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Using geospatial technologies to relate landscape . . .

Field-Scale Aflatoxin Risk Index Development and Validation

(account # 5-33741)

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Objectives

The objective of this study was to determine if soil landscape characterization could be used to group pre-harvest, field-scale peanut aflatoxin contamination. Soils and landscapes were characterized using field surveys coupled with GIS-based multivariate techniques.

Methods

The study sites (15.8 and 20.3 acres, Miller and Mathis site, respectively) were located in Dale and Henry Counties, AL, where parent materials are Eocene age fluvio-marine sediments of the Claiborne formation. Intensive soil and peanut grid sampling and analyses were conducted. Following digging and inversion, 0.5 acre geo-referenced grids (in 2004, 1 acre grids in 2002) were established for each field. Soil and peanut samples were taken from the center of each grid in fall 2002 and 2004. Soil samples (0-20 cm) collected for each grid point were analyzed for routine soil test (pH, CEC, P, K, Mg, and Ca) and soil texture (% sand, silt and clay) using standard methodologies. Peanut samples were assayed for aflatoxins. Aflatoxin data for 2004 for the Mathis site were disregarded, as the grower applied an aflatoxin control agent (Aflaguard) to this field.

Taxonomic based first-order soil surveys (1:5,000) were generated for each field using standard soil survey mapping techniques coupled with electrical conductivity mapping (Figures 1 and 2 for the Mathis and Miller sites, respectively). Soil samples were obtained from horizons of selected pedons for laboratory analysis to facilitate classification to the family level for survey development. Geo-referenced survey sample locations [obtained using a Trimble® Pro XRS global positioning system (Trimble, Sunnyvale, CA)] were overlaid onto the maximum downhill slope map using ArcGIS (ESRI, Redlands, CA). Soil map units were digitized based on soils and slope class.

Electrical conductivity (EC) data for both fields were collected using the Veris ® 3100 (Veris Technology, Salina, KS). This method uses direct contact sensors to measure soil electrical resistivity, which is converted to apparent electrical conductivity (ECa) (mS m-1). EC data were collected on 1-s intervals at speeds between 2.2 m s^{-1} and 4.4 m s^{-1}. Estimated depths of data resolution are 0-30 cm [(EC(0-30cm))] and 0-90 cm [(EC(0-90cm))] (Veris Technologies, 2003). Electrical conductivity data were collected two times to minimize temporal variability effects. Digital elevation models (DEMs) were developed using elevation data collected with real time kinematic (RTK) GPS. Real-time kinematic GPS elevation data were collected on 1-s time intervals using a base station and GPS receiver (Trimble, Sunnyvale, CA). ArcInfo (ESRI, Redlands, CA) was used to generate 5-m DEMs for both research sites. Terrain attributes of maximum downhill slope, aspect, profile and planimetric curvature, flow accumulation, catchment area, specific catchment area, and CTI were calculated from the DEM.

Landscape zones were developed using the multivariate data (Figures 3 and 4 for the Mathis and Miller sites, respectively). Electrical conductivity, elevation, and terrain attribute (profile and planimetric curvatures, flow accumulation, and CTI) layers were combined into one grid file and were normalized (0-100) to account for scale differences between data layers. Multivariate factor analysis was performed on the normalized data layers prior to the clustering procedure. The factors explaining 80% of the cumulative variation were selected for k-means clustering. Three factors were used for zone creation at both sites. Factor scores were calculated and used for fuzzy k-means clustering. The Management Zone Analyst (MZA) software (Fridgen et al., 2004), using fuzzy k-means clustering, was used to create multivariate clusters from factor scores for both research sites.

In addition to the Miller and Mathis site, soil and landscape data for a third field (25 acres, Gamble field) have been acquired using funds from this grant. The EC surveys are complete, the elevation survey has been completed, and a DEM and terrain attributes are being developed. This field will be grid sampled in September; this field was in cotton last year (04) and has rotated into peanuts in 2005. Although this grant will have expired, the analyses as described above will be applied to the Gamble field this Fall.

Results

Soils and landscapes differ between sites. At the Mathis sites, soils vary mostly due to differences in subsoil texture (as related by particle size family). Thus, the soils mostly classify within coarse-loamy to fine families of Typic Kanhapludults. At the Miller site, soils mainly differ in the thickness of sandy surfaces overlying the relatively more clayey subsoil. Thus, soils are mostly in Groassarenic (sands > 1 m), Arenic (sands 0.5-1m), and Rhodic or Typic subgroups (sands < 0.5 m) of Kanhapludults. Soils are acid, have relatively limited capacity to sorb nutrients, and the sandier soils (coarse-loamy and Grossarenic and Arenic subgroups) possess limited water holding capacity.

Significant differences in soil nutrients as a function of both soil map unit and landscape zone existed. For example, K values at the Mathis site were affected by soil map unit, and both P and K values were affected by soil map unit and landscape zone at the Miller site (Table 1). The reasons P and K values were significantly affected by these soil landscapes could be due to both different retention of nutrients between soil landscapes (largely due to texture differences and depth to clayey subsoils), and differential uptake of nutrients due to differences in inherent productivity between soil landscapes. Regardless, the aggregate of these findings suggest that clusters created by either the soil survey or the landscape zone approach can be used to stratify nutrient levels in these Coastal Plain fields, and facilitate sampling and application of soil amendments.

Table 1. F values and significance levels of the analysis of variance (ANOVA) of soil map unit and landscape zone effects on soil fertility (P and K) values.

Source of variation	df	F values	Significance levels (P)
		Mathis P	
map unit	3	0.47	NS
landscape zone	5	0.32	NS
		Mathis K	
map unit	3	2.61	0.06
landscape zone	5	0.73	NS
		Miller P	
map unit	6	7.93	**
landscape zone	4	2.60	*
		Miller K	
map unit	6	6.22	**
landscape zone	4	10.66	**

*,** Significant at 0.05 and 0.01 probability levels, respectively; NS is not significant. Means followed by same letter are not significantly different.

Results for total aflatoxin levels were mixed. Significant differences in total aflatoxin levels existed between the Mathis and Miller sites, as the Mathis site had significantly higher aflatoxin levels compared with the Miller site (Table 2). However, aflatoxin levels were only significantly affected by landscapes (as opposed to the soil survey) in 2002 at the Miller site. The 2002 growing season was dry (9.73 in. for June-Aug) compared with the 2004 season (14.72 in.). The dry growing season and delayed harvest due to heavy September and October rains contributed to high risk for aflatoxin in 2002, and aflatoxin levels were significantly higher for the 2002 (485 ppb) versus the 2004 (19 ppb) season at the Miller site. Because our approach would likely capture inherent differences in the field-scale water regime (landscape zones capture differences in terrain that control runoff), it is apparent this approach works better during relatively drier seasons. Reasons why this approach did not work as well on the Mathis site in 2002 are unclear. As is common for this region, these fields are intensively terraced, and this possibly complicated the application of this soil and landscape approach.

Table 2. F values and significance levels of the analysis of variance (ANOVA) of soil map unit and landscape zone effects on total aflatoxin values.

Source of variation	df	F values	Significance levels (P)	Total aflatoxin (ppb)
Site	1	6.78	**	
Mathis				1571A
Miller				168B
		Mathis 2002		
map unit	3	0.25	NS	
landscape zone		0.25	NS	
		Miller 2002		
map unit	5	1.44	NS	
landscape zone	4	112.5	**	
		Miller 2004		
map unit	6	0.66	NS	
landscape zone	4	0.75	NS	

*,** Significant at 0.05 and 0.01 probability levels, respectively; NS is not significant.
Means followed by same letter are not significantly different.

Conclusion

The soil landscapes differ in soil nutrient levels at both sites. Aflatoxin levels were significantly grouped by soil landscapes during a dry year at one site; this approach was not effective at an additional site or during the relatively wetter 2004 year. The technique of characterizing soil landscapes (i.e. soil survey versus multivariate landscape zones) made a difference, as the multivariate landscape zone approach appeared superior to a conventional soil survey for grouping the aflatoxin contamination. The summary of findings indicates that the soil landscape approach does effectively characterize field-scale total aflatoxin levels in some instances, but the approach used in this study is not universal.

References

Fridgen, J.J., N.R. Kitchen, K.A. Sudduth, S.T. Drummond, W.J. Wiebold, and C.W. Fraisse. 2004. Management zone analyst (MZA): Software for subfield management zone delineation. Agron. J. 96: 100-108.

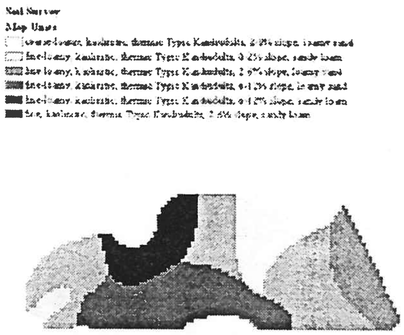

Figure 1. Soil Survey of Mathis site.

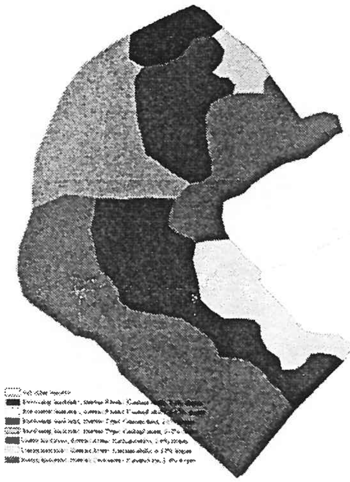

Figure 2. Soil Survey of Miller site, developed using conventional techniques coupled with EC survey.

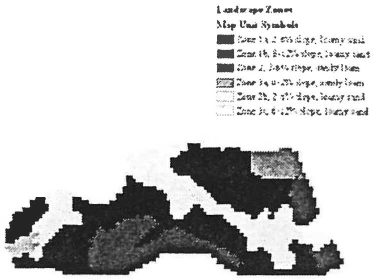

Figure 3. Landscape zones for Mathis site.

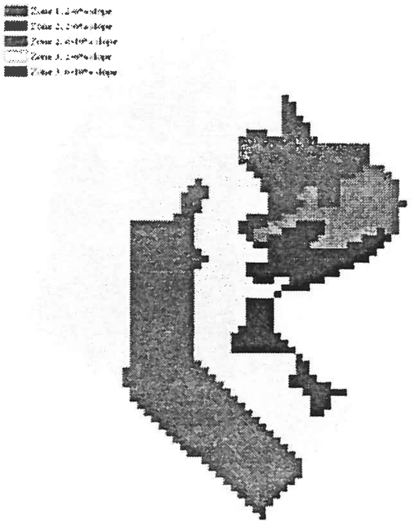

Figure 4. Landscape zones for Miller site.