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SPATIAL VARIATION OF COTTON YIELD: INFLUENCE OF SOIL MANAGEMENT AND TERRAIN ATTRIBUTES

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Abstract

Spatial variability in crop yields is largely due to the arrangement of soils and landscapes within fields. Site-specific agriculture (SSA), is a method of production in which zones and soils are delineated and managed according to their unique properties (Plant, 2001). The ultimate goal of SSA is to optimize inputs for agronomic and environmental benefits. This has motivated the need to identify management zones in fields, which can be delineated, grouped, and managed in a similar fashion in order to optimize inputs and or maximize profits (Fraisse et al., 1999).

Development of a fundamental understanding of what controls the systematic components of variability can lead to development of rapid and cost effective methods for constructing management zones. Zone delineation techniques include: 1) remote sensing and aerial photography; 2) conventional soil testing; 3) conventional soil survey; 4) digital elevation models; 5) farmer knowledge and 6) yield mapping. Because landscape attributes can be easily assessed and visualized, it is critical to evaluate how these attributes affect productivity and soil quality. Similar landscape elements can be grouped, facilitating management zone creation. Additionally, the ability to rapidly map soil electrical conductivity (EC) offers great potential as a tool for constructing or refining management zones (Johnson et al., 1997), provided we determine and quantify the complex relationships between soil quality indicators, productivity and EC readings.

The evaluation of SSA must be assessed through its impacts on soil quality and associated productivity. Soil management practices affect soil quality and crop productivity. However, these impacts are rarely assessed at the landscape level. Technological advances and new management strategies may provide a way to improve crop productivity, while improving environmental stewardship.

In this paper we evaluated cotton (*Gossypium hirsutum L.)* yield response to soil management practices and their interactions with landscape and soil attributes in a 24 acre strip trial located in Central Alabama at the Alabama Agricultural Experiment Station's E.V. Smith Research Center. Soils at the experiment are mostly Aquic and Typic Paleudults.

A soil survey, geo-referenced elevation, and electrical conductivity maps were developed for delineating field variability and potential management zones. A detailed soil map (order 1 level) was developed according to National Cooperative Soil Survey (NCSS) standards. The field was mapped in fall 2000 and spring 2001 with a Veris® Technologies 3100 Soil EC Mapping System equipped with a DGPS. Electrical conductivity measurements were taken for two depths: 1 ft and 3 ft. A Trimble® 4600 L.S. Surveyor Total Station was used to derive elevations for position across the field. Detailed topographical maps were generated, and digital elevation models (DEMs) and terrain attributes were created using several software packages.

A factorial arrangement of two soil management systems with and without annual application of dairy manure was evaluated in a corn (*Zea mays*)-cotton rotation. Treatments were: a conventional system (CT), a conventional system + dairy bedding manure (CTM), a conservation system (NT) and conservation system + manure (NTM). In the conventional systems, tillage consists chisel plowing/disking + in-row subsoiling; no cover crop was used in winter, but winter weeds were not controlled. The conservation systems included non-inversion in-row subsoiling and winter cover crops of a white lupin (*Lupinus albus* L.) and crimson clover (*Trifolium incarnaatum* L.) mix prior to corn and a black oat (*Avena strigosa* Schreb.) and rye (*Secale cereale* L.) mix prior to cotton. Treatments were established in 20-ft wide strips intercepting zones of landscape variability in a randomized complete block design with 6 replications. The field was divided into 496 (20 x 60 feet) cells, and composite soil samples were collected inside and analyzed for organic carbon and texture. Additionally, eight terrain attributes were derived from the elevation map. Seed cotton yield was determined across the field with a spindle-harvester equipped with GPS and yield monitors during 2001 and 2002.

The experiment was analyzed using four procedures similarly to the ones selected by Bermudez and Mallarino (2002) in a similar strip experiment: Two procedures analyzed treatment effects on yield assuming a RCB with or without considering the spatial correlation of yield, the third procedure used regression analysis to establish relationships between yield and average terrain and soil properties within the cells, and the fourth procedure assessed treatment effects for zones of the field with different landscape attributes. In the first approach we analyzed the experiment by the conventional Randomized Complete Block design and the yield data input were the yield means of the strips. In the second approach we accounted for the spatial correlation of yield in the analysis of variance, using the modeled semivariogram. The idea in the 2^{nd} method was to reduce the experimental error in order to better detect treatment differences.

Due to 50% less rainfall in 2002 than in 2001 during the critical period between first bloom and peak bloom, seed cotton yield was 50% lower in 2002 (1315 lb $acre^{-1}$ vs 2676 lb $acre^{-1}$). No interactions were found between years and treatments. The NT and NTM yields (2182 and 2159 lb $acre^{-1}$) were significantly higher than the CTM (1949 lb $acre^{-1}$). Lowest yields occurred with CT (1841 lb $acre^{-1}$). The conventional systems yields were 10% and 19% lower than the conservation systems in 2001 and 2002, respectively. The coefficient of variation was significantly higher in the conventional systems compared with the conventional systems (9.7% vs 8.15% and 17% vs 13.5% in 2001 and 2002 respectively).

When treatment and replication effects were removed from the cell yields averages, the modeled semivariogram of the residuals revealed a strong spatial correlation of cotton yield to ranges of 200 feet. Removal of the spatial correlation in field experiment is critical for some kind of experiments (Bhatti et al., 1991). However, when the spatial correlation was included in the analysis of variance, little improvement in the model fit was observed and the same significant differences were obtained.

Regression analysis, showed that electrical conductivity, slope, soil texture and elevation were the main variables explaining yield variability within treatments, however, they only explained between 15 to 60% of the variability depending on the year and treatment. Subjective potential management zones created using simple terrain attribute information were similarly effective in delineate areas of different cotton yield response suggesting that economic and simplicity may determine the selection process. The conservation system had the highest yields in almost all potential zones created, however the effect of the manure was more inconsistent and some interactions with management zones and management systems were found.
The conservation system had significantly higher yield and less variation than conventional in both years. Significant yield differences among potential management zones were found in both years. Yield was more affected in the drier year (2002) by terrain attributes. Results suggested that the conservation system have greater impacts in dried years and in the zones with lower yield potential.

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