Assessment of the Nutrient Supply on Livestock and Poultry Farms

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Introduction

A manure utilization plan is a plan that addresses manure production and how manure nutrients are utilized on the farm . Typically, the manure is used as a nutrient and organic matter source in a cropping system. However, there are other possible end uses of manure. The plan must describe all manure nutrients and the ultimate end use of all manure (crops, local landowners, composted and bagged, re-feeding blends, incineration, etc.). Manure nutrients must be tracked because livestock and poultry use only a small portion of the nutrients fed to them to produce meat, milk, and eggs. The remaining nutrients are excreted in the urine and feces. Depending on the species of livestock, about 70% to 80% of the nitrogen (N), 60% to 85% of the phosphorus (P), and 80% to 90% of the potassium (K) is returned in the manure.

Manure utilization planning is a two-part process. The first component can be termed *strategic planning*, because it focuses on average manure generation volumes, manure storage times, and average manure nutrient contents to develop a general cropping plan and to estimate the number of acres needed to properly land apply the manure. The second component can be referred to as the *annual plan*. The annual plan refers to the actual implementation of the strategic plan. It covers such things as how many acres of which crops will be grown during the year, the planned times for manure applications, results from periodic soil tests and manure analyses, and records of manure applications and crop yields. Once manure begins to be produced on the farm, the manure utilization plan must be implemented. A manure utilization plan requires careful attention to make it work properly. The farm owner or manager will need to understand how to use the information in the plan, along with monitoring information and equipment calibration to make the plan work. Accurate crediting of manure nutrients within a total crop nutrient program is fundamental to utilizing manure as a resource.

Components of a Manure Utilization Plan

Manure utilization plans can vary a great deal in the components and the way in which they are organized. However written, all plans should address the following basic components:

1) Manure generation and other sources of nutrients (can be referred to as Sources)
2) Manure nutrient availability (can also include Placement and Timing)
3) Crop selection and crop nutrient requirements (can be referred to as Amounts or Needs)
4) Best management practices (BMPs)
5) Summary of laws, rules, and regulations that must be followed.

While the first three components must be considered together to ensure that the manure nutrients generated on the farm are applied in harmony with crop needs and soil characteristics, this lesson will concentrate on the first component, nutrient sources and quantities.

Manure utilization plans may be written for one primary nutrient (often nitrogen) or several plant nutrients. Generally, two major plant nutrients (nitrogen and phosphorus) are the ones targeted in manure utilization plans because they are required in relatively large quantities for plant growth, and if mismanaged are likely to have the most adverse affect on the environment. Other nutrients, including potassium and micronutrients, may also have some effect on a manure utilization plan.

Nutrient Sources

Animal manures contain significant levels of plant nutrients and crop residues and/or legumes can provide nutrients for the subsequent crop. Accounting for and utilizing these nutrients can improve both the environmental and economic response of the fields. Planning starts with an inventory of the nutrients produced in the manure of animals grown on the farm, the quantities of manure collected and stored, either dry or as liquid, and analyses of the nutrient content of the stored manure. An inventory of any other by-products available, such as mortality compost or lagoon sludge (if lagoon cleaning is planned), and of any crop residue nutrients or legume nitrogen expected in each field should also be performed. This information will allow manure nutrients to be balanced with purchased fertilizer nutrients to support the expected yields of the crops grown. If the crop acreage is small relative to the number of animals, it will also allow evaluation of the extent that it may be necessary to move nutrients off the farm, and thus avoid over application of manure with the increased potential for movement of nutrients to ground and surface water.

Animal manure

The first part of developing a manure utilization plan is assessing the amounts of manure nutrients that are being generated, or for new operations, the amounts that are expected to be generated. There are four basic methods for estimating the quantities of manure nutrients produced and available for use as fertilizer. The first method involves multiplying the weight of the animals by average excretion estimates for each species and class of animal. After this value is adjusted for the amount of time that the animals are present on the farm, expected losses due to handling, treatment, and storage are calculated to estimate the amounts of nutrients that will be available for utilization. A second method, which will give a more accurate estimate of nutrient excretion in most cases, involves the development of a nutrient balance for the animals. The nutrient content of the feeds used on the farm during the year is calculated, thus the total pounds of nitrogen (N, calculated from protein content), phosphorus (P), and potassium (K) that were fed are known. Next the total amount of animals or animal product sold or moved off the farm during the year is calculated. This is multiplied by the N, P, and K content of the animals or animal products (usually based on average compositions, but may be adjusted for lean percentage, milk protein content, etc.) to get the amounts of nutrients moved off the farm. The difference between the feed nutrients and the animal nutrients is an accurate estimate of the quantities of manure nutrients. This estimate is then corrected for the expected handling, treatment, and storage losses to estimate the amount of nutrients available for use as fertilizer. The third method for estimating manure nutrients involves the use of standard concentration values multiplied by the quantity of manure in storage. While this method has some application for litter based situations, the variation in nutrient content (especially N) of manures held as liquids or slurries generally precludes its use in those situations. The fourth method involves measuring the amounts of manure removed from treatment or storage, sampling the manure for analysis of nutrient content, and calculating the total nutrients available for use as fertilizer. This method is most accurate from the standpoint of developing a cropping plan (because it also accounts for treatment and storage losses), and should be a goal of the nutrient management plan.

However, one of the methods of estimating the quantity of nutrients excreted should also be used, especially if there is a need to reduce the amounts of nutrients produced on the farm, there is a need for additional N fertilizer on the farm and loss estimates are helpful, or a lagoon treatment and storage system is used. When lagoons are used, much of the P may accumulate in sludge on the bottom, where it is usually not available for the annual cropping plan. In those cases, the difference between the estimated P excretion and the amount of P calculated from manure volumes and concentrations pumped from a lagoon is likely to be present in the sludge, and it will have to be managed when the lagoon is emptied.

Other nutrient sources

When developing manure utilization plans, all sources of nutrients on the farm need to be considered. Sources of nutrients include nutrients already in the soil, commercial fertilizers, crop residues, and other manure or by-product applications. To account for these nutrients, manure and soil analysis should be used. Examples of other sources would include legumes and crop residues which can leave plant-available nitrogen (PAN, discussed in another lesson) for the following crop. Manure and soil sampling and analysis will be covered in other lessons. When planning manure applications, the producer should account for all nutrient sources when determining manure application rates to fields.

What Are the Amounts of Manure Nutrients Produced on a Farm.

The nutrient value of manure can vary from farm to farm and from time to time on the same farm. Factors that affect the nutrient levels include:

- The lean growth potential or other production characteristics of the animals.
- The animal diets fed (ration composition).
- The amounts of feed wastage.
- Time of year (season, temperatures).
- The handling and treatment of the manure between animal excretion and land application.
- Length of time manure is in a storage structure and/or the level of sludge buildup.
- The timing of land application and the method used.

On a per unit of body weight basis, animals with greater lean gain, or other product production potential will require greater protein intakes and will excrete larger amounts of N than less productive animals. However, on a per pound of lean growth (or unit of other product), their excretion of N may be no more, and usually less, than that of animals with lower potential. Manure nutrient excretion can be minimized by feeding animals according to their needs at any given time. In addition to balancing diets with needs, the availability or digestibility of the feed nutrients will affect excretion. These concepts will be covered in more detail in another lesson.

Feed wastage can be a significant contribution to waste nutrients in some cases. For example, if properly adjusted, most modern swine feeders are capable of limiting feed wastage to 5% or less (and others, especially some wet/dry feeders, to 1%), while some older feeders allowed feed wastage as high as 20%, which can be especially important in slotted floor housing. A 20% feed wastage can result in an increase of 30% or more in the manure N and P. Pelleting or crumbling feed also generally reduces feed wastage and reduces separation of nutrients during handling, contributing to improved animal feed efficiency. Season differences in manure nutrient excretion are related to the increased feed intake, decreased water intake associated with cold conditions and the decreased feed intake, increased water intake associated with hot environments. These fluctuations can be minimized by formulating diets to counteract part of these effects. Manure nutrient losses related to handling and treatment will be discussed in another lesson but will also be covered to some extent later in this lesson. Nitrogen is the nutrient that is most influenced by handling and treatment since it occurs in several forms, some of which are gases that can and will be lost to the atmosphere. Storage losses can also affect the supply of manure nutrients available for use as fertilizer. In addition to N, P management is often influenced by storage, especially for lagoons where much of it may end up in the sludge, rather than being available for the yearly soil fertility program. Manure application methods and timing will be covered and discussed in another lesson. All these possible variations are reasons to have manure analyzed frequently.

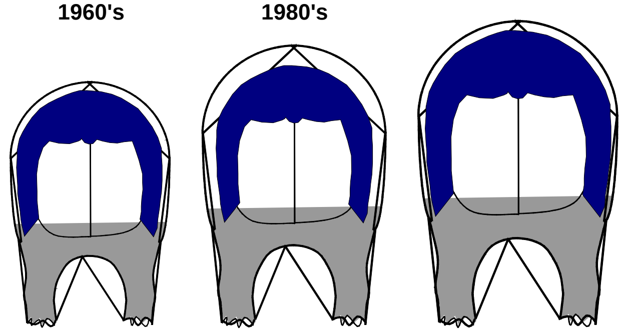
Calculating Manure Nutrient Excretion using Standard Excretion Estimates.

Table 1 (all Tables are attached at the end of the lesson) illustrates the use of standard excretion estimates to calculate the yearly nutrient excretion of the animals. In all the tables, nitrogen is calculate as N, phosphorus is calculated as phosphate (P_2O_5), and potassium is calculated as potash (K_2O). In order to use Table 1, locate the proper animal class in column 1, fill in the yearly average number of animals of that class in column 2, fill in the average weight of the animals in column 3 (mean of starting and ending weight, ending weight - starting weight / 2, for growing animals), and do the indicated multiplications for the remaining columns. (Multiply animal numbers by animal weight to get total weight of animals, then multiply that total by the excretion factors given for N, P_2O_5, and K_2O - an example line for finishing swine is given in the table.) When that is done, add up the N, P_2O_5, and K_2O (across the bottom of the table) for all the animal classes to get the total excretions for the farm. The average capacity should be the yearly average. For example, if the farm has a 3,000 head capacity swine feeding floor that is open 4 weeks per year, the yearly average number of animals might be 2,770 (3,000 pigs X 337days/365days, or 3,000 X 0.923 = 2,770).

The excretion factors given in Table 1 were developed from data collected during the mid to late 1980's. As a consequence, the resulting excretion estimates will likely be somewhat inaccurate, especially for pigs. The differences in finished pigs over time is illustrated in Figure 1, below, which also lists the previous excretion factors (for N and P_2O_5), which were developed from mid to late 1960's data. Similar changes may have occurred for other animal species, so excretion factors for most classes of animals are currently being re-evaluated, and revised factors may be available in the near future.

For the swine example, there were significant numbers of very lean, “stress susceptible”, “double muscled” pigs during the late 1960's. Because of production problems associated with these pigs, they were selected against, and, on average, pigs reaching slaughter houses became slightly fatter. During the 1990's, with productivity back in the swine herd, increased leanness was achieved and slaughter weights were further increased. In addition, a 1995 survey of states producing 75% of the US slaughter hogs estimated that 67% of pigs were fed more than two grower/finisher diets (29% were fed two diets), and that 25% of the hogs marketed in the Southeast were split-sex fed (38% in the Midwest). The management and feeding of nursery

Figure 1. Some Changes in Pigs Over the Past 30 Years



	Mid to Late 1960's	Mid to Late 1980's	Late 1990's
Market Wt (lb)	210	225	255
lb/lb body wt/yr			
N Excretion	0.164	0.153	?
P Excretion	0.125	0.134	?

pigs has also changed, with more early weaning and phase nursery diets, including increased use of animal products and amino acids. As an indirect result, many nursery diets contain a higher proportion of highly available P sources than in the past (lower levels of phytate P, covered in another lesson), which should result in lower P excretion. Using nutrient balance estimates for current practices and pigs, it appears that on a body weight basis, N excretion has returned to 1960's levels, or greater, and that P excretion has returned
to 1960's levels, or lower. Since it is difficult and cumbersome to have tables which list estimated excretion factors for a large number of animal and feeding alternatives and provide space for calculations, a computer aided excretion estimator has been developed which should provide improved nutrient excretion estimates compared to those derived from Table 1. This program will be available at training sessions, and after testing and further review, at County Extension Offices and on the Web. In addition, a number of other manure nutrient calculating programs and models are available. A good place to start looking for other manure software is the UGA AWARE web page (www.agp2.org/aware/). Other animal and farm management models are also available which calculate estimated nutrient excretion, and some ration balancing programs are also useful when using the nutrient balance method of estimating nutrient excretion.

Calculating Manure Nutrient Excretion using Nutrient Balance Estimates.

Tables 2a, b, and c illustrate the procedures for calculating manure nutrient excretion estimates using nutrient balance procedures. It has been shown that calculating manure nutrients by subtracting the nutrient content of the animals or animal products moved off the farm from the feed nutrients fed to the animals generally provides a more accurate estimate of nutrient excretion than does the use of standard excretion estimates. Table 2a list the factors which are used to convert feed protein, phosphorus, and potassium to amounts of N, P_2O_5, and K_2O and the average composition values of whole animals and products necessary to convert animal live weights and products to amounts of N, P_2O_5, and K_2O.

Table 2b contains an example calculation for a swine finishing farm marketing 6,000 pigs per year. In that example it was assumed that the feeds were purchased and that only two diets were fed, in order to make the example shorter and simpler. Any number of diets could be included, or if diets are mixed on-farm, it is usually simpler to calculate from ingredients. In that case, the total quantity of corn, soybean meal, other protein supplements (milk by-products in nursery diets, amino acids, etc.), and phosphorus supplements would be entered on a separate line for each. Purchased animals moving onto the farm would complete the nutrient inputs. Nutrient outputs from the swine operation would include all animals sold or otherwise moved off the farm. The difference in nutrient inputs and nutrient outputs will be a close estimate of manure nutrients produced on that farm. Table 2c is a blank table for use in calculating manure nutrients for a farm, should this method be selected.

Calculating manure nutrient output using the estimated balance method will usually result in larger values than would be obtained by using the standard excretion method. Part of this difference is due to the fact that normal feed "shrinkage" is included as input, and especially since any spilled and wasted feed is included in the manure nutrient estimate. Even more accurate estimates can be obtained by adjusting the animal and product composition factors to account for differences in lean percentage and product nutrient content between different herds or flocks, some software allows this to be done.

Calculating Manure Nutrients Using Standard Concentration Values.

As noted above, when manure is in a relatively dry state and nutrient concentrations are not affected by widely varying amounts of dilution water, such as with poultry litter, manure nutrients can be calculated by estimating manure production of the animals and multiplying this amount by standard nutrient concentration values for the particular type of manure and storage system. This procedure thus also estimates the storage losses which occur prior to removal of the manure for land application. The procedures for calculating manure nutrients using this method are illustrated in Tables 3a, b, and c. Table 3a lists manure production and nutrient concentration values for some classes of poultry. The per bird manure production estimates are used in Table 3b to estimate the total quantity of manure produced on the farm during the year, example calculations are shown for broilers and layers, with additional lines for other calculations. The quantity of manure calculated in Table 3b is then entered into Table 3c, along with the appropriate concentration (pounds/ton) values for nitrogen, phosphate, and potash from Table 3a. The calculations in Table 3c are then completed to estimate the total quantities of nutrients produced on the farm during the year. Example calculations are again provided, along with additional blank lines for other calculations.

Treatment and storage losses.

Before discussing the fourth method of estimating manure nutrient production on farms, it is necessary to briefly discuss nutrient losses during handling, treatment, and storage. Table 4 lists some manure treatment and storage options along with factors used to estimate the quantities of nutrients remaining after treatment and/or storage. The example given in the table is for a top loaded manure storage tank or structure. To use the table to estimate the nutrients remaining after storage, find the appropriate system in column 1, place the N excretion estimate (from either Table1 or 2, or a software derived estimate) in column 2, the P_2O_5 excretion estimate in column 5, the K_2O excretion estimate in column 8, and perform the indicated multiplications. Notice that for lagoons, much of the P_2O_5 is calculated as lost during storage. This is not really the case, as most of this P actually remains in the lagoon sludge and will have to be managed at some point when sludge is removed from the lagoon.

The amount of P_2O_5 in the lagoon sludge can be estimated by filling in Table 5. If the lagoon is emptied essentially completely at some point during the year, P reductions will be minimal. If all lagoons are agitated during pumping such that some sludge is re-suspended, P reductions will be much less than 65%, but will depend upon the degree of agitation. The computer aided nutrient calculator mentioned above includes calculations for nutrient losses during treatment and storage, but does not include separating lagoon P between sludge and effluent, since it will likely vary from farm to farm, depending upon effluent removal practices. If lagoons are not agitated and only effluent is removed, P_2O_5 calculations from the computer calculation should be factored as in Table 5. In addition, the computer estimate will provide a ranges for N losses. If the treatment and storage time are relatively short (90 days or less) the N values will likely be near the larger amount, whereas if manure is applied only once per year, the N value will likely be nearer the lower value.

Calculating Manure Nutrients from Measured Quantities and Sample Analyses.

If amounts of manure handled on the farm each year are known, plus there are manure nutrient analyses, calculation of manure nutrients available for use as fertilizer can be calculated in a straight forward manner. For farms that handle slurry and dry manures, the manure quantity may be estimated from the number of loads handled during a typical clean-out operation along with the number of clean-outs per year. For operations that use a liquid manure management option such as flush floors and lagoons, the volume of manure generated is more difficult to determine. Liquid system manure generation can be estimated if good records on irrigation applications (from a meter, pump capacity X run times, or rain gauges in the field) are maintained. These quantities will need to be multiplied by concentration values obtained from samples submitted to a laboratory, in order to obtain total yearly nutrient estimates. Manure sampling procedures are covered in another lesson. In some cases there may be a need or desire to estimate micronutrient (such as copper or zinc) production and land application. Manure sampling and analysis is a logical way of obtaining those values. Table 6a and b are provided for making manure nutrient calculations from measured quantities and nutrient concentrations. If the concentration of nutrients in manure from the animals varies with the time of year, an average composition should be used or calculate an amount for each clean out by season of the year and add them for a yearly total, or develop seasonal land application plans. Table 6a contains an example to illustrate how the calculations are made and Table 6b is a blank table for additional calculations.

If there is a good handle on manure generation and manure composition, this is likely the most accurate estimate of manure nutrients available for use as crop fertilizer. This estimate will include animal effects, diet effects, feed wastage effects, and, most importantly, treatment and storage losses. It should be a goal of the plan to arrive at this point, in order to more accurately manage nutrients on the farm. However, if the farm uses lagoons, one of the first two methods should also be used in order to estimate the quantity of P_2O_5 accumulating in lagoon sludge, that will have to be managed at some point in time.

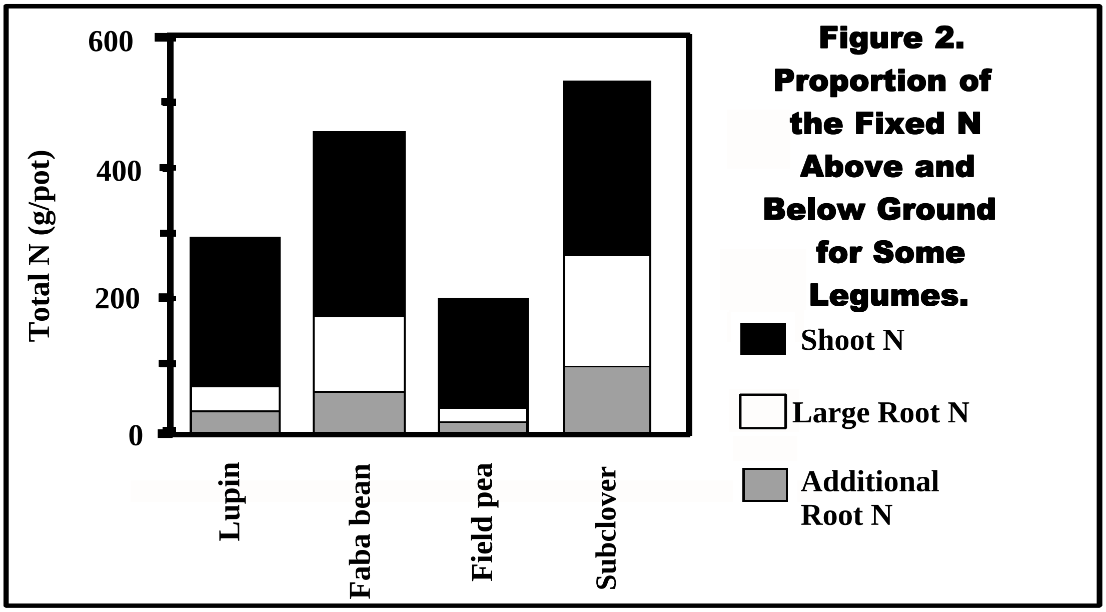


Figure 2. Proportion of the Fixed N Above and Below Ground for Some Legumes.

(From: http://www.agric.wa.gov.au/cropupdates/1998/pulses/nitro.html-ssi)

Results from either method of manure nutrient estimation may be used for planning purposes (strategic plan). As records of manure quantities are developed and manure samples are submitted to a laboratory to determine the actual nutrient content, the plan will be updated and modified to reflect these more accurate estimates. *Where manure analyses and quantities are available, they should be used to develop the initial manure utilization plans and application rates.*

Other Nutrient Sources

Note that Table 6 includes a line (6) used to enter other on-farm nutrient sources. This could be mortality compost (an amount and nutrient analysis will be needed) or possibly nitrogen fixed by legumes. Table 7 lists estimates for available N amounts following some legumes. The actual amount of N will vary with management of the legume, especially if none of the plant was harvested (as with a winter legume which was not grazed cut for hay), part of the plant was harvested (as with soybeans), or most of the plant was harvested (as with peanuts plus peanut hay). Soybeans, peanuts, and lupin for example, may accumulate more than 250 lbs of N per acre, but much of this N is removed with seed harvest. Figure 2 shows above and below ground N accumulations for some legumes as an illustration of how harvest can affect N remaining after a legume crop. (It should be noted that subclover seed develop below the soil surface.)

Parts of this lesson were taken from National Curriculum Lesson 31: Manure Utilization Plans, written by Karl Shaffer, 6/1/2000 draft.

Summary

The manure nutrient supply on an animal farm originally came from the feed which was fed to the animals. Therefore the quantity of manure nutrients is affected by the productivity of the animals (the proportion of the feed nutrients converted into growth or other products). This conversion efficiency is affected by the nutritional balance of the diets fed relative to the nutritional needs of the animals at their current productivity stage. In addition, feed wastage often contributes nutrients directly to manure management systems, without the reduction in amounts associated with animal digestion. Two of the easiest and least costly (often profitable) methods of reducing manure nutrient production are to more closely balance the diets to the needs of the animals and to take steps to minimize feed wastage (such as frequent feeder adjustment, use of pelleted feeds, or installing feeders of newer design).

There are four basic methods for estimating the production of manure nutrients on farms. The first involves multiplying animal weight by excretion factors for nitrogen (N), phosphorus (P), and potassium (K). For pigs, and likely other animals, as their feeding and management have changed, the published standard excretion factors currently in use most likely underestimate N excretion and overestimate P excretion, as leaner pigs tend to excrete more N and less P than fatter pigs. The second method involves subtracting the estimated nutrient content of animals and animal products leaving the farm from the nutrient content of the feeds used on the farm. Manure N is derived from the protein and amino acids in the feed and manure P and K are derived from minerals in the feedstuffs and mineral supplements. Since all of the nutrients in the feed must go somewhere, if the amounts fed are known, this procedure will generally produce a more accurate estimate than the use of standard excretion estimates.

For both of these nutrient excretion estimation methods, nutrient losses which occur during treatment and storage of manure must be taken into account in order to estimate the quantities of nutrients available for use as fertilizer. Nitrogen voided in the urine (about half of the N excretion in most animals) is quickly converted to ammonia. Loss of this ammonia to the air can occur quickly under some conditions. During treatment and storage of manure, additional N is often converted to ammonia (and in some cases to nitrate, which is subject to denitrification and loss to the atmosphere as well). Nitrogen losses will often have larger effects on the amount of manure N available for use as plant fertilizer than the amount actually excreted.

The third method for estimating manure nutrient quantities is to calculate the expected manure production and multiply it by standard nutrient concentration values. These concentration values are usually for manures as they are removed from storage, thus this method does account for an average nutrient loss. The fourth method is to measure the quantity of manure removed from storage each year, sample and analyze it to determine the nutrient concentration of the manure, and multiply the concentrations by the quantity to estimate the total manure nutrients. This method automatically accounts for everything from wasted feed to treatment and storage losses, but it does not account for some nutrient separations, such as P in lagoon sludge, which will eventually have to be managed. It should be a goal of the nutrient management plan to develop a measurement and sampling procedure for calculating nutrient quantities, since it will be less likely that manure nutrients will be under or over applied to fields, since either could be uneconomic and over application could also be environmentally unsound. With either calculation method, other on-farm nutrient sources may also need to be accounted, such as mortality compost, or, on a field by field basis, legume N fixation.