

Soil Sampling for Precision Farming

BACKGROUND: WHAT IS PRECISION FARMING?

Precision farming technology has the potential to provide more stringent control over the rates of inputs to farmland based on variations in the landscape and soil across fields. The technology that makes this practical has four distinct parts:

1) a Global Positioning System (GPS) for location coordinates, 2) a Yield Monitor for yield recording at every instance, 3) a GIS system for yield mapping and 4) Variable Rate Applicators.

The strategy of precision farming is to detect variations in crop yields that occur across a field and to use variable application rates and micro-management techniques in an attempt to achieve more efficient use of inputs such as fertilizer and pesticides. Identification of precise locations in a field is made possible by the **GPS**. Signals from earth-orbiting satellites are used to locate exact positions on the face of the earth, virtually instantly.

Yield monitoring of crop responses can be made for areas that are as small as 100 sq ft, and subsequent mapping of yield variations across the field can provide information about variability of the soil. This is accomplished with a yield monitoring device mounted onto a conventional harvester. The challenge is to associate variations in plant responses with soil characteristics, weed populations, insect infestations, and other potentially yield-limiting factors that might account for these variations. To the extent that yield variations can be associated with nutrient supplies or pest populations, management inputs can be varied accordingly.

A **GIS** system is basically software which is vital to the storage, retrieval, and superpositioning of data that are gathered.

When used in combination, these technologies allow the yield for any small area or location in the field to be graphically recorded and subsequently displayed in the form of a map. The Yield Monitor and the GPS guidance system can be mounted on top of a combine. Then the exact position and the corresponding yield measurements can be continuously detected and recorded for subsequent analysis. Farmers can generate precise yield maps, showing yield variations across fields. Once areas with low yields are mapped, the GPS guidance system can be used to locate exactly the area for sampling, analysis, and problem identification.

Soil sampling becomes a major issue for site-specific or precision farming to the extent that nutrient concentrations in the soil may account for yield variation and can be modified to the advantage of the farmer. Soil samples should be obtained to truly reflect the nutrient level and other physical variability in different parts of the field, so a corrective action can be taken. Information from soil tests can be used to generate a map of soil fertility status. However yield maps will probably have a resolution of perhaps 10 to 15 linear ft of harvested area (width determined by the harvester and length by its ground speed), while soil sampling is commonly done with a resolution (sampling area) of 20 acres. Obviously, to take advantage of the technology and to determine whether variation in soil fertility is causing yield variation, soil sampling for precision farming requires a much different sampling strategy than normal. Once soil test information is available at the resolution appropriate for a field, soil fertility can be mapped and compared to yield maps.

VARIABILITY IN THE SOILS

How variable are yields? According to Dr. Cliff Snyder, Midsouth Director of Phosphorus and Potash

Institute (1996 Southern Soil Fertility Conference, Memphis, TN) numerous fertilizer dealers, consultants, and farmers still question whether we have the soil variability in the South to justify the time and expense that is being invested in detailed soil sampling needed to support variable rate application of fertilizer. Yet research has indicated that spatial variability in the physical and chemical properties in soils can be great. Snyder reviewed the results of a statistical study done at University of Arkansas on intensive grid soil sampling. Keogh and Maples conducted the experiment which was published in 1967 in Agricultural Experiment Station Report Series 157. They concluded that:

- 1) The reduction in size of the field did not give a comparable reduction in variability.
- 2) Soil sampling by soil type was difficult due to irregular patterns in which soil types occurred.
- 3) Areas of high and low soil test crossed soil types rather than followed soil types.
- 4) Highs and lows in fertility often followed no distinct pattern, with highs and lows occurring side by side in some places.
- 5) Fields of 29 to 40 acres needed 25 samples to keep the results of the field composite within the "allowable variation," 20 samples were needed for 20 acre fields, 15 samples were needed for 10 acre fields, and 10 samples were needed for 5 acre fields. Therefore definition of "allowable variation" is critical in evaluating the adequacy of sampling intensity.
- 6) One composite sample may not always be the best method of sampling. In case of lime applications, average recommendations based on composite samples can leave areas under-limed or over-limed. With the other nutrients, knowledge of the type of variation can help interpretation of borderline tests.

In another study in 1994 by Slaton at University of Arkansas, it was found that on a 70-acre rice field the pH values ranged from 6.1 to 7.2 with an arithmetic average of 6.62. Extractable P (Mehlich 3) varied from 17 to 105 lb/A with an average of 38 lb/A, and extractable K (Mehlich 3) varied from 62 to 130 lb/A with an average of 99 lb/A. The areas with lower levels of P did tend to correspond with areas of lower K levels. Nutrient levels were not related to

surface soil texture and slope of the land. In this case, precision tools may have helped in analyzing the patterns and developing an appropriate fertilization plan.

Soil variability is therefore a reality and a soil sampling scheme should be devised to suit each individual field probably for optimum resolution.

SOIL SAMPLING- GRID VS. ROUTINE SAMPLING SCHEMES

It is imperative that care be exercised when obtaining and compositing soil samples. Information about soil variability may be lost whenever samples are composited. A composite sample will not necessarily reveal the high degree of soil variability that may exist in a field. Therefore, to be effective, precision farming requires intensive sampling, even if restricted to the areas where lower yields were obtained. The number of samples required will depend upon the variability of the soil and the resolution desired. To illustrate, for routine soil testing, we recommend taking at least one composite soil sample consisting of 10 to 20 individual soil cores per 20 acres. Twenty acres is equivalent to an area about 930 ft x 930 ft. If 16 cores were taken at equally spaced spots in that field each one would be about 230 ft apart. The composite sample is assumed to provide a good estimate of the soil nutrient status. However, it provides no information about the variability that may exist within the 20-acre field. Even though yields may vary over distances of tens or hundreds of feet and even though application of fertilizer might be varied accordingly, unless the soil sampling grid is sufficiently detailed, there will be no soil test information available upon which to base variable rate application. Thus a more detailed soil sampling is required for precision farming and that requires extra work, time, and money. A viable and economic soil sampling scheme should be formulated on need basis for an individual farm.

A lower yield within a field may not be due to a lower nutrient level compared to other parts of the field that have higher yield. It may be due to other soil characteristics. If soil test results indicate adequate levels of nutrients, then one should go back to

the same spots and examine the soil for compaction and other physical characteristics, especially those that affect water storage or drainage.

Another major factor to consider is how often soil sampling should be repeated. How long can the effect of any corrective action last? Is it necessary to go back to the area and collect samples and test again in a year or two?

We recommend that soil samples be collected each year for conventional practices. To what extent should sampling frequency be changed to provide a basis for variable rate application of fertilizer and lime? Variable rate application of fertilizer and lime has the potential to increase nutrient level variability in the soil if the soil sampling grid, the basis for spatial variation of application rate, is not sufficiently detailed. Whenever application is varied without testing the soil, there is the risk that nutrient level variability is being affected, and the longer the time interval between soil sampling, the greater the risk. So, with regard to the question, "How often should soil fertility maps be reverified?," the answer may be as frequently as fertilizer applications are to be varied.

The new technology will not reduce the burden of intensive sampling. It will increase soil testing costs. If soil tests do not identify problems related to fertility, then the farmer or adviser will need to seek other explanations for yield variation. This will involve further examination for other contributing factors and perhaps additional and deeper soil sampling. Time and cost/benefit should be the limiting factors. Farmer acceptance of added costs and labor demands for intensive sampling will be based on the potential return.

Several people have posted their thoughts on the Internet about precision agriculture. Nyle C. Wollenhaupt, a soil scientist with Soil Teq, Inc., Minnesota, noted that if the base soil sampling data on which decisions are made is inaccurate, a farmer may actually end up losing income rather than generating income by intensive soil sampling on a grid. Areas that have a potential to respond to addition of fertilizer should be documented by increased sampling density in these areas. Fertilizer additions without yield response predictions may prove uneconomical.

Don Bullock, University of Illinois, in his web page on the Internet, suggests that dealers practicing precision application should consider providing statistical analysis for their soil tests and other data. Attractive maps can be created, but they are valuable only to the extent that data points used to create the maps represent accurate measurement of variation across the field.

A new version of combines that can also take soil samples without human labor is being developed. In combination with the GPS guidance system, soil samples can be obtained during harvesting, especially in the areas where yield variations are recorded. In that case, the timing of soil sampling should coincide with the harvesting. However, cost for testing such samples will increase in proportion to the number of samples analyzed.

VARIABLE-RATE APPLICATORS DETERMINE THE SUCCESS OF SITE-SPECIFIC/PRECISION FARMING PHILOSOPHY

Once nutrient and weed maps have been developed using the data from soil tests and scouting, fertilizers and herbicides need to be applied at variable rates. This should reduce excess applications to some areas and increase inputs to other areas according to yield expectation or potential. Current studies do not reveal reductions in the quantities of fertilizers consumed due to this variable-rate application. Rather, the same amounts of inputs are simply redistributed across a field.

A variable-rate applicator is needed for precision farming. Presently the estimated price for a multi-nutrient/herbicide variable-rate applicator ranges from \$250,000 to \$300,000. It is believed that there are less than 25 such applicators in use in the South. Several agricultural engineers have estimated that for approximately \$25,000, conventional spinner spreaders can be equipped with a variable-rate controller and also a GPS guidance system. However, this would only provide for a single input. Single-nutrient applicators would require multiple trips for each different material. So availability of the multi-input, multi-rate variable applicators holds the key for the success of this technology.

Another factor to be considered is the narrow window of planting time available for fertilizer and preplant herbicide spreading prior to planting. Since a dealer is unlikely to invest in more than one applicator given the high cost of investment, logistically there may be problems reaching all farmers in a geographical area in a timely manner because of the narrow windows of opportunity prior to planting. For example, starting fertilizer and herbicide applications a month before planting is likely to be unrealistic and unacceptable.

Such practical problems limit experience with precision farming. In turn, manufacturing companies lack the driving force for accelerating research and development created by consumer demand. Several smaller dealerships are closely watching the improvements being made and are very cautious about making large-scale investments. It is estimated that it may be at least two years before low-priced alternatives enter the market.

WHAT THE FUTURE HOLDS??

One study from southeast Missouri by Buchholz and Wollenhaupt, showed that varying fertilizer applications in an 80-acre field based on grid sampling technique, increased gross returns by \$7000. An investment of \$1000 in soil sampling and additional fertilizer increased yields from 90-100 bu/A to 136 bu/A. Cost for soil sampling, mapping, and variable rate application over and above uniform farming methods was about \$12.50 per acre. It should be realized however that every one should not expect similar returns. It depends mainly on what type of fertility levels a particular soil has to begin with.

How often this additional investment needs to be made remains to be seen. It is necessary to develop reliable soil sampling strategies that are based on an optimum number for soil samples. In South Carolina, Woody Green and Will Mims of Green Farms, Sumter County, have equipped their combine with a yield monitor. With the help of a software package,

they were able to create a colorful yield map of their field. Some areas on his field have been intensively sampled. However, no clear relationships could be established between yield and fertility variations. Although no cost analysis has been made, Woody realizes that this technology may not be economical for small farms. He feels that the technology, when fully developed, will prove useful for their farming operation. Woody is looking forward to having a combine that can also automatically take soil samples since he thinks that grid sampling is really time-consuming and labor-intensive. He also believes that there may not be enough time prior to and during the planting periods for rigorous soil sampling.

Farmers in South Carolina are cautious, as they should be. The farming community is suddenly faced with this amazing technology and adoption is uncertain at this time. Although the technology is being promoted by many, how widely it will be used and how soon will depend on how quickly costs and benefits can be documented for South Carolina. The information generated can be overwhelming if not organized and properly interpreted. Optimum sampling density to provide enough resolution on the yield maps dictates the success.

Precision farming technology at this time is still in the experimental stage. Improvements in software mapping packages, yield monitoring devices to suit all crops, and reception of satellite signals are needed. However, many opportunities for field scale research exist for relating soil variability to yield levels. Most of the studies conducted until this time have been directed at individual components of this technology like either grid sampling or yield monitoring. A field research study that encompasses all the components of site-specific farming has to be designed and conducted to see the benefits of this technology in totality.

by Rao S. Mylavarapu, Department of Agronomy and Soils, Clemson University