Paper No. 1328

GIS in Nutrient Management--A 21st Century Paradigm Shift

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ABSTRACT

Initial ideas on using spatial information to manage crop nutrients focused on using yield maps and soil test maps to determine where fertilizer applications could be increased or decreased to correct deficiencies, save input costs, and make fields more uniform. Experience shows that this view is too simplistic, and in fact does not work. Many other factors are involved. Proper nutrient management means managing the different areas differently to optimize yield and profits. This revelation means GIS is even more important as a nutrient management tool for modern farmers. New technologies are being implemented to manage the variability in fields rather than remove it. Sensors, controllers, and a variety of GIS databases are becoming key components of nutrient management. This presentation reviews the tools and data bases and how they are being integrated into 21st century crop and soil nutrient management planning systems. ArcGIS and ArcPad make it work.

PAPER BODY

Spatial information is gaining importance as a management tool for crop and soil management, but as with most technological innovations, it has evolved considerably as its use has become more common. While most farmers have used some components of site-specific management technology, the majority have not yet implemented a GIS system on their farms. So we can anticipate that there will be considerable evolution yet to come as GIS becomes a standard component of the 21st century agricultural toolbox.

Initial applications were focused on using a GIS-based record system to map the spatial variability in soil test nutrient levels within individual fields. These data sets and maps were used to apply variable-rates of nutrients within the field, with the idea that variability could be removed and the fields would become more uniform in nutrient content, and thus support more uniform yield levels. As yield monitors for most major crops became available, this provided another tool to assess within-field variability. Since yields vary in a response to nutrient supply, another simplistic idea was that by measuring yield variability, farmers and their advisers could estimate nutrient needs on the basis of yield maps and adjust fertilizer applications accordingly.

While these ideas are conceptually true, they grossly oversimplify the real-world situation. Yield, in fact, integrates a wide range of factors related to natural soil variability, and man-made variability from nutrient applications, past and current management practices, and a variety of weather-related impacts. So experience has resulted in a paradigm shift in the goals of precision farming, so that emphasis is more on managing variability in the field rather than attempting to eliminate variability. Areas of higher productivity can be managed to better develop their potential and areas of lower productivity can either be improved or removed from the production system as economics dictate. Either way, GIS and other precision technology tools provide an opportunity to improve the profitability of the farm operation, and help to ensure that inputs are applied in the right amounts in the right places and for the right reasons.

Figure 1 shows a map of actual phosphorus (P) soil test variability in an Illinois field, with results of different soil sample grids imposed to characterize the field's P levels. The lower part of the figure shows the percentage of the field needing P fertilizer that would be missed with the respective sampling pattern. It illustrates that even a course grid sampling pattern identified more nutrient needs (9% missed) than were corrected with a field-average fertilizer recommendation (38% needed application, but none was recommended). Site-specific management, using GIS, helped improve the productivity of the field.

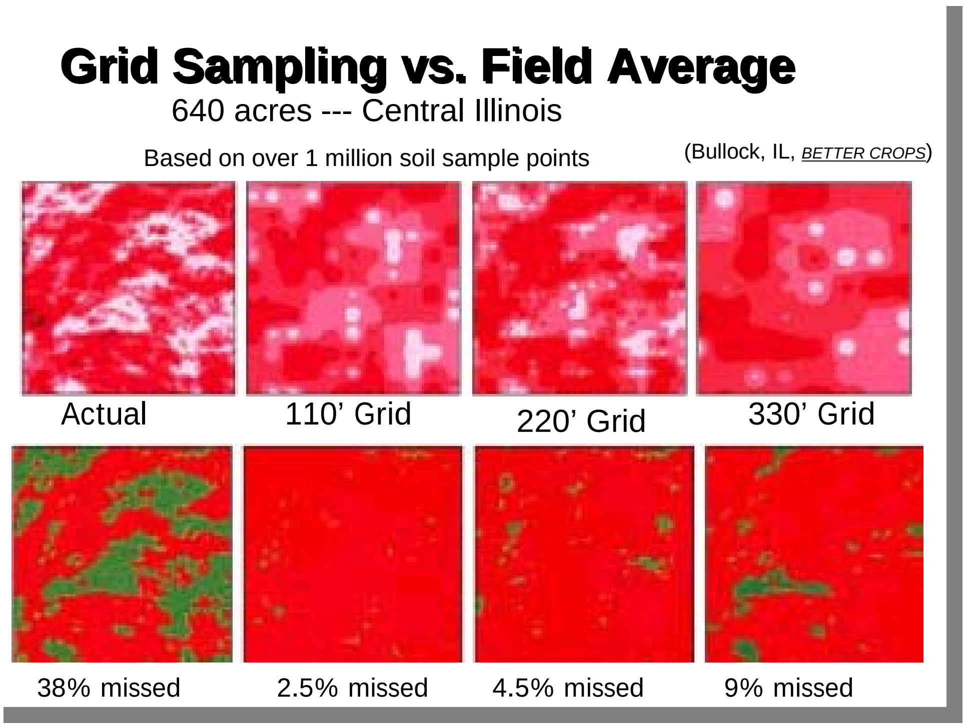

Figure 1. Advantage of grid sampling and GIS-based nutrient management in identifying phosphorus needs in an Illinois field. (Simulation based on real sampling data from a sub-sampled area of the field).

Most fields are still managed with a uniform management plan, using a constant rate of seed, fertilizer, and other inputs. Decisions on rates are based upon the average needs of the field, average soil tests, and average previous and anticipated yields. This approach has been successful and requires the least effort in record keeping and decision-making. New technology in controllers and application equipment, along with GIS tools, provides opportunities to fine-tune management on a site-specific basis to address within-field variability and even adjust yield goals within the field if appropriate.

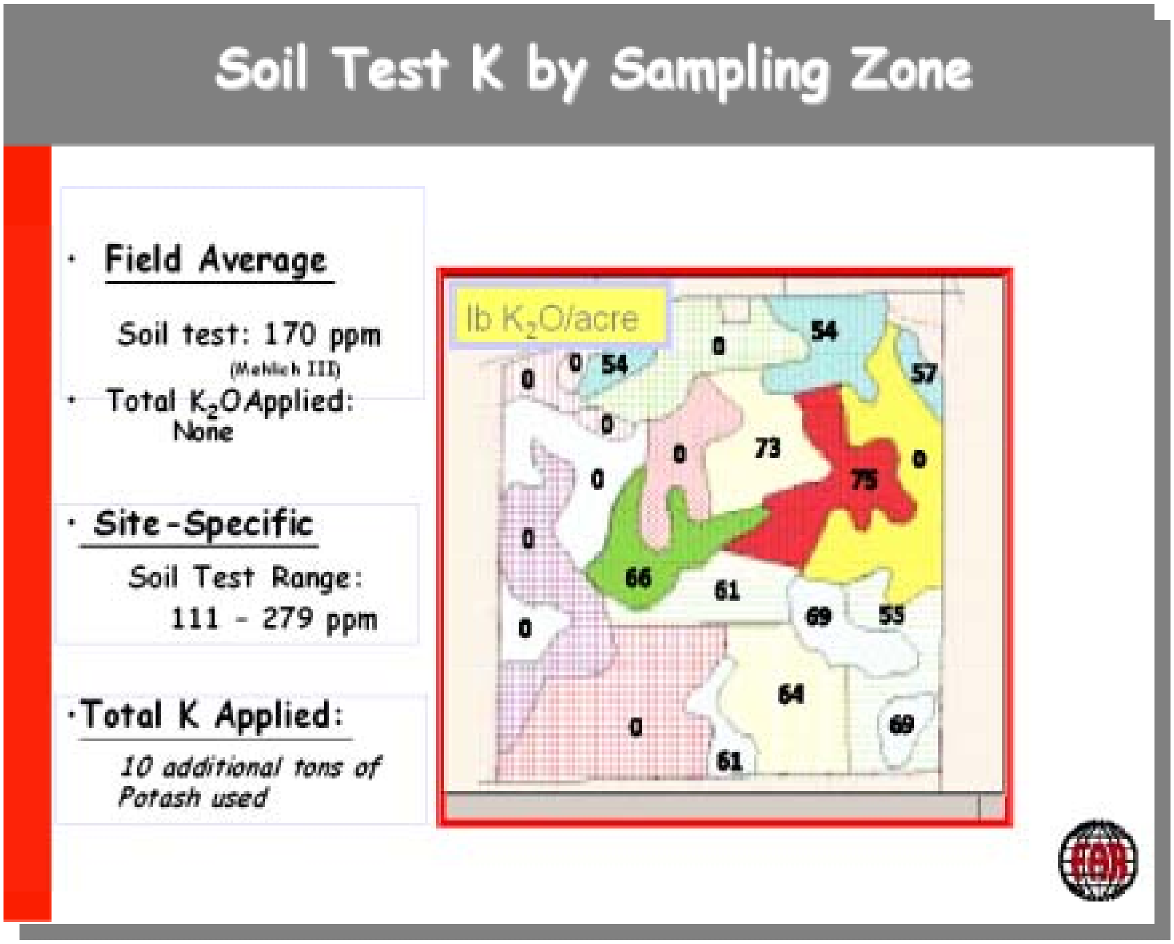

Figure 2. Impact of site-specific nutrient management on an Indiana corn field.

Figure 2. shows how site-specific potassium (K) management led to identification of significant areas of an Indiana field that needed K fertilizer, even though the average soil test for the field indicated none was needed. A total of 10 tons of potash fertilizer was needed to correct the deficient areas. This represents an additional market for the fertilizer dealer and additional productivity for the farmer, who gained 30 bushels per acre from using GIS and site-specific K recommendations.

Variability within fields often cannot be removed, but rather should be managed to optimize productivity. That may be a change from the early thoughts about the goal of precision farming, but it makes GIS an even more important data management and interpretation tool. A good GIS data base will become increasingly important as farmers work to sharpen their management decision skills and focus on the details of using site-specific information to fine-tune production practices.

In many cases, there is very poor correlation between soil test levels and yield levels. There are good reasons for this:

1. Fields managed with uniform nutrient applications, based on field average soil tests and yields, will show a buildup of nutrients in the lower-yielding areas (crop removal is less than nutrient application rates) and a depletion of nutrients in the higher yielding areas (crop removal exceeds nutrient application). So the poorer-yielding areas of the field will often have the highest soil tests.
2. Yield is very dependent on seasonal weather. Areas of a field with poor drainage, for example, will have low yields in a wet season, but may have high yields in a dry season. So basing nutrient applications on one or two years of yield data will lead to the wrong decisions.
3. In a corn-soybean rotation cropping system, it takes six years of yield data to get three years of data for each crop. Even the early adopters of yield monitors are just reaching the point of having such a data base available.

Proper nutrient management systems include intensive soil sampling to assess variability of nutrients across the field. GIS provides the opportunity to catalog the data and map the variability of different nutrients, and to do various types of queries and analyses. For example, using GIS to compare soil samples from successive years can help monitor rates and magnitude of change. Comparing these changes to fertilizer applications and crop removal helps farmers and their advisers evaluate their nutrient management program on a site-specific basis. Over a period of years, this on-farm, intensive data base can be used to develop calibration curves for various nutrients. These local data sets may be used in place of the standard university response curves that are designed for general situations, but cannot account as well for local conditions.

Economic analysis can be applied on a spatial basis with such data sets to help further evaluate the nutrient management program. By targeting nutrient applications to where the needs are greatest and not applying nutrients where soil tests indicate supplies are adequate, farmers can more efficiently use their input dollars. Such site-specific management avoids over-application of nutrients, saving money on inputs, but also avoids under-application, which can reduce yield potential. Such fine-tuning of nutrient use is not only more economical, but also helps avoid potential environmental problems.

New sensors are being evaluated to help measure nutrient variability in the field with. Purdue University researchers helped develop a pH sensor that is now available commercially to monitor soil pH on-the-go, allowing for a more intensive, spatial data set upon which lime recommendations can be made. They are also experimenting with a similar system for on-the-go potassium measurement. Oklahoma State University researchers have developed a commercially available sensor that estimates nitrogen status of crops using foliar reflectance monitors that guide real-time adjustment of N fertilizer as the unit moves across the field.

New sensors, monitors, and wireless communication systems are leading to revolutionary applications of these technologies in various field applications. GIS is an important part of the database development and management that makes use of these tools for site-specific management of nutrients more practical and economical.

Remote sensing adds another source of spatial information. Imagery captured by satellite or aerial remote sensing scanners can be geo-referenced and included in the GIS database for each field. The data layers associated with different wavelengths of reflected energy can then be associated with other data layers of information and manipulated and analyzed with GIS tools to determine relationships of interest and importance to crop and soil management. Nutrient stress, pest pressures, and weather effects are among the factors that can be included.

Models to simulate crop growth, nutrient use, pest development, etc., can incorporate data from remote sensing and relate it to other data layers. These models are used to simulate crop development and predict effects of different variables on productivity. Such applications are in early stages of development, but promise to add whole new dimensions to simulation by allowing models previously limited to point data to be applied on a spatial basis to be implemented on a spatial basis to predict variability within the field. Application of economics to GIS datasets and models can then predict field variability in costs, income, and profitability. This is an important step in putting agronomic information into terms that are better visualized and understood by landowners and other stakeholders not directly involved in the production enterprise. A map of variability in economics within the field becomes a critical communication and decision tool for the farmer.

A further step in 21st-century crop and soil nutrient management is the use of handheld computers with ArcPAD to carry the databases and decision tools to the field for scouting, linking to on-board electronics on tractors and combines, and even communication of the data or analytical results to other stakeholders in the operation, such as the landowner, input supplier, or farm manager. GIS and the tools to utilize the data in real-time decisions in the field are opening new opportunities for farmers to improve their management and their profitability.

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