Spatial Variability of Nutrients in Soils Following Long-Term Poultry Litter Applications

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INTRODUCTION

In the U.S. approximately 7.6 billion broilers are produced each year generating about 11.4 million tons of broiler litter (BL) annually (Georgia Agric. Stat. Serv., 1997; Moore, 1998). It has been estimated that each broiler produces between 1.46-2.67 kg of BL in its lifetime (U.S. Dept. of Agr., 2004). Broadcasting BL on the surface of agricultural land is the most common method of manure application in northeastern and southeastern United States (Kephart, 2000; Dou et al., 2001). The advantages in applying BL to agricultural land are that it:

- contains plant nutrients other than N, P and K, which may be limited in the soil
- can reduce nutrient leaching, as plant uptake is maximized with organic matter decay and slower release of soluble nutrients
- can improve soil structure, microbial activity and water and nutrient holding capacity of the soil from the added organic matter
- helps maintain soil pH from the basic elements in BL
- can be more economical than commercial fertilizer (Edwards, 1996; Woods,1992).

However, long-term land application can result in water quality issues such as eutrophication from runoff of P. When P is introduced to water bodies it leads to depletion of oxygen levels in ponds, harmful to aquatic wildlife; additionally, nitrate losses by leaching to groundwater may exceed acceptable limits for human consumption. In 1996 the USEPA identified eutrophication as the most extensive water quality impairment in the USA, and agriculture was the leading contributor of P to surface waters (United States Geological Survey, 1999).

Nutrient management plans are used in making application rate recommendations as a way to reduce environmental problems concerning P and N when applying BL to agricultural land. Current management plans are based on variables such as soil fertility, the nutrient requirement of the crop, and the slope of the land with little consideration of the entire landscape topography or the relationship of landscape topography and drainage. Recently, to improve nutrient management plans researchers have been dividing fields into smaller grids so that current nutrient management plans could become more site specific and variable nutrient application rates within a field could be accomplished. However, the literature suggests that grid size should be examined due to variation of soil nutrient concentrations within the zones (Lauzon et al., 2005). Daniels et al., (2001) took soil samples in 3-by-3m grids from 12 different pastures to determine the effect of spatial variability of soil P in pastures on implementation of a 150 mg kg^{-1} soil P threshold. They observed that mapping kriged soil P distribution in pastures with GIS resulted in as much as 50% of the field area below the 150 mg kg^{-1} threshold although the mean equaled or was slightly greater than the threshold. Franzen and Peck (1995), who investigated the effect of soil sampling grid size on soil test P, compared P and K maps when soil samples were taken in 25, 50 and 100 m grids. They found that correlations of 50 and 100 m grid P values with 25 m grid P values resulted in r^2 values of 0.22 to 0.48 respectively. In addition, Wollenhaupt et al. (1994), who evaluated mapped soil test P and K for variable fertilizer rate, recommended a grid size of 32m.

Improvement of application rate recommendations are a potential way on reducing the environmental risks associated with poultry litter application. As an alternative to using conventional grid sampling to determine variable nutrient rates, the objective of this study is to examine the effectiveness of irregular soil sampling that targets landscape positions to predict areas of accumulation and losses of nutrients in a field that received long-term BL application.

MATERIALS AND METHODS

Two forage pastures near Mize, Mississippi that had 55+ years of poultry litter applications, with similar soils but different topography were soil sampled from 0-15 cm. Soil samples were collected on an irregular grid at georeferenced points using a hand-held Garmin GPS. The soil samples were air-dried and ground on a Wiley Mill to pass through a 2-mm sieve then analyzed for nutrient content (total N, total C, Mehlich III P, and TP). Nutrient analysis was done by using the Thermo Jarrell-Ash Inductively Coupled Plasma (ICP Franklin, MA). A Mehlich 3 extraction of 2 g of soil was performed to determine extractable P and K (Southern Cooperative Series, 1983) and was also analyzed using the ICP. To determine total N and C, a 0.6g sample of ground soil was analyzed by the CE Elantech NC analyzer (Lakewood, NJ). Soil pH measurements were taken using a 1:1 soil to solution ratio with 10ml of 0.01 M $CaCl_2$ and 10 g of soil. The field elevation data was collected with Trimble AgGPS 214 RTK receiver, which had a relative accuracy of 1 cm in x, y direction and 2 cm in z direction.

Geostatistical analysis tools, i.e. semivariograms, were calculated for each nutrient. Structured semivariogram functions were used to generate fine-scale kriged contour maps of each variable at each depth. Pearson's correlation was performed using Statistical Analysis System (SAS Inst., 1998).

RESULTS & DISCUSSION

The elevation map of field A showed that the highest elevation was 147 m located in the central section of the field and the average field elevation was 145 m with a range of 3.4 m. Field B highest elevation was 148.5 m and was also located in the center of the field, with a mean elevation of 146.48 and a range elevation of 4.68 m (Figure 1). The largest topographical difference in the fields was the direction of the highest slope. Field A highest slope was found in the southern direction where as field B highest slope was in the western direction.

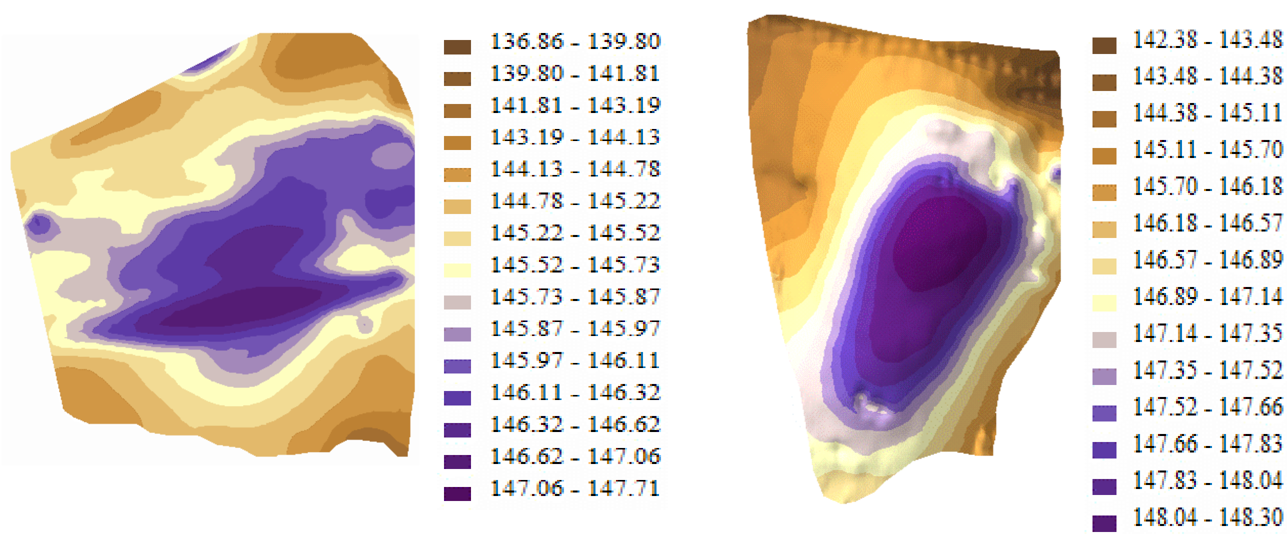

Figure 1. Elevation (m) map of field A (left) and field B (right) developed from Real Time Kinematic GPS data.

Nitrogen

After 55 years of poultry litter application N distribution for both fields varied with elevation and landscape positions. Field A nitrogen distribution had a negative relationship with elevation (Figure 2), meaning that as elevation increased %TN (total nitrogen) decreased. The highest %TN was found in the west and northeast portion of the field where the elevation ranges from 147-145 and 146-144 respectively. The %TN of both the west and northeast section of the field A together ranged from 0.14-0.11 %, which was greater than the mean %TN of the entire field of 0.10 %. A possible explanation for the N accumulation in these areas of field A could be that the western and northeast portion of the field had the lowest elevation resulting in deposition of eroded sediment with NH_4+ attached along with NO_3- that is transported through natural drainage. The lowest % TN (0.09) was observed where the highest elevation occurred. These results observed from the N distribution map of field A agreed well with the Pearson's correlation r^2 value (r^2 = -0.266; p=0.045) that also indicates a significant negative relation of %TN and elevation (Table 1).

Only a portion of field B followed the inverse relationship between % TN and elevation observed in field A. The western portion of field B where the highest slope was identified had the highest %TN of the entire field with a range of 0.17-0.15 %. The next highest % TN was observed on a small slope located on the southeastern portion of the field where the % TN range was 0.16-0.14 %. Although the elevation range of the previous mentioned western portion of the field and the northern relief area was similar the northern relief area did not follow the same inverse relationship between %TN and elevation. The northern relief area showed a positive relationship between %TN and elevation. This contrast in nutrient distribution within field B indicates that the application of poultry litter may not have been even or the natural drainage pattern of the water in the field deposits more on the western relief relative to the northern relief area where there was less accumulation of %TN. Due to this difference in N distribution with the field, the correlation of %TN and elevation resulted in a positive (r^2 = .134) indicating that a large portion of field B % TN increased with elevation (Table 1).

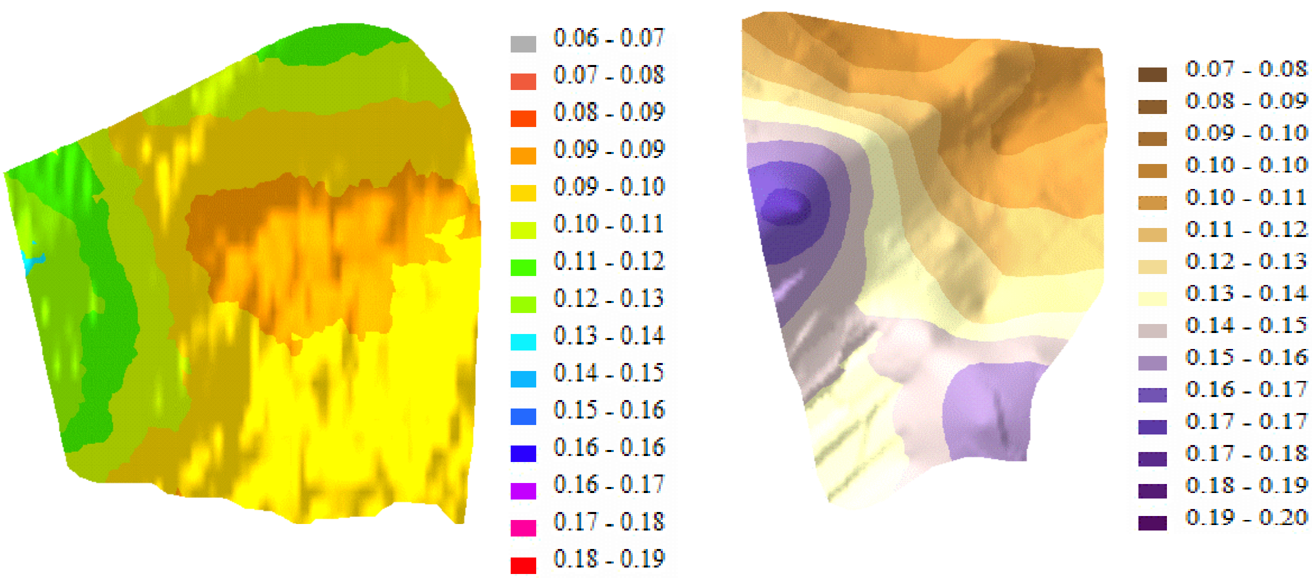

Figure 2. Field A (left) and field B (right) kriged map of total nitrogen (%) distribution on the landscape.

Mehlich III P (M3P)

The P distribution of both fields after long-term BL application was very similar to the distribution of % TN. The western and northeast relief areas of the field A contained the highest concentration of M3P that ranged from 1,119-760 kg ha^{-1} and 970 -760 kg mg^{-1} respectively (Figure 3). Although the correlation of M3P and elevation resulted in a non-significant negative r^2 value (-0.073; p=0.58), the value agrees with the inverse relationship of M3P and the elevation in the western portion of the field according to the M3P distribution map (Table 1). Similar to the % TN distribution in field B the western portions of the field contained the greatest M3P concentration that ranged from 1,534-2,088.

High concentrations of N and P in similar areas in each field after long-term litter application were confirmed by the significant r^2 value (r^2=0.606, p=<0.001) of the %TN and M3P correlation (Table 1). The positive relationship indicates that as P increased the concentration of %TN increased, indicating that both nutrients were transported and deposited in the same area of each field.

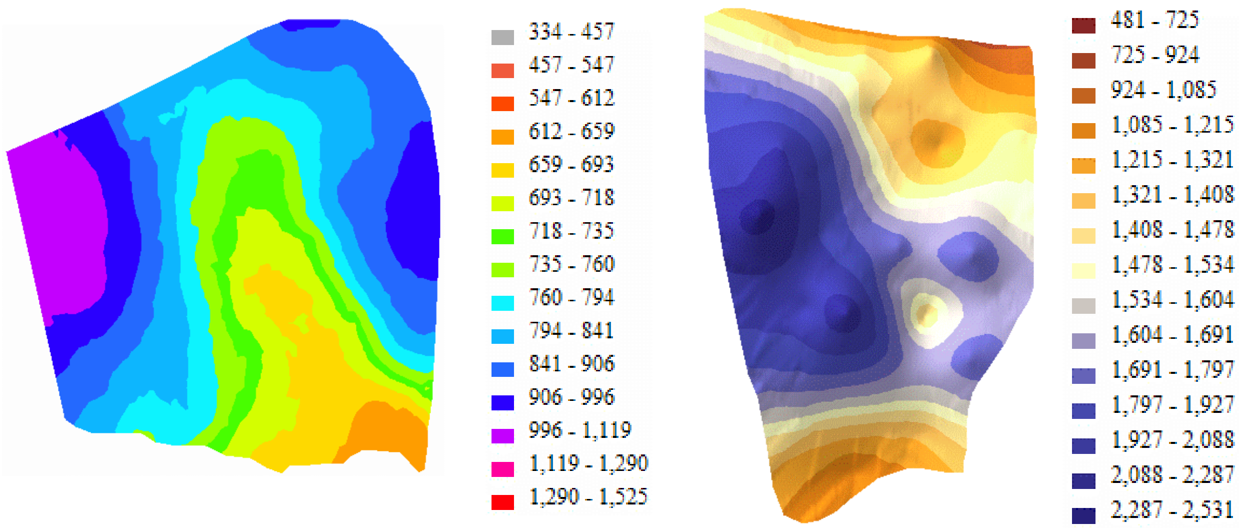

Figure 3. Field A (left) and field B (right) kriged map of Mehlich III P (mg kg^{-1}) distribution on the landscape.

Table 1. Pearson correlation r^2 values of Mehlich III P, total N and elevation for both fields A and B.

Field A		
	Mehlich III P	Total N
Mehlich III P	----	----
Total N	0.61*	----
Elevation	-0.07	-0.45*

Field B		
	Mehlich III P	Total N
Mehlich III P	----	----
Total N	0.65*	----
Elevation	0.37*	0.13

*Significant at the 0.05 alpha level

CONCLUSIONS

Nutrient accumulation and loss areas of both fields A and B were easily identified using the irregular soil sampling method that targeted the landscape positions with the fields. Also, variable nutrient levels within each field were observed, from the % TN and Mehlich III P distribution maps, as a result of annual poultry litter applications. The relationship of elevation and N and P was inversed for field A and a large portion of the western section of the field was identified as an accumulation area for N and P. However, field B had a positive relationship between elevation and N and P, although the western portion of the field was an accumulation site. In addition, using the N and P distribution map that was based on targeting landscape position, the central section of each field had the lesser concentration of N and P and was identified as the areas where nutrients have been transported.

This research has demonstrated that nutrient accumulations in fields that received long-term BL application could be identified by focusing on differences in topography and landscape. Topography and landscape positions are excellent clues for determining hydrological paths of water movement. Areas of high elevation normally are the source of nutrients that accumulate in low-line areas through erosion of soil particles and adsorbed nutrients. Also, water transports and deposits soluble N and P as it drains from areas of high elevation to a lower elevation. This technique of soil sampling in an irregular grid at georeferenced points could also be useful when recommending best management practices, such as grass waterways or terrace borders, to prevent runoff of fertilizer nutrients from grass pastures and row crops within a watershed. Considering irregular soil sampling that targets landscape positions within a field as a tool for creating more accurate and site specific nutrient plans could potentially decrease surface and ground water degradation in areas of high annual poultry litter applications and fertilizer usage.

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