# Manure Phosphorus: Problems And Solutions

*It's important to understand that best management practices are only a temporary fix for the problem of too much phosphorus. More permanent solutions are needed.*

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According to a recent survey by the EPA, accelerated eutrophication is the main cause of water quality impairment in the USA (U.S. EPA, 1996). Eutrophications is the natural aging of lakes or streams brought on by nutrient enrichment. This process is accelerated by human activities which increase nutrient loading rates to water. While phosphorus (P) and nitrogen (N) contribute to eutrophication, P is the primary agent in freshwater eutrophication.

Eutrophication restricts water use for fisheries, recreation, industry and drinking, due to the increased growth of undesirable algae and aquatic weeds and oxygen shortages caused by their death and decomposition. Also, an increasing number of water resources are experiencing periodic algal blooms. These blooms contribute to a wide range of water-related problems including summer fish kills, unpalatability of drinking water and formation of carcinogens during drinking water chlorination (Sharpley and Sheffield, 2000).

Lakes are more sensitive to P than streams and rivers. In a 1993 survey of major lakes in Georgia conducted by the Department of Natural Resources, five lakes were considered to be in a state of accelerated eutrophication (High Falls Lake, Lake Walter F. George, Lake Blackshear, Lake Oconee and Lake Tobesofkee, DNR, 1995). The Department of Natural Resources has set limitations for three lakes in Georgia on the amount of P that can enter from tributaries. These are Lake Jackson, West Point Lake and Lake Walter F. George. Phosphorus limitations for Lake Allatoona and Lake Lanier have been proposed.

The sources of P entering streams, rivers and lakes in Georgia include sewage treatment plants and factories that discharge into streams, runoff from lawns with failing septic systems or fertilizer, runoff from agricultural land with manure or fertilizer and natural background sources such as rock minerals and wildlife. Ground water is not affected by P because of the absence of algae. Only when ground water returns quickly to a stream, river, or lake, do we need to worry about P leaching to ground water.

## When Phosphorus Is Added To Soils

Phosphorus is added to agricultural land as fertilizer or manure because it supplies an important element needed for plant growth. Phosphorus in soils exists in a number of mineral and organic forms, but most of it is adsorbed to iron and aluminum oxides in soils of the southeastern USA. These oxides have a large, but not unlimited, number of adsorption sites for P, and when the adsorption sites start to fill up, there is more and more P dissolved in the soil water. It is mainly this dissolved P that is available to plants and as we shall see, susceptible to runoff.

In most soils, the P content of the topsoil is much greater than the subsoil. As manure and fertilizers are added to soil, the levels at the surface increase sharply, but there is little effect in the subsoil in most cases. This is because most of the P is tightly adsorbed and doesn't move very far (in very sandy soils, which are low in iron and aluminum oxides, P can move into the subsoil).

In recent years, we have learned that the concentration of P in runoff from agricultural fields increases as the soil P level goes up. Part of the reason for this can be soil erosion where soil particles with high concentrations of adsorbed P are being washed off the field. But even in grass fields, where there is almost no erosion, research has shown that dissolved P concentrations in runoff increase with soil P (Fig. 1). When rain occurs, there is

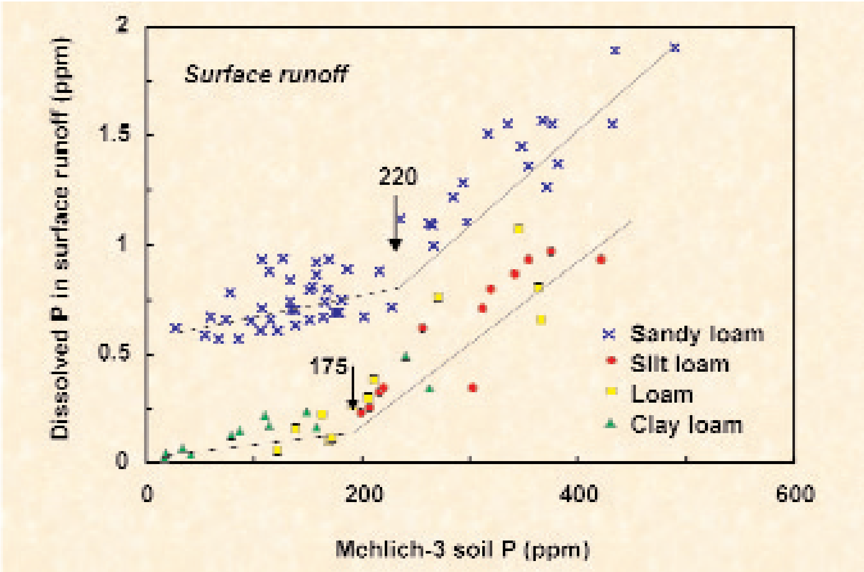


**Figure 1.** Dissolved phosphorus in runoff as a function of soil test phosphorus in four soils (adapted from Sharpley and Sheffield, 2000).

a thin layer of water near the surface that mixes with the soil water and can run off. If the concentration of P in the soil water is high (because most of the adsorption sites near the surface are filled with P), then the concentration in the runoff water will also be high. In Fig. 1, P concentrations in runoff increase more sharply beyond a certain level of soil P. This probably represents the level where most of the adsorption sites near the soil surface are filled.

There is no clear answer to what is an unacceptable concentration for P in runoff. The concentration of total P that is thought to trigger eutrophication in lakes is only 0.05 parts per million (ppm). In Fig. 1, even the lowest levels of soil P produce concentrations in this range. Most soil scientists agree that a realistic target is to try to keep agricultural runoff P concentrations below 1.0 ppm.

## Manures: Special Problem For Phosphorus

For the most part, soil phosphorus levels at the surface high enough to cause runoff concentrations in excess of 1.0 ppm are unlikely to occur unless manures are being used. Even though farmers have been encouraged to build soil P levels in the past, the cost of fertilizers discourages over-application of P in most cases. Manures present a special problem because the N-to-P ratio in manure is fixed (unlike fertilizers where different formulations of N, P and K are available) and not the same as what most crops need.

> *For every 8 pounds of broiler litter nitrogen applied, one applies 6.7 pounds of phosphorus (8 divided by 1.2), or 6.7 times as much as the crop needs.*

Most crops use about 8 pounds of N for every pound of P, or a ratio of 8-to-1. But manures usually have a much lower ratio. For example, a typical sample of broiler litter would have 71 pounds of total N and 30 pounds of total P per ton a litter, a ratio of 2.4-to-1 (Barker *et al.*, 1994). Since only about half of the manure N is usually available to plants (due to losses and limited organic N decomposition), the effective ratio is 1.2-1. Manure application rates are currently determined on the basis of the N requirements of the crop. This means for every 8 pounds of broiler litter N applied, one applies 6.7 pounds of P (8 divided by 1.2), or 6.7 times as much as the crop needs. As a result, excess P builds up at the soil surface in fields that receive repeated manure applications.

## Short-Term Solutions

There are a number of best management practices (BMPs) that can be adopted to reduce phosphorus losses to surface waters. The most obvious BMP is to base manure application rates on the crop's need for P rather than N. For example, using the average values given above for broiler litter, when we change from applying 6.7 times as much P as the crop needs to applying just the amount needed, we must reduce manure applications rates to 15 percent (1.0÷6.7=0.15) of the current, N-based rate. This means that additional land must be found for manure application or livestock numbers must be reduced.

Other ways to reduce P losses are to alter the feed ration (the use of phytase enzyme and/or highly available P grain), adding alum to the litter to form an insoluble P compound and the use of grass filter strips and stream-side buffers.

However, it's important to understand these BMPs are only a temporary fix. One eventually runs out of extra land for applying excess P, buffers and filter strips can become saturated with P, and insoluble forms of P can be eroded in large storms.

## Long-Term Solution

The only long-term solution is to address the problem we have in the southeast of a regional imbalance of P. This problem has become more severe in recent years because of the way livestock production systems have evolved. Before World War II, livestock production was rather evenly spread out over the agricultural producing regions of the United States. Livestock and grain production occurred in the same region and manure was applied to fields that produced the grain that was fed to the livestock, often on the same farm. In this way, P was cycled from the manure back into the feed (Fig. 2). Today, fertilizer P is mined in Florida and shipped to the Midwest where most of the grain fed to livestock is produced. The grain is then shipped to centers of livestock production including the Southeast (Fig. 3). But the manure isn't shipped back to the Midwest! As a result, P levels continue to build in southeastern soils. One way to restore a regional balance of P would be to feed more locally grown grain and return the manure P to these fields. This would expand the acreage available for manure application in the Southeast and lessen the importation of P to the region.

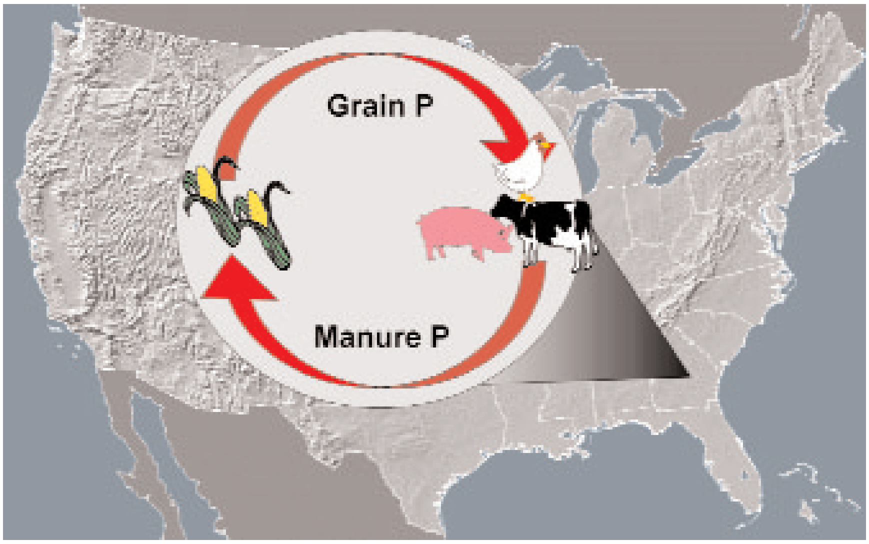


**Figure 2.** Before World War II, phosphorus livestock and grain production occurred in the same watersheds and phosphorus was cycled (Sharpley and Sheffield, 2000).

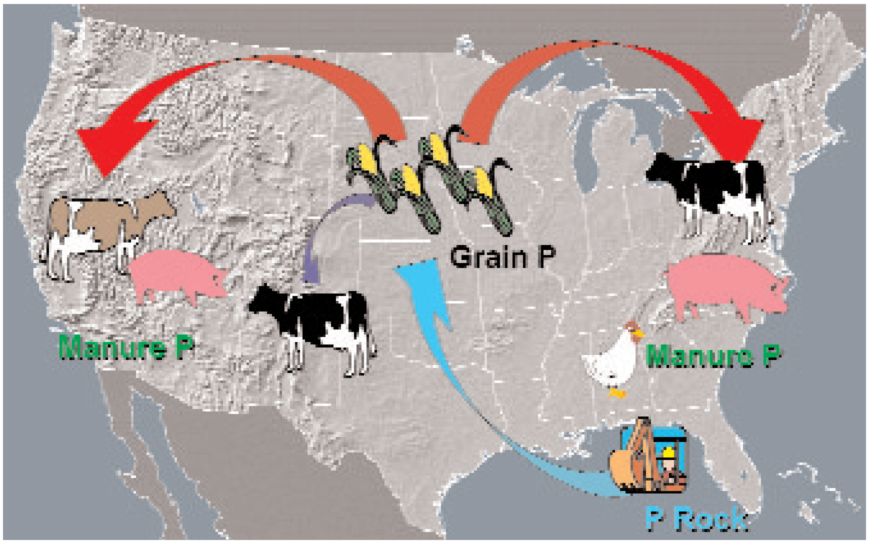


**Figure 3.** In recent years, the phosphorus cycle has been broken, with phosphorus moving from areas of grain production in the Midwest to areas of livestock production such as the Southeast (Sharpley and Sheffield, 2000).

## Locally Grown Grain In Poultry Rations

A typical poultry feed contains approximately 60 percent corn and 25 percent soybean meal. Georgia and other southeastern states have simply not been able to produce the amount of grain or soy needed by their poultry industries. In fact, less than 10 percent of the corn used in Georgia poultry feeds is actually produced in the state. It is estimated that approximately 135 million bushels of corn are imported into Georgia per year. In addition to energy and protein, this amount of corn contains over 10,000 tons of phosphorus. As most phosphorus in plant materials is indigestible, it can be calculated that nearly 8,000 tons of the phosphorus which enter the state per year in imported corn passes directly into the excreta of poultry and eventually is spread on the soil.

By increasing grain production in Georgia, the amount of imported phosphorus would, of course, be drastically reduced. Increased corn production is a possible means of addressing this question. Even more promising, however, is the development of pearl millet as a grain for poultry. Initial studies by poultry scientists at the University of Georgia have given very positive results. Broilers fed diets containing millet grow at least as well, and frequently better, than those receiving diets with corn as the only grain.

Each year more than 1.2 billion broilers are produced in the state of Georgia. While these are grown to different sizes according to market demands, a reasonable estimate is that each broiler consumes 10 pounds of feed during its life. Of this, about 6 pounds are corn. If we consider substituting millet for corn, the potential for reducing phosphorus entering Georgia is truly significant. Interestingly, because millet contains almost twice as much of protein as corn, the use of millet decreases not only the amount of corn brought into the state but also reduces the amount of imported soy. Soybean meal is the principal source of protein in poultry feeds. By using more high protein millet, substantially less soybean meal need be imported. As soy has approximately twice the amount of phosphorus as corn, with a similarly low digestibility, the use of millet will also prevent thousands of tons per year of phosphate in soy products from entering Georgia soils.

## Pearl Millet As A Local Grain

Pearl millet has been grown in the United States for over 75 years as a forage and cover crop. However, there are over

50 million acres grown in India and Africa for grain because of its drought tolerance, high quality grain and its ability to produce a grain crop under the most stressed growing conditions. Since the late 1980s, dwarf disease resistant pearl millet hybrids have been developed that are adapted to the humid Southeast and that are short enough to be combine harvested.

Some of the advantages of pearl millet as a new grain crop in the U.S. include:

- high grain yield under non-irrigated and drought conditions
- high grain protein/quality with feeding value equal to or exceeding corn
- insignificant preharvest aflatoxins and other mytotoxins
- tolerant of broad range of soil conditions (pH, texture, etc., except waterlogged soils)

***Feeding locally grown grain is one way to return to a regional phosphorus balance.***

- deep-rooted and can scavenge nitrogen and other nutrients leached to subsoil levels (largely due to tolerance to low soil pH)
- relatively low production costs
- well-suited for double cropping and rotations

New rust (a major problem on this crop late in the season) resistant hybrids that yield about 5,000 pounds of grain per acre have been developed that are in the final stages of evaluation. Commercial quantities of the hybrids should be available for planting in Georgia in 2003.

Pearl millet can fit well into cropping systems in Georgia, due to its long window for planting. Successful harvests have been obtained in research for planting dates from May to August using both conventional-(disk or moldboard plow) or strip-tillage. Therefore, it can be planted following harvest of any winter crop and possibly even following harvest of corn in south Georgia. It has low fertility requirements in relation to other grain crops and in particular in relation to corn. Research in Georgia has indicated grain yield and protein yield responses to N fertilizers from 0 to 100 pound/acre, depending on previous crop species and fertilization (Gascho, *et al.*, 1995; Menezes, *et al.*, 1999). In addition, residual soil N can be taken up from depths as great as 90 inches (Menezes, *et al.*, 1997). Since the N requirements for pearl millet are relatively low, pearl millet should be part of a crop rotation system that includes crops with a high demand for N so that litter application rates can be maximized.

## Addressing Regional Imbalance

The primary water quality concern with phosphorus is that it can cause eutrophication of lakes, and several large lakes in Georgia already show signs of eutrophication. Manures present a special problem because the N-to-P ratio in manure is not the same as what most crops need. As a result, P is over-applied when a N-based NMP is used. There are a number of best management practices that limit the short-term losses of P, but the only long-term solution is to address the regional imbalance of P in the Southeast caused by importing grain from the Midwest. Using locally fed grain is one way to return to a regional P balance. Research is showing that pearl millet has exciting potential as a new grain crop for Georgia and the Southeast. However, much information is still needed on cropping systems, planting dates, fertility requirements following various crops, poultry nutrition and economics.—*References available upon request from the authors.*

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