Nutrient Management

The economics of nutrient management are clear. Manage plant nutrients for maximum economic benefit to the farmer. That is an easy concept to accept. Profit is the bottom line in farming, as in any business.

The environmental effects of nutrient management are a more recent concern brought to public attention by the Chesapeake Bay Program. An Environmental Protection Agency (EPA) study of water quality problems in the bay found fertilizer nutrients coming from contaminated surface waters were major contributors to the pollution. How does this concern Pennsylvania? About 70 percent of the fresh water which feeds the bay comes from the Susquehanna River and Pennsylvania. Pollution of our own groundwaters and surface waters are problems of concern for Pennsylvania, also.

FARM NUTRIENT CYCLE

On a cash crop farm, the flow of nutrients is basically a straight flow-through system. Fertilizer and other inputs are applied to the land, crops are removed and stored, and eventually sold to off-farm destinations (Figure 1a). Removal and sale of the crop also removes nutrients from the farm. By keeping track of of what moves through the system and what leaves the farm, a manager can predict the supplemental fertilizer nutrient requirements of the crop. The cash crop system is typical for many of the farms in the Midwest and for some farms in Pennsylvania.

The majority of Pennsylvania farms grow a number of different crops, usually in some type of rotation. Most farms have animals, too. This makes the situation much more complicated than the cash grain farm where only crops are usually grown. The nutrient flow is more complex. Where livestock and multiple crops are involved, the crops generally are harvested for feed and/or bedding; additional feed, protein supplements and minerals are purchased and brought onto the farm. These purchases also bring nutrients onto the farm (Figure 1b).

Penn State studies measuring the movement of nutrients on dairy farms have shown that in many cases as many or more fertilizer nutrients were purchased in the form of feed and bedding as were bought in actual fertilizer. The nutrient contributions coming from the purchased feed and bedding must be considered because they can cause an excess of nutrients on the fields, even when a good job of manure spreading has been done. Other forms of nutrients may be available on the farm; nitrogen contributed by legumes is one example.

Where do all these nutrients go? On a typical Pennsylvania livestock farm, about 25 percent of the original nutrients leave the farm in milk, eggs, meat, and other items sold. Since about 75 percent of the original nutrients from feed and bedding remain in the manure, each farm has a tremendous potential for recycling nutrients each year. Supplemental fertilizer purchases may be required only to replace the nutrients sold.

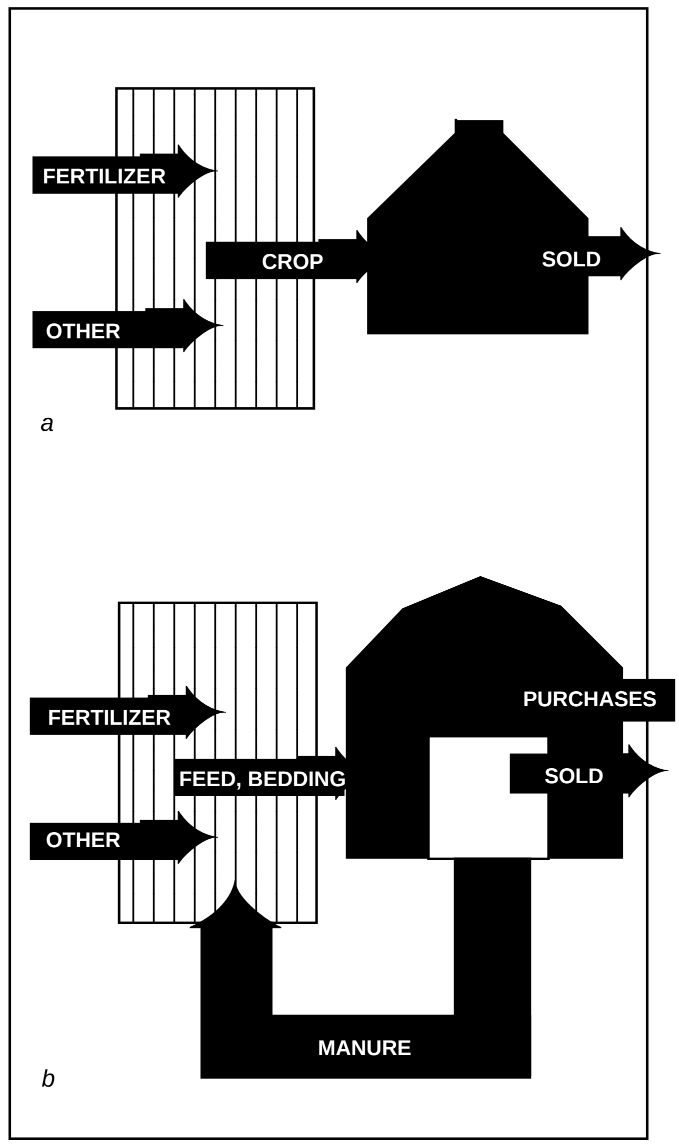

Figure 1. Nutrient flows on cash crop (a) and crop/livestock farms (b).

RECYCLING NUTRIENTS

Planning is essential in recycling this quantity of nutrients. All too often, these nutrients end up in the field nearest the barn, particularly in the winter. However, the nutrients in manure come from the whole farm and should be distributed onto the whole farm, not just the fields close to the barn. While it often is not practical to spread the nutrients over the whole farm every year, the goal should be to get the nutrients back on the field where they came from sometime during every rotational cycle.

The key to effectively recycling these nutrients is soil testing. Soil tests will indicate which fields need nutrients and how much they need to meet the requirements for optimum crop yields, and to avoid imbalances.

The probability of a profitable return from applying nutrients to a field is related to the soil test level (Figure 2). As the soil test level goes up, the probability of a profitable return from adding additional nutrients goes down. Therefore, concentrate on applying nutrients, as manure or fertilizer, on the low-testing fields as opposed to the high-testing fields.

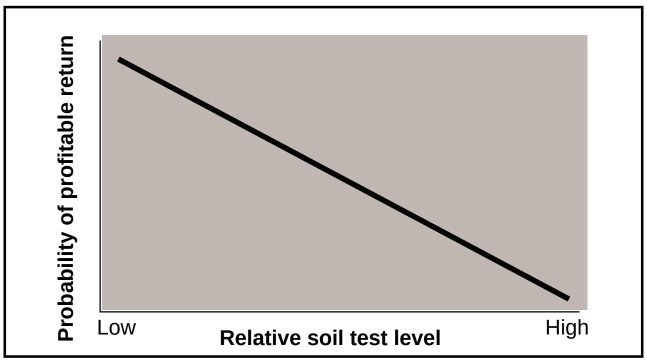

Figure 2. Relationship between soil test level and probability of profitable returns from fertilization.

Avoid nutrient applications on high-testing fields for three reasons. First, there is a low probability of profitable return. Second, excessive nutrients can actually reduce crop yields on a high-testing field. Third, nutrients applied to high-testing fields are more likely to contribute to pollution.

MANURE MANAGEMENT

Production

Manure produced by farm animals is an important carrier of nutrients. Consider the quantity of manure produced by the animals. In the case of the dairy cow, this figure is 21 tons of manure per year. That is a lot of manure to deal with and more than twice the weight most cows produce in milk. Typical amounts of manure produced by farm animals are (tons/year):

Unit	Species	Tons
1	dairy cow	21
1	horse	9
1	sow and litter	6
1	sheep	1
100	chickens	2

Nutrient content

An efficient manager knows what kinds and amounts of plant nutrients are in manure, as these are the nutrients utilized to grow crops. The concentration of nutrients varies greatly among animal species. However, some typical manure nutrient concentrations are (pounds per ton, averaged):

Species	N	$P_2 0_5$	$K_2 0$
Cattle	10	4	8
Poultry	60	55	30
Swine	14	11	11

Although these numbers may seem small, the *typical* manure application is between 20 and 40 tons per acre for cattle and swine manure, and between 5 and 10 tons per acre for poultry manure. This is equivalent to 200 to 600 pounds of nitrogen per acre!

Be aware that these are averaged amounts of nutrients and that variations within species and among farms are large. The variability in manure analyses between any two similar livestock farms can vary by a large percentage. Variations (+ or -) for some common manure types are (percentage variation):

Species	N	$P_2 0_5$	$K_2 0$
Cattle	68	93	43
Poultry	40	43	41
Swine	47	76	74

It is important to use an actual manure analysis figure rather than depend on averaged or typical values from these tables. Farm-to-farm variability can be significant. However, little variation on the same farm is noticed from year to year if the management stays the same. Thus, an analysis made from a particular farm this year generally can be used as a guideline in planning management on that farm for next year.

MANURE NUTRIENT BEHAVIOR

Effective use of the nutrients in manure requires an understanding of their behavior.

Nitrogen

Manure nitrogen behavior is complicated. The total nitrogen (N) content is split about equally between the solid and liquid portions of most manure (Figure 3). The liquid one-half contains unstable N. It is essentially urea, the same as in urea fertilizer, and very rapidly available. Thus, one-half of the N in manure is potentially available to the crop the same as fertilizer N. The solid fraction of manure N is tied up in very stable organic N compounds, and is very slowly available to the crop. Small amounts become available each year as these organic compounds breakdown.

The urea form of N from the liquid fraction presents the same problem presented with urea from fertilizer. Nitrogen

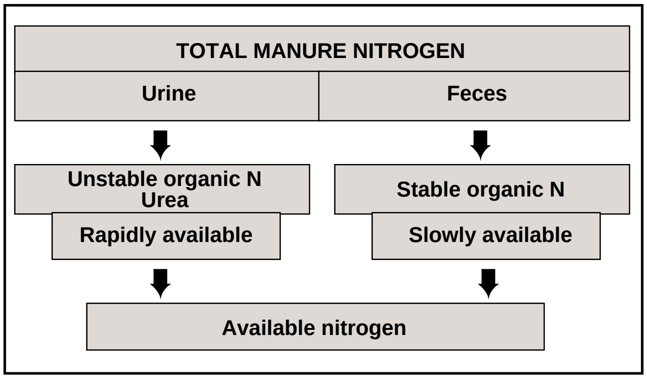

Figure 3. Relationship between total and available manure nitrogen.

in urea left exposed on the soil surface converts readily to ammonia gas and can be lost by volatilization. Data from New York provide an example of loss (Figure 4). Dairy manure was spread over a soil surface and ammonia loss was measured over a period of time. After a week, nearly 50 percent of the available N had been lost into the air. In two weeks, 80 to 90 percent of the available N from the manure had been lost.

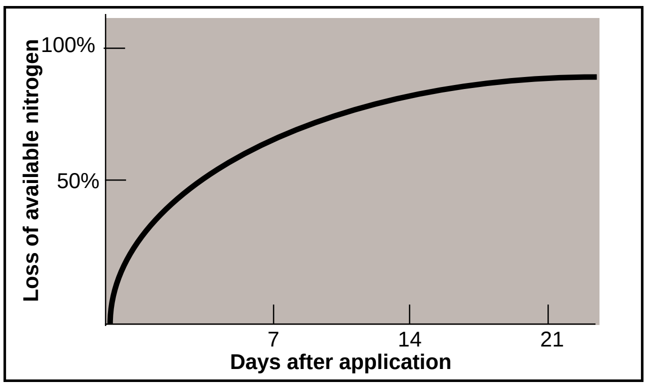

Figure 4. Loss of available nitrogen from manure due to volatilization.

Volatilization losses can be reduced or eliminated by incorporation. For example, when manure is incorporated immediately, 50 percent of the total N will be available to the crop that year (with poultry manure this value is 75 percent because a larger proportion of nitrogen is in the urea form). The percentage of available N decreases steadily the longer the manure is exposed. After one week, only 20 percent of the total N is available. The approximate amount of manure nitrogen available over a period of time after incorporation is (percentage of total N):

Incorporation	%
Immediately	50
Within 2 days	40
Within 3-4 days	35
Within 5-6 days	30
After 7 days	20

A fall application results in about 20 percent of the total N being available the next year. These losses are due to leaching, denitrification, volatilization, and other winter losses. A cover crop can increase this percentage of crop-available N. If the cover crop is left in the field as a green manure, approximately 40 percent of the total N will be available to the crop. The N found in the solid portion of the manure is slowly available over time. If manure has been spread rarely or never on a given field, this residual nitrogen contribution is insignificant. However, if manure is applied frequently to a particular field, an amount of N equivalent to 15 percent of the total manure nitrogen spread in a given year is available from this residual nitrogen to the current year's crop. If the field has received manure continuously, then the annual credit is 25 percent. Thus, even though the release from residual N in a given year is small and difficult to predict, it does add up over time to be a very significant amount of crop-available N. Because of the potentially large pool of residual N in manured soils, you should not add extra fertilizer N "just to be safe." The pre-sidedress soil nitrate test (PSNT) for corn can be used to estimate the availabililty of this residual nitrogen and account for it in an improved sidedress N recommendation. (See Agronomy Facts 17, *Nitrogen Soil Test for Corn in Pennsylvania* for details.

Phosphorus

Almost all the phosphorus (P) is tied up in the solid portion of the manure. Very little manure phosphorus is soluble, like fertilizer P. Yet the P in manure is essentially equivalent in effectiveness to P in commercial fertilizer because about 80-90 percent of the soluble fertilizer P becomes fixed in the soil upon application. In this form, it is no longer available to the plant. Manure P, having a very small soluble portion, is not fixed; the organic P is protected. As the organic fraction gradually decomposes in the soil, P is released. If a crop is growing, the plant utilizes the P before fixation occurs. For these reasons, P in manure is equivalent to P in fertilizer. If a test calls for a certain quantity of P, manure P can be applied at the same rate as fertilizer P and the same results can be obtained. One exception is starter fertilizer. A key property for starter fertilizer is high water solubility, a property not found in manure P. If needed, a starter fertilizer should be used even when most of the P requirements of the crop are being met with manure. Because P is bound to the soil it is susceptible to loss through soil erosion. Thus soil conservation is critical for protecting the environment from P pollution from agriculture.

Potassium

The properties of manure potassium (K) are the opposite of manure P, because 75 percent of manure K is in the liquid fraction. Manure K behaves the same as fertilizer K and can be applied at the same rate. Potassium does not appear to be an environmental threat.

CROP DIVERSITY AND ROTATION

Other nutrient management considerations are crop diversity and rotations. Different crops have very different nutrient requirements and respond differently to added nutrients.

Consider the requirements for a continuous corn crop (Figure 5). Appreciable amounts of nitrogen, about one-half as much phosphate, and even smaller amounts of potash are needed to grow corn. The nutrient requirement picture changes dramatically when the corn crop is rotated with alfalfa. Now, for the whole rotation, there is a greater need for potash, not as much phosphate, and even less nitrogen.

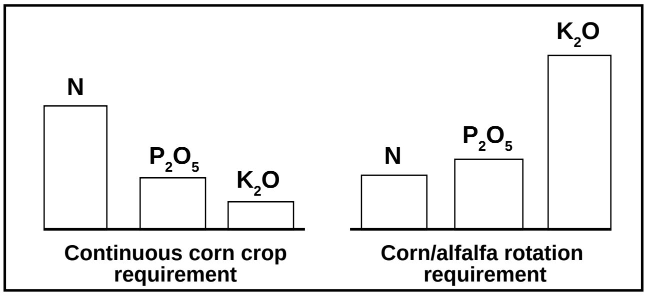

Figure 5. Relative nutrient requirements for two different cropping systems.

When manure is incorporated immediately to meet the nitrogen requirements of the continuous corn crop, twice as much phosphate is applied than the corn needs. This also results in excessive potash levels (Figure 6). In a corn-alfalfa rotation, when manure is applied at levels to meet the nitrogen needs of the corn crop, the phosphate and potash levels fall short of the needs of the whole rotation. Excess phosphate and potash levels build up during the corn part of the rotation. However, this excess will be used during the alfalfa phase of the rotation. These reserves of phosphate and potash eventually are drawn down to a point where supplemental fertilizer may be necessary. Otherwise, yield will be affected. Soil levels of phosphate and potash should be monitored with soil tests and rebuilt during the next corn rotation (Figure 7).

Nutrient management should be viewed over a period of time, such as a rotation interval. There are years for building up the soils, times to apply lime, times for starter fertilizer, and a period for soil maintenance. A soil test is the primary tool in deciding where and when to apply manure for optimum return. Manure is too often applied for needs of a corn crop and then fertilizer applied as a

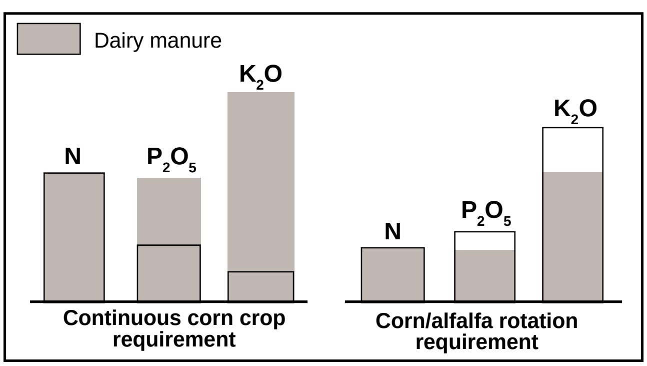

Figure 6. Comparison of crop nutrient needs and manure nutrients.

topdressing for the alfalfa, even though a soil test does not call for any nutrients. Applying manure to alfalfa is a waste of nitrogen because alfalfa, being a legume, fixes nitrogen from the air. Unnecessary manure applications also have other disadvantages. Nitrogen stimulates weed and grass growth which can crowd out and shorten the stand life of alfalfa. Manure spreading operations can also physically damage alfalfa plants. An exception is manure applied to old and unproductive stands of alfalfa being rotated to corn, or where safe manure disposal is the major concern rather than efficient use of the nutrients.

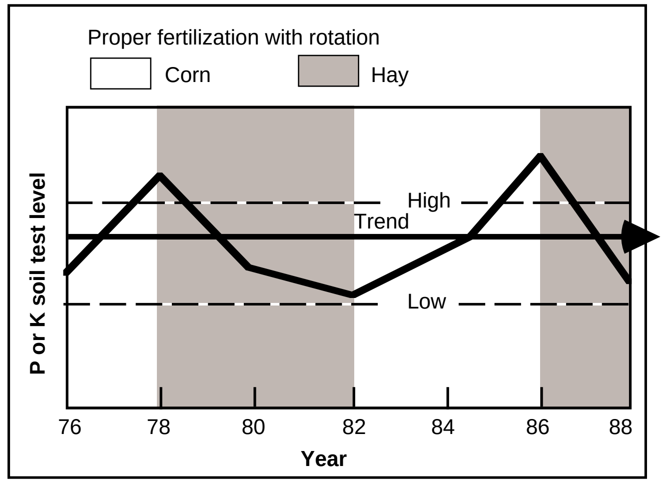

Figure 7. Soil test trend with proper fertilization over a rotation.

FARM RECORDS

Records contain extremely important information when managers are looking for trends that help maximize profitable crop response (Figure 7). Records are just as important in managing nutrients for maximum economic benefit and minimal environmental impact.

Several programs developed at Penn State help make record keeping easier. They organize information into a more useful form, while alleviating the drudgery of evaluating and condensing a pile of accumulated soil test results. Both computer worksheets and standard paper worksheets have been developed.

Computer programs

One computer program uses information such as the number and size of animals, length of confinement during the year, and other factors to estimate manure production on a farm. Another program works on a field by field basis, matching up soil and manure analyses and determining manure application rates to meet the nutrient needs of the crop. The most comprehensive program integrates farm nutrient management. This program takes the whole farm into account. Soil test information from each field on the farm is entered, along with manure analyses and rotation information. This program organizes fields on a priority system, indicating which fields stand to benefit the most from manure application and which could be harmed by additional manure. It also helps calculate appropriate manure and fertilizer rates.

Another program uses farm records to assess the nutrient status of the farm. It provides information on the nutritional balance of the individual fields and that of the whole farm.

Worksheets

A paper worksheet is sent to the farmer with each manure analysis that is run. It helps match up the soil test requirements with the manure analysis to decide how much manure should be applied to each field. A second worksheet on manure utilization is a more complicated version of the manure analysis worksheet. It includes a section for calculating manure production and takes other factors into account. A third worksheet helps with calibrating manure spreaders.

SUMMARY

Proper nutrient management begins with a look at the whole farm, not just each field individually. Fields must be prioritized. Manure and fertilizer must be applied to fields for maximum profitability. This includes consideration of the whole rotation within each field.

The most important tools to management are crop records and soil testing and manure analysis. The soil test will help to decide where to put the nutrients for maximum benefit. The manure analysis will help to better utilize the manure in meeting the crop requirements specified by the soil test. Applying too much manure or fertilizer can cause environmental problems. The bottom line is the need for good crop records.

Remember, manure is no longer a costly waste disposal problem; it is a valuable nutrient resource that needs to be managed. Effective use of manure can help off-set costs of farm nutrient replacement and avoid environmental problems.

RESOURCES

This has been a brief overview introducing the more important concepts for farm nutrient management. The following are sources of more detailed information to assist you in implementing the recommendations made here.

Available through county offices of Penn State Cooperative Extension:

Soil Test Kits (Standard and PSNT)
Manure Analysis Kits
Penn State Agronomy Guide
Nitrogen Fertilization of Corn, Agronomy Facts 12
Managing Phosphorus for Crop Production, Agronomy Facts 13
Managing Potassium for Crop Production, Agronomy Facts 14
Manure Spreader Calibration Worksheet
Nitrogen Soil Test for Corn in Pennsylvania, Agronomy Facts 17.
Local nutrient management expertise

Available from the Agricultural Analytical Services Laboratory at Penn State:

Fertilizer Recommendation Table, ST-2.
Interpreting Soil Tests for Agronomic Crops, ST-4.
Use of Manure, ST-10.

Available from Penn State College of Agriculture Computer Services (for Apple Macintosh computers):

Manure Production Worksheet, AAG-0102.
Manure Application Rate Worksheet, AAG-0101.
Farm Nutrient Management Worksheet, AAG-0103.

Computer software available from the Department of Agronomy at Penn State:

Farm Nutrient Management Planning Worksheet v 2.01, IBM, RBase v 1.1, Agronomy Series #107.
Nutrient Management Assessment Worksheets 2nd ed., IBM, Lotus 1-2-3 v 2.0, Agronomy Series #102.
The Crop Management Record-Keeping Computer Database System v 1.0, Macintosh, FileMaker Pro.

Available from Pennsylvania Department of Environmental Resources:

Manure Management Manual: Field Application of Manure, Supplement FA

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