by Dr. James S. Schepers

Precision Farming: One Key To Quality Water

Author discusses the elements of site-specific management that ensure maximum nutrient-use efficiency and environmental stewardship.

The influence of soil fertility management on water quality is a legitimate concern because nutrients intended for crop use are either soluble in water and therefore subject to leaching, or are in equilibrium with the soil-water complex and can be carried off the land in runoff. In either case, water is the medium for movement. That is why water quality management must be considered any time crop nutrient availability and efficiency are discussed.

Pesky N

Because of the different forms and properties of crop nutrients, each has unique set of management considerations.

Of the three crop nutrients (N, P, and K), N is the most evasive and difficult to manage. This is because it exists in both organic and inorganic forms. Conversion between these forms typically involves biological systems either in the soil as microorganisms, or above the ground as part of plant growth. This situation begins to explain why N management is so incredibly complex. The process is further complicated because inorganic N exists as nitrate (NO_3^-) in one extreme and ammonium (NH_4^+)in the other, with several intermediate forms. In the NO_3^- form (anion), N is soluble in water and moves with water as it percolates through the root zone or flows along the soil surface in runoff. As NH_4^+ (cation), N is attracted to soil particles and organic matter, which are essentially anions. The exception is volcanic derived soils. Therefore, most NH_4^+ in runoff is transported with soil particles in runoff.

When combined with organic N sources, particle-borne N amounts to 80 to 90 percent of the total N load in agricultural runoff. Similarly, particle-bound P amounts to the same portion of total P in runoff water. Sediment-bound forms of N and P are in equilibrium with soluble forms of both nutrients. The soluble forms of N and P serve as the sources of nutrients for aquatic plants in eutrophic ponds, lakes, streams, and wetlands.

Trading off

Soluble forms of P are not considered a health hazard, except that even at low concentrations (<1 ppm) they promote eutrophication. In contrast, NO_3^- is considered a health hazard at concentrations above 10 ppm NO_3^--N. The concern over high NO_3^- water (>10 ppm) is somewhat misdirected because humans and livestock also ingest NO_3^- from sources other than drinking water. For example, many vegetables contain relatively high levels of nitrate that add to the total load of ingested NO_3^-. To put this concern in perspective, a two-ounce serving of fresh beets contains about 38 mg NO_3^--N. A person would have to drink over four quarts of water containing 10 ppm NO_3^--N to get an equal dose of NO_3^-. It seems that emotion frequently dominates when making such comparisons. People don't mind taking a risk if it is their choice (smoking, drinking, etc.). Problems arise when alternatives are beyond our control or we perceive that someone else has imposed a situation upon us without our consent. We may choose not to eat beets, but in the U.S. we feel it is our right to have a supply of safe drinking water while having at the same time no regard for what it takes to produce an abundant and pleasing supply of food.

If the truth was known about how inefficient N fertilizer is when used in the production of fruits and vegetables compared to grain crops, it might change our eating habits. The net effect might be the consumption of more legumes that grow quite well without N fertilizer. Problem is, humans don't get much enjoyment out of eating alfalfa or clover until it first has been fed to livestock or poultry. All too often, consumers don't associate the cost of manure handling and efficient use of nutrients with the cost of food and environmental steward-ship. While society should not downplay the importance of maintaining an adequate supply of drinking water with <10 ppm NO_3^--N, there are other forms of contamination that contribute to the problem we call "blue baby syndrome" (methemoglobinemia). Medical reports that document methemoglobinemia from drinking water also show that in a majority of the cases there was excessive bacterial contamination.

Because of consumer demand for high quality food, producers are more inclined to follow a strategy of “better safe than sorry” rather than “better never late” or “better late than never” when it comes to nutrient management. The problem of N nutrition is confounded because the impact of organic matter mineralization on NO; is difficult to predict. Considering the uncertainties with nutrient control of animal wastes, uniformity of manure application rates, mineralization of manure, and climate, it is no wonder producers migrate toward a “better safe than sorry” strategy for N management.

Carrying the fight

One mighty tool helping producers to address water quality issues is an unfolding new technology known as precision farming or site-specific management. This rapidly spreading concept recognizes the existence of spatial variability in fields and offers a variety of farm management tools. In essence, it is little more than a strategy to compensate for natural and man-made variability in fields by altering those factors we think influence yield, profitability, environmental quality, etc.

Tools that make site-specific management possible are many and varied. Two basic approaches that have evolved for corn production are: 1) harvesting with a yield monitoring combine, and 2) grid sampling and variable rate fertilizer application.

Yield monitoring. This approach is more conservative in that it first assesses spatial variability in crop growth and yield, which has a major impact on profitability. Unfortunately, a yield map alone does little to explain the causes of yield variability in a field. The reality of examining a yield map for the first time can be rather emotional because variability translates into everything from embarrassment (because it implies poor management) to irritation over reduced profits. After the initial shock of seeing a yield map (assuming yield variability is obvious), producers can frequently account for variability in terms of soil features, cropping history, or cultural practices. Many times, producers have difficulty grasping the magnitude of yield map variability.

Grid sampling. Spatial variability in yield is good justification for considering grid sampling and variable rate nutrient application. Here producers assume soil fertility is a major source of spatial variability in crop growth and yield. The perception is that variable rate fertilizer application must be more environmentally sound than uniform rate. The goal is that fertilizer rates will be reduced enough to offset the extra cost of soil sampling, chemical analysis and variable rate fertilizer application, or that increased yields will cover these costs.

However, without a comparison or source of reference, it is hard to know if anything would be gained by the extra effort and cost involved in variable rate fertilizer application. That is why it is best accompanied by yield monitoring to evaluate how much of the variability was removed. Producers who have generated yield maps over several years frequently comment on the lack of similarities between maps. In essence, these maps express the net interaction between soil, climate, management, and crop growth. Considering that crop yield integrates these factors and others over an entire growing season, it would be unusual for yield maps to resemble one another. That is why a series of yield maps over three to five years is needed to make a comprehensive statement about the role of site-specific management on crop yield and environmental stewardship. This time can be reduced if some type of in-season assessment of crop growth is available to compare with a yield map.

A cheaper way

Remote sensing is another valuable environmental tool that holds promise in site-specific management. Early in a year, an aerial photograph of bare soil color (after planting) provides a good indication of relative soil organic matter content. With minimal computer hardware and software, such a photo-graph can be digitized and the colors grouped into categories. Reasonable calibration usually can be attained by sampling a range of five to six representative colors, analyzing the samples for organic matter content by using the digitized version or the original color map and the calibration data. Such a map can be used to predict relative N mineralization, or adjust herbicide application rates.

The cost of generating an organic matter map in this way is considerably less expensive and much more informative than using grid sampling. High-intensity grid sampling and chemical analysis are usually cost prohibitive. Decreasing the sampling frequency introduces considerable uncertainty unless soil type, topography, and landscape position are used to select the sampling sites. Only a few studies exist where sampling intensity was great enough to evaluate the effect of sample spacing. In a study from a center-pivot irrigated corn field (160 acres) in the Platte River Valley of central Nebraska, an organic map (>2000 samples) generated by sampling on an alternate 40- by 80-foot grid (0.073 acre) closely resembled the photograph of bare soil color.

Systematically removing v sampling points from data in the above example resulted in a series of organic matter maps representing progressively coarser grids. Comparison of these maps showed distinctly different patterns as grid spacing increased, raising concern about the common grid sampling strategy that uses a 450-foot grid. Intensive grid sampling such a field for available P resulted in a map that resembled both the bare soil color photograph and organic matter map, with an exception of high values in the area of an old farmstead and associated livestock operation. Based on its average Bray P concentration of 13 ppm, this field would be expected to show a slight to moderate P response. The grid map showed that 74 percent of the field should respond to P. Consultants typically use a higher critical level because they recognize the likelihood of spatial variability in fields and the need to meet plant nutrient needs. Fertilizer recommendations generated from such plot data do not incorporate a scaling factor that includes the reality of spatial variability. A critical level of 24 ppm in the above scenario indicated 87 percent of the field would be expected to respond to P. Systematically removing data points to increase grid size generated a sequence of P maps that showed a number of inaccuracies when using a 240-foot grid.

These examples suggest that aerial photography of bare soil can be a useful tool to help make more intelligent soil sampling decisions that are environmentally friendly. Photographs taken during the growing season can be a powerful tool to identify spatial variability in crop growth.

Looking ahead

Ultimately, on-the-go crop sensors under development for high-clearance vehicles or mobile irrigation systems may be able to detect certain crop stresses and permit real-time correction measures. This could be accomplished without aid of GPS technology and perhaps remove a level of intimidation associated with some aspects of precision management.

Equally viable may be the use of aircraft or satellite images to identify problem areas in fields and use of available technology to control ON-OFF or variable rate applications of nutrients, pesticides, etc.

While the concept of site-specific management offers many possibilities, time will tell if the intuitive benefits of variable rate application technology and site-specific management translate into environmental stewardship and producer profitability.

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