SUMMARY OF FORTY YEARS OF GRID SAMPLING RESEARCH

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ABSTRACT

Between the years of 1961 and 2001, two 12.5-ha fields in Illinois were sampled for soil pH, and available P and K in a 24.3-m grid. One field was sampled beginning in 1961 while the other field was sampled from 1982. At each sampling, the samples were obtained in the same grid. This resulted in the ability not only to compare grid sample density to delineate fertility patterns within the fields, but also to determine the rate of soil test change with P and K applications, the change in fertility patterns and the change in each grid sample soil test value with time. The results of the study show that without heavy fertilizer applications soil P and K patterns are stable. Heavy applications of P and K mask natural P and K patterns. Changes in soil P and K values are not uniform over time, but vary with soil differences, and resemble natural fertility patterns. Areas requiring limestone additions at the beginning of the study were similar to areas requiring limestone all through the study. Other areas needed little or no pH amendment throughout the study. Individual grids whose values changed drastically between sampling were affected by fertilizer misapplication (P and K), or natural/manmade pH differences at a small spatial scale.

INTRODUCTION

In 1961 a soil sampling project was initiated by Dr. Sig Melsted at the University of Illinois. A 12.5-ha field about 33-km west of Champaign, Il, and another field near Urbana, were sampled in an 24.3-m grid. In 1962, Dr. Ted Peck joined the study and ultimately took over subsequent sampling on the spatial study. The purpose of the study was to examine the variability of soil pH, P and K in actual farm fields, and to devise less aggressive and expensive sampling strategies to determine the central-tendency of those nutrients within fields. There are no records of the Urbana field ever being sampled again, however, the west field, called ‘Mansfield’ (the field is about 1.5-km southwest of Mansfield, IL) or the ‘Warren Tract’ (the field is owned by the University of Illinois) was periodically sampled until 1982, then sampled annually from 1986 until 2002 under the direction of Peck.

In 1982, Peck began sampling another University of Illinois-owned 12.5-ha field northwest of Thomasboro, IL in the same 24.3-m grid as Mansfield. This field was sampled continuously from 1986 until 1999. The following are soil sampling and grid-harvested crop yield dates for the two fields:

Mansfield- soil sampling dates- 1961, 1976, 1982, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1994, 1999.
Mansfield corn yield- 1991, 1993, 1999.
Mansfield soybean yield- 1992, 1994.

Thomasboro- soil sampling dates- 1982, 1986, 1987, 1988, June and October 1989, 1990, 1991, 1992, 1994, 1995, 1999, 2001.
Thomasboro corn yield- 1992, 1994, 1995, 1999.
Thomasboro soybean yield- 1996.

METHODS AND MATERIALS

All soil sampling was conducted using the same procedure in all years. The fields were 12.5-ha in size, and were flagged at each sampling location using a tape measure. The samples were 24.3-m (80-ft) apart. The Mansfield site had 256 samples taken each year. The GPS coordinates of Mansfield are found in Figure 1.

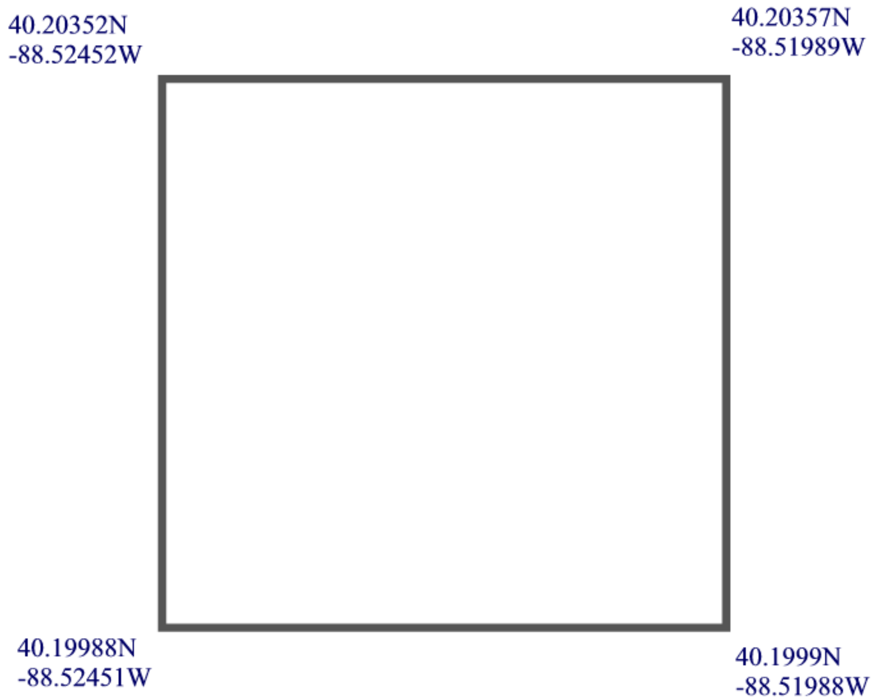

Figure 1. GPS coordinates for Mansfield.

The Thomasboro site was a US Air Force radar facility before being acquired by the University of Illinois. In the southeast, a small building was present, along with a radar pole slightly to the northeast of the building. At Thomasboro, there was a cottonwood tree belt along the west border, and another tree belt between ranks 6 and 7 from the west side running almost the entire length of the field. The number of samples at Thomasboro varied due to the building site, but generally there were about 250 sampling points.

Each soil sample consisted of 5 soil cores 0-15 cm in depth. These cores were collected in a common bag, dried and ground prior to analysis for soil pH (1-1 water), P by the Bray P1 test, and K by ammonium acetate.

Corn yield in 1991 was determined by determining plant harvest population in each plot, then collecting 10 representative ears. In 1992, after considerable discussion about this method, a measured 6.12-m of row from two interior rows in each plot was collected. Soybean yield was determined using a plot combine in 1992 using a long pole to separate the end of each plot area so that the combine did not extend farther into the next plot. From 1994 corn and soybean yields were determined using a plot combine.

Mapping for this publication was conducted using Surfer 8.0 for windows (Golden Software Co., Golden, CO). Parameters for kriged contour maps were determined using GS+ 5.0 for Windows, with the maps developed using these parameters within Surfer 8.0.

Elevations for use in terrain modeling were measured October, 2006 using a laser transit device with a stationary laser emitter. The readings are relative within each field independently.

Electrical conductivity measurements were conducted in November, 2006 using a Geonics® EM-38 magnetic electrical conductivity sensor set for shallow EC measurement.

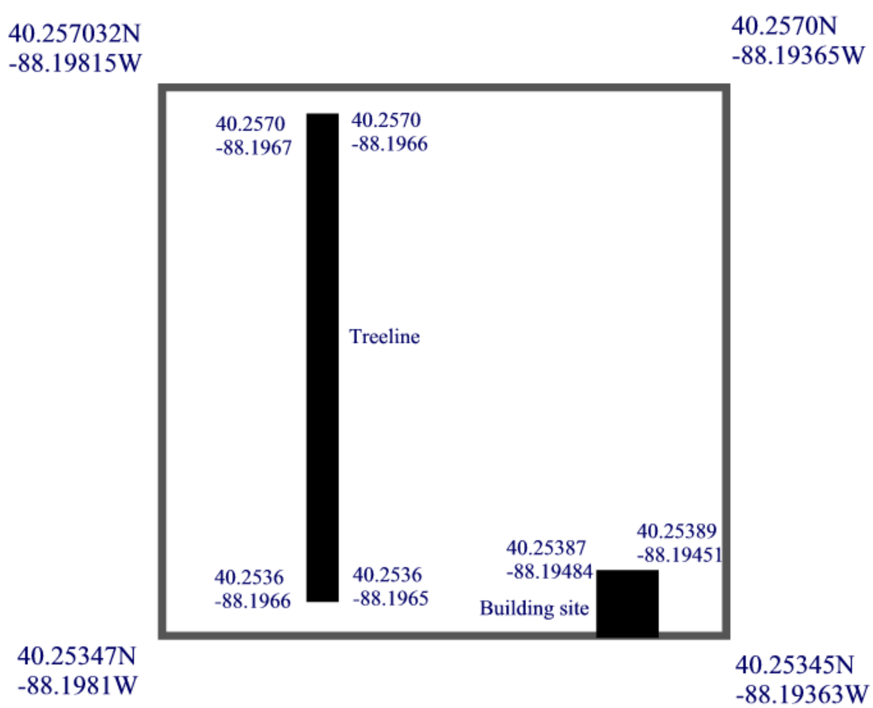

Figure 2. Thomasboro GPS coordinates, including GPS coordinates of the borders of the tree-line and building site.

RESULTS and DISCUSSION

It would be impossible and impractical to present each soil/crop factor year of data into this proceeding. However, the following data are presented to provide support for the summarization of the data for this conference.

Lesson 1- Soil pH, P and K patterns were persistent unless obscured by large fertilizer and limestone application.

Between 1976 and 1991, limestone applications were made to parts of Mansfield. As Figure 3 shows, patterns in 1991 were very similar to those in 1976. Areas high in pH remained so; those with a tendency towards acidity retained that characteristic.

Soil P and K patterns were also persistent as shown in Figure 4. Thomasboro P patterns showed particularly low P in the northwest, south-central areas. After large P application between 1982 and 1988, the P was allowed to decline due to crop removal. The final P map shows patterns similar to those in 1982, although the values of P had generally increased in the field due to earlier fertilization.

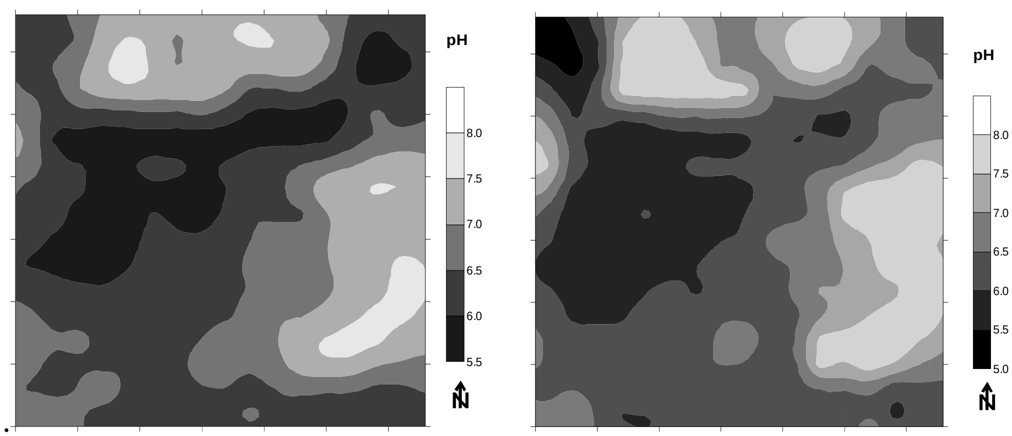

Figure 3. Mansfield pH, 1976 Mansfield pH, 1991.

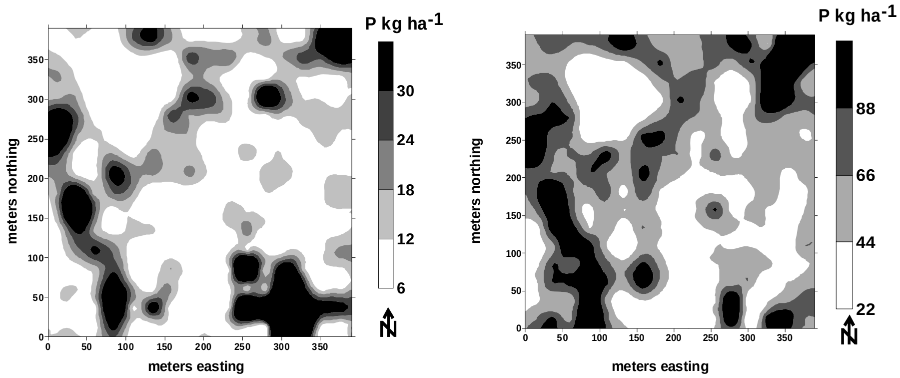

Figure 4. Thomasboro P, 1982 Thomasboro P, 1991.

Lesson 2- When P and K applications were discontinued, yields remained high and total P and K removal at both sites exceeded P and K inputs, while P and K levels remained high. The rate of P soil test draw-down was slower than fertilization buildup rates. The rate of K soil test draw-down was faster than fertilization buildup rates.

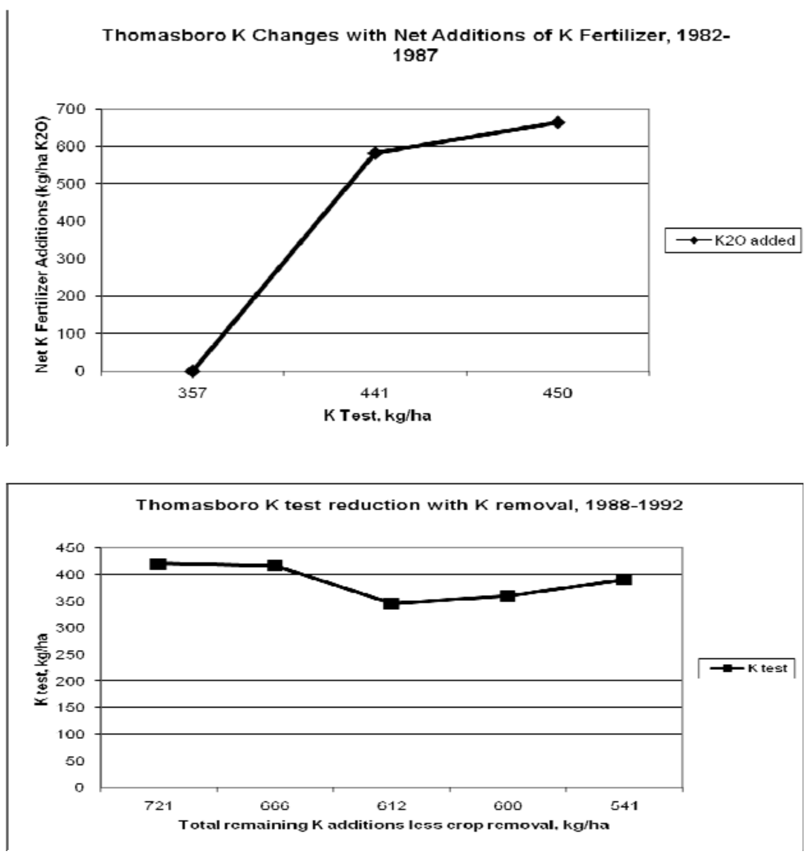

Figure 5. Differences in rate of K buildup and K draw-down due to crop removal.

Figure 5 shows an example of differences in rate of K buildup compared to draw-down rate. The rate of draw-down is slower than buildup. During this period, crop yields remained high, as soil test K levels suggest.

At Mansfield, 5.4 kg ha^{-1} P_2O_5 added resulted in a 1 kg ha^{-1} increase in P1 test. It took 7.9 kg ha^{-1} P_2O_5 draw-down to decrease the P1 test 1 kg ha^{-1}. It took 6 kg ha^{-1} K_2O to increase the K test 1 kg ha^{-1}, but only 1.7 kg ha^{-1} K_2O draw-down to decrease the K test 1 kg ha^{-1}.
At Thomasboro, 5.8 kg ha^{-1} P_2O_5 added resulted in a 1 kg ha^{-1} increase in the P1 test. It took 15 kg ha^{-1} P_2O_5 draw-down to decrease the P1 test 1 kg ha^{-1}. It took 7.1 kg ha^{-1} K_2O to increase the K test 1 kg ha^{-1}, but it took only 3 kg ha^{-1} K_2O draw-down to decrease the K test 1 kg ha^{-1}.

Lesson 3- Nutrient difference maps did not generally represent historic nutrient patterns within two-three years of each sampling, however, long-term difference maps tended to be similar in pattern to soil/landscape.

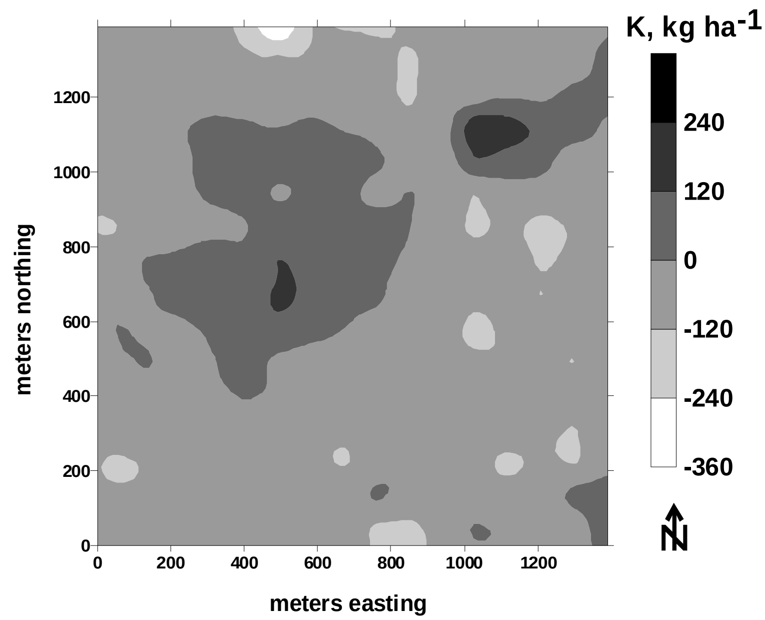

Figure 6. K changes Mansfield, 1988-1990. Positive numbers mean a decrease in K from 1988 to 1990. Positive numbers indicate an increase in K. The lower K areas are in a region characteristic of initial K patterns in the field.

Usually, two to three-year nutrient difference analysis did not show any particularly characteristic pattern in the field. However, often, particularly with pH, but also with P and K, nutrient change maps over a period of years showed characteristic patterns in the field initially seen with the nutrient levels of each nutrient. This indicates that patterns are initially seen in the field because there are intrinsic properties of the soils within the field to reveal those patterns over time. Figure 6 is an example of this property.

Lesson 4. Yield frequency mapping more consistently represented nutrient patterns and were more related to nutrient levels than single-year yield maps.

Yield frequency maps use data from multiple years of normalized yield, regardless of crop type, combined to create new data that reflects tendencies of yield from most consistently high yield to most consistently low yield. Figure 7 shows the yield frequency map for Thomasboro. It shows the effects of the tree line and also several characteristic zones that relate directly to nutrient levels.

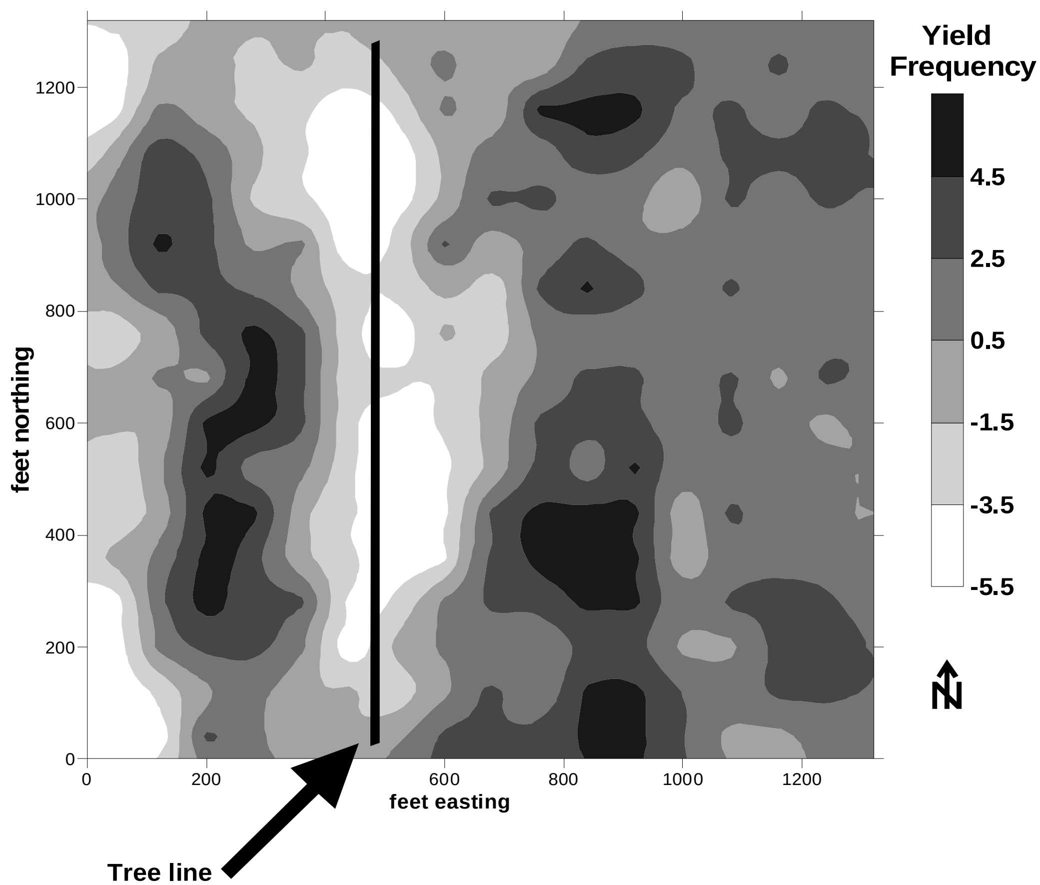

Figure 7. Yield frequency map for Thomasboro. Note the tree-line effect, and also high yield tendencies for the south-central area and the middle of the west sub-field.

Lesson 5- Simulated zone sampling using topography and soil EC were generally similar in pattern to dense (1 sample per acre) grid sampling for pH, P and K.

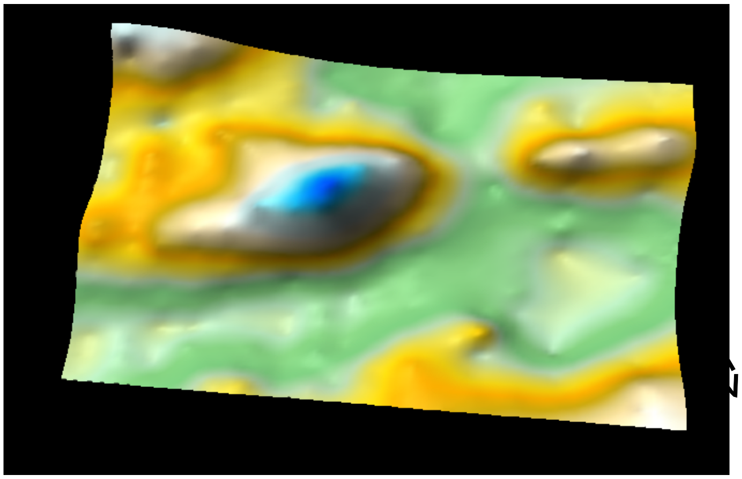

Figure 8. Elevation surface of Mansfield.

Mapping the elevation surfaces of both fields provided insight into crop yield and nutrient patterns. Patterns of elevation were similar to long-term patterns in pH and other nutrients. Layering EC with elevation provided additional relationships with nutrients (Figure 8).

Figure 8. Layered and clustered zones derived from elevations and EM readings, Mansfield. This image was derived using a combination of ArcMap to register the elevation and EM maps, then were imported into ERDAS Imagine as a .img file. The files were layered, and the layers were subjected to unsupervised classification using the isodata clustering method embedded within Imagine. This map shows the higher landscape positions being segregated from the rest of the field.

Table 1 shows the correlation values (r) for Mansfield pH, P and K between the original data and meta-data for those points generated using a 66-m or 100-m grid kriged map. A 66-m grid, with r values higher than 0.15 would be significantly correlated. Tables 2 and 3 show correlation developed similarly for electromagnetic sensor zones (EM), elevation (EL) zones and combination zones. P was particularly difficult at Mansfield due to heavy past fertilization and an old feedlot/building site in the northwest corner (see technical bulletin) unrelated to landscape or other field physical properties. However, the zone relationship with pH and K was similar with zone maps as the 66-m grid relationships.

Table 1. Comparison of a 100-m grid (1 sample per 2.5 acres) and a 66-m grid (1 sample per acre) with original sampling values, Mansfield, 1992.

		Sampling grid	
		100-m	66-m
Location	Soil test	r	
Mansfield	pH	0.54	0.70
	P	0.16	0.42
	K	0.17	0.41

Table 2. Comparisons of electro-magnetic and elevation zones with soil pH, P and K, Mansfield, 1961.

Comparison	r	P
EM vs pH	0.51	4.6×10^{-18}
EM vs P	0.17	0.006
EM vs K	0.46	1.6×10^{-14}
El vs pH	0.41	9.1×10^{-12}
El vs P	0.10	0.13 NS
El vs K	0.37	1.7×10^{-9}
EM + El vs pH	0.25	4.8×10^{-5}
EM + El vs P	0.07	0.26 NS
EM + El vs K	0.17	0.007

Table 3. Comparisons of electro-magnetic and elevation zones with soil pH, P and K, Mansfield 1991.

Comparison	r	P
EM vs pH	0.64	1.7×10^{-30}
EM vs P	0.01	0.92 NS
EM vs K	0.25	6.5×10^{-5}
El vs pH	0.53	6.4×10^{-20}
El vs P	0.02	0.78 NS
El vs K	0.32	1.5×10^{-7}
EM + El vs pH	0.28	4.8×10^{-6}
EM + El vs P	0.08	0.23 NS
EM + El vs K	0.14	0.02

Lesson 6- Satellite imagery of July-growing crops showed similar patterns as nutrients, soil EC, yield frequency maps and topography.

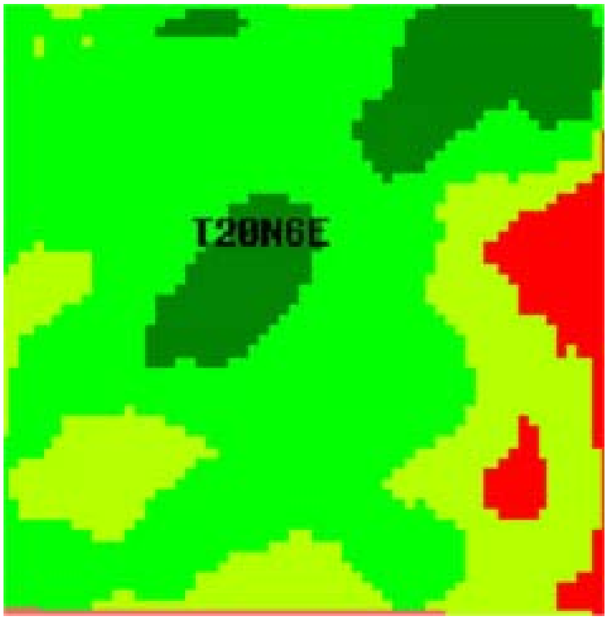

Figure 9. Mansfield Landsat image, July 4, 1999. The growing crop image shows similar patterns as landscape, EC and native pH, P and K patterns.

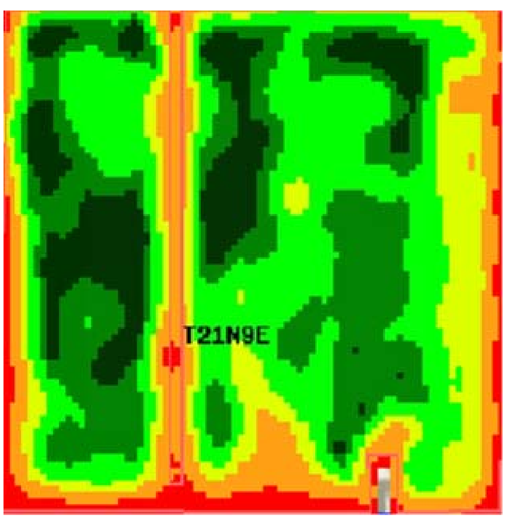

Figure 10. Thomasboro Landsat image, July 16, 2006, 15-m resolution. Darker areas are high in productivity; darker areas around the field boundary and in the tree line and building areas indicate roadsides or tree line/building sites. Lighter areas indicate lower productivity. Areas of high and low productivity are similar in pattern to topography and soil EC measurements.

Lesson 7- Small-scale nutrient sampling (2.4-m grids) showed that attention needs to be paid to fertilizer application to avoid streaking. The small-scale sampling also shows that although zone and grid sampling maps suggest long transitions between nutrient levels, the transition can also be abrupt.

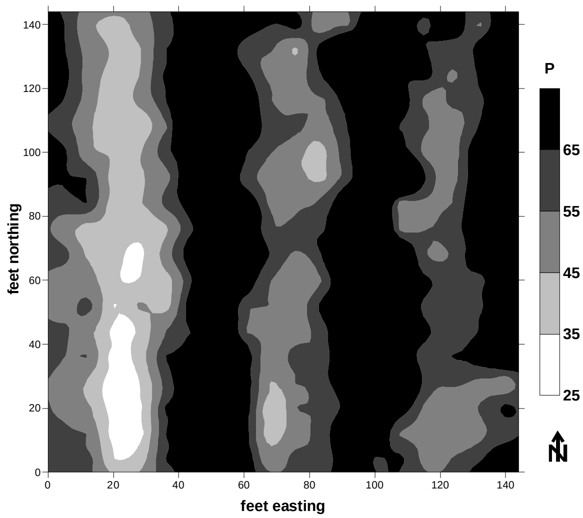

Figure 11. One small area, about 49-m square, centered on the 4-8 (four columns from the west, 8 sampling points from the south) sampling point that tended to change values periodically through the history of sampling. The map shows fertilizer application streaks about 15-m apart, suggesting poor calibration of application equipment sometime in the history of the Thomasboro field. (Map values are in English units, P in lb acre^{-1}.)

CONCLUSIONS

The data set of Mansfield consists of grid-sampled data dating to 1961. The data set of Thomasboro dates from 1982. These data are presented in a technical publication that is soon to be released. The lessons learned from this summary should help guide growers and consultants in their movement towards site-specific management of crop nutrients. The full data sets for each field are available online at http://www.soilsci.ndsu.edu/franzen/franzen.html under the heading “Illinois Grid Sampling Technical Bulletin” (Franzen, 2008).

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