PATTERNS OF ZONE MANAGEMENT UNCERTAINTY IN COTTON USING TARNISHED PLANT BUG DISTRIBUTIONS, NDVI, SOIL EC, YIELD AND THERMAL IMAGERY

Patrick J. English
Delta Research and Extension Center, Mississippi State University
Stoneville, MS
Sherri L. DeFauw
USDA, ARS, NEPSWL
Orono, ME
Steven J. Thomson
USDA, ARS, CPSRU
Stoneville, MS

Abstract

Management zones for various crops have been delineated using NDVI (Normalized Difference Vegetation Index), apparent bulk soil electrical conductivity (EC_a - Veris), and yield data; however, estimations of uncertainty for these data layers are equally important considerations. The objective of this study was to evaluate the extent of spatially non-autocorrelated areas in an irrigated cotton field in the Mississippi Delta (5.8 acres - with substantial contrasts in soil texture and water-holding capacities) using NDVI, EC_a, yield, and thermal imagery as well as Tarnished Plant Bug (*Lygus lineolaris*) distribution maps (the latter taken at peak bloom). Three year composites for plant NDVI and TPB distributions (analyzed using univariate Local Moran's I Spatial Autocorrelation – LISA) exhibited the highest levels of uncertainty (with 2.7 and 2.6 acres or 46.0% and 45.5% of the field extent, respectively); whereas, multi-year compositing of yield monitor data more closely matched the shallow EC_a map acquired in October 2004 (involving 2.0 and 1.5 acres or 34.7% and 26.5% of the field extent, respectively). Comparison of thermal datasets (acquired from July to September over two growing seasons) with the multi-year yield map highlighted the significance of the linkages of low yield zones with areas of the field subjected to the highest temperatures as well as the pairing of high yield zones with cooler canopy temperatures. These types of uncertainty assessments demonstrate that the fusion of multi-year datasets may allow predictive field-specific models to be created and then used by producers to more effectively manage risk.

Introduction

Precision-based agricultural application of insecticide relies on a non-random distribution of pests; tarnished plant bugs (TPB - *Lygus lineolaris*) are known to prefer vigorously growing patches of cotton (e.g., Willers et al., 1999; Willers and Akins 2000). Management zones for various crops have been delineated using NDVI (Normalized Difference Vegetation Index), apparent bulk soil electrical conductivity (EC_a - Veris), and yield data (e.g., Sudduth et al., 1995; Corwin and Lesch, 2003; Iqbal et al., 2005). Estimations of uncertainty for these data layers are equally important considerations as we build geodatabases that integrate multi-year datasets (for a given field setting) in an effort to more effectively model and subsequently use these derived data as supplemental aids in the management of crop risks. The objective of this study was to evaluate the extent of spatially non-autocorrelated areas in an irrigated cotton field in the Mississippi Delta (5.8 acres - with substantial contrasts in soil texture and water-holding capacities) using NDVI, EC_a, yield, and thermal imagery as well as TPB distribution maps (the latter taken at peak bloom).

Materials and Methods

TPB counts were acquired from 32 field locations at or near peak bloom for three successive years (2001–2003). All locations were recorded using GPS equipment (Trimble Ag132). A cumulative TPB distribution map was generated from these point datasets (Fig. 1) using the Spline technique in ArcView (v. 3.3).

Image acquisitions for this 5.8-acre irrigated cotton field in Washington County, MS consisted of multi-year color infrared (CIR) and thermal. Additional maps available for this field included a detailed geophysical survey and 3 years of yield data. The CIR image series (not shown) was acquired at peak bloom (2001– 2003) using a Duncan Tech camera flown at an altitude of 1.7 km (ground resolution of 1.0 m). A cumulative NDVI map was derived by compositing the aforementioned images (Fig. 2). A Veris survey was conducted in October 2004; transects were taken every 4 m and an interpolated EC_a map was generated (Fig. 3). Three years of yield data were normalized and then composited to produce a cumulative yield map (Fig. 4). Thermal imagery was acquired using an Electrophysics PV320T camera mounted in an agricultural aircraft and flown at an altitude of 460 m; images from two flight dates (at or near peak bloom, July 2006 and 2007) were used to derive a cumulative thermal map (Fig. 5). Subsequently, the TPB, NDVI, EC_a (Veris), yield, and thermal datasets were analyzed separately using Local Moran's I Spatial Autocorrelation (LISA; GeoDa v0.9.5-i5 – Anselin, 2004).

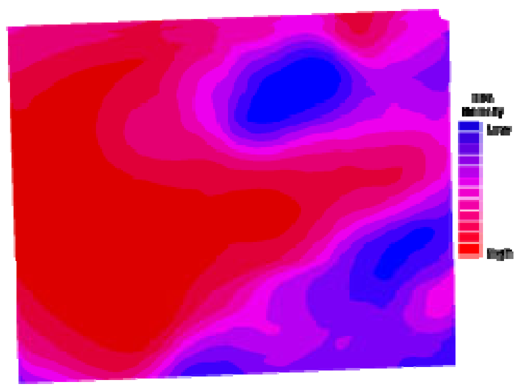

Figure 1. A cumulative TPB distribution map based on three years of data (2001-2003) collected from 32 established field locations each year.

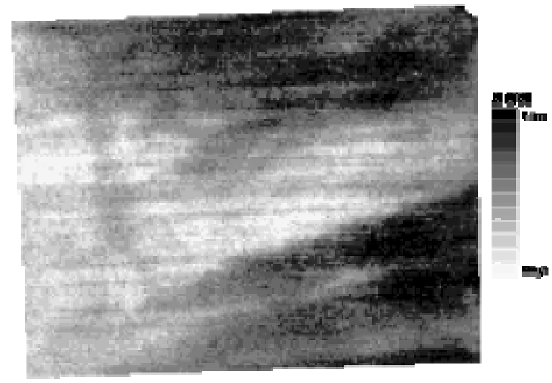

Figure 2. A cumulative NDVI map derived by compositing a multi-year (2001-2003) CIR image series.

Figure 3. An interpolated EC_a map based on a Veris survey (Oct 2004).

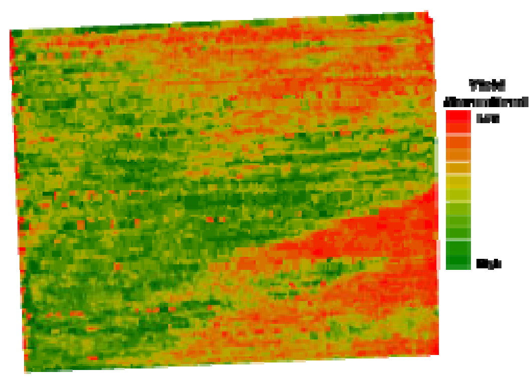

Figure 4. A cumulative yield map derived by compositing normalized data from 2001-2003.

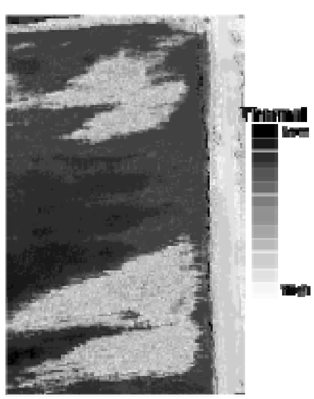

Figure 5. A cumulative thermal map of a portion of the field that displayed the most significant contrasts in soils and water-holding capacities. This portion of the field is located in the southeastern quadrant and encompasses parts of the field where plants appear to be subjected to high heat and/or water stress. The map was produced by compositing two years of data (2006-2007) and depicts the pattern thermal zonation characteristic of this irrigated cotton field based on soils and drainage issues.

Results and Discussion

The aerial extents of the significantly spatially autocorrelated as well as the non-spatially-autocorrelated components of this 5.8-acre irrigated cotton field are summarized in Table 1. Local Moran's I spatial analysis (LISA) of the cumulative TPB map (Fig. 1) highlights non-autocorrelated patches (Fig. 6 - depicted in light gray) which represent areas with high degrees of heterogeneity between adjacent pixels (encompassing 2.6 a). The red areas represent spatially autocorrelated high TPB counts (with an interpolated aerial extent of 1.7 a), whereas the blue zones depict spatially autocorrelated low TPB counts (spanning an interpolated aerial extent of 1.5 a).

Table 1. Summary of significant spatially-autocorrelated and non-spatially-autocorrelated areas of the field for the TPB distributions as well as the NDVI, ECa, and yield maps.

Data	Spatially Autocorrelated (High-High)	Spatially Autocorrelated (Low-Low)	Not Autocorrelated (Areas of Uncertainty)
TPB	1.7 acres (29.0 %)	1.5 acres (25.5 %)	2.6 acres (45.5 %)
NDVI	1.6 acres (28.1 %)	1.5 acres (26.4 %)	2.7 acres (46.0 %)
EC_a	2.0 acres (33.9 %)	2.3 acres (39.6 %)	1.5 acres (26.5 %)
Yield*	1.9 acres (33.5 %)	1.8 acres (30.4 %)	2.0 acres (34.7 %)

*Yield data include other spatial autocorrelated categories not accounted for in the acreage (i.e., couplings of High-Low and Low-High values that contributed to only 1.4% of the field extent).

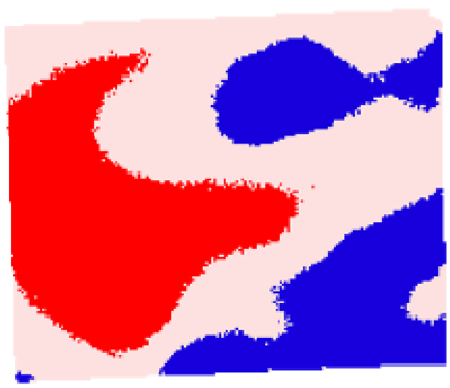

Figure 6. LISA map based on cumulative TPB distribution map (2001-2003).

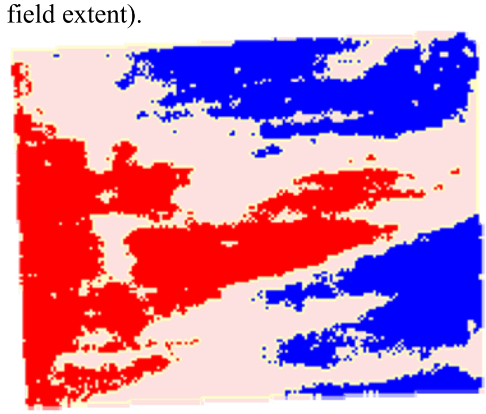

Figure 7. LISA map results from the cumulative NDVI map (2001-2003).

Local Moran's I spatial analysis (LISA – Fig. 7) of the cumulative NDVI (Fig. 2 – where white to light gray areas represent high-vigor cotton) highlights non-autocorrelated patches (depicted in light cream-color) which depict areas of the field with high degrees of heterogeneity between adjacent pixels (encompassing 2.6 a). In contrast to the aforementioned areas where uncertainty is high from one year to the next, the red areas represent spatially autocorrelated high NDVI values (with an aerial extent of 1.6 a) where crop performance appears to be stable from year-to-year. The blue zones depict spatially autocorrelated low NDVI values (spanning 1.5 a); these areas correspond with stable albeit low to moderate crop performance portions of the field. The soil-based LISA map (Fig. 8) produced from the shallow EC_a dataset (Fig. 3) highlights non-autocorrelated patches (depicted in gray) which represent areas of uncertainty (encompassing 1.5 a). The red areas represent spatially autocorrelated high EC_a values (with an aerial extent of 2.0 a), whereas the blue zones depict spatially autocorrelated low EC_a values (spanning 2.3 a).

Figure 8. LISA map based on the shallow EC_a survey conducted in October 2004.

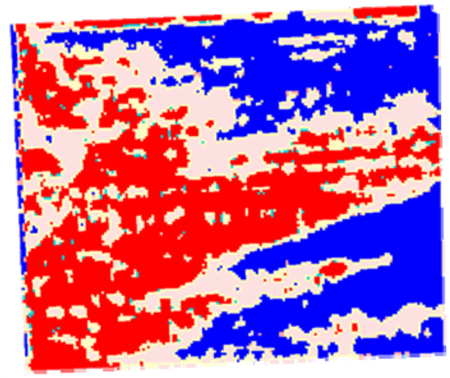

Figure 9. LISA map based on normalized yield data composited over three years (2001-2003).

A LISA map resulting from three years of yield data (Fig. 9) shows highly dispersed, non-autocorrelated patches (depicted in light cream-color) which, in turn, represent areas of uncertainty (encompassing 2.0 a). The red areas represent spatially autocorrelated high yield values (with an aerial extent of 1.9 a), whereas the blue zones depict spatially autocorrelated low yield values (spanning 1.8 a).

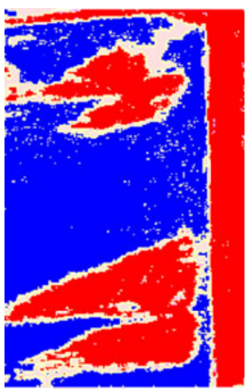

Figure 10. LISA results based on a cumulative thermal map (0.5 m resolution) produced by compositing two images taken at peak bloom (July 2006 and July 2007). Gray patches represent non-spatially-autocorrelated areas that are highly-variable from one pixel to the next. The red areas represent significant spatially autocorrelated high thermal values; blue zones depict spatially autocorrelated low thermal values.

The LISA map results from the cumulative thermal data (Fig. 10) highlight non-autocorrelated patches (depicted in gray) which represent areas of uncertainty. Thin gray patches represent sharp transitions whereas irregularly-shaped, omni-directional patches define transitional areas that are highly-variable from one pixel to the next. The red areas represent spatially autocorrelated high thermal values; blue zones depict spatially autocorrelated low thermal values. Comparison of the cumulative thermal map (based on acquisitions from 2006 and 2007) with the multi-year yield map shows apparent linkages of low yield zones with areas of the field subjected to the highest temperatures as well as the pairing of high yield zones with cooler canopy temperatures The significance of these linkages was previously reported by Thomson et al. (2007 and 2008).

Conclusions

Geospatial analyses of TPB, NDVI, EC_a, thermal and yield maps using Local Moran's I highlighted non-spatially-autocorrelated regions that represent assessments of uncertainty based on multi-year composites. Spatial autocorrelation analysis is a very effective method to delineate these higher risk areas resulting from the soil-plant-atmosphere-water-pest interactions that contribute to the field response heterogeneities depicted in various maps (e.g., DeFauw et al., 2006; Thomson et al., 2007; English et al., 2007, 2008 and 2009). Thin linear non-autocorrelated patches represent abrupt transitions between potential management zones where crop risk may be at a minimum because of adjacencies of zones that are stable through time. However, large omni-directional, non-autocorrelated patches depict highly heterogeneous habitats that may not be properly managed in a site-specific application (and in all likelihood not sprayed), thereby serving as refugia and loci for reinfestation of the field by

TPBs. The Local Moran's I Spatial Autocorrelation (LISA) analysis represents a useful tool to augment the accuracy of scouting maps by defining zones of uncertainty and to acquire additional information on the structure of these transitional areas between the well-defined or more stable management zones. A better understanding of these field-scale patterns will facilitate risk management decisions when deploying site-specific insecticides or defoliants. These types of uncertainty assessments demonstrate that the fusion of multi-year datasets may allow predictive field-specific models to be created and then used by producers to more effectively manage risk and, in turn, help improve cotton production capacity in highly heterogeneous field settings.

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