FERTILIZER RECOMMENDATIONS BASED UPON NUTRIENT REMOVAL OR SOIL TESTING: A SPATIAL ANALYSIS

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Abstract

Introduction

Costs for nutrient management are generally high in crop production systems. Those costs are associated with activities related to: a) gathering information regarding soil fertility and plant nutrition for a field, b) acquisition of the actual soil amendments intended to improve the field's fertility and future crop nutrition, and c) application of the purchased soil amendments at the right rate in the appropriate place within the field. Information gathering usually consists of plant tissue and/or soil sample acquisition, analysis and interpretation. The results of soil sample analysis are particularly important in guiding phosphorus (P), potassium (K) and pH management in cropped soils.

Soil sampling requires time and skill. Time is not always readily available, especially when newly harvested fields are soon to be planted to a succeeding crop. An example is where winter wheat immediately follows corn or full-season soybean. Skill is needed to take the multiple cores in each soil sample, with proper consideration of the nutrient stratification found in modern conservation tillage soil management systems, and also earlier nutrient applications, especially banding. The soil test results are not always timely, causing further uncertainty in the nutrient management plan. Is there a better alternative?

The use of combines equipped with yield monitors and global positioning units is expanding. Some growers and dealers have suggested that the maps resulting from spatially referenced grain yield monitoring could be the basis of fertilizer rate prescription maps. The maps clearly show the spatial distribution of grain yield within a field. Nutrient removal is a function of grain yield. Converting grain yield to nutrient removal gives a map that could be the basis of a future fertilizer application to the field.

The possibility of using nutrient removal maps as fertilizer rate prescription maps has a number of attractive features. Fertilizer application guidelines could be very timely. The grower could take the data card from the yield monitor as each field is harvested and use tabulated grain nutrient concentration information to immediately make yield based nutrient removal/fertilizer rate prescription maps. These could be sent electronically to the fertilizer dealer, who could quickly dispatch applicators with the required fertilizer materials. No soil sampling, especially expensive grid soil sampling, would necessarily be involved. Intuitively, nutrients would be applied where needed, at the rates needed. For otherwise fertile fields, this approach is an extension of maintenance fertilization philosophy.

There are, of course, a number of possible problems. Yield monitors require attention. Maintenance and calibration are needed if the monitor is to accurately record the yields that are to be the basis of future fertilization. Every grower may not be inclined to apply nutrients after every crop. Some apply fertilizer P and K only once every two or three years. These growers might have to "integrate", or spear through, several nutrient removal maps in order to arrive at a single fertilizer prescription map. Such software is not universally available.

Another issue is related to the variables that drive the spatial pattern for yield observed in the field. Water, interacting with soil and landscape properties that influence plant available soil moisture, is extremely important in many Kentucky fields, but weed, insect and disease infestation patterns can be important, too. Should the fertilizer application be driven by this year's water stress/weed competition pattern?

Nutrient removal is the product of the yield and the grain nutrient concentration. The use of tabular values for the latter term in the product relationship implies a large degree of numerical stability across differing levels of nutrient availability, space, time and corn cultivar. This is not the case. Data for corn grain P concentration, taken from a long-term P fertility experiment, show that these values change with season, cultivar and soil test phosphorus (data not shown). This suggests that such values will likely vary within the field. Further, corn grain P responds positively, along with corn grain yield, as soil test P is raised from low to medium-high levels (data not shown). This implies that fields where the spatial yield pattern is driven by nutrient stress, fertilized in accordance with nutrient removal, will not be fertilized optimally. The least fertilizer will be applied where the most is needed. In such cases, only soil testing would identify areas where low yield was driven by low nutrient availability. However, soil test surveys suggests that such fields may be few, with most growers practicing aggressive nutrient management.

The objective of our study was to compare fertilizer rate prescriptions for P and K derived from four sources of information. The first, and our "expensive" standard, was based on grid soil sampling. The second was a single, uniform rate of fertilization, based on a single "composite" soil sample created from the average of the grid samples in a field. The third was based on a yield map, with single values for grain P and K taken from a published table. The fourth was also based on a yield map, but with values for grain P and K measured on the grain taken from the field.

Materials and Methods

Two fields, designated 112 and 950 and located in Marion County, Kentucky, were chosen for this study. Both were planted to corn (cv. Garst 8220 and Garst 8481, respectively) on 24 and 19 April, 1999, respectively, without prior tillage. No-tillage management has been used on all crops grown in these fields since the 1991 season. Field 112 is 51.4 acres in area, while 950 contains 43.7 acres. The soil in both is largely Crider silt loam, a well-drained Typic Paleudalf. Both fields contain significant areas of fragipan soils, Nicholson silt loam (Typic Fragiudalf) in 950 and Tilsit silt loam (Typic Fragiudult) in 112. Field 950 contains an area of Lowell silty clay loam (Typic Hapludult). Field 112 had a history of uniform chemical fertilizer application. Field 950 had a history of liquid swine manure and chemical fertilizer N applications.

Corn yield was monitored with a calibrated Ag Leader 2000 system installed on a eight-row John Deere 9600 series combine equipped with a Trimble global positioning system (GPS). Raw yield monitor data were collected each second, with an average area of 70ft^2 for each data point in these two fields. Soil (8 cores to a 4-inch depth) and grain (4 ears) samples were taken on an approximate 180ft by 200ft grid in each field. Each grid sample location was recorded on a hand-held CMT GPS unit. A digital elevation was determined with a Trimble real-time kinematic GPS system on a 23ft x 23ft grid interval.

Mehlich III extractable P and K, water pH, soil organic carbon (dry combustion method) and soil texture (pipette method) were determined on each soil sample. Ears were dried, shelled and the grain analyzed for P (micro-Kjeldahl digestion) and K (wet nitric-perchloric acid digestion) by automated colorimetry and atomic absorption spectroscopy, respectively.

For spatial analysis, the grain monitor yield maps were "cleaned up" to remove the effects of point rows, a clogged monitor (at times), header drop without harvest, and other spurious data points. Less than 2% of the individual raw data points were removed in this way. Yields at the four points nearest each grid sampling point were predicted by kriging. These four yield values were averaged and nutrient removal calculated as; a) the product of the average yield and the measured grain P and K concentration at the grid sampling point, or b) the product of the average yield and tabular values for grain P and grain K of 0.326% and 0.221% (Eakin, 1976), respectively. Grid soil sample test information was examined for normality, and the resulting semi-variograms examined for aniosotropy and stationarity. None was found and an omni directional semi-variogram was used for each of these variates. Soil test P and K maps were then generated by kriging.

Fertilizer P and K rate prescriptions were "classified" in 30lb P_2O_5 and 30lb K_2O increments according to P and K removal and soil test P and K values (Anonymous, 1999) as shown in Table 1. Fertilizer P or K rate prescription maps were then generated on the basis of the existing P or K removal or soil test maps. Areas receiving each rate of fertilizer were determined.

Results and Discussion

"Composite" soil test, grain yield and grain tissue P and K information for the two fields are given in Table 2. Field 112 is lower than 950 in soil test P, but higher in soil test K. Field 950 has a higher organic matter content. Soil water pH and soil texture were, on average, similar in these two fields. The grain yield was lower, and much more variable, in 112 than in 950. Grain P and K concentrations were both lower in 112 than in 950. Grain K in both fields was well above the tabular value of 0.221%, while grain P in both fields was much closer to the tabulated value of 0.326%.

Lower elevation was generally associated with lower yield in 950 (Fig. 1a, 1b). This was also true in 112 (not shown), and was probably due to greater erosion of surface soil in these areas of each field. This was also associated with soil map unit (not shown). In 950, the Lowell map unit was associated with greater erosion and lowest yield, while the Crider map unit was more eroded and less productive in 112.

The soil test P map for field 950 (Fig. 2a) indicated that considerable variation in this parameter existed within the field, but no values below 56lb P/acre (at which point fertilizer P would be recommended) were found. The lower soil test P values were found in areas associated with the fragic Nicholson and eroded Lowell map units. The fertilizer P rate prescription map based upon nutrient removal from the yield map and the tabular grain P concentration value (Fig. 2b) gave 2 different areas, the larger of which had generally greater yields (Fig. 1b) and required the greater P fertilization rate. This resulted in a greater fertilizer P recommendation for the area with the greater soil test P values in this field. There was little difference in this P removal/fertilizer P rate prescription map and that generated with measured grain P concentration values (not shown).

The soil test K map for field 112 (Fig. 3a) also evidenced considerable variation. In this field, lower soil test K values were associated with the Tilsit map unit and resulted in a fertilizer K prescription (Fig. 3b). There was great variation in the soil test K values within the Crider map unit, but none were below the 300lb K/acre threshold triggering a fertilizer K recommendation.

Tables 3 and 4 contain the fraction of each field's area that would be prescribed a given rate of P or K fertilizer. In field 112, both fertilizer P and K are overprescribed, relative to that recommended from the grid soil test results, by the two yield map based nutrient removal approaches. The composite soil sample analysis would have resulted in a recommended uniform rate of 30lb P_2O_5 per acre for this field, and no fertilizer K. The same thing happens in field 950, where the composite soil sample analysis would not have resulted in either fertilizer P or K application.

In conclusion, we found that: a) composite soil sampling over these medium-large field areas would not necessarily have been inferior to grid soil sampling in terms of the resulting fertilizer P or K recommendations, b) that yield map based nutrient removal resulted in greater fertilizer P and K rate recommendations that either soil test based approach, and c) that our chosen tabular grain P and K concentrations were sometimes inferior to actual grain P and/or K concentration measurements. The results suggest that the yield map could best be used as a field stratification tool, where areas of similar crop performance are delineated. Then, random soil sampling within those areas might be done to give optimal nutrient management information.

References

Eakin, J.H., Jr. 1976. Food and fertilizers. In. W.C. White and D.N. Collins (eds). The Fertilizer Handbook. The Fertilizer Institute. Washington, D.C.

Anonymous. 1999. 2000-2001 Lime and Fertilizer Recommendations. AGR-1. Univ. of Kentucky Cooperative Extension Service. Lexington, KY.

Table 1. Fertilizer recommendations as related to removal or soil test values.

Fertilizer Recommendation (lb P_2O_5 or K_2O / ac)	**Removal (lb /ac)**		**Soil test (lb/ac)**	
	P_2O_5	**K_2O**	**P**	**K**
0	0–15	0–15	> 56	> 300
30	15-45	15-45	42 – 56	225-300
60	45-75	45-75	28 – 42	175-225
90	75-105	75-105	14-28	100-175
120	105-135	105-135	0-14	< 100

Table 2. Soil test, yield, and grain composition information.

Property	**Field 112**	**Field 950**
P (MIII)	53.9 ± 30.9	147 ± 64
K (MIII)	429 ± 158	392 ± 121
OM	2.57 ± 0.44	3.26 ± 0.56
pH	6.32 ± 0.60	6.41 ± 0.27
Clay	19.5 ±3.9	17.7 ± 2.8
Silt	71.2 ± 4.3	72.8 ± 3.3
Sand	9.2 ± 9.1	9.5 ± 1.8
Yield (bu/ac)	130.4 ± 46.9	137.6 ± 22.4
Grain P (%)	0.29 ± 0.04	0.35 ± 0.03
Grain K (%)	0.33 ± 0.03	0.41 ± 0.03

Figure 1.- Field 950 A) Elevation and sampling points; B) Map of predicted yield.

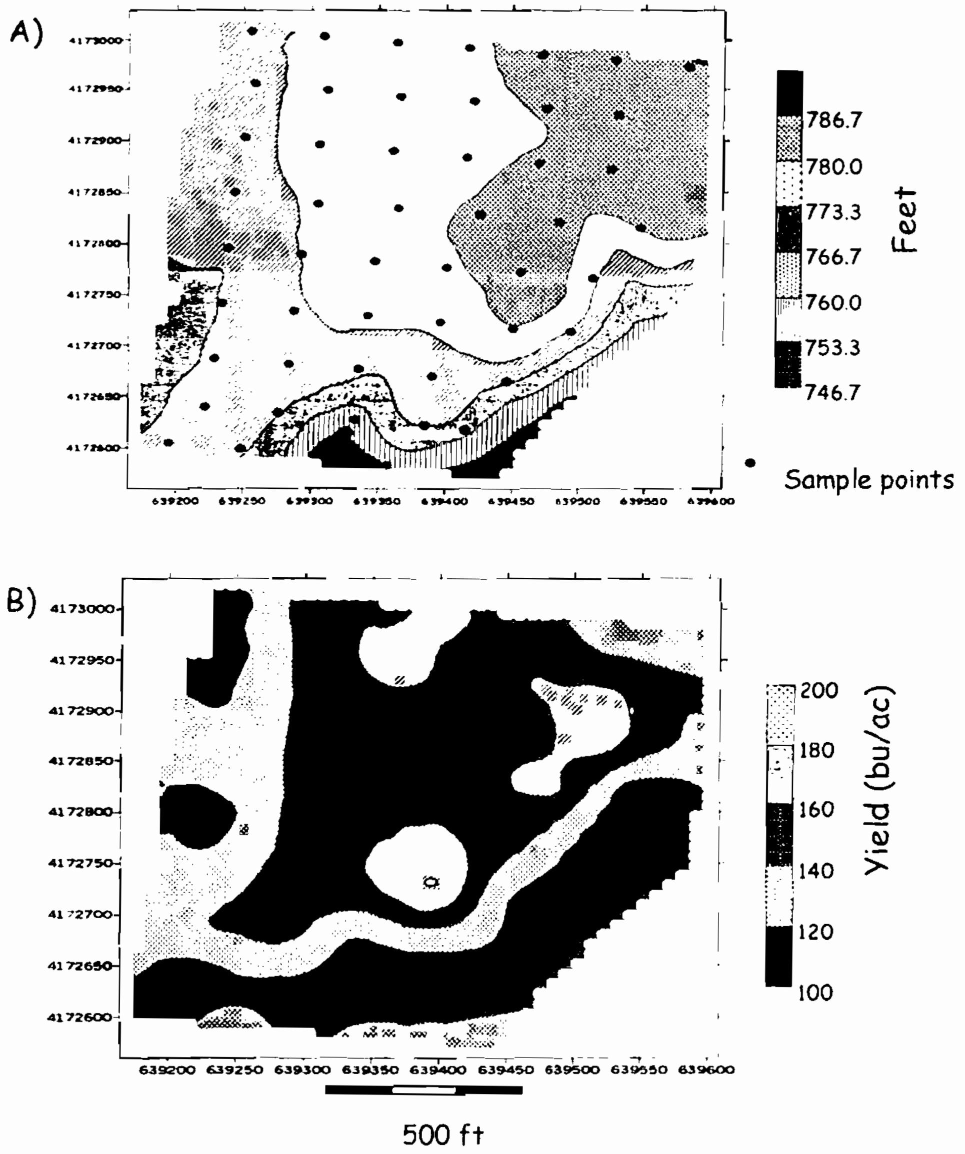

Figure 2.- Field 950 A) Map of soil test P; B) Fertilizer P prescription from P removal using tabulated grain P concentration.

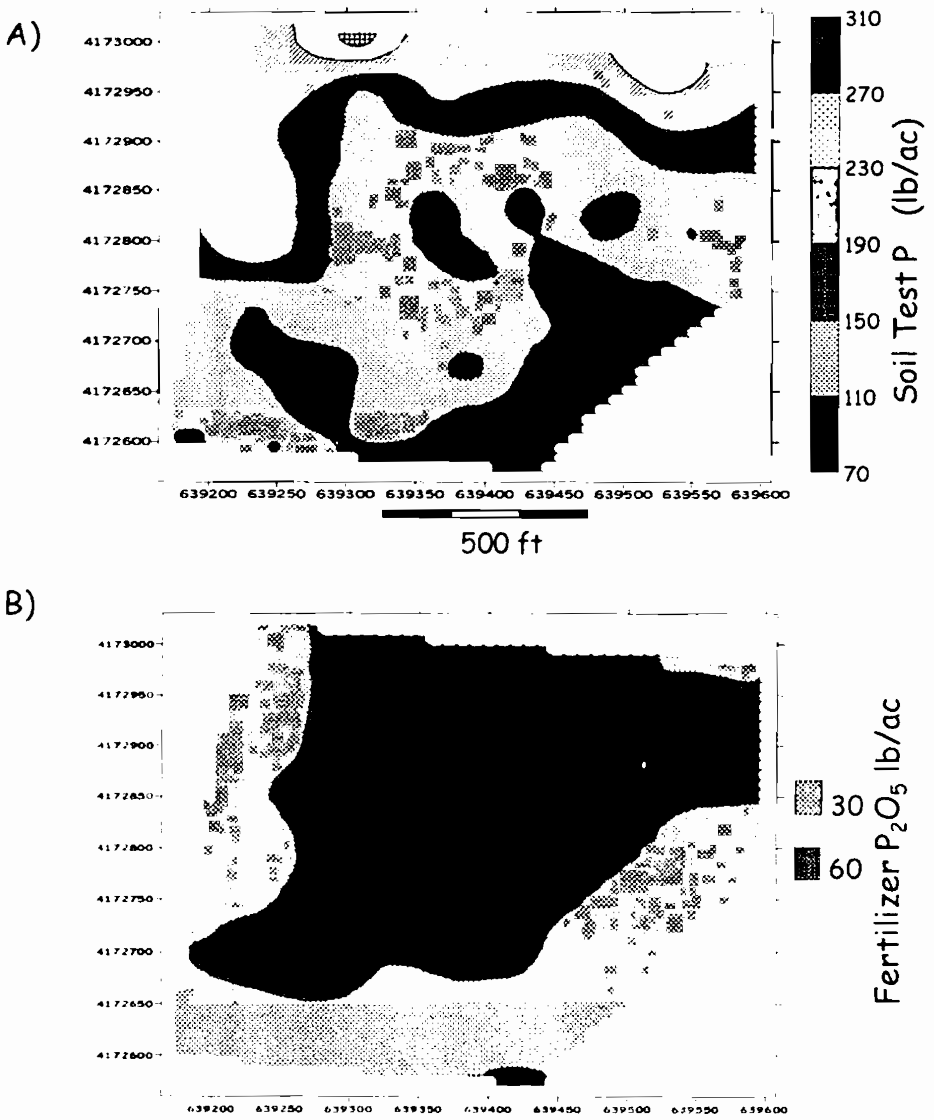

Figure 3.- Field 112 A) Map of soil test K; B) Fertilizer K prescription from soil test K.

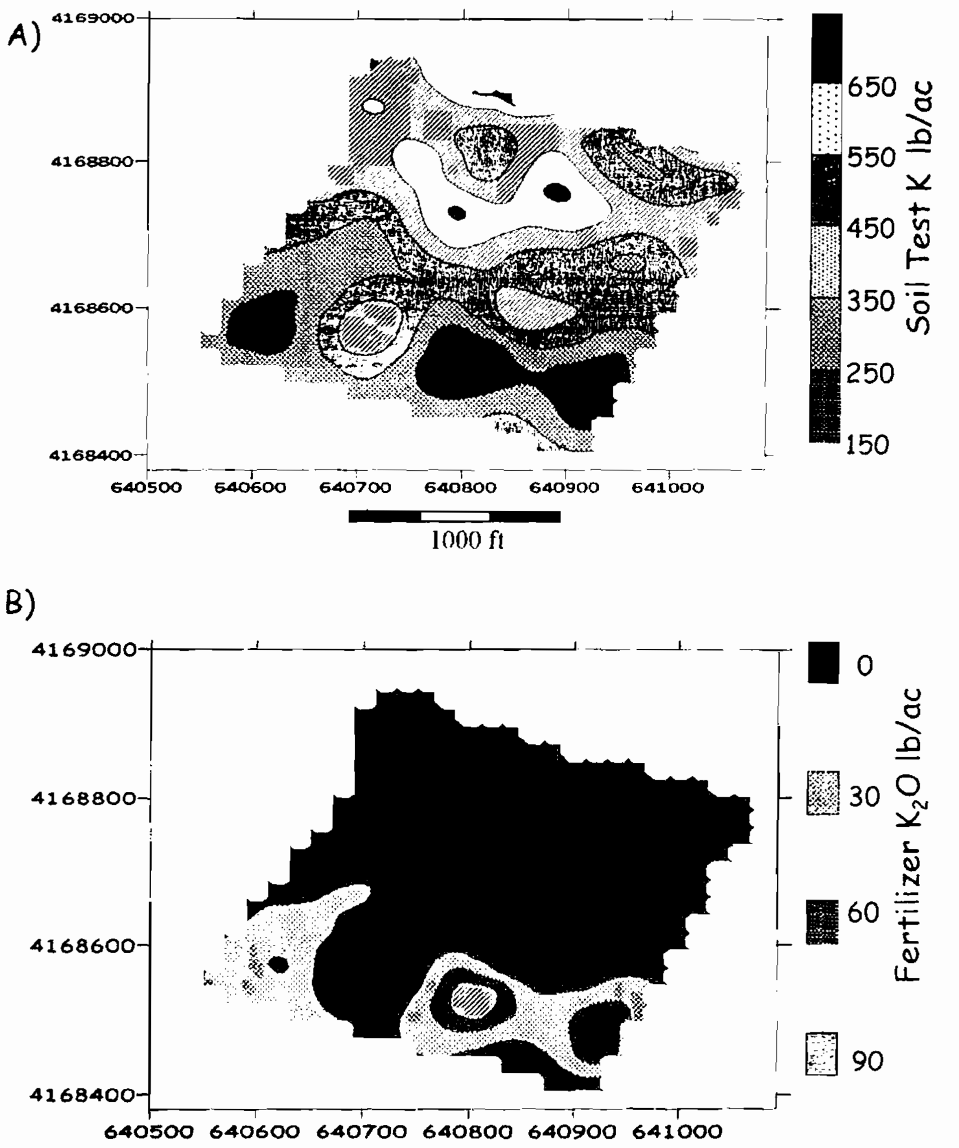

Table 3a. Areal distribution of fertilizer P rates for field 112 according to prescription method.

Fertilizer Recommendation lb P_2O_5 /ac	Soil Test P (%)	Tabulated P-Removal (%)	Measured P-Removal (%)
0	30.5	0	0
30	36.0	43.1	94.5
60	31.7	56.5	5.5
90	1.7	0.5	0
120	0	0	0

Table 3b. Areal distribution of fertilizer K rates for field 112 according to prescription method

Fertilizer Recommendation lb K_2O /ac	Soil Test K (%)	Tabulated K-Removal (%)	Measured K-Removal (%)
0	79.2	0	25.2
30	15.9	92.4	68.8
60	4.3	7.6	5.9
90	0.6	0	0
120	0	0	0

Table 4a. Areal distribution of fertilizer P rates for field 950 according to prescription method.

Fertilizer Recommendation lb P_2O_5 /ac	Soil Test P (%)	Tabulated P-Removal (%)	Measured P-Removal (%)
0	100	0	0
30	0	38.4	30.5
60	0	61.7	69.5
90	0	0	0
120	0	0	0

Table 4b. Areal distribution of fertilizer K rates for field 950 according to prescription method.

Fertilizer Recommendation lb K_2O /ac	Soil Test K (%)	Tabulated K-Removal (%)	Measured K-Removal (%)
0	78.6	0	0
30	21.2	99.0	100
60	0.2	1.0	0
90	0	0	0
120	0	0	0

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