Management Options for Farms with High Soil Test Phosphorus Levels

Introduction

Agricultural nutrient management is a concern of many people, including crop consultants, regulators, farmers, environmentalists, and the general public. The nutrient phosphorus (P) receives the attention of these people because crops depend on it and animals need it; but when it leaves a farm in runoff, P can degrade the quality of lakes and streams. Specifically, P additions into freshwater lakes and streams can stimulate the excessive growth of algae and aquatic weeds. A potential consequence of this stimulated growth can be odors, fish kills, and an overall reduction in the recreational value of lakes.

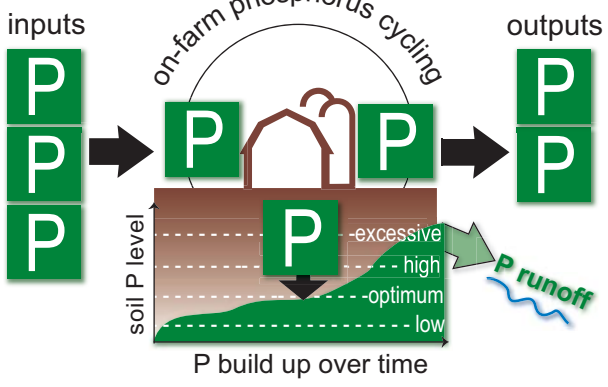
The potential for P losses from farms increases if the soil P levels of fields are excessively high relative to crop needs. Soil test P levels build up over time when P additions exceed crop P removal (Figure 1). In order to lower P loss from agricultural landscapes, the amount of P entering the soil (from fertilizer or manure) should be no more than the amount of P leaving the soil (crop removal or animal products). When P input equals P removal, a farm attains P balance. Balancing P inputs with P removals should be a goal of every producer because soil test levels should neither increase nor decrease in such a system.

Managing nutrients by thinking in terms of P balance minimizes potential negative impacts on water quality by supplying crop and animal needs while eliminating excess nutrient application. Farmers dealing only with crops can achieve P balance by controlling fertilizer inputs. Farmers with livestock must consider manure management.

Phosphorus balance may not be possible on some farms because the number of animals present is too large for the land base. Management decisions, however, influence P loss. Soils that are already high in P have less flexible management options than those soils with low soil test P levels. But carefully thought-out decisions can provide options for the producer that do not require either buying more land for applying manure or reducing the number of livestock.

This publication suggests options for farmers and nutrient management planners who have soils with high soil test P levels and, therefore, present greater environmental risks. Although the ultimate solution is to achieve input/output balance, we have attempted to identify least risky alternatives for farms still working toward P balance.

Figure 1. On-farm phosphorus balance.



What is considered a high soil test P site?

Soil test phosphorus (STP) is determined when a soil sample (soil cores from the top 6 to 7 inches) is analyzed in a lab for P availability. In Wisconsin, STP is measured using the Bray P-1 extractant. Results of these tests are reported in concentration of P as parts per million (ppm). Guidelines for P application according to the USDA-Natural Resources Conservation Service's 590 standard for nutrient management suggest the following:

- 50 ppm P or less: Manure applications allowed up to the rate that meets the crop N need;
- 50 to 100 ppm P: P applications from all sources shall not exceed crop removal of P over a 4-year rotation;
- 100 ppm P or greater: Eliminate P applications if possible, but yearly P applications must be at rates lower than crop removal.

For environmental purposes, a high STP site is one in which the soil test level is above 100 ppm. For crop production, a "high" soil is one where the chance for responses from added fertilizer is relatively low (<30%). This typically is at soil test P levels ranging from 20 to 30 ppm.

Approaches to Improving Phosphorus Balance

1. Manage Dietary Phosphorus

Dairy - For dairy producers, a first step in balancing P inputs and outputs is to examine the amount of P being supplied in the dairy diet. In January 2001, the National Research Council (NRC) published their most recent recommendations for dairy dietary P intake. Varying with milk production, the NRC recommends a diet with 0.32 to 0.38% P (Table 1). Studies have shown that these levels of P are adequate for high milk production and successful reproduction. Adding more dietary P increases the P excreted in manure. More P in manure increases the potential for P loss when the manure is land applied (Figure 2). Producers should know how much P is in dietary supplements (Table 2). By monitoring protein supplements and inorganic P additions, producers can keep diets close to recommended levels and minimize the amount of P applied when manure is spread on a field. For more details, contact the University of Wisconsin-Extension, Nutrient and Pest Management Program for the publication Dietary Phosphorus Considerations in Dairy Management or download the pdf at http://ipcm.wisc.edu.

Swine/Poultry - For non-ruminant (monogastric) animals such as swine and poultry, dietary P manipulations are also possible. Two management options are available that attempt to reduce P in manure by helping the non-ruminant animal get more P out of feed. Both result in reducing the need for inorganic P supplements in the diet. One strategy is to reduce the phytate level of feed grains by feeding low-phytate, high available-P (HAP) varieties. In corn and other feed grains, P is stored as phytate, which is largely unavailable to non-ruminant livestock. As a result, inorganic P is often added to diets as a supplement. Phytate-P not used from the plant is excreted by the ani-

Table 1. Dietary Recommendations of the National Research Council (January 2001).

Milk Production Level	Dietary P Level
(lbs/day)	(%)
55	0.32
77	0.35
99	0.36
120	0.38

Figure 2. Cumulative P load in runoff from fields receiving manure of various P content.

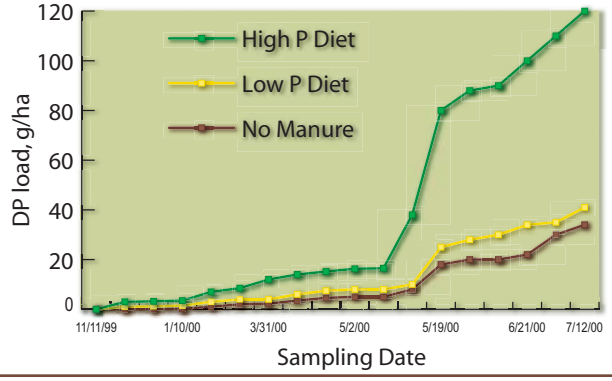


Table 2. Examples of protein supplements indicating crude protein content and % P (National Research Council, 2001).

Protein supplement/ By-product feed	Crude protein %	Phosphorus %
Blood meal	95.5	0.30
Soybean meal (expellers)	49.9	0.70
Cottonseed	23.5	0.60
Corn distiller's grain	29.7	0.83
Wheat bran	17.3	1.18
Porcine meat and bone meal	54.2	4.73

mals, resulting in manure that is enriched in P. Using corn hybrids developed to contain lower amounts of phytate and that store more P in the available phosphate form will increase P uptake of a non-ruminant animal. Since more P is available to the animal, less inorganic P needs to be added as a supplement. The result can be a decrease in the amount of P excreted in manure.

Another option for reducing manure P from monogastric livestock is to use commercially produced phytase enzymes as a feed supplement. Phytase enzymes are capable of releasing phytate-P from plants into animal-available forms. Phytase enzymes occur naturally in some microorganisms, plants, and ruminant animals. Monogastric animals lack phytase and can only poorly utilize the P reserves in many grains. By adding phytase enzymes to non-ruminant animal feed, P uptake from the feed during digestion can be increased. As with HAP corn, using phytase lowers the amount of inorganic P needed as a supplement, which in turn reduces the amount of P excreted in the manure.

The options of using HAP hybrids or adding a phytase supplement only provide benefits if their use is combined with a reduction in supplemental P in the diet. If a diet contains adequate P without supplementation, using phytase or HAP corn does not lower P excretion. Similarly, using HAP hybrids or phytase enzymes without lowering supplemental P does not lower P excretion.

2. Reduce or Eliminate Other Phosphorus Inputs

Follow Soil Test Recommendations - In addition to imported feed and/or dietary P supplements, another major P input to Wisconsin farms is purchased fertilizer. Applying only the amount of fertilizer P needed by the intended crop can eliminate P build-up and improve farm profits. To determine crop need, farmers need to account for available nutrients in the soil. Routine soil testing measures nitrogen, P, and potassium availability and pH, as well as minor nutrients if requested. Farmers who follow a well-calibrated soil test recommendation program will apply nutrients according to crop needs. At optimum soil test levels, the recommended nutrient additions are approximately equal to anticipated crop removal. To avoid over-fertilizing P and other nutrients, fertilizer and manure additions should be made according to soil test results. Soil and crop experts recommend that soil samples be taken at least every three to four years to evaluate the effectiveness of the fertilizer program and to monitor soil test P changes. On sandy and other soils with low buffering capacity soil samples should be taken more frequently.

Soil test P levels can be used to help prioritize fields for manure applications. Fields with lower soil test P results are most likely to respond to applied nutrients, including those from manure. However, soil test P is not the only factor to consider when deciding where to apply manure; crop to be grown, runoff risk, spreading restrictions, and hauling conveniences are a few others.

Credit All Nutrient Sources - To determine commercial fertilizer application rates, it is critical to credit nutrient contributions from all sources, including soil, manure, and legumes. Both economic and environmental benefits result if all nutrient sources are correctly estimated. Economically, crediting soil, manure, and legume nutrients lowers fertilizer costs. Environmentally, preventing over-fertilization reduces threats to water quality. Using appropriate nutrient credits is particularly important in Wisconsin where manure applications to cropland, legume crop production, and the land application of organic wastes are common.

Manure can supply crop nutrients as effectively as commercial fertilizers. To utilize manure efficiently, the nutrient content and the application rate need to be accurately estimated. The most effective method of determining the nutrient content of manure is to have samples analyzed by a commercial or university laboratory. Large farm-to-farm variation in nutrient content can occur due to

Table 3. Estimated available nutrient content of solid and liquid manure from various livestock species.

Livestock	------- Solid -------			------ Liquid ------		
	Nitrogen [1] (N)	Phosphate (P_2O_5)	Potash (K_2O)	Nitrogen [1] (N)	Phosphate (P_2O_5)	Potash (K_2O)
	- - - - - - - lbs/ton [2] - - - - - -			- - - - - - lbs/1,000 gal [2] - - - - -		
Dairy	3 / 4	3	7	7 / 10	5	16
Beef	4 / 5	5	9	5 / 7	5	16
Swine [3]	7 / 9	6	7	25 / 33 [4]	25	24
Poultry	20 / 24	30	24	8 / 10	6	10

[1] Use higher value for manure that is incorporated within three days of application. [2] Values rounded to the nearest whole pound.
[3] Values for finishing operations. [4] Values for indoor pit.

manure storage, handling, livestock feed, or other farm management differences. In instances when laboratory analysis is not convenient or available, estimates of crop nutrients supplied by animal manures can be made. Table 3 summarizes the University of Wisconsin estimates of first-year available nutrient values for various livestock manures. Manure application rates can be determined through the calibration of the manure spreading equipment.

Knowing the nutrient values in your soil, manure, and legume crops will allow the most efficient use of the resources on the farm, while supplying crop needs and protecting the environment. More detailed information regarding manure and legume credits is available from the Nutrient and Pest Management Program at http://ipcm.wisc.edu or 608-265-2660.

Use Starter Fertilizer Judiciously - Starter fertilizer is recommended for corn planted in Wisconsin. A minimum application of 10 lb N, 20 lb P_2O_5, and 20 lb K_2O per acre on medium- and fine-textured soils is recommended. In most corn fields, all the recommended P_2O_5 and K_2O can be applied as starter fertilizer. On soils with test levels in the excessively high range, starter fertilizer applications in excess of 10 lb N, 20 lb P_2O_5, and 20 lb K_2O per acre should be avoided.

Corn yield responses to starter fertilizer additions can still occur on soils that are excessively high in P and K. The probability of a yield response can be estimated using site-specific information for the individual field. Crop yield increases from starter additions on excessively high soils are much more likely if soil test K levels are less than 140 ppm and/or the combined effect of corn hybrid relative maturity (RM) and planting date result in an inadequate growth period for the crop to achieve its full yield potential. Specifically, responses are more likely with late planting dates and long-season RM hybrids. The probability of response to starter fertilizer on excessively high testing soils for various hybrid RM and planting dates is shown in Table 4.

3. Increase the Land Base for Manure Spreading

For dairy operations where regulatory measures require manure application rates to be limited to crop removal of P, about 1.5 to 2.0 acres of cropland is needed per adult cow. Such restrictions have caused many farmers to increase the amount of land available to them for spreading. Purchasing additional land for the sole purpose of applying manure is seldom an economically viable option. Several other approaches can be used to effectively increase a farm's manure spreading land base without pur-

Table 4. Probability of obtaining a positive economic return from starter fertilizer for several corn relative maturity ratings at various planting dates on soils with excessively high P and K levels.*

	Planting Date							
Relative Maturity	4/25	5/1	5/5	5/10	5/15	5/20	5/25	5/30
	----------% probability----------							
90	10	15	20	25	30	35	40	45
95	15	20	25	30	35	40	45	50
100	20	25	30	35	40	45	50	55
105	25	30	35	40	45	50	55	60
110	30	35	40	45	50	55	60	65

* This table does not alter current recommendations for early planting and selection of corn hybrids with appropriate relative maturities for the production zone.

chasing additional land. These include: (a) ensuring that all cropland receives manure at some time during the rotation; (b) applying manure to rented land; and (c) obtaining manure application rights from neighboring grain farmers.

Another option for farmers that does not involve purchasing additional land is applying manure at rates that meet the P needs of crops for the length of the rotation. For example, research has shown that manure applications at high rates prior to seeding alfalfa can actually benefit the crop, reduce the need for topdress fertilizer, and eliminate runoff P losses from annual topdress manure or fertilizer applications. A major caution to growers considering this practice, however, is that they must be prepared to deal with a potential flush of annual weeds due to the enriched fertility of the soil.

Management to Reduce Phosphorus Losses

1. Identify Low Risk Sites

Phosphorus loss from a site depends on the source and quantity of P at the site and how readily that P is transported to a vulnerable water system. Source and transport are site-specific factors, meaning that they vary from field-to-field. For P (as well as other nutrients) to be released to water there must be a source, either high soil test P levels or applied manure and fertilizer. Transport of P occurs through runoff, erosion, and occasionally leaching. Phosphorus is more likely to be transported off sites with steep slopes. Sites located adjacent to or near waterways, streams, and lakes are more susceptible to transporting P off the fields and into surface water. Fields with the highest risk for P loss are those with both high source and transport factors, i.e. those with high soil test P and located near water. If a site has high soil test P or high manure or fertilizer applications but is not located near a lake or stream, the risk for P loss to water is much less. Likewise, if a field is located next to a stream but has low levels of soil test P and no P is applied, the risk for P loss is also low.

The P index is a management tool being developed in many states. The P index considers both P source and P transport criteria when ranking fields for risk of P loss.

Definitions for Phosphorus Terminology:

Particulate P (PP): Phosphorus bound to eroded sediment or organic matter; also called sediment-P.

Soluble P (SP): Phosphorus in runoff that is readily available for plant and algal uptake; also called dissolved P (DP).

Total P (TP): Total amount of P carried in runoff water. Total P includes P attached to eroded sediment as well as P dissolved in runoff. TP = PP + SP.

Specifically, the Wisconsin P index considers soil test P level for a site; expected erosion loss for the crop rotation in place; slope; amount, form, and placement of P additions; distance to concentrated flow; soil type; soil condition (frozen or unfrozen); and residue management practices. The P index also identifies whether the risk is mostly associated with sediment loss or with P dissolved in runoff. This knowledge can guide specific management to reduce P losses. By accurately identifying lower risk sites, the land manager may then choose to allow soil test P to build on very low risk sites while minimizing or eliminating manure or fertilizer P applications on very high risk areas.

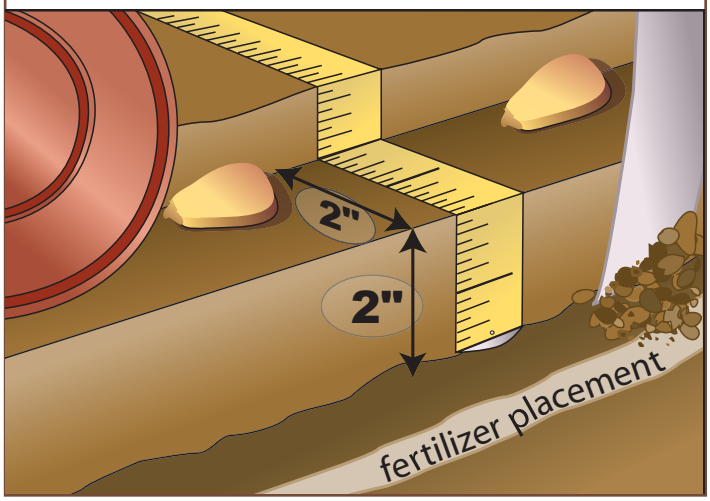
2. Consider Seasonal Limitations When Applying Manure

Deciding when to apply manure is an important consideration for minimizing P contributions to surface waters. First consider weather predictions. Manure should not be spread on sloping lands any time the weather is likely to cause runoff, i.e. before a heavy rain or snowmelt is forecast. Unfortunately, sudden rain or snowmelt events are difficult to predict and eliminating manure applications on sloping lands is seldom a practical option for landowners. Nonetheless, being aware of weather conditions guides decision making. Secondly, time of year should be considered. University of Wisconsin experts recommend avoiding winter (frozen soil) applications. For farmers with storage facilities this is not a problem. For farms without storage, winter applications cannot be avoided. Manure applications to frozen soils should be limited to slopes of less than 6%. Preferably these soils are corn stalk covered, roughly tilled, and protected from up-slope runoff. Winter applications should not be on alfalfa or other vegetation-covered, smooth-surfaced fields. If manure must be applied to frozen soils with slopes of 6 to 12%, conservation measures, such as buffer strips, contouring, strip-cropping, terraces, etc., need to be in place to protect surface waters. Manure should not be applied to frozen soils on slopes greater than 12% because the risk of P loss is high.

3. Incorporate Phosphorus Fertilizer

How and where P-containing materials are placed in the soil directly influences the amount of P transported to lakes and streams by runoff. Phosphorus can strongly bind to soil particles; however, there must be adequate contact between soil and P source for this to occur. Incorporation by tillage or subsurface band placement of commercial fertilizer is a very effective means of achieving this contact. When P fertilizer is broadcast on the soil surface and not incorporated, the concentration of P in runoff increases and more P is lost. To avoid enriching surface waters with soil nutrients, it is recommended that annual fertilizer applications for row crops such as corn be band-applied near the row as starter fertilizer at planting (Figure 3). Annual starter applications of P can usually supply all of the P required for corn. This practice reduces the chance for P enrichment of the soil surface and reduces P loss in runoff from cropland.

Figure 3. Starter fertilizer in a 2 x 2 placement.



4. Incorporate Manure?

Until recently, the recommendation for land-applied manure was to incorporate it within three days of application whenever possible. Similar to fertilizer-P, manure-P will bind with soil particles when they are in close contact. Incorporating manure reduces the amount of soluble P in runoff because P can bind to soil particles. Alternatively, incorporating manure usually involves tillage, which increases soil erosion. Loss of sediment by soil erosion increases total P loss (total P is the sum of sediment-P and soluble P). Manure broadcast on the surface (without incorporation) acts as mulch, lowering soil erosion. Unincorporated manure applications tend to reduce total P losses by lowering soil erosion but increase dissolved P losses; while incorporating manure with tillage may lower dissolved P losses but tends to increase total P losses. Recent Wisconsin findings suggest that the long-established management recommendation for incorporating manure may not minimize cropland P losses if total P reductions are the objective. This is particularly true for spring manure applications. With regulatory agencies leaning towards using total P as the parameter on which to base regulations, a general recommendation to surface apply manure without incorporation to fields with soil conservation practices in place is appropriate. As a general practice, using conservation tillage, whether no-till

or reduced tillage, will help keep soil particles on the field by increasing surface residue and as a result lower the loss of P in runoff to lakes and streams.

5. Use Soil Conservation Practices

One key to minimizing nutrient contributions to surface waters is to reduce the amount of runoff and eroded sediment that reaches surface waters. Numerous management practices for runoff and soil erosion control have been researched, developed, and implemented. Runoff and erosion control practices range from changes in agricultural land management (cover crops, diverse rotations, conservation tillage, contour farming, and contour strip cropping) to the installation of structural devices (buffer strips, diversions, grade stabilization structures, grassed waterways, and terraces). The most commonly used, widely adopted, and easily accomplished conservation practice is maintaining surface residue through various types of conservation tillage.

6. Consider Buffer Strips

Strips of close-growing vegetation adjacent to water bodies or within cropped fields can reduce the sediment and nutrient content of runoff waters. Runoff slows down when passing through a buffer strip allowing sediment to deposit and runoff to infiltrate. Because many nutrients are bound to sediment, when sediment falls out of runoff the remaining water continuing to the stream has a substantially reduced nutrient load. Buffers as narrow as 15 feet have been shown to reduce P loads. Buffers are most effective when combined with up-slope practices that reduce sediment and nutrient loss, such as conservation tillage. Practices that promote ponding of the runoff up-slope from buffer strips enhance infiltration and sediment deposition and improve the effectiveness of the buffer.

Summary

Selection of appropriate P management practices for individual crop and livestock operations needs to be tailored to the specific conditions existing at the farm or field within the farm. An overall goal of any agricultural operation should be to balance inputs of P (fertilizer, feed, etc.) with outputs (crop and animal products) and to manage fields in ways that retain soil nutrients on the land. Agricultural management practices for reducing the impact of P on water quality from farms with high soil test P fields include:

Improve Phosphorus Balance

* *Livestock Diet:*

Dairy - Supply P supplements at recommended levels; know the P content of protein supplements and account for it in the total diet ration.

Non-ruminant - Consider using high available P (HAP) corn hybrids and/or phytase enzymes to increase the P available from feed.

* *Reduce or Eliminate Other P Inputs:*

Base nutrient (commercial fertilizer and manure) application recommendations on soil test results; credit all nutrient sources; apply minimal amounts of starter (10-20-20) fertilizer.

* *Spread manure on more acres*

Spread manure on all cropland, including fields going into alfalfa and rented land; obtain manure application rights from neighboring farmers.

Reduce Phosphorus Loss

**Identify sites with low risk for P loss and use those for manure applications.*

**Consider seasonal limitations to manure applications. If winter applications must be made, use fields with soil conservation practices in place and avoid slopes greater than 6%.*

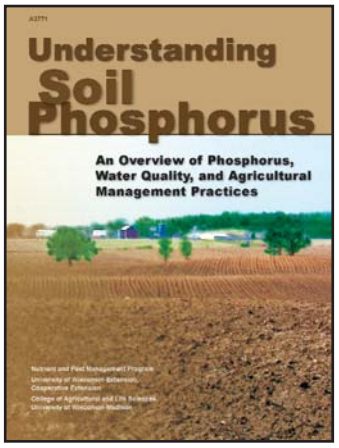
**Incorporate commercial P fertilizer applications.*

**Apply manure to fields that have soil conservation practices in place and do not incorporate it.*

**Use soil conservation practices to prevent soil erosion.*

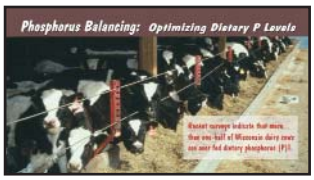
Additional Phosphorus Related Resources Available from the Nutrient and Pest Management (NPM) Program:

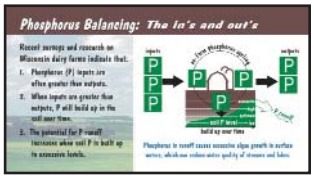
Understanding Soil Phosphorus: An Overview of Phosphorus, Water Quality, and Agricultural Management Practices is a new publication available from the NPM Program. The 32 page, color publication summarizes the issues associated with phosphorus (P) and its potential for impact on the environment. Specific topics include the phosphorus cycle, nomenclature, sources, transport, and a summary of agricultural management practices for minimizing the impact of phosphorus on water quality.



Dietary Phosphorus Considerations in Dairy Management is a four page, color publication that covers the impact of dietary-P intake on the P content of manure, soil test P, and the amount of land required for manure spreading.

A series of four *Phosphorus Balancing* cards are available from the NPM Program. Each card has its own message relative to P management. One card graphically illustrates the balancing of P inputs with farm outputs. Another contains the National Research Council dairy feeding recommendations for P. A third promotes lowering dairy dietary P in order to reduce the acreage required for manure spreading. The final card shows the P content of various protein and feed supplements common to Wisconsin farms. All NPM publications are free of charge. See below for ordering information.





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