Manure Management

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Nutrient management should be looked at as an integrated, continuous process. It starts with an assessment of the overall nutrient balance on the farm. If this simple assessment indicates a nutrient imbalance, a more detailed assessment will indicate specific field imbalances that need to be considered in the manure management process. Once an assessment has been accomplished, management options for dealing with the situation can be explored. If there is an overall nutrient imbalance on the farm, options for developing a plan to get rid of excess manure will be the main emphasis. If the farm is near to being in balance, then a field by field plan for manure utilization will be the priority. If the farm is in a nutrient deficit situation, then the plan will emphasize maximizing the utilization of the manure on the farm and on supplementing these nutrients with fertilizer or maybe manure from a farm with an excess. These options are then developed into a nutrient management plan for the farm. As this plan is implemented good records must be kept for use in the subsequent assessment and revision of the farm nutrient management plan. It is important to recognize that this process must be comprehensive and it is continuous.

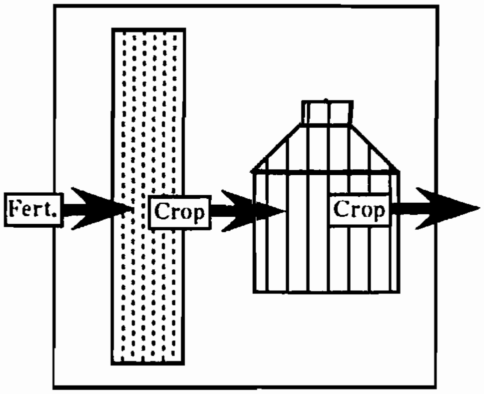

Figure 1a. Cash Crop Farm

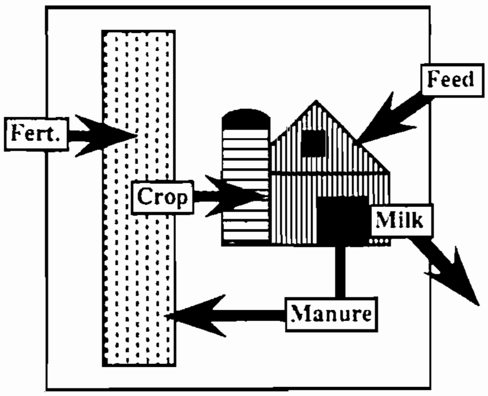

Figure 1b. Dairy Farm

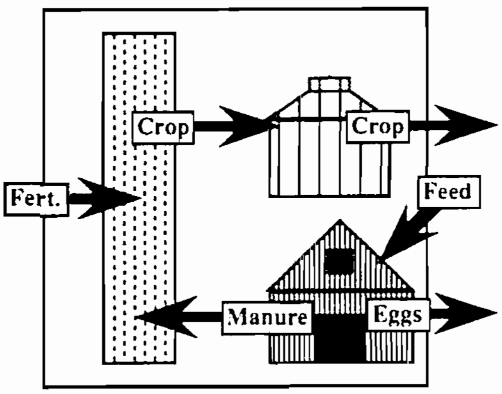

Figure 1c. Intensive Poultry Farm

Understanding farm nutrient flow can be very useful in developing a farm nutrient management plan. On a cash grain farm the nutrient flow is a fairly simple straight through flow. On such farms nutrients leave the farm in the crop produced and fertilizer nutrients are brought onto the farm to replace this removal (See figure 1a).

On a primarily feed-self-sufficient livestock farm, nutrients are harvested from the farm fields with the crops. The crops are then used as feed in the animal enterprise resulting in some nutrients (usually less than 25%) leaving the farm in the animal products and the rest of the nutrients being returned to the farm fields in the manure. Nutrients may be added to this cycle as fertilizer on the farm fields and as nutrients contained in feed purchased for the livestock operation, but the primary nutrient flow is from the farm field to the barn and back (See figure 1b). The most important consideration in managing nutrients on this type of farm is accounting for all sources of nutrients especially as purchased feed increases, and effectively recycling them in the cropping program. This type of system is the common one on dairy farms.

On some intensive livestock and poultry farms there is often a third system which is a combination of the first two, where the connection between the cropping program and the livestock operation is short circuited (See figure 1c). In this case, the animal enterprise is not linked to the cropping program by the necessity that the crops support the animals. Often the crop acreage is very limited and thus most, if not all, of the feed and the large quantities of nutrients it contains, are purchased to support the animal enterprise. As in the livestock system discussed above, only a small proportion of this large quantity of nutrients leaves the farm in the animal products; the rest remains in the manure and is applied to the cropland. However in this case, the amount of nutrients in the manure is in no way related to what was harvested in the crops grown on the soil where the manure is being spread. Because of this short circuiting there is the potential for major nutrient imbalances to occur. Attempts must be made to try to bring the nutrients into balance by removing some of the manure from the farm otherwise potentially polluting accumulations of nutrients will occur. On this type of farm, with large excess of nutrients, a crop nutrient management plan for the farm is an academic exercise unless it is complemented by a manure disposal plan.

Another important consideration in managing manure nutrients is the effect of the cropping system. Different crops have very different nutrient requirements. For example a corn crop requires a large amount of nitrogen, a smaller amount of phosphate and potash. An alfalfa crop however requires no nitrogen, some phosphate, and a large amount of potash. Generally forage crops such as hay or corn silage, will utilize much larger amounts of nutrients than grain crops. Therefore a rotation of grain and forage crops will have a very different nutrient requirement than either one of the individual crops grown in a field in a given year. This becomes very important when manure is used to meet some of the crop nutrient needs. For example, when dairy manure is applied to continuous corn at a rate to meet the nitrogen needs of the corn crop, an excess of phosphate and potash will be applied. However, in a rotation of 4 years of corn and 4 years of alfalfa, when dairy manure is applied to meet the N needs of the corn, less phosphate and potash is applied than is needed in the rotation. This is especially true when some of the corn is harvested for silage.

Information on the manure production for the farm, nutrient content and application system(s) must also be collected. Manure production can best be determined from the amount of manure in a manure storage. However, not all farms have a manure storage and it is not always possible to determine the amount of manure in a storage even if there is one on a farm. In this case manure production can be estimated from animal numbers, animal weights, and time of confinement.

Manure nutrient content must be determined by manure analysis. "Book" values for manure nutrient content are good as averages for a type of manure on many farms but because of farm to farm variability they are of no value for making decisions on an individual farm. Results of analysis of many manure samples in Pennsylvania illustrates this very wide range in nutrient content for nominally similar samples of manure from different farms. Table 1 gives an example of these results for dairy manure. The averages are very close to standard "book" values but the ranges are very wide. Similar variation has been found for other types of manure.

Table 1. Manure analysis summary for 311 liquid dairy manure samples.

	Nitrogen	Phosphate	Potash
		lb/100 gal.	
Mean	2.7	1.2	2.5
Std. Dev.	0.9	0.5	0.9
Minimum	0.1	0.1	0.1
Maximum	5.5	3.5	5.4

Table 2. Nitrogen availability factors for manure.

Timing and Incorporation	% N Available Poultry	Other
Manure applied for CORN or SUMMER ANNUALS the following year:		
Applied in the Spring		
Same Day as Application	75	50
Within 2 Days	50	40
Within 3 to 4 Days	45	35
Within 5 to 6 Days	30	30
After 7 Days or None	15	20
Applied Fall or Winter		
No Cover Crop	15	20
Cover Crop Harvested*	15	20
Cover Crop for Green Manure	50	40
Manure applied for small grains:		
Applied Fall or Winter	50	40

* Factors for this situation do not imply a loss of N. N will be recycled in manure when the silage is fed.

Finally the behavior of the nutrients in manure in terms of how they can contribute to the nutrition of a crop must be known if the true fertilizer value of the manure is to be determined. You cannot determine the fertilizer value of manure simply by multiplying the nutrient content by the current fertilizer nutrient price. Such a calculation will give an indication of the potential value of the nutrients in the manure but the actual fertilizer value realized will depend on how the manure is handled and used.

The behavior of manure nitrogen is dependent on handling. The nitrogen in most manure is about 50% urea nitrogen and 50% organic nitrogen (75% and 25% in poultry manure). Like fertilizer urea, the urea in manure is readily available to a crop. The organic nitrogen in manure is very slowly available over time as the organic matter decays in the soil and releases the nitrogen in mineral form. The first assumption about the availability of nitrogen from manure is that the urea nitrogen is potentially available to crops immediately. However, as with urea fertilizer, there is a significant potential for volatilization loss of nitrogen from manure. Urea is rapidly converted to ammonia in the soil. If this reaction occurs on the soil surface, the ammonia is free to go off into the atmosphere, and thus very large losses of nitrogen can occur by this mechanism. If, however, the manure is incorporated so that the ammonia that is produced is trapped in the soil, this loss will not occur. Consequently the availability of manure nitrogen will depend strongly on whether it is incorporated and how soon the incorporation follows application. Table 2 gives the nitrogen availability factors used in Pennsylvania to estimate the amount of nitrogen that will be available to a crop in the year that the manure is spread.

As was noted above, the remaining nitrogen that is in organic form will become available over a period of time. Thus the amount of this residual nitrogen that will be available in a given year will depend on the history of manure applications on a field. The more frequent the applications the more residual nitrogen that will be released. Because this decay and release is a very variable process only a rather crude estimate of residual nitrogen availability is possible. Table 3 gives the factors used in Pennsylvania to estimate this residual nitrogen from previous manure applications.

Table 3. Residual nitrogen availability factors from manure.

Manure History	% N Available* Poultry	Other
Rare or Never (<4 out of 10 years)	0	0
Frequent (4 to 8 out of 10 years)	7	15
Continuous (>8 out of 10 years)	12	25

* Based on total N in the typical annual application.

Once the nitrogen in the manure is in the soil it is not automatically taken up by the crop. The nitrogen transformations that can occur in the soil are many and complex and can often have negative impact on nitrogen availability. The two most important such processes are leaching in well drained soils and denitrification in poorly drained soils. Both processes can occur in most soils and can result in significant losses of available nitrogen. Leaching is of particular concern because of the potential for the nitrate to contaminate the groundwater. The best management approach to avoiding these losses is timing the manure application as near to the time of crop need as possible. This will generally help to avoid the wetter times of the year when the potential for loss is highest and it will improve the probability that the nitrogen will be rapidly taken up by the growing crop before it can be lost. For fall applied nitrogen it has been our experience that a large proportion of the nitrogen is lost regardless of incorporation. This is mainly due to the extended time period and climatic conditions between application and uptake by the crop. Applying manure in the fall, incorporating it, and establishing a cover crop should significantly improve the retention of this nitrogen for the following year's crop. This effect is included in the table of nitrogen availability factors given in table 2.

Thus the nitrogen available from manure is a combination of that available from the current application, plus a residual amount from previous manure applications. Estimating the amount of available N from either source is difficult, because N is highly dependent on management and environmental factors. Until recently there was no reliable test for N availability for corn in the more humid regions of the country. The development of the Pre-Sidedress Nitrogen Test for corn (PSNT) has changed that and provides a big improvement in managing manure nitrogen. This in-season soil test for nitrate-N is run on a 12" deep sample that is taken when the corn is approximately 12" tall, thus any supplemental fertilizer nitrogen must be applied as a sidedressing. From analysis of these samples, either by a soil testing lab or in the field with a quicktest kit, an improved sidedress N recommendation can be determined that will take the residual nitrogen from present or past manure applications into account. This test is especially useful where there is a history of manure application and/or legumes in rotation because, as noted above these are known to be large sources of available N. It is very difficult without the PSNT to predict exactly how much N will be available in a given season.

Phosphorus in manure is mainly in the organic fraction of the manure and is thus only slowly available to a crop. However, unlike soluble phosphorus sources, phosphorus in this form is less subject to soil fixation. The net result appears to be that the phosphorus in manure is about as effective as fertilizer phosphorus in building and maintaining soil phosphorus levels. Because of its low solubility, manure phosphorus can not be substituted for starter fertilizer, where starter is needed. Once in the soil, phosphorus is not very mobile and thus will accumulate in the soil. The major loss pathways for phosphorus are physical, primarily by runoff of the manure and by erosion of the soil. The key to managing phosphorus for environmental protection is the establishment of good soil conservation practices on the farm to reduce runoff and erosion. Phosphorus soil tests are very useful for managing manure phosphorus. They can provide information on which fields will benefit from the phosphorus in the manure and which fields already have excessive amounts of phosphorus and shouldn't receive any more manure.

Potassium in manure is primarily in the soluble fraction of the manure and is thus readily available to crops like fertilizer potassium. Potassium is relatively immobile in the soil and thus like phosphorus it will accumulate in the soil. The major loss pathways for potassium are also physical, primarily by runoff of the manure and by erosion of the soil. Soil tests are effective tools for managing manure potassium also.

Developing a nutrient management plan requires soil tests for the entire farm or land where manure will be applied, cropping and manure application history, planned crop rotation, and other characteristics such as field location and soil characteristics. Using this information the fields on the farm can be prioritized from high to low for manure applications as follows:

- By Crop
  - N requiring crops ---> Non-N requiring crops
- By N Requirement and Residual N
  - Highest N requirement ---> Lowest N requirement
  - Lowest residual N ---> Highest residual N
- By P and K soil test level
  - Lowest P soil test level ---> Highest P soil test level
  - Lowest K soil test level ---> Higest K soil test level
- By Other management considerations
  - Proximity to: Neighbors
    - Water bodies
    - Sink holes
    - Flood plain
  - Soil Limitations: N Leaching potential
    - P Runoff potential
    - Slope
    - Cropping System

After the fields have been prioritized and the manure amount, nutrient content and nutrient availability have been established we allocate the available manure to the fields in the priority order. Base the rate calculations on the priority nutrient (usually N or P). If the rate is based on N the manure analysis must be adjusted for N availability as outlined above and the crop requirement must be adjusted for residual N from previous manure applications and legume crops. The best approach to determining an environmentally sound manure application rate would be to use the rate that does not apply an excess of any nutrient over what is needed for the crop as indicated by a soil test. In our expericence P is usually the limiting nutrient when this approach is followed. In fields where there is a crop rotation this limit should be calculated on the basis of the nutrient needs of the entire rotation rather than just on the current crop, as discussed earlier. However, this can still be very restrictive. Currently in Pennsylvania, we usually base the manure application rate on N and try to limit the P and K applications based on the rotation requirements. In practice many farmers still apply excess P and K. Discussions are underway on establishing an absolute limit for soil P levels above which no more P should be applied. Since the major loss pathways for P and K are runoff and erosion, good soil conservation practices are critical in minimizing the environmental effect of excess P and K applications in manure.

Once a manure rate has been established for each field on the farm, the rates are adjusted for practicality. This usually results in the fields being grouped into one or a few standard rates that the farmer is able and willing to apply. Using these standard rates the available manure is allocated to the fields in the priority order until all of the manure is allocated or all of the fields have been used up. If all of the fields are used up and there is still manure left then the emphasis shifts to developing a plan for dealing with the excess. This usually means finding ways to get the excess off of the farm. Sometimes, if the excess is small, the cropping program can be adjusted to utilize the excess manure nutrients. Note that this priority order has nothing to do with the order that the manure is spread on the fields. That is a tactical management decision. The main point is that when the manure is spread, it is spread on the high priority fields rather than on the low priority fields.

Finally, the nutrients supplied in the manure must be compared to the needs of the crop to determine if additional nutrients are required or if there is a serious excess of any nutrient being applied. Deficiencies are taken care of by applying supplemental fertilizer nutrients. Serious excesses must be evaluated in light of the nutrient needs of the crop rotation and may require a change in the manure application plan.

The level of detail required and the emphasis of a manure management plan will vary depending on the situation on each farm. In Pennsylvania we attempt to categorize farms and target nutrient management efforts as follows:

1. *Low intensity farms* are those where there is not enough manure produced to meet total crop nutrient needs. In this group the objective of the plan will be to utilize soil tests and manure analysis to assure distribution and timing of manure applications to maximize nutrient utilization from the manure and minimize purchase of commercial fertilizer. The environmental impact of these operations should be nominal except where there is currently gross mismanagement. Changes in these operations would have a small beneficial effect on the environment. While a formal nutrient management plan may not be required for this group, there is the possibility for substantial economic benefits to the farmer for having an improved manure management plan.

2. *Medium intensity farms* are those that generally produce enough manure to meet total crop nutrient needs. In this group the objective will be to utilize soil tests and manure analysis in conjunction with appropriate management practices to match as closely as possible nutrients available in manure with crop needs over the entire rotation. Intense management will be needed to provide the most favorable economic situation while protecting the environment. There is good potential for environmental benefits from improved management on these farms. Generally the economic impact on these farms will be small. A detailed manure management plan will probably be necessary on these farms. Also, other changes in the overall farm management, such as altering the cropping system, may be necessary on this group of farms. Most farmers in this group will probably want to take advantage of technical assistance from public agencies and/or private consultants in developing an implementing a manure management plan.

3. *High intensity farms* where livestock manure production significantly exceeds total crop nutrient needs. In this group the objective will be to utilize every available means to remove all excess manure not needed for crop production. Alternative off-farm uses for the manure will need to be explored. In most instances this will mean locating a market for the manure and arranging the logistics of transportation and appropriate application. A high level of detailed nutrient management will not usually be necessary on these farms. The on-farm plans for this group of farms will involve determining the maximum amount of manure that can be safely disposed of on the farm. However, in most cases the available land and the high residual nutrient levels in the soil may severly restrict on-farm use of the manure. Detailed nutrient management plans will be important for the farms where the manure is ultimately utilized. This group of farms has the highest potential to negatively impact the environment. In many cases, unless a favorable marketing arrangement can developed, implementing improved nutrient management on this group of farms will have a negative economic impact on the farm. Assistance from public agencies and private consultants, manure brokers, and manure haulers will be critical to improving nutrient management. Unfortunately, this is an area that is not currently well developed.

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