CAN CONTAMINATION POTENTIAL OF GROUND WATER TO PESTICIDES BE IDENTIFIED FROM HYDROGEOLOGICAL PARAMETERS?

B. Dixon
Department of Geography
University of South Florida St. Petersburg
140 Seventh Avenue South
Saint Petersburg, Florida 33701

1. INTRODUCTION

Detection of pesticide residues in irrigation wells in the Arkansas Delta region has demonstrated the need to understand parameters and processes involved in contamination of ground water (GW). GW contamination potential depends on the various physical, chemical and biological processes that determine the fate of pesticides. The importance and rates of these processes are, in turn, strongly dependent on space and/or time dependent environmental parameters and the properties of the pesticide itself (Soutter and Pannatier, 1996). This study examines spatial variability of physical parameters such as soil, geology, land use, clay cap thickness, annual GW recharge, and depth to GW that might play a critical role in contamination of the GW by pesticides using Geographic Information System (GIS) and statistics/geostatistics (descriptive & semivariogram).

2. LITERATURE REVIEW

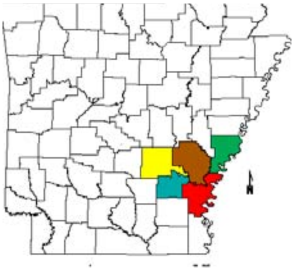
GIS has been used extensively in GW studies, particularly for spatial analyses. Kamaraju et al. (1996) used GIS to evaluate GW contamination potential from lithology, geomorphology, structure and recharge conditions. Lin and Scott (1996) have used GIS to predict GW contamination potential to pesticides in the Mississippi Delta of eastern Arkansas. Smith et. al (1994) used GIS with a modified DRASTIC to predict contamination potential of GW to agricultural chemicals. Rautman and Istok (1996) used a geostatistical framework for assessment of GW contamination. They concluded that probabilistic assessment of GW contamination has uncertainty, however, usefulness of prediction depends on the accuracy a user wants. Multivariate statistical methods also have been used in hydrologic problems to identify parameters that affect the outcome (Sarle, 1994).

3. THE STUDY AREA

The study area is located in the southeastern Arkansas (Figure 1), in the five counties of Phillips, Arkansas, Desha, Jefferson and Lincoln, and is comprised of 939,279 ha. Perry-Portland-Rilla is the dominant STATSGO (State level soil associations) soil association, followed by Sharkey-Alligator-Tunica and Crowley-Stuttgart-Hillman. This region belongs to Major Land Resources Areas (MLRAs) 131 and 134. The Mississippi River Valley alluvial aquifer underlies the region, the upper aquifer of the Mississippi embayment aquifer system (Mahon and Poynter, 1993), the depth of which ranges from near 0 m to over 42 m. The

Mississippi embayment extends southward in a fan-shaped geosyncline from southern Illinois to the Gulf of Mexico (Ackerman, 1996). The Mississippi Delta region of Arkansas is one of the most extensively farmed regions in the U.S. with agricultural production consisting primarily of rice, soybeans, cotton, wheat, corn and grain sorghum. Each of these crops has a certain suite of recommended pesticides and fertilizers applied annually (Arkansas Cooperative Extension Service, ACES, 1997). Another major factor affecting agricultural production in eastern Arkansas is irrigation. Arkansas ranks in the top five states nationally in cropland irrigated, with greater than 1.3 million hectares annually. Virtually all of the irrigation water is extracted from the alluvial aquifer, (Scott et al., 1998).

FIGURE 1
STUDY AREA



4. METHODOLOGIES

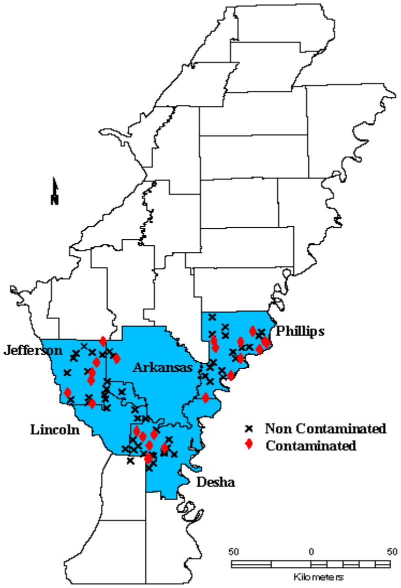
Data layers used in this study were obtained from various sources and in various formats (Table 1). Where necessary, data layers were converted into digital format. The STATSGO soils data were obtained from Natural Resources Conservation Service (NRCS), and were used for relating soil texture information to the GW contamination potential. Landuse data were obtained from Center for Advanced Spatial Technologies (CAST), and are based on Landsat TM imagery. Geology was obtained from the Louisiana Geological Society (LSG) and was converted into digital format using LT4x 4.2 [NOTE: What does this mean?]. The thickness of the confining unit (claycap) overlying the alluvial aquifer was obtained from USGS at 3 m aprox. (10 feet) contour interval. Spatial interpolation was performed to extend the contour lines of thickness of the confining unit to a full surface using a full surface modeling function in GRASS 4.2 called regularized spline with tension (s.surf.tps, Matasova, 1992). Depth to GW was calculated by subtracting potentiometric surface values from elevation data. The potentiometric surface of Spring 1992 (Westfield and Poynter, 1994) was used to create the potentiometric data layer. This potentiometric surface was recorded with a contour interval of 6.09 m (20 feet). To use this data layer for raster map calculation, the raster maps were interpolated using a regularized spline with tension method (s.surf.tps, Matasova, 1992). Point data for recharge were obtained from US Geological Survey (USGS) for the entire Mississippi River Valley alluvial aquifer. The net recharge rate was calculated based on the past behavior (water level change) of the alluvial aquifer using the MODFLOW model at a one-square-mile cell resolution (Mahon and Poynter, 1993). The MODFLOW model simulated ground water flow in one layer with recharge entering the aquifer from surface infiltration through the overlying confining unit and from seepage though river beds. The one-square-mile grid site file was interpolated into a full surface using regularized spline with tension module of GRASS4.2 (s.surf.tps, Matasova, 1992).

Water quality data were obtained from Department of Environmental Quality (DEQ). DEQ sampled 76 irrigation wells (average 25+ m deep) in 5 counties during the summer of 1996 as a part of state management plan (SMP) for pesticide monitoring of ground water. (Figure 2) A total of 61 pesticides and degradation products were analyzed by DEQ. These well data were used in this study to understand the spatial variability of contamination. GIS, performed using GRASS (v .4.2), was used for buffer and coincidence analyses. Buffers of 160 m were generated for each irrigation well. Coincidence analyses were performed between seven physical parameters for the buffer zone. These analyses provided information on surrounding physical parameters (within the buffer zone) for each well. The resolution of data used in this study was 80 m.

TABLE 1
SOURCES AND FORMATS OF DATA USED IN THIS STUDY

Data layers	Sources*	Format	Data Type
Well Location/Contamination	DEQ	Tabular	Point
Soils	NRCS	Mylar	Polygon
Landuse	CAST	Digital	Raster
Geology	LGS	Paper	Polygon
Claycap	USGS	Paper	Point
Recharge	USGS	Paper	Point
Depth to GW	USGS	Paper	Point

FIGURE 2
LOCATION OF WELLS



Frequency distribution and associated descriptive statistics were calculated between pesticide contamination and physical parameters. These analyses provided information on the distribution of contaminated/non-contaminated wells vs. physical parameters. Semivariogram analyses (with the spherical model) were performed using concentrations of contaminants present in the irrigation wells. Descriptive statistical analyses were performed using JMP (v. 3.2.1). Semivariogram analyses were performed using the software GS+ (v.3.1). Buffer analysis was performed for multiple cells, whereas statistical analyses were performed for single cells.

5. RESULTS AND DISCUSSIONS

Of the 77 wells sampled, 24 had detectable pesticides, some wells with more than one contaminant. Bentazon was by far the most frequently found pesticide in contaminated wells, followed by Metolachlor (Table 2). Bentazon is a herbicide used commonly for soybeans. Therefore, this discussion will focus on contamination of Bentazon in particular and examine relationships between contamination of Bentazon and spatial parameters such as soils, geology, land use, clay cap, recharge, and depth to GW.

TABLE 2
NUMBER OF CONTAMINATED WELLS FOR EACH PESTICIDE

Pesticide	**Number of wells**
Bentazon	14
metalochlor	3
Atrazine	2
Ametryn	2
Prometryn	2
Silvex	2
Cyanazine	1
Atraton	1
Aciflurofen	1
Metribuzin	1

Spatial distributions of soil associations are presented in Figure 3. Perry-Portland-Rilla covered 27 percent of the study area. The highest number of contaminated wells occured in the Rilla-Herbert-Perry soil association, which covers about 12 percent of the total area. Almost equal numbers of contaminated wells are found in Perry-Portland-Rilla soil association, which covers 27 percent of the area and Sharkey-Alligator-Tunica, which covers about 18 percent of the total area. When compared on the basis of soil texture, coarse texture soils coincided with Bentazon contamination.

FIGURE 3
STATSGO Soil

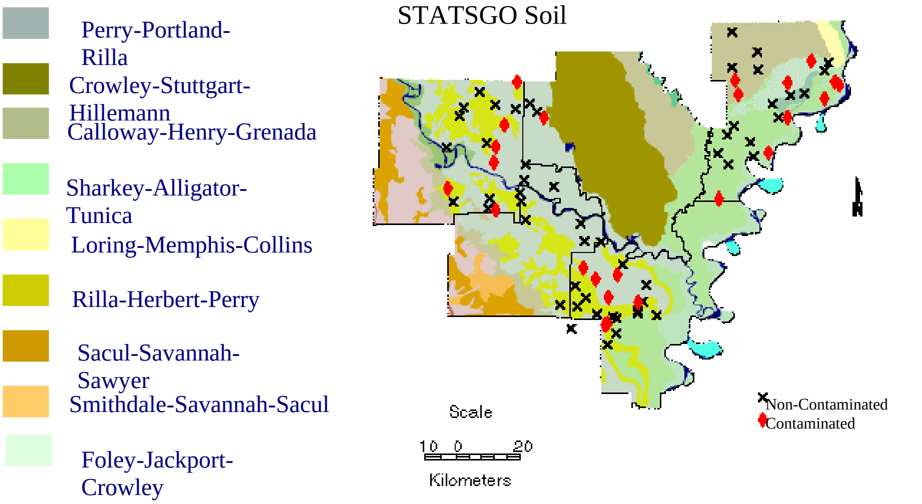
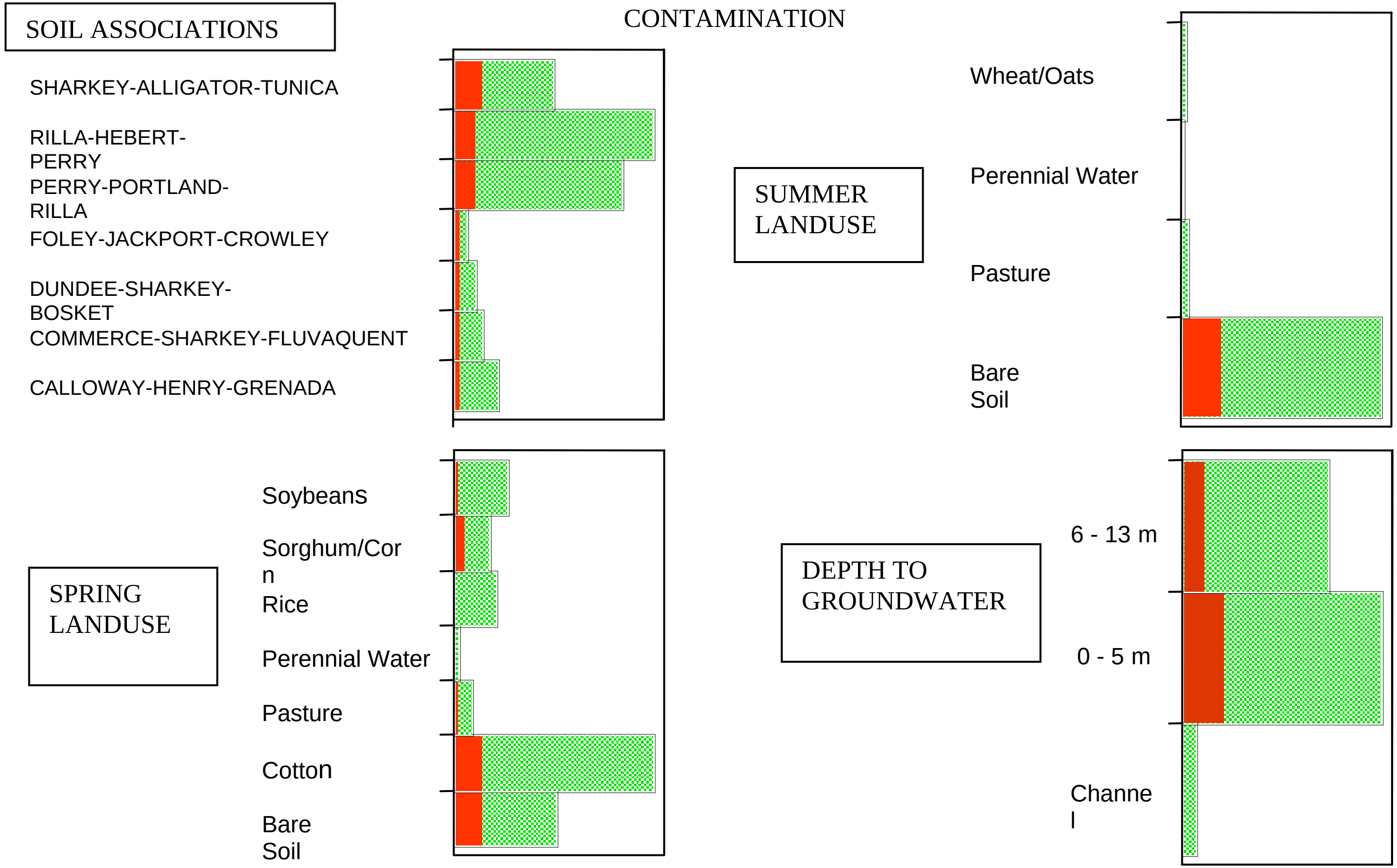
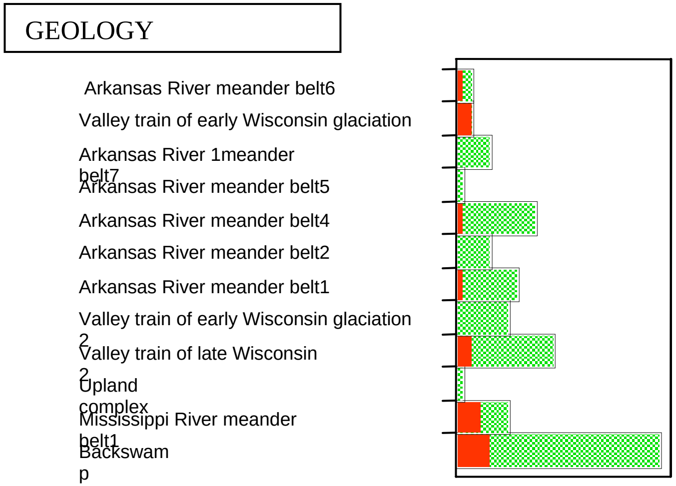
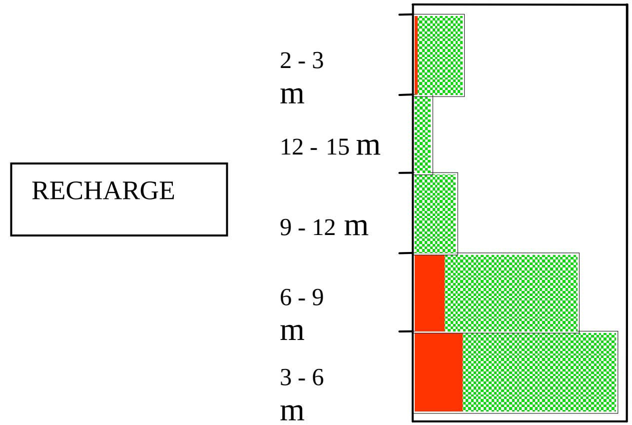
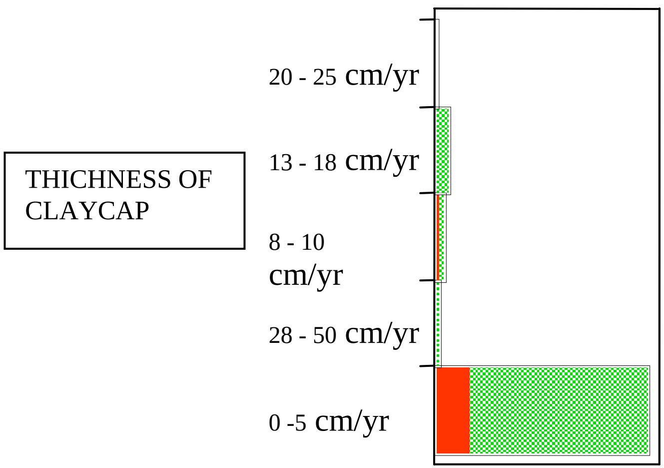


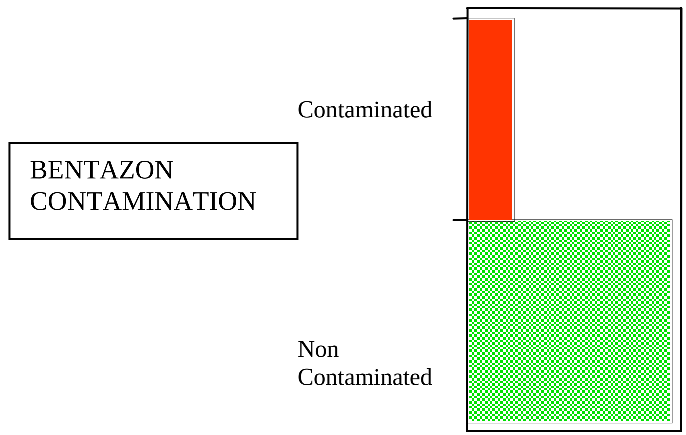
FIGURE 4
HYDROGEOLOGIC PARAMETERS AND BENTAZON CONTAMINATION




GEOLOGY
Arkansas River meander belt6
Valley train of early Wisconsin glaciation
Arkansas River 1meander belt7
Arkansas River meander belt5
Arkansas River meander belt4
Arkansas River meander belt2
Arkansas River meander belt1
Valley train of early Wisconsin glaciation 2
Valley train of late Wisconsin 2
Upland complex
Mississippi River meander belt1
Backswamp


RECHARGE
2 - 3 m
12 - 15 m
9 - 12 m
6 - 9 m
3 - 6 m


THICHNESS OF CLAYCAP
20 - 25 cm/yr
13 - 18 cm/yr
8 - 10 cm/yr
28 - 50 cm/yr
0 -5 cm/yr


BENTAZON CONTAMINATION
Contaminated
Non Contaminated

Buffer analysis (160 m) revealed that the maximum number of wells contaminated with Bentazon was associated with the following physical parameters: Sharkey-Alligator-Tunica soils, bare soils in spring, cotton and bare soils in summer, backswamp, 3 - 6 m thick claycap, recharge of 0 - 5 cm/yr and depth to GW of 0 - 5 m (Figure 4).

During the spring (Figure 5), most of the land is bare (42 percent) followed by forest (38 percent). However, during summer farmers cultivate most of the bare soil. They grow soybeans (24 percent) followed by rice (10 percent) and cotton (10 percent) in the summer (Figure 6). Most of the contamination occurs with cotton and soybeans followed bysorghum/corn. Soybeans occupied twice as much land area as cotton, yet the number of contaminated wells associated with cotton and soybeans is equal. This distribution indicates that more contaminated wells were associated with cotton production.

FIGURE 5
SUMMER LANDUSE

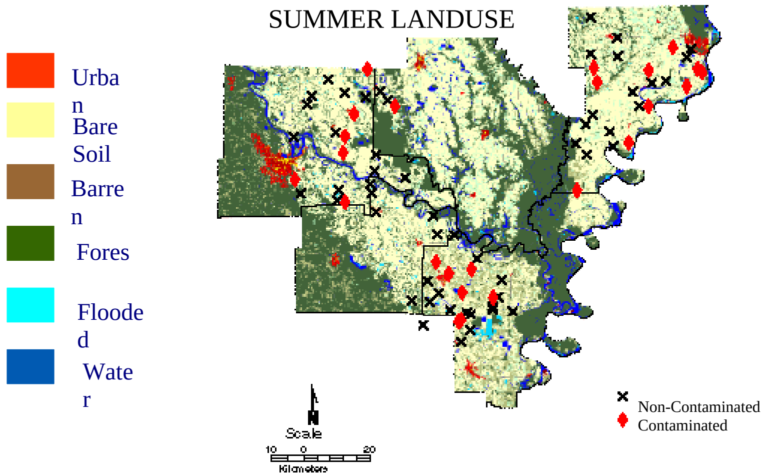
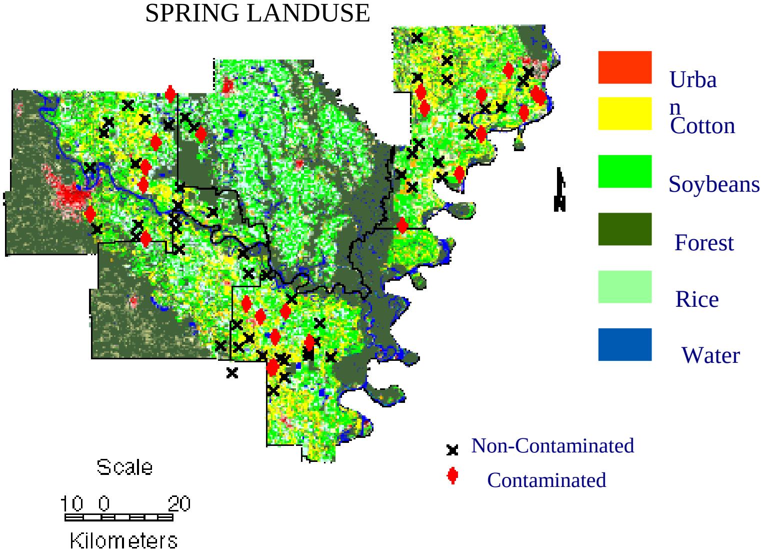
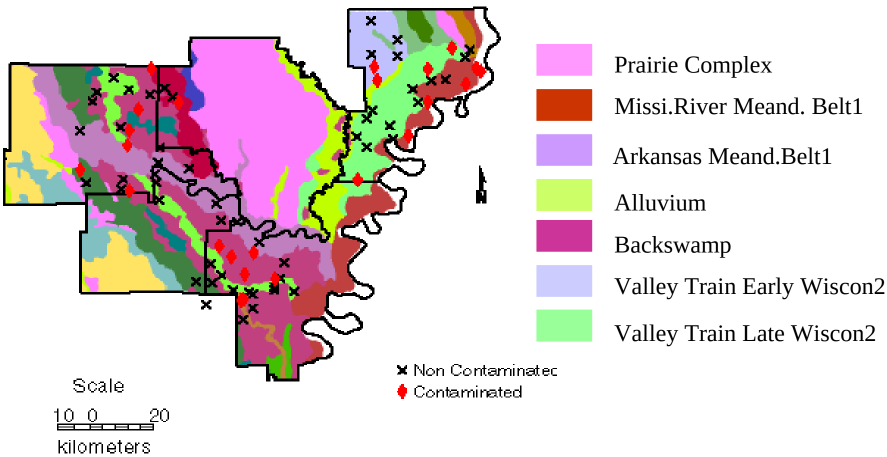


FIGURE 6
SPRING LANDUSE



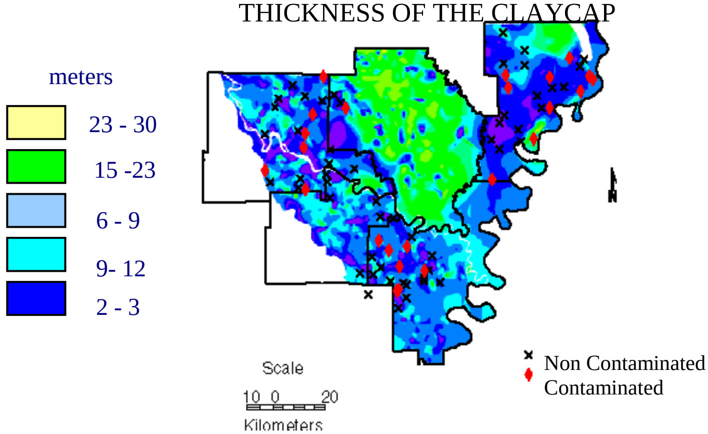
The most extensive geological formation of the area is the terraces (prairie complex, 19 percent) followed by backswamp (17 percent). Arkansas river meander belt covers about 10 percent of the total area (Figure 7). The maximum number of contaminated wells occurs in backswamp, followed by the Mississippi River valley meander belt1 (MRMB1), which covers about 7 percent of the total area.Valley train early wisconsin glaciation (VTEWG1) and valley train late wisconsin glaciation (VTLWG2) show equal number of contaminated wells.

FIGURE 7
GEOLOGY



The maximum number of contaminated wells occurred in areas where clay cap thicknesses of 4 - 6 m occur followed by thickness of 7 - 9 m. Most of the area (31 percent) is covered by a claycap 7 - 9 m thick, followed by 4 - 6 m (22 percent). About 15 percent of the total area is covered by 16 - 22 m thick claycap (Figure 8). Interestingly, only one out of eight wells was contaminated where claycaps were 2 - 3 m thick, whereas only one out of three wells was contaminated for 13 - 15 m thick claycaps.

FIGURE 8
THICKNESS OF THE CLAYCAP



The majority of the area is characterized by 0 - 5 cm/yr recharge (Figure 9). Recharge categories 6 - 10 cm/yr have two contaminated wells and none of the wells sampled in 11 - 18 cm/yr were contaminated. These two categories cover about 8 percent and 5 percent of the total area, respectively.

About 55 percent of the total area has a depth to ground water of 0 - 5 m (Figure 10). The maximum number of contaminated wells also occurred in this category. Thirty percent of the area has depth to ground water of 6 - 13 m. Five out of 77 wells sampled occur in this category.

FIGURE 9
RECHARGE

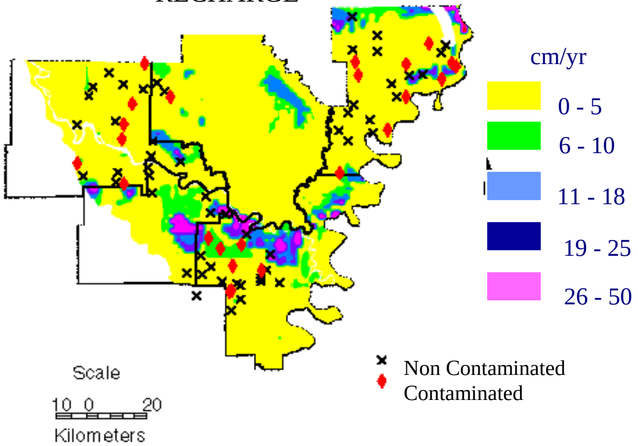
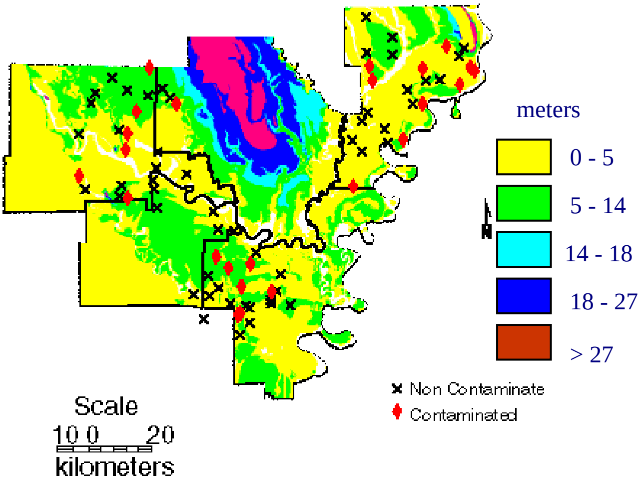
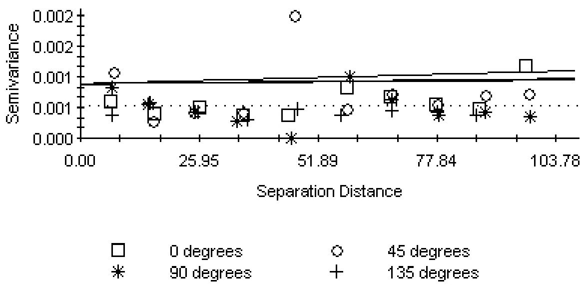


FIGURE 10
DEPTH TO GROUND WATER



Geostatistical analyses for Bentazon contamination in GW using a spherical model did not reveal any spatial relationships. In other words no relationship was found between proximity of wells and contamination. The anisotropic semivariogram is presented in FIGURE 11. This indicates two wells were not contaminated, because they were located within the close proximity of each other.

FIGURE 11
SEMIVARIANCE ANALYSIS OF WELL



6. CONCLUSION

Sixteen out of 76 wells sampled by DEQ in five counties in Southeast Arkansas were contaminated with pesticides. Each of the environmental parameters has its own spatial distribution, which affects the spatial variability of well contamination. Contamination coincided primarily with cotton and soybeans landuse in summer, mostly coarser-textured soils (Rilla-Herbert-Perry and the Perry-Portland-Rilla), depth to GW of 0 - 5 m and backswamp geomorphic environment. No spatial correlation was found from semivariogram analyses i.e. wells were not found to be contaminated because they were close to each other.

7. REFERENCES

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