PRECISION AGRICULTURE TO FURTHER ENHANCE LIVESTOCK AND PERRENIAL-BASED PEANUT/COTTON CROPPING SYSTEMS

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ABSTRACT

Site-specific management can be used in livestock/ peanut/cotton cropping systems to increase efficiency and economic returns. Spatial variability of plant height, leaf area index, soil organic matter, NPK and yield for cotton in a sod/livestock/peanut/cotton cropping system was evaluated in Florida in 2006. The parameters were evaluated for irrigated and non-irrigated conditions and under conservation tillage. Geostatisticals techniques were used to analyze the spatial distribution of soil fertility status, plant growth and yield, and maps were produced using ArcGIS. All variables showed spatial variation across the field. Plant height showed moderate to strong spatial dependence. Areas of the field with the tallest plants did not necessarily produce highest yield, and no yield differences were found between irrigated and non-irrigated areas. Site-specific management has potential to increase cotton management efficiency. It will, however, be necessary to create individual zone maps for some variables since the maps for different variables did not always overlap. There is also a need to test the spatial distribution of the variables over a number of years to determine if the management zones remain the same across different climatic conditions.

INTRODUCTION

Both site-specific (precision agriculture) and perennial grass - based peanut/cotton production systems are management systems developed to increase efficiency and ultimately increase income. The premise behind site specific management is that a precise amount of inputs is applied only where needed, based on spatial variation across the fields as opposed to the standard blanket application recommendations from extension services. Site specific management enables efficient use of agricultural resources to include fertilizers, pesticides and irrigation water. However, site-specific management has not been extensively researched in cotton. An Australian study reported no yield benefit with site specific fertilizer application but reported more efficient fertilizer use (Boydell et al., 2001). On the other hand a study from the southern US showed a slight yield increase with site specific fertilizer application. The same study also showed no fertilizer reductions overall, however, specific zone recommendations either decreased or increase by up to 57%, depending on yield potential (Watson et al., 2005) and this can potentially reduce nutrient leaching. With so much potential, site-specific management is often described as “The farming of the future”.

Integrated production of crops and livestock offers improved efficiencies, whether in early, primitive agriculture or modern production systems. Recently, economic and environmental concerns have resulted in increased interest in these systems. A growing body of literature reports on the many benefits of integrated cropping systems in several row- crop production systems (Katsvairo et al. 2006; Franzluebbers and Triplett, 2006). Perennial pastures including bahiagrass and Bermuda grass are ideal for production systems in the Southeast due to their extensive root systems that penetrate an underlying compaction layer prevalent in soils in the southeast (Elkins et al., 1977; Kashirad et al., 1967; Campbell et al., 1974). Channels created in the compaction layer can be utilized by crop roots in subsequent years to access water and nutrients that are available below this layer. The perennial grasses also increase soil moisture, organic matter, reduce soil compaction, earthworm numbers and activities (Katsvairo et al., 2007a; Franzluebbers and Triplett, 2006). Perennial grasses such as bahiagrass are also a non host of several important cotton diseases and nematodes (Katsvairo et al., 2006). A combination of enhanced resource-uptake by the plants grown in rotation with perennial grasses, accelerating crop growth and development plus the fact that perennial grasses are non-host to major cotton pests would be expected to be a major boast to cotton production. Vigorous growing plants are better able to tolerate pest pressure. In fact inclusion of perennial grasses in cotton and peanut cropping systems is often described as “the next step in crop production after conservation tillage”.

Unlike other major row crops such as corn and soybean, there is still substantial room for improvement in the use of precision agriculture principles in cotton production. Information on spatial variation for soil nutrients and plant growth characteristics such as leaf area index, height, nematode populations, nutrients, organic matter, and yield for in cotton fields is scarce. While many advantages have been observed with a sod/livestock/peanut/cotton cropping sequence, integrating this system with the use of precision agriculture tools has not been explored. We hypothesize that this integrated system would offer further benefits beyond those obtained from the cropping sequence alone. The objectives of this study were to evaluate spatial variability in soil nutrients, crop growth parameters and yield for cotton in a sod/livestock/peanut/cotton system under both irrigated and non-irrigated conditions using conservation tillage.

MATERIALS AND METHODS

An experiment was conducted in Marianna, Florida in 2003 to examine the influence of 2 years of bahiagrass rotation on the spatial variation of soil nutrients, moisture and plant phenotypical development of subsequent cotton crops in the rotation. This experiment is part of a long-term multi-disciplinary study which looks at integrated livestock/peanut/cotton/perennial grass cropping systems. The 50 ha experimental site encompassed two soil types, a Fuquay coarse sand, the dominant soil in the field, and an Orangeburg loamy sand. The northern section of the field was generally wetter and the north central area of the field was occasionally water logged. The field was planted to bahiagrass for 2003 and 2004, peanuts in 2005 and cotton in 2006. The southwest section of the field was not irrigated but the rest of the field was irrigated. Irrigation was based upon extension recommendations for Florida (Smajstrla et al., 2006). Standard crop management procedures were followed, and conservation tillage practices were utilized for cotton production.

A systematic unaligned sampling grid (Wollenhaupt et al., 1994) with a spacing of 88 x 88 m was superimposed over the experimental site to establish sampling locations. The location coordinates for each station were recorded with a global positioning system unit. Soil samples were taken to a depth of 20 cm from each sampling location at the end of the growing season to determine residual soil nutrients. All cores were a composite of 10 soil cores taken on a 4 m grid centered on the geo referenced sampling location. The soil samples were sealed in plastic bags, placed in a cooler in the field, transferred to cardboard cartons at the end of the day, and dried in a forced-air oven (55°C) to constant moisture. Samples were submitted to a lab for N, P, and K soil nutrient analysis and soil organic matter. Plant height was measured 3 times during the early, mid and late growing season by estimating the height of 12 representative plants a taken from a 3 m radius from each sampling location. Chlorophyll index was measured on the last fully expanded leaf of thirty plants per location with Minolta's SPAD meter and leaf area index (LAI) was determined with a Licor LAI 2000. Both chlorophyll and LAI were measured several times during the growing season. Cotton was manually harvested from two areas of 1 m^{-2} for each sampling station.

Geostatistics were used to analyze spatial variability and create maps of all variables including yield, LAI, plant height, chlorophyll, soil moisture and residual soil nutrient concentrations using the geostatistical software package, Arc GIS (ESRI, 2004). Sample variograms were fitted with spherical variogram models (best fit) using the following equation:

$$?(h) = c_o + c[1.5(h/a) - 0.5(h/a)^3]$$

where $\gamma(h)$ is the spatial structure of the variable, h is the distance between sampling locations, c_o is the nugget component of the variogram, c is the positive variance component, and a is the variogram range. The variogram range is the distance beyond which spatial correlation of the data no longer exists. The nugget value represents unsampled spatial variation or the random component of the variation. The ratio of the nugget (c_o) to sill ($c_o + c$) indicates the degree of randomness in the spatial variability of the data. Cambardella and Karlen (1999) suggested that a ratio of <0.25 indicates the measured variable is strongly spatially dependent. A ratio of 0.25 to 0.75 indicates moderate spatial dependence, whereas a ratio >0.75 indicates weak spatial dependence.

RESULTS AND DISCUSSION

Plant height differed across the field for all three sampling stages. The nugget/sill ratio of the variograms showed moderate spatial dependence during the first sampling date (0.45), and a strong spatial dependence during the second sampling date (0.23) (Table 1). In the early to mid season, plants were tallest in the north section of the field which was the wetter section of the field (Fig 1). Spatial height differences became pronounced as the season progressed. By maturity cotton plants were almost twice as tall in the east section of the field close to the edge compared to most of the field. Uneven irrigation distribution may have further influenced the differences in plant height. The center pivot irrigation stopped at the west end of the field where it would have applied more water as the irrigation rig slowed down. In general, the tallest plants were observed in the wetter regions of the soil and the shortest plants were observed in the non-irrigated area.

Table 1. Nugget value (c_o), nugget/sill fraction (c_o/c_o +c) for SOM, plant height, yield and NPK in Florida in 2006.

Variable	Nugget	sill	(c_o/c_o +c)	range
Height (early season)	0.54	0.76	0.41	330
Height (mid-season)	1.80	6.04	0.23	330
Height (late season)	0.00	61.06	0.00	330
Yield	0.00	179610	0.00	75
Soil organic matter	0.00	0.17	0.00	115
N	31.73	24.48	0.56	184
P	1177	1110	0.51	330
K	3008	448	0.87	330

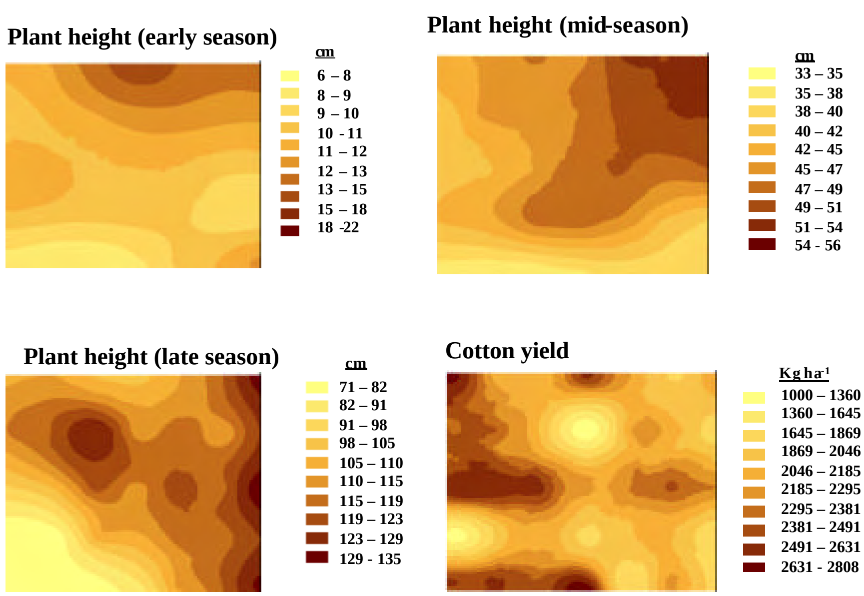

Fig 1. Krigged interpolations using ArcGIS of plant height at three stages of growth and yield in cotton in a bahiagrass rotation in Florida in 2006.

Cotton was hand harvested, collecting more fiber than machine harvesting and as a result, our yields are generally higher than normal average yields for the Mariana region. Like plant height, yield showed spatial variation across the field. The yield differences ranged between 1000 to 2808 kg ha^{-1}. The variogram range was 75 m. Yield was generally higher in the west side of the field and lowest in the north central part of the field which occasionally water logged (Fig. 1). Yield under non-irrigated conditions was equal to the best yield under irrigated conditions. Our other studies conducted over 5 years have not shown any advantages to irrigating cotton unless there is severe soil moisture deficit. Yield was greater in the regions with shorter cotton compared to the regions with the tallest cotton. Plot test studies showed no yield benefits to cotton with greater biomass (Katsvairo et al., 2007b). The greater biomass is produced at the expense of yield. If variable rate N management was practiced, the sections of the field with the excessively tall plants would be expected to receive less N. Yield was also greater across the entire Orangeburg loamy sand, soil type but it should be noted that the Orangeburg loamy sand, soil type covered only a small portion of the field.

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All soil macronutrients showed spatial variation across the field. Residual soil NO_3–N was greatest in the non-irrigated section and lowest in the north end of the field. The north end was also the portion of the field which was wettest and had the tallest plants in the early to mid-season. It is possible that soil NO_3–N could have leached out of the soil since that portion of the field was wettest. N leaches more rapidly in sandy soil and moist soils, but mostly likely, partially due to more rapid denitrification under the wet soil conditions. An additional factor may have been greater assimilation of NO_3–N due to the taller plants in that section of the field. In another study, we also observed taller plants in cotton after bahiagrass than cotton in the conventional peanut/cotton rotation. The taller plants in the bahiagrass rotation could have been a result of more N from the decomposing sod. The nugget/sill ratio of the variograms showed moderate spatial dependence for N (Table 1).

P levels showed a definite pattern, with higher levels observed in the west section of the field. In general the west section of the field also had the greater yield (Fig. 2). Higher levels of K were distributed around the west and south edges of the field. The areas of the field which had the tallest plants tended to have lower K levels indicating more uptake (Fig. 2).

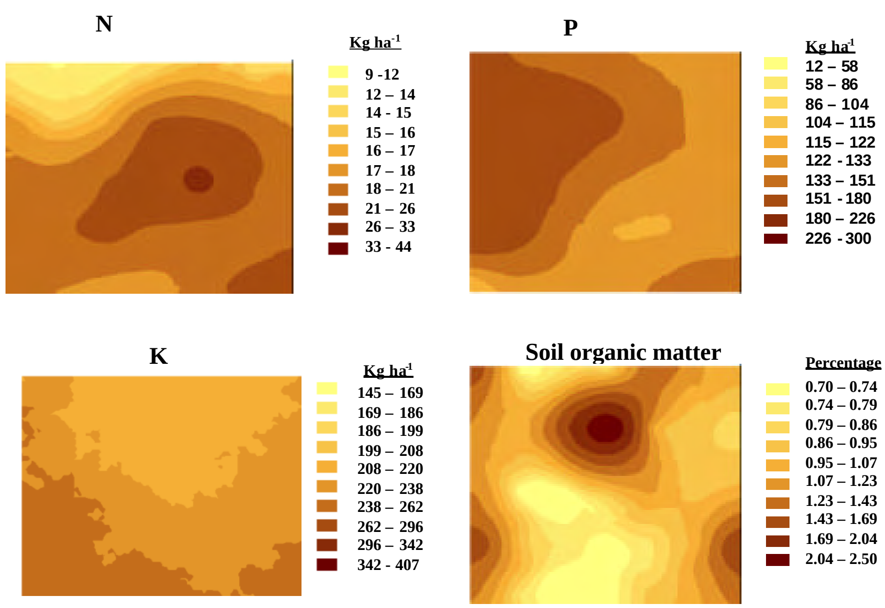

Fig 2. Krigged interpolations using ArcGIS of N, P,K and soil organic matter in cotton in a bahiagrass rotation at the end of the growing season in Florida in 2006.

The nugget/sill ratio of the variograms showed moderate spatial dependence for P and less spatial dependence for K (Table 1).Organic matter levels were greatest in the north central section of the field, which is also the section that tended to be water logged (Fig.2). This may have been a result of more decomposition of plant matter. The higher amount of organic matter in this section did not improve yield even though plants were larger. The west section of the field which had greater yield, partially overlapped with areas of higher organic matter.

CONCLUSION

Plant height, chlorophyll levels, soil macro nutrients, soil organic matter and yield all showed spatial variation across the field. Plants were generally tallest in wet sections of the field. However the taller plants did not necessarily result in greater yield. Plant height showed moderate to strong spatial dependence based on nugget/ (nugget + sill) ratios. P levels were greater in the west section of the field. K levels were highest in the outlying west and south section of the field, coinciding with regions of shorter plants and less K uptake. Yield was negatively affected by plant height and tended to be greater in areas with shorter plants. Non-irrigated areas had yields equal to the best irrigated areas. In this field, the spatial variation in plant height, macro nutrients, organic matter and yield would justify site-specific management of inputs. However, because the management zones for the different parameter (plant measurements and nutrients) did not always overlap, this may necessitate creating several management zones, making site-specific management more challenging to implement.

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