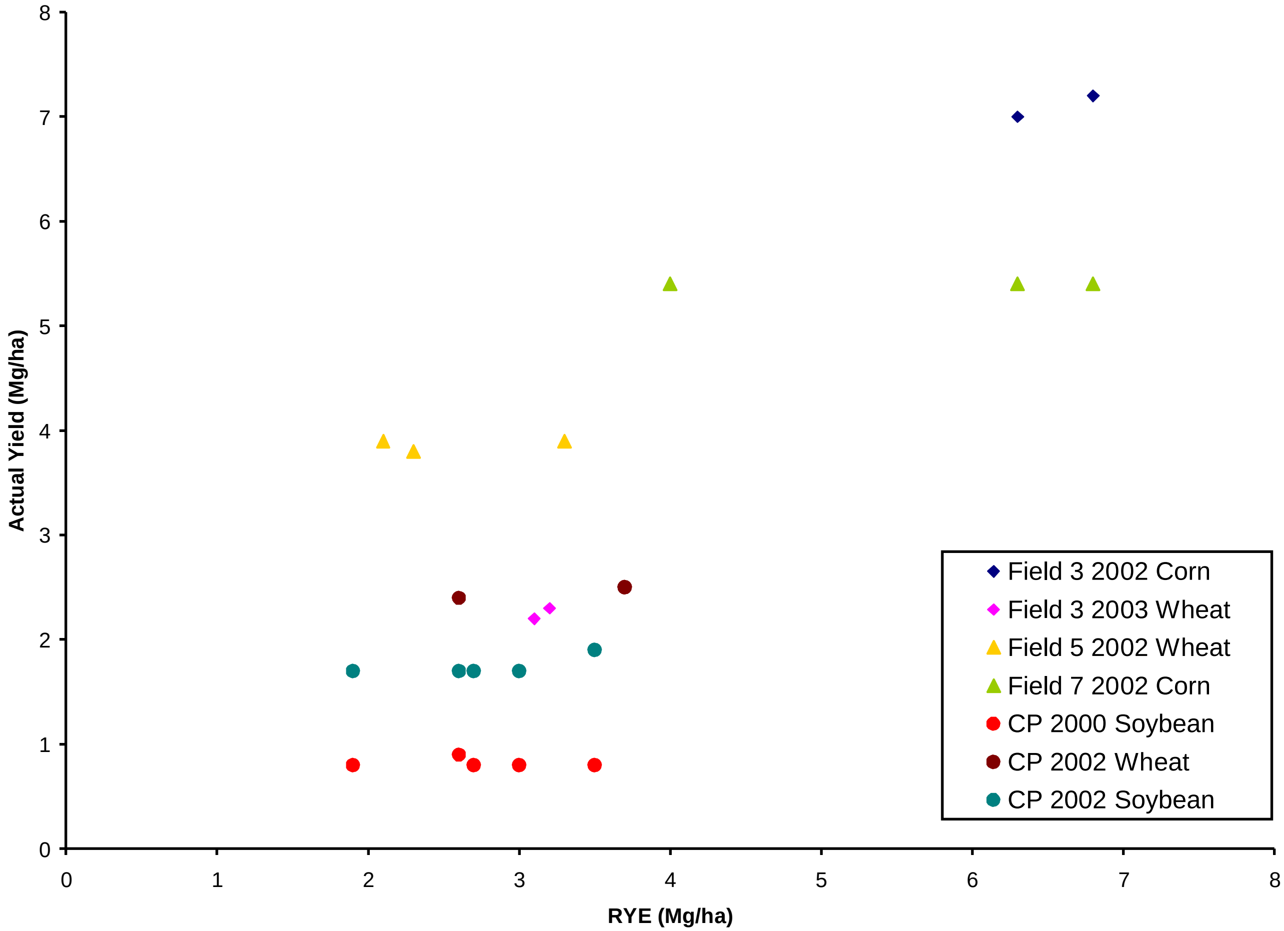

Fig. D2. Scatterplot comparing the RYE values with the actual yield from each field among the original soil map units. Each site-year of data was differentiated by a different color and fields were differentiated by unique symbols.