GRID SOIL SAMPLING FOR PRECISION AND PROFIT

N. C. Wollenhaupt and R. P. Wolkowski [1]

Site specific management of plant nutrients for crop production begins with an inventory of soil test levels in a field. Fertilizer recommendations are based on the expected response to addition of fertilizers as a function of soil test levels. Therefore, the accuracy of site specific fertilizer applications depends on the precision of the soil test map from which the fertilizer recommendations are based. Precision usually increases as fields are divided and sampled as smaller areas.

Mapping accuracy also influences profitability. More soil samples means greater expense. Based on research in Wisconsin, a grower can afford a substantial investment in soil sampling when fields contain soils that would respond to additions of fertilizer greater than would be applied with a uniform rate application based on field average soil tests. Where the soil sampling density is inadequate, potentially responsive areas in a field may be incorrectly classified. In this case, site specific fertilizer management may lower profits compared to a field average program. The cost of grid soil sampling on fields where soil test levels are in "non responsive categories" must be offset by savings gained from not applying unneeded fertilizer.

Grid Soil Sampling

Soil scientists are being challenged to develop efficient soil sampling and mapping procedures that accurately map soil test spatial variability. Soil sampling by soil type has not proven adequate for developing accurate maps for site-specific fertilizer applications. This has led to an emphasis on systematic soil sampling.

The common approach to achieve systematic soil sampling is to overlay a square or rectangular grid on a map or photograph of the field, identify and drive to the middle of each grid cell, and collect a soil sample at that point (Figure 1). The soil sample consists of several soil cores collected within a small radius of the cell center. The soil cores are composited and bagged as one soil sample for analysis at a soil testing laboratory. The purpose of compositing several cores is to average or "bulk" out variability in soil test properties that occurs over small distances.

Grid sampling can be efficiently conducted by counting crop rows and using distance measuring devices to locate sampling points. While inexpensive to implement in the field, this practice can lead to bias. Tillage, fertilizer, manure application, drainage, old field boundaries and cropping patterns tend to occur in regular patterns across fields. If the grid sampling pattern is a multiple or fraction of

[1] Associate Professor and Extension Soils Specialist, Department of Soil Science, University of Wisconsin-Madison.

other patterns, the soil samples may not correctly represent the soil test variability within the field.

The potential for bias can be minimized by alternating sample locations to the right or left of the cell center, perpendicular to the management pattern (e.g. row direction). The resulting sampling grid takes on the appearance of a diamond pattern (Figure 2). This sampling pattern can also be implemented by counting rows and measuring distances. This pattern will improve mapping in the direction of management, but does not correct pattern effects in the other direction.

With the development of the Global Positioning System (GPS), we can now navigate to locations in a field without counting rows or physically measuring distance. We recommend adopting a systematic unaligned sampling protocol as farm level GPS hardware and software become available. This method combines the best of systematic sampling and random sampling.

Systematic unaligned sampling locations as illustrated in Figure 3 can be determined for a field by the following procedure adapted from Webster and Oliver (1990).

- Divide the field into cells by means of a coarse grid. Square cells are the norm but not mandatory.

- Superimpose a finer grid (reference grid) in each coarse cell. For example, if there are 5 rows and 5 columns in the coarse grid, you might choose to divide each coarse cell into 25 smaller cells.

- Choose a corner of the coarse grid, say top left, and randomly select 1 of the 25 reference cells.

- Move horizontally to the next coarse cell in the top row and keep the X coordinate the same but randomly select a new Y coordinate.

- Repeat the process for all the coarse cells in the top row.

- Return to the upper left corner and repeat the process down the first column of cells, this time keeping the Y coordinate the same, but changing the X coordinate in each successively lower coarse cell.

- The X coordinate of the reference cell immediately to the left and the Y coordinate of the reference cell immediately above the coarse cell of interest are used to determine the sampling points in the remaining coarse grid cells.

This procedure provides a constant interval both along rows and down columns without alignment. A more complete discussion on sampling and estimation can be found in the reference by Webster and Oliver (1990).

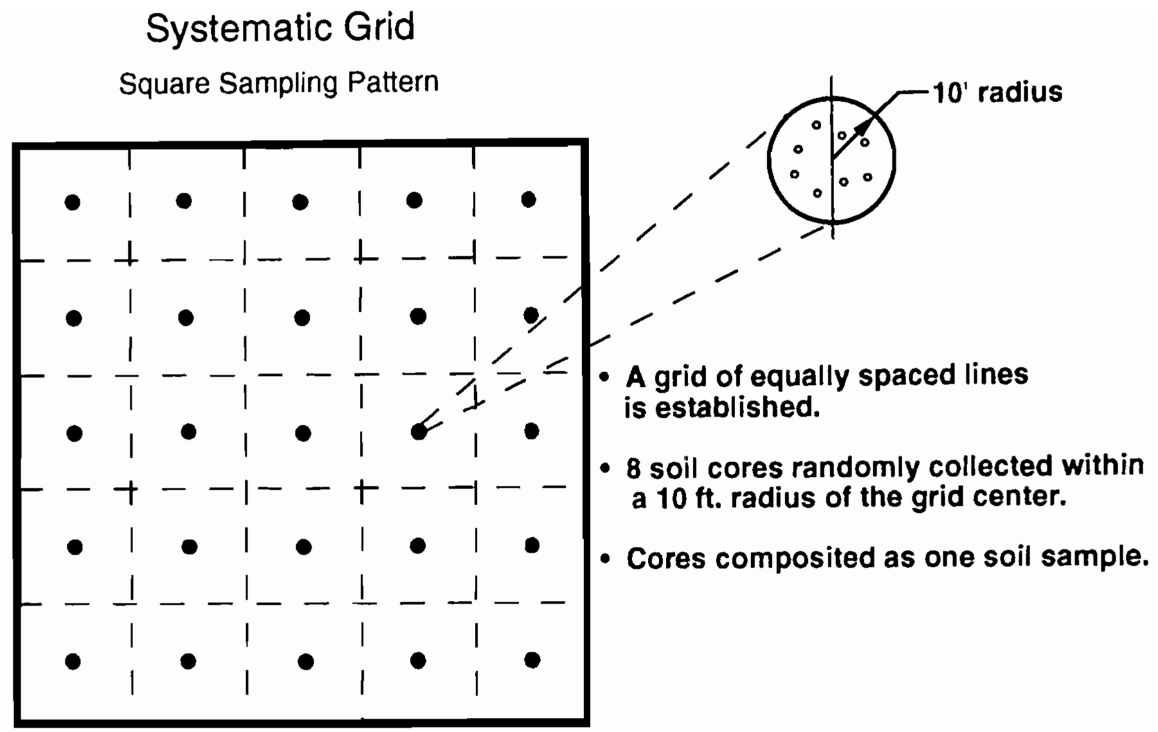

Figure 1. Schematic showing the layout of a square grid and locations where soil cores would be collected.

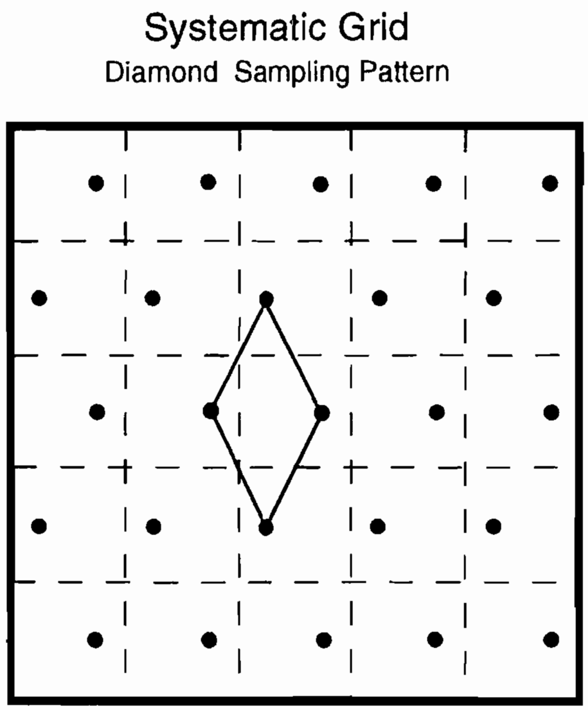

Figure 2. Modification of a square grid where alternativing rows of sample points are shifted one half the distance form the cell center and edge.

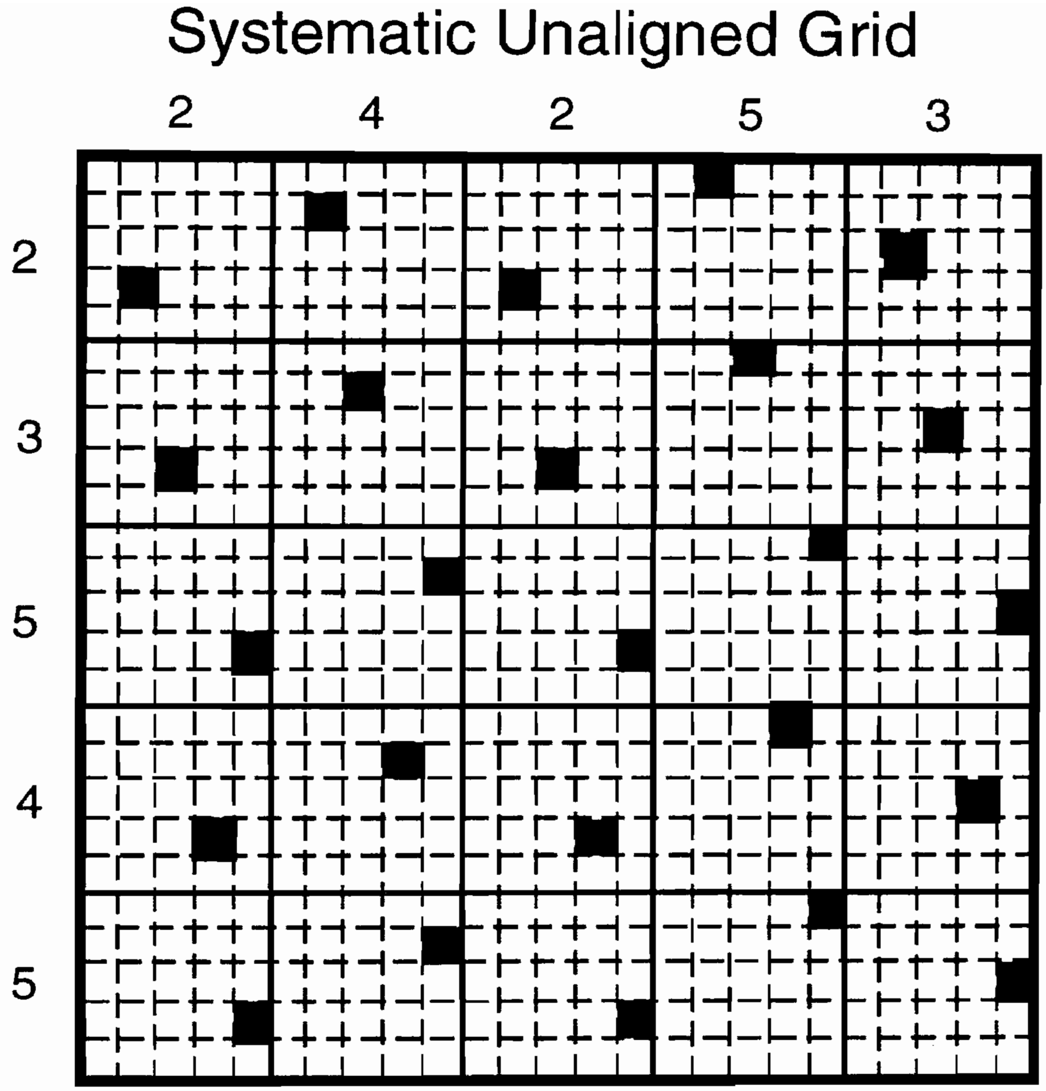

Figure 3. Schematic showing the layout of a systematic unaligned grid. The x,y coordinates were determined using a random number table.

It is important to recognize that soil sampling for site-specific fertilizer application is different than soil sampling to determine the field average for a uniform rate application. Many Extension soil sampling guidelines recommend dividing fields into smaller areas and collecting soil cores in a zig-zag pattern across each area. The intent is to obtain a representative soil sample which averages out soil test variability within the each small field area. An average or median value is calculated from the multiple soil test results to arrive at a uniform rate fertilizer application for the large field. This sampling method leads to a loss in spatial variability information that can be managed for in a site-specific fertilizer program.

Sampling Costs

Soil sampling, fertilizer application and data management are costs associated with site-specific application of phosphate and potash fertilizers. These costs must be subtracted from any change in gross return attributed to site-specific fertilizer application in order to evaluate profitability.

Initial grid soil sampling is a substantial cost associated with site-specific fertilizer management. Grid soil sampling studies conducted in Wisconsin show that soil test map accuracy depends on sampling method and sampling density. Soil sampling points in a field on a systematic grid improves mapping accuracy over sampling cell areas on a grid (Wollenhaupt et. al., 1994). Increasing the number of sample points also improves mapping accuracy.

The costs in Table 1 are based on the authors' experiences and limited data shared by fertilizer and fertilizer equipment dealers. Labor was billed at $25.00 per hour and soil testing at $6.00 per soil sample. The goal was to develop a cost estimate that included a profit margin for the fertilizer dealer and/or crop consultant, and soil testing laboratory. Note the fertilizer application charge is an annual charge and represents the additional charge for variable rate application versus use of a single rate applicator.

Table 1. Variable-rate soil sampling, fertilizer application, and data management costs.*

	Grid Spacing			
	450 ft (≈5 acres)	300 ft (≈2 acres)	200 ft (≈1 acre)	100 ft (≈0.25 acres)
	$/acre			
Sampling				
2 hr (20 samples)	$1.70			
5.7 hr (48 samples)		$4.29		
10.9 hr (106 samples)			$9.09	
36 hr (436 samples)				$35.16
Data Summary and Mapping	$2.00	$2.00	$2.00	$2.00
Fertilizer Application (additional variable-rate charge)	$1.50	$1.50	$1.50	$1.50
TOTAL COST	$5.20	$7.79	$12.59	$38.66

* 100-acre field with labor @ $25.00/hr and soil testing @ $6.00/soil sample

Costs associated with variable rate P and K applications increase rapidly at grid spacings smaller than 200-ft. The costs are easier to accept of they are amortized over a period of 4 years or longer. We speculate that intense (expensive) grid sampling is only required once if soil test information, fertilizer applications, and crop removals (yield) are geo-referenced so that a nutrient balance budget can be maintained. Additional soil sampling at a later date may be needed in fields with contrasting soil types (textures) where the general fertilizer response function may not apply equally well to all soil types, or to spot check for changes in soil test levels.

Site-Specific Profitability

Mis-application of fertilizer where inadequate soil sampling led to an incorrect map of soil test variability is a potential cost not discussed in the previous section. Yield and/or income losses were measured when soils were classified as not needing additional fertilizer when in fact they were responsive to nutrient additions. Any assessment of the profitability of variable rate fertilizer application must also include an evaluation of soil test map accuracy.

Budgets were created for five Wisconsin farm fields. Returns are reported as the difference between a single composite soil sample and uniform fertilizer rate program for the Trinrud and Kohel fields, or the most recent fertilizer program for the other three fields (Table 2). Corn was valued at $2.50/bu, nitrogen (N) at $0.24, phosphate ($P_2O_5$) at $0.25, and potash ($K_2O$) at $0.12/lb. Changes in corn yield and amount of fertilizer applied for the soil sampling and mapping methods were calculated using a procedure described by Buchholz (1991). The procedure is based on a theoretical technique proposed by Fisher (1974) to relate soil test measurements to crop yields. The technique was validated with yield measurements from replicated stripped fertilizer treatments within the fields.

The changes in income derived from yield gains and reduced or added fertilizer costs, compared to a single soil sample, uniform fertilizer rate program are presented in Table 2 in the column labeled additional gross returns. The additional returns in the Kohel and Trinrud fields are due to increased yields from additions of fertilizer. The soil test P and K levels in the Metcalf, Sommers and Waller fields were in the excessively high soil test category. The gross income improvement for these fields is solely due to cost savings by not applying N-P-K starter fertilizer. Yield measurements in these fields did not show responses to phosphate and potash fertilizer.

Previous research (Wollenhaupt, et al., 1994) showed that mapping accuracy was affected by sampling density and method. The first column in Table 2 assumes each method resulted in the correct application of fertilizer to the field. For the Metcalf, Sommers and Waller fields mapping accuracy does not enter into a determination of profitability. But for the Kohel and Trinrud fields the gross returns were adjusted based on mapping accuracy. The adjusted "true" gross return is reported in column 2 (Table 2).

The costs for the variable rate program (Table 1) were amortized over 4 years and are located in column 3 (Table 2) and include 3 additional years of spreading charges ($1.50/ac) for the Trinrud and Kohel fields. Variable rate spreading charges and the cost of a computer chip map were deducted for the Metcalf, Sommers and Waller fields because no additional P and K was recommended. The choice of amortizing cost over 4 years does not imply that grid sampling would be conducted ever 5 th year.

Table 2. Summary of variable-rate practice costs and returns for several soil sampling densities assuming continuous corn. †

Field site	Soil sampling method	Additional gross return	Additional corrected gross return	Variable rate costs§	Net return to variable-rate practice¶
Trinrud	Grid point, 106-ft	$13.14	$13.14	$10.79	$2.35
	Grid point, 212-ft	$10.14	$3.76	$4.28	($0.52)
	Grid point, 318-ft	$10.29	$5.14	$3.07	$2.07
	Cell (area), 318-ft	$5.72	($13.94)	$2.42	($16.37)
Kohel	Grid point, 106-ft	$7.64	$7.64	$10.79	($3.15)
	Grid point, 212-ft	$7.46	$4.30	$4.28	$0.02
	Grid point, 318-ft	$10.29	$6.23	$3.07	$3.16
	Cell (area), 318-ft	$5.09	($0.38)	$2.42	($2.80)
Metcalf	Grid point, 100-ft	$15.92	--	$9.16	$6.76
	Grid point, 200-ft	$15.92	--	$2.65	$13.27
	Grid point, 300-ft	$15.92	--	$1.44	$14.48
Sommers	Grid point, 100-ft	$6.91	--	$9.16	($2.25)
	Grid point, 200-ft	$6.91	--	$2.65	$4.26
	Grid point, 300-ft	$6.91	--	$1.44	$5.47
Waller	Grid point, 100-ft	$11.96	--	$9.16	$2.80
	Grid point, 200-ft	$11.96	--	$2.65	$9.31
	Grid point, 300-ft	$11.96	--	$1.44	$10.52

† Variable-rate costs include soil sampling and data management for Metcalf, Sommers and Kohel fields. In addition, a fertilizer application charge is included for the Trinrud and Kohel fields

§ The costs are amortized over 4 years.

¶ Gross return minus variable-rate costs.

Even before the costs of site-specific programs are added in, the cell sampling method shows less income than a uniform rate fertilizer program. The cell method (multiple soil cores collected to represent the whole cell area rather than a point) resulted in some low and very low test areas being classified in the high test category. Income was lowered due to yield losses caused by under fertilization. We conclude that incorrect mapping of responsive soils in a site-specific program can lead to less profit than with a single rate program.

The Trinrud, Metcalf and Waller fields showed a profit, even at the 100-ft sample spacing. The Trinrud profit was due to improved yields whereas the improvement in profit for the Metcalf and Waller fields was due to reduced fertilizer costs. Only P and K were managed in these examples. The organic matter and pH information from soil testing is additional information that might be used in site-specific management decisions - - possibly adding to the profitability of variable rate practices.

Soil Sampling Recommendations

Soil sampling patterns were discussed previously in the grid sampling section. We concluded that systematic unaligned sampling is the preferred soil sampling pattern.

The need for precision and the cost of soil sampling must be weighed when determining sampling density (spacing). It was learned after the fact that the Metcalf, Sommers and Waller fields were high in soil test P and K. While intensive soil sampling revealed a large amount of soil test variability, the variability was in the excessively high category and therefore fertilizer additions are not needed for many years. In contrast, the Trinrud and Kohel fields contained areas where soil test P and K were in low and very low soil test categories. The responsive areas were small and required intensive sampling to accurately determine soil test category boundaries prior to variable rate fertilizer application.

In light of these findings, we propose the use of prior soil test and fertilizer management history as a guide for determining the appropriate sampling density. We also propose that soil sampling may require more than one trip to some fields. The recommendation is as follows:

<u>Field History</u>

1) Prior soil tests in optimum or lower soil test categories. Fertilizer rate matched with crop removal.

   Soil sample on a 200-ft grid. Supplement with additional sampling to better define low and very low test boundaries.

2) Prior soil test higher than optimum soil test category. Fertilizer applied at rates meeting or exceeding crop removal.

Soil sample on a 300-ft grid. Supplement with additional sampling if first sampling identifies soils in responsive soil test categories.

3) No prior soil test records available.

Soil sample on a 200-ft grid. Supplement with additional sampling to better define low and very low test boundaries.

References

Buchholz, D.D. 1991. Missouri grid soil sampling project. In Proc 21 st North Central Extension-Industry Soil Fertility Conference. Potash & Phosphate Institute, Manhattan, KS.

Fisher, T.R. 1974. Some considerations for interpretation of soil tests for phosphorus and potassium. Missouri Agric. Exp. Stn. Bull. 1007, Columbia, MO.

Webster, R. and M.A. Oliver. 1990. Statistical methods in soil and land resource survey. Oxford University Press. New York, NY.

Wollenhaupt, N.C., R.P. Wolkowski, and M.K. Clayton. 1994. Mapping soil phosphorus and potassium for variable-rate fertilizer application. J. Prod. Agrc. (to be published Fall 1994).

PROCEEDINGS OF THE TWENTY-FOURTH

NORTH CENTRAL EXTENSION-INDUSTRY

SOIL FERTILITY CONFERENCE

October 26-27, 1994

Holiday Inn St. Louis Airport

Bridgeton, Missouri

Volume 10

Program Chairman and Editor:

Dr. Maurice Vitosh
Michigan State University
Dept. of Crop and Soil Sciences
Plant and Soil Sciences Building
East Lansing, MI 48824-1325