Phosphorus and the Environment

Phosphorus is an extremely immobile nutrient in the soil. It is adsorbed very strongly to soil particle surfaces and quickly forms stable compounds by reacting with common soil constituents such as iron (Fe), aluminum (Al) and calcium (Ca). For this very reason, P is commonly a limiting nutrient for plant growth, and P inputs are needed for crop production.

Phosphorus (P) is essential for all life. Without adequate levels, profitable agriculture would be impossible and food production inadequate. The loss of P to surface water is an environmental risk that can be controlled with attention to erosion and runoff factors influencing P transport and appropriate management of P sources.

Its tendency to remain undissolved is also the reason why P is often the limiting nutrient in surface waters for the growth of aquatic plants and algae. When P losses increase, enrichment or eutrophication to the point of undesirable blooms of algae can occur in some situations.

Eutrophic conditions can occur in surface waters when P concentrations exceed 0.01 to 0.03 parts per million (ppm). However, most crop plants need to have P concentrations roughly 10-fold greater in the soil solution in the rooting zone throughout the growing season. Although it would appear there is a direct conflict between levels of P desired for agronomic and environmental concerns, the conflict is not nearly so fundamental. In aquatic systems, just as in soil, P tends to form stable compounds, precipitate, and settle out.

One well-known example is Lake Erie. Programs implemented in the last 25 years to reduce P loadings to the lake from industrial, municipal, and agricultural sources have resulted in reduced lakewater P concentrations. In the lake's central basin, P concentrations have declined from as high as 0.025 ppm in the early 1970s to less than 0.010 ppm in the 1990s. In fact, P loadings have declined to the point where fisheries agencies have called for a halt to further reductions. There is concern that additional reductions in P inputs would cause serious harm to the lake's most important fish species, such as yellow perch, rainbow smelt, and walleye.

The main pathway of P loss to surface water is in runoff water. Runoff can carry suspended particles of soil, which carry the bulk of P lost from agricultural fields. In addition, runoff carries some dissolved P. Drainage water, particularly from tile drains, can also carry small amounts of both forms of P. The relative amounts lost in each pathway depend on the crop, soil management, and the level and source of nutrient loading. The pathways other than erosion generally become important only for soils with excessive loadings from organic sources of P.

Tillage management to reduce erosion and runoff also reduces P losses. When one of

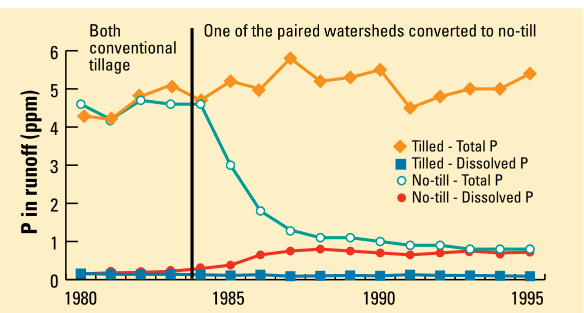

Figure 1. No-till management, starting in 1984, reduced the concentration of total P in runoff in an Oklahoma watershed.

a pair of watersheds in a wheat growing area of Oklahoma was converted to no-till management, it reduced the concentration of total P much more than it increased dissolved P concentrations (**Figure 1**). In addition, runoff volume and erosion were reduced by 95 percent with no-till, so no-till management dramatically reduced the total loss of P.

An estimated 50 percent of total soil loss due to erosion in recent years in the U.S. occurred on 10 percent of the nation's cropland. This suggests big gains could be made by controlling erosion on these very erodible acres.

TABLE 1. Percentage of soils testing medium or less for P.

State	Percent medium or less for P 1975	1986	1997
Manure-surplus states			
North Carolina	37	37	26
Delaware	37	39	26
Maryland	54	43	33
Crop-surplus states			
Illinois	48	44	36
Ohio	45	38	49
South Dakota	59	76	71
North American average	**60**	**53**	**46**

Soil Test Phosphorus Status

Where localized surpluses of animal manure are applied to cropland, soil test P levels tend to build up. On the other hand, nutrient exports from states producing surpluses of crops can lead to declining soil test levels if not balanced by adequate fertilization. The percentage of soils testing medium or less for P is declining where manure is in surplus, but usually holding steady or increasing where the major crops are grown, as shown for selected states in **Table 1**. Regions with a small percentage of soils medium or less in P are not necessarily a greater risk to the environment, as the critical level used here is for agronomic rather than environmental purposes, and important soil hydrological factors are not considered.

While some soils have been built to high P levels, a very substantial number of soils still test in the medium or less range. Across North America in 1997, 46 percent of soils tested medium or less in P. With good crop production management, many of these soils would benefit from buildup applications of P, in addition to the annual maintenance rates, to help assure a profitable yield level and the most efficient use of nitrogen (N) and other inputs.

Nutrient Balance

The total amount of P applied in the U.S. as commercial fertilizer was 4.6 million tons in 1997. In comparison, estimates of the amount of P_2O_5 in recoverable manures range from 1.4 to 3.1 million tons. In the Corn Belt, the corn-soybean rotation is in deficit, removing more P in the crop than is applied in

TABLE 2. A modified Phosphorus Index, with suggested weighting factors. The transport factors are multiplied by the sum of the source factors to rate the site for potential risk of P loss. For example, a site with every characteristic at 'medium' would have a rating of (0.8 x 0.8 x 0.8 x 0.6) x (1.0 x 2 + 0.75 x 2 + 0.5 x 2 + 1.0 x 2 + 1.0 x 2) = 3.5.

Site characteristic	Weighting factor	Loss rating Zero	Low	Medium	High	Very high
Transport						
Soil erosion	1.0	0.6	0.7	0.8	0.9	1.0
Irrigation erosion	1.0	0.6	0.7	0.8	0.9	1.0
Soil runoff class	1.0	0.6	0.7	0.8	0.9	1.0
Distance from watercourse	1.0	0.2	0.4	0.6	0.8	1.0
Source						
Soil test P	1.0	0	1	2	4	8
Fertilizer rate	0.75	0	1	2	4	8
Fertilizer P placement	0.5	0	1	2	4	8
Organic P rate	1.0	0	1	2	4	8
Organic P placement	1.0	0	1	2	4	8

TABLE 3. Generalized interpretation of the Phosphorus Index.

Phosphorus Index	Generalized interpretation
less than 5	**LOW** potential for P loss. If current farming practices are maintained, there is a low probability of adverse impacts on surface waters.
5-8	**MEDIUM** potential for P loss. The chance for adverse impacts on surface waters exists, and some remediation should be taken to minimize the probability of P loss.
9-22	**HIGH** potential for P loss and adverse impacts on surface waters. Soil and water conservation measures and a P management plan are needed to minimize the probability of P loss.
more than 22	**VERY HIGH** potential for P loss and adverse impacts on surface waters. All necessary soil and water conservation measures and a P management plan must be implemented to minimize the P loss.

manure and fertilizers. However, in areas of the country with concentrated animal production, local P surpluses can be large.

The Phosphorus Index

Soil test levels are not adequate indicators of risk of P loss. An index must consider both source (soil test P and applied P) and transport factors. Erosion and runoff are the primary transport pathways. These depend on soil and landscape properties such as slope, soil cover, distance to watercourse, and infiltration properties. Placement of applied P is important, as these transport pathways are most active at the soil surface.

The Phosphorus Index is being developed as a screening tool to rank sites for potential loss of P. The site characteristics used in the index are shown in **Table 2**. Weighting of the factors and the method of calculating the index vary in different versions. **Table 3** shows how the index can be interpreted.

Several watershed studies have shown that 90 percent of the P lost to surface water arises from 10 percent or less of the land area. Such areas occur where both the source and transport factors are high. Use of the Phosphorus Index will allow greater flexibility in placement of manure and fertilizer to build soil fertility in areas where the benefit to crop production will be the greatest and the risk of harm to the environment will be at a minimum. Management efforts for high yield cropping systems, focused on areas unlikely to harm the environment, will produce more food on less land, relieving pressure to use marginal, erodible land for crops. BC

Phosphorus Fertilizer Placement... *(continued from page 36)*

and vegetable crops make P placement an important management practice.

- Where P fixation is an overriding factor, banding all the P is probably advisable. High P concentrations in bands help delay fixation reactions.
- High yielding row crops, especially corn, may require relatively high P levels throughout the rooting zone for maximum yields. On low to medium P soils, banding at least some of the P may provide a yield advantage.
- Where P use has been minimal in the past and resources are limited, banding moderate amounts of P on more acres will likely optimize returns. BC