Map Making for Variable Rate Fertilization

By Harold F. Reetz, Jr.

Variable rate technology (VRT) fertilizer application requires a guidance map to relate the position of the equipment to prescribed application rates for specific areas of the field. Even the most extensive soil sampling schemes measure only a small fraction of the soil and then use that information to estimate the plant-available nutrient levels across the field. For example, to estimate the soil test levels for point ***x*** in **Figure 1**, information gathered from points A, B, C, and D can be used, each adding a little more information about point ***x***. The ability to estimate values for point ***x*** (and other unknown points) improves as the number of sample points increases. For this reason, more intensive sampling is desirable when developing a site-specific nutrient management plan. But there is a limit to the cost/benefit relationship of intensive sampling at some point. Sampling at distances as short as 110 feet, or a one-acre grid, becomes too expensive for most farmers.

Larger grid sizes for soil sampling often miss some areas needing nutrients. But sampling at smaller grid sizes, such as one acre, becomes too expensive for most farmers. A study at the University of Illinois is looking at effectiveness of various alternatives.

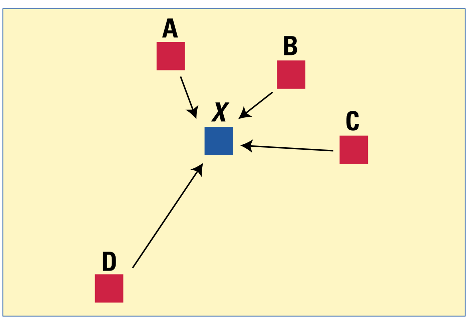
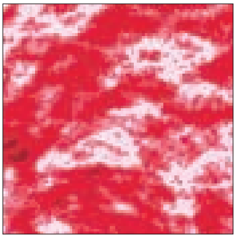
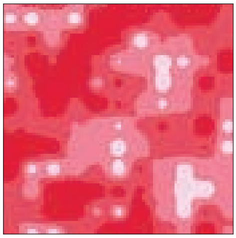
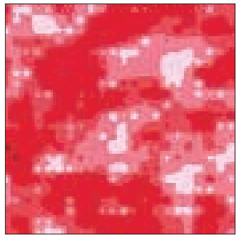
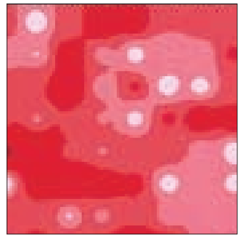


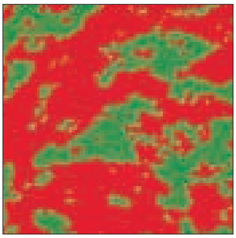
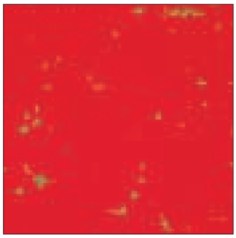
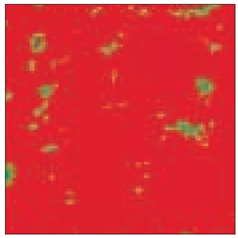
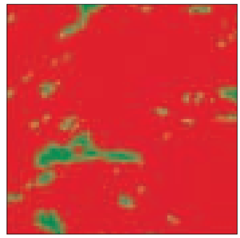
Figure 1. The soil test P level value of point x can be estimated from information known about points A, B, C, and D. A larger number of nearby samples provides more information on which the estimate of x can be based.

To demonstrate the importance of intensive sampling, Dr. Don Bullock, University of Illinois, produced a series of simulated sampling scenarios based on the characteristics of an actual central Illinois field, with the phosphorus (P) fertility variability shown in **Figure 2**. This P fertility map was generated by collecting more than 1,500 actual samples at various distances apart, then using the spatial structure of the data to develop a 1,000 x 1,000 point grid of the 640-acre field, or the equivalent of *1 million soil samples*. Darker color indicates a greater P soil test in that part of the field. The database generated was then "sampled" at 110-foot, 220-foot, and 330-foot grids to compare the relative effectiveness of these sampling densities in characterizing the real soil nutrient status of the field.

This field has a mean P fertility of about 40 lb P/A and has a range of spatial correlation of 600 feet. In other words, information from any given point can be expected to help estimate information about another point within 600 feet. **Figure 3** shows a 110-foot grid sampling simulation of the field. **Figures 4** and **5** show 220-foot and 330-foot grid sampling, respectively. Current University of Illinois recommendations suggest that fields be sampled on a 2.5-acre (330-foot grid) basis.

(From left to right):
Figure 2. Actual P fertility map based on very intensive sampling. Darker areas indicate higher P.
Figure 3. P fertility map based on 110-foot grid sampling simulation of data from **Figure 2**.
Figure 4. P fertility map based upon 220-foot grid sampling simulation of data from **Figure 2**.
Figure 5. P fertility map based upon 330-foot grid sampling simulation of data from **Figure 2**.

(From left to right):
Figure 6. Areas of field actually needing buildup P are shown in green.
Figure 7. Areas needing P that are missed with a 110-foot (1-acre) sampling grid are shown in green.
Figure 8. Areas needing P that are missed with a 220-foot sampling grid are shown in green.
Figure 9. Areas needing P that are missed with a 330-foot (2.5 acre) sampling grid are shown in green.

Comparing **Figures 3**, **4** and **5** to **Figure 2** (the actual field), it is clear that P fertility maps become progressively poorer as the grid size increases. More areas needing fertilizer are missed with the larger grid sizes.

Which map will best estimate the true nutrient status of the field? The worst mistake would be to declare that an area does not require fertilizer (e.g. P > 40 lb P/A), when in fact, fertilizer is needed to optimize crop growth (e.g. P < 30 lb P/A), based on the University of Illinois Agronomy Handbook. Areas of the actual field which have P soil test values of less than 30 lb P/A are shown as green and represent 38 percent of the field (**Figure 6**). Simply using a mean P soil test value and a uniform, field-average application rate, very little P fertilizer would be applied, since the mean of the field is approximately 40 lb P/A. So 38 percent of the field represents the missed opportunity for increased yield potential if the farmer used a field-average nutrient management program. It also represents missed market opportunity for the dealer supplying fertilizer to that farmer.

Comparison of **Figure 6** to **Figures 7**, **8**, and **9** indicates progressively more mistakes (i.e. not fertilizing areas that need fertilizing) as grid size increases. However, even the 330-foot grid (**Figure 9**), misses only 9 percent of the field needing P buildup, and thus is much better than the simple field-average uniform rate.

The 220-foot and 110-foot sampling grids miss only 4.5 and about 2.5 percent of the areas requiring fertilization, and are thus substantially better than the 330-foot grid. The generally good performance of the 330-foot (2.5-acre) grid in this example is mainly due to the 600-foot spatial correlation. As the range of spatial correlation decreases, the performance of the 330-foot grid will decline.

To determine whether a 330-foot grid gives an accurate estimate of nutrient variability, Dr. Bullock recommends sampling on a 330-foot grid, then collecting 25 percent more samples at random to help identify additional variability not captured by that sampling grid. That would mean collecting 32 grid samples on an 80-acre field, with eight additional random samples, for a total for 40 samples. Plotting a semi-variogram, you can determine whether the sampling points are close enough together to assume spatial correlation between points. If the plot shows points are not correlated, accurate interpolation between points is not possible and they should be treated as independent values. BC

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Fertilizing for Wheat... *(continued from page 17)*

Environmental risks are also present. Fertilizing for higher yields when moisture becomes limiting can lead to higher residual N left in the soil profile. Soil testing to determine the quantity of N present at the start of the next growing season is critical to using N effectively.

TABLE 2. Response of the Hi-Line hard red spring wheat variety to N and P fertilization (five-year average), G.R. Carlson, unpublished.

Variety	Treatment	Yield, bu/A	Protein, %
Hi-line	66-33-0	42.58	14.31
Hi-line	unfertilized	24.41	10.97
Increase from fertilizer		+18.71	+3.34

TABLE 3. Economic impact of N and P fertilization on the Hi-Line hard red spring wheat variety, G.R. Carlson, unpublished (prices used are same as for **Figure 2**).

Treatment	Selling price $/bu	Total costs	Return to fertilization costs	Return to total costs
		$/A		
66-33-0	2.93	128.16	28.93	-17.45
Unfertilized	2.62	109.85	0.00	-53.95
Difference	+0.31	+18.31		+36.50

Balanced fertility is important to environmental protection as well as profits. Paying attention to all nutrient needs is central to profitable wheat production. As an example, data in **Tables 2** and **3** show the impact of a fertility program that includes both N and P. These data show that N and P work together to increase yield, protein content, selling price, and returns. Although returns to fertilization were good, returns to total costs were negative for both the fertilized and unfertilized cases. Under current low crop prices and depressed economic times, fertilization may not guarantee positive returns, but proper fertilization can minimize losses. A recent survey by PPI found that 34 to 90 percent of the soil samples tested in major wheat producing states were medium or below in P. Rectifying deficiencies of nutrients, such as P, is necessary for increasing production and gross revenue.

One of the major concerns of dryland wheat production has been financing a fertilization program. Margins in such systems are narrow. Producers often struggle to get loans for needed fertilizer. Balanced fertility that targets higher protein may help producers find much needed revenue that will widen profit margins and further develop an upward cycle of land improvement and profitability. BC

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