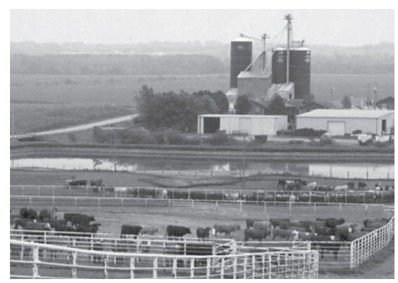
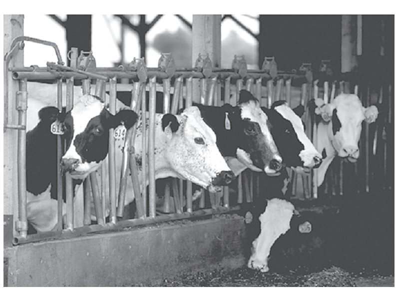
Lesson 31

Manure Utilization Plans

By Karl Shaffer, North Carolina State University





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Disclaimer

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Intended Outcomes

The participants will
- Identify the components of a manure utilization plan.
- Be able to determine crop nutrient/manure requirements.
- Understand the differences between manure nutrient sources.
- Determine the difference in land requirements between nitrogen- and phosphorus-based manure management.

Contents

Activities

The participants will
- Determine manure/nutrient production.
- Calculate the nutrient requirement for specific crops.
- Calculate nutrient availability.
- Determine the land requirement for nitrogen- and phosphorus-based manure applications.
- Determine the appropriate manure application rates based on nitrogen and phosphorus.

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:
- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application and Nutrient Management
- Outdoor Air Quality
- Related Issues

Note: Page numbers highlighted in green are linked to corresponding text.

Introduction

This section focuses on how to follow a manure utilization plan. Although some information relates to how a plan is written, the intent is not to teach you how to write one but to improve your understanding of what goes into a plan. Developing manure utilization plans requires many sources of information specific to your state and location; this lesson provides some of that information but in a broader national scope to cover a variety of situations.

A manure utilization plan is a component of a total farm *comprehensive nutrient management plan*. Comprehensive nutrient planning is covered in Lesson 2, Whole Farm Nutrient Planning. Since proper nutrient management is the goal, one should be concerned with all nutrients on the farm, regardless of the source. This lesson focuses primarily on managing the nutrients present in manure, but following the comprehensive plan should always be the goal of the livestock or poultry producer.

As issues related to manure utilization planning are discussed in this lesson, producers are encouraged to evaluate their own manure utilization planning using the following assessment tools:

- Total Manure Nutrient Production (Table 31-1) and Availability After Storage and Application Losses (Tables 31-3 to -6)
- Land Requirements for Managing N (Table 31C-1) and P (Tables 31C-2 and -3)
- Alternative Worksheet 31-1 for Manure Nutrient Generation (if manure generation volume or weight and typical manure analysis is known)
- Environmental Stewardship Assessment (Appendix A)
- Regulatory Compliance Assessment (Appendix B)

A ***manure utilization plan*** **addresses manure production on a farm and how the manure nutrients are utilized.**

A *manure utilization plan* addresses manure production on a farm and how the manure nutrients are utilized. 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,

Figure 31-1. Successful crop production depends on proper nutrient management.

compostedand 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 livestock species, 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.

For the typical land application system, a manure utilization plan is a tool that helps you define the number of acres and types of crops to be grown on the basis of the volume of manure produced and the nutrient requirements of your crops. The process requires estimating the volume of animal manure produced and determining the amount of plant-available nutrients that the manure contains. On the basis of these factors, environmentally sound cropping systems are matched with your manure-handling systems to develop acceptable methods for manure utilization. Poor nutrient management is costly to the environment and to your pocketbook. Applying more nutrients than a crop can use increases the risk of polluting groundwater and nearby surface waters.

Once manure begins to be produced on your farm, a manure utilization plan must be implemented. A manure utilization plan requires careful attention to make it work properly.

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 your farm, a manure utilization plan must be implemented. A manure utilization plan requires careful attention to make it work properly; you will need to understand how to use the information in your plan, along with monitoring information and equipment calibration. 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:

- Manure generation and other sources of nutrients (also referred to as Source)
- Manure nutrient availability (also referred to as Placement and Timing)
- Crop selection and crop nutrient requirements (also referred to as Amount)
- Best management practices (BMPs)
- Summary of laws, rules, and regulations that must be followed

The first three components must be considered together to ensure that the manure nutrients generated on your farm are applied in harmony with crop needs and soil characteristics. In addition, a manure utilization plan will identify BMPs that will help prevent nutrient runoff from fields. Each of these components and how their interaction together is necessary for manure-handling systems will be discussed.

A summary of regulations is important so that the manure utilization plan will be managed and modified within the regulatory framework allowed. Regulations may deal with nutrient application rates based on N or P, the requirements to have a manure or total nutrient management plan, manure application buffers, odor control, and possibly several other topics. The table in Appendix B summarizes the key regulatory issues that are relevant to manure nutrient utilization.

Manure utilization plans may be written for one primary nutrient (often N) or several plant nutrients. Generally, two major plant nutrients (N and P) 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 micronutrients, may also have some effect on a manure utilization plan. This will be discussed in more detail later in the lesson.

A manure utilization plan works like a balance sheet. Simply put, a manure utilization plan balances manure generated on the farm with the ultimate end use of the manure. Most often, this will be adjacent crops and forages. While the concept may appear simple, a comprehensive manure utilization plan can become very complex on a large animal operation, with many acres and different crops being grown. A step-by-step outline is essential to preparing a manure utilization plan that is both comprehensive for the animal operation and useful for the manager of the operation. A manure utilization plan will be of little benefit if it is not easily implemented and understood by the producer.

Manure utilization plans should be combined with some type of reference map. An aerial photograph makes a good base for a plan, because all fields can be easily noted. The relevant fields that receive manure applications can then be noted on the map with the appropriate acreage that is used for manure application. Aerial photos can be obtained through government agencies (Natural Resources Conservation Service [NRCS], Soil and Water Conservation Districts) or county tax offices. Appendix A lists the specific items needed to complete a manure utilization plan.

Note: A manure utilization plan may be written based on average conditions for a given type of manure management system and for a given set of crops typically used in an area. This is especially true for plans written for new facilities prior to the stocking of animals. Once an actual farm is operating, specific operating conditions need to be assessed to properly manage the annual plan. Examples of items in the plan that may be based on state or regional averages include

- Manure production rates.
- Manure nutrient values.
- Manure nutrient availability coefficients.
- Crop realistic yield expectations.
- Crop removal rates for nutrients.
- Soil nutrient tests.

These items and others will need to be revisited periodically to ensure that the manure utilization plan is properly implemented to gain maximum nutrient value and to minimize the possibility of negative environmental impacts associated with manure-handling practices. Using average nutrient values can lead to manure applications that do not match crop requirements.

Using average nutrient values can lead to manure applications that do not match crop requirements.

EXAMPLE 1

How much N, P_2O_5, and K_2O are produced by a broiler operation with a 100,000-bird capacity? Assume a 2.5-lb average bird weight. (Use Table 31-1 as a reference.)

(1) The total animal weight =
100,000 birds x 2.5 lbs/bird = 250,000 lbs

(2) The N production =
250,000 lbs x 0.40 lb N/lbs animal weight =
100,000 lbs N/year

(3) The P_2O_5 production =
250,000 lbs x 0.28 lb P_2O_5/lbs animal weight =
70,000 lbs P_2O_5/year

(4) The K_2O production =
250,000 lbs x 0.20 lb K_2O/lbs animal weight =
50,000 lbs K_2O/year

If the producer had good records on manure cleanout volumes and has current lab analysis for the manure, then the manure nutrient production can be determined from these on-farm records.

EXAMPLE 2

How many pounds of N, P_2O_5, and K_2O are generated from a broiler operation with an annual cleanout that produces 350 tons of litter, and the litter nutrient concentration (from a lab sample) is 28 pounds of N per ton of litter, 45.6 pounds of P_2O_5 per ton of litter, and 34.5 pounds of K_2O per ton of litter?

(1) The N production =
350 tons litter x 28 lbs N/ton of litter = 9,800 lbs N/year

(2) The P_2O_5 production =
350 tons litter x 45.6 lbs P_2O_5/ton of litter =
15,960 lbs P_2O_5/year

(3) The K_2O production =
350 tons litter x 34.5 lbs K_2O/ton of litter = 12,075 lbs K_2O/year

Source

Animal manure

The first part of developing a manure utilization plan is assessing the amount of manure that is being generated. For a facility that handles slurry and dry manures, this volume may be known by the number of loads handled during a typical clean-out operation on a monthly or yearly basis. Since the manure utilization plan must include the crops being grown with the manure as fertilizer, a yearly base for the plan is preferred. For operations that use a liquid manure management option such as flush floors or deep pits, the volume of manure generated is more difficult to determine. Liquid system manure generation can be estimated if good records on irrigation application and rainfall are maintained.

If the producer has a good handle on manure generation at a facility based on clean-out records, that rate should be used. For other systems where data is incomplete or for liquid systems, standard manure generation tables may be used. Table 31-1 combines the manure generation rates for a variety of animal operations with the typical nutrient composition of the manure. The result is that

Table 31-1 can be used to generate manure nutrients produced from livestock and poultry operations.

Values shown in Table 31-1 are averages that can be used for planning purposes (strategic plan). They cover a wide range of factors such as animal diet, age, productivity, management, and location, and do not include losses such as N volatilization. On an existing facility, a more accurate estimate of nutrients remaining after losses can be obtained by keeping track of actual manure applications and knowing the volume (spreader) or capacity (irrigation system) of the application equipment. Also, manure samples submitted to a laboratory will determine the actual nutrient content in the manure. *Where manure analyses are available for existing facilities, they should be used to develop manure utilization plans and application rates instead of these estimates.*

The first part of developing a manure utilization plan is assessing the amount of manure that is being generated.

Manure nutrient availability

Nutrients come in two major forms: organic or inorganic. Organic forms of nutrients include manure, crop residues, and sludges or other similar amendments. Inorganic forms of nutrients are typically from commercial fertilizers but could be from other amendments or byproducts. Inorganic nutrients are readily available to growing plants; in other words, they are already in a form that plants can readily uptake. Organic nutrients, on the other hand, must go through a *mineralization* process to become plant available. Mineralization is the conversion from an organic form to an inorganic form so that nutrients become plant available. It is performed by soil microbes and takes place over time. The rate is affected by soil temperature, moisture content, soil pH, and available food for the microbes. Organic nutrient sources are a “slow-release” nutrient source. However, if plant-available nutrients are needed in a short time for a crop, manure may not provide sufficient plant-available nutrients without being supplemented by a readily available (inorganic) nutrient source.

Crops require the following three major plant nutrients: N, P, and K. In this lesson and in other references, you will see P and K referred to in the oxide (or fertilizer) forms, which are P_2O_5 and K_2O. To convert from P to P_2O_5, multiply by 2.29. To convert from K to K_2O, multiply by 1.20. For

Inorganic nutrients are readily available to growing plants; in other words, they are already in a form for plant uptake. Organic nutrients, on the other hand, must go through a *mineralization* process to become plant available.

Table 31-1. Total manure nutrients produced by livestock and poultry. Nitrogen, P_2O_5 and K_2O production can be calculated by entering livestock or poultry operation information into Columns 2 and 3 for the appropriate animal species and multiplying by the relevant factors.

1. Livestock or Poultry Species	2. Number of animals (average capacity)	3. Average Weight, lbs	4. Total Animal Weight (No. x Avg. Weight)	5. Lbs of N/lbs of animal weight/yr	6. Lbs N/yr (Total weight x N)	7. Lbs o P_2O_5/lbs of animal weight/yr	8. Lbs P_2O_5/yr (Total weight x P_2O_5)	9. Lbs of K_2O/lbs of animal weight/yr	10. Lb K_2O/yr (Total weight x K_2O)
Example: Swine...Finish	*2,000*	*150*	*300,000*	*0.15*	*45,000*	*0.13*	*39,000*	*0.10*	*30,000*
Swine Nursery				0.22		0.21		0.15	
Grow				0.15		0.13		0.10	
Finish				0.15		0.13		0.10	
Sows & Litter				0.17		0.12		0.13	
Sows (Gestation)				0.07		0.05		0.05	
Gilts				0.088		0.066		0.058	
Boars				0.055		0.042		0.044	
Beef (450-750 lbs)				0.11		0.083		0.088	
Beef Feeder (high-energy diet)				0.11		0.078		0.092	
Beef Feeder (high-forage diet)				0.11		0.091		0.11	
Beef Cow				0.12		0.10		0.11	
Dairy Cow...50 lbs/d				0.18		0.087		0.100	
Dairy Cow...70 lbs/d				0.22		0.096		0.110	
Dairy Cow...100 lbs/d				0.27		0.110		0.130	
Dry Cow				0.11		0.074		0.079	
Heifer/Calves				0.11		0.033		0.11	
Layer				0.30		0.26		0.15	
Pullet				0.23		0.20		0.11	
Broiler				0.40		0.28		0.20	
Turkey				0.27		0.23		0.12	
Total: If more than one manure storage or treatment system is used for different groups of animals, it is best to separate the groupings of animals and their nutrient excretion totals for each manure system.				System 1:					
				System 2:					

Source: NRCS Agricultural Waste Management Field Handbook, 1992 with exception of lactating and dry dairy cows. Dairy estimates are from Van Horn 1991.

example, to apply 40 pounds of P, you must apply 40 x 2.29 = 91.6 pounds of P_2O_5. Most soil test recommendations already use the oxide forms of P and K; in that case, these conversions are not required.

Nitrogen is found in the soil and animal manures in several forms. The largest percentage of N in raw manure is in the organic form and is not directly plant available. Organic N must be mineralized to inorganic forms such as ammonium-N and nitrate-N to become plant available. The term "plant-available nitrogen" (PAN) is used to describe the portion of the total N that is available for crop uptake. Figures 31-2 and 31-3 show the forms of manure N.

Plant-available N, then, is the total of the following three forms of N:

(1) The organic form of N x an estimated mineralization rate

(2) The ammonium-N form x a volatilization factor reflecting the method of application and time of year

(3) The nitrate-N and nitrite-N fraction (these are almost nonexistent in manure unless there has been some aeration or agitation in manure treatment)

Plant-available N can be expressed as a formula representing these three N components:

PAN = M.R. (organic N) + V.F. (ammonium-N) + (nitrate-N + nitrite-N)
where M.R. is the mineralization rate and V.F. is the volatilization factor

Most laboratories report total manure nutrients, and the producer must apply a plant availability factor to determine the actual nutrients available to the crop.

Most laboratories report total manure nutrients, and the producer must apply a plant availability factor to determine the actual nutrients available to the crop. If a lab provides an estimate of plant-available nutrients, check their plant-available factors to be sure it fits your situation. Some typically used availability coefficients can be found in Table 31-2.

When providing manure analysis, the laboratory will ideally give you the results in the same units of measure as you calibrate your manure application system... .

When providing a manure analysis, the laboratory will ideally give you the results in the same units of measure as you calibrate your manure application system (for example: pounds of nutrients per ton of manure or pounds of nutrients per 1,000 gallons). The lab results should be on a wet, or "as-is," basis for your manure. Otherwise, additional calculations must be made after lab analyses are received. Some labs also will provide nutrient analyses as plant-available nutrients, so that no calculations at all are necessary prior to manure application. If you do not receive results as plant available, you must use the availability coefficients found in Table 31-2. If the lab reports manure analyses in parts per million (abbreviated ppm) or milligrams per liter (abbreviated mg/l), you must convert these units to pounds. Milligrams per liter and ppm can be assumed to be equal units of measure (1 ppm = 1 mg/l). The conversion factors used for this situation are as follows:

For liquid or slurry manures

(a) ppm (mg/l) x 0.226 = pounds per acre-inch

(b) ppm (mg/l) x 0.008 = pounds per 1,000 gallons

For solid manures and composts

(a) ppm (mg/l) x 0.002 pounds per ton

To receive lab results in plant-available nutrients, you must supply the application equipment and method used for manure application (for example, surface broadcast with tanker spreader without incorporation). If you are

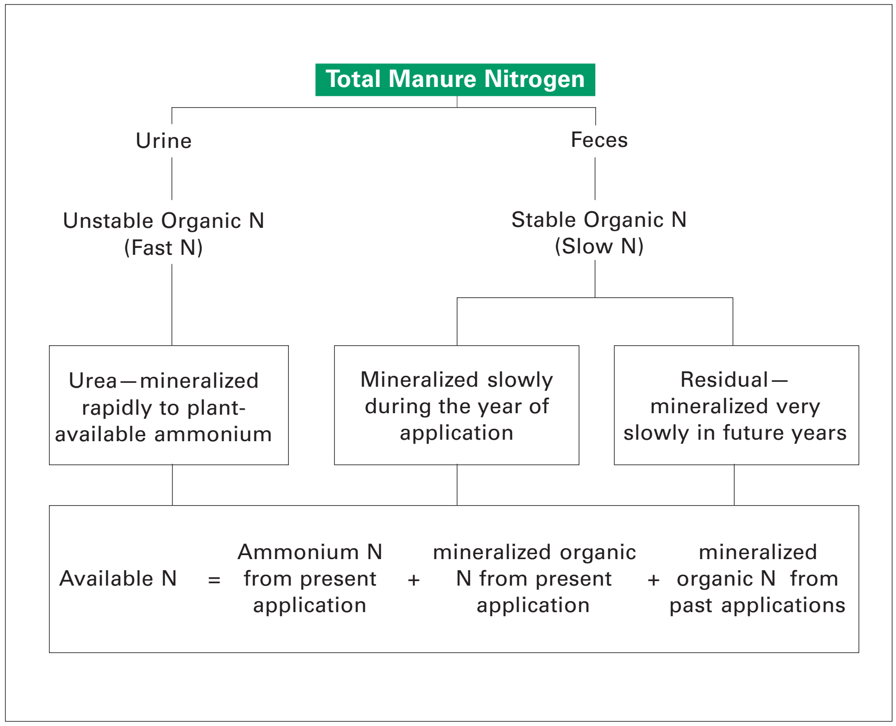
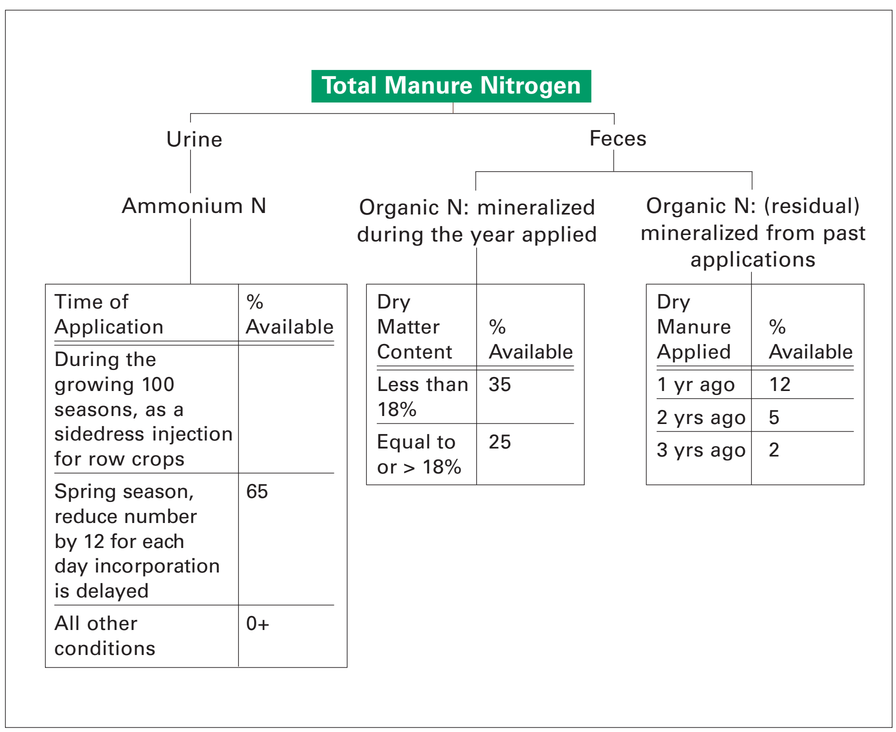


Figure 31-2. Form and degree of N availability in manure.



Time of Application	% Available
During the growing seasons, as a sidedress injection for row crops	100
Spring season, reduce number by 12 for each day incorporation is delayed	65
All other conditions	0+

Dry Matter Content	% Available
Less than 18%	35
Equal to or > 18%	25

Dry Manure Applied	% Available
1 yr ago	12
2 yrs ago	5
3 yrs ago	2

Figure 31-3. Estimated availability of the different forms of N in manure.

using incorporation, the timing between application and incorporation must also be known. If you are using an irrigation or tanker-spreader manure application method, it is easiest to know the plant-available nutrients per 1,000 gallons of manure or per acre-inch (one acre-inch = 27,000 gallons). With a litter spreader or other types of solid spreaders, you need to know pounds of plant-available nutrients per ton of manure.

Table 31-3 shows manure nutrients after losses for a variety of manure storage and treatment methods. It starts with data generated from Table 31-1 and does not account for the application losses shown in Table 31-2. Table 31-4 is used to estimate P_2O_5 in anaerobic lagoon sludge. Table 31-6 is a more specific version of Table 31-2 for N. Specifics on application timing and temperature are needed to use these estimates. Use Table 31-2 to complete Table 31-5, which is the N summary after losses.

When assessing manure generation rates, you should also consider if there will be special cases periodically where additional manure might have to be handled. This is not an issue when a confinement house or barn is periodically and regularly cleaned out. It is necessary though, for example, when using an anaerobic lagoon. Periodic sludge removal will generate nutrients that must be land applied, and this should be budgeted. Sludge generation in a lagoon depends on many factors and can be highly variable, but if a plan is made with estimates on sludge quantity and nutrient content, then the overall manure management plan (strategic plan) will not suffer when it comes time for sludge application. Fields should be readily available for periodic sludge cleanouts by having appropriate crop rotations available.

Table 31-2. Livestock manure nutrient first-year availability coefficients.

	Application Method								
	Soil incorporation			Broadcast			Irrigation		
Type of Manure	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Scraped manure									
Dairy	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Beef	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Swine	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Sheep/Goat	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Horse, stable	0.5	0.8	1.0	0.5	0.7	0.9	*	*	*
Poultry house litter									
All poultry litters	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Liquid manure slurry									
Dairy	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Beef	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Swine	0.7	0.8	1.0	0.4	0.7	1.0	0.3	0.7	1.0
Layer	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Anaerobic lagoon liquid									
Dairy	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Beef	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Swine	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Layer	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0

* Not applicable

Table 31-3. Nutrients available (annually) after losses from open lot, storage, or lagoon.[1] Enter the total manure nutrients produced (from Table 31-1) in Columns 2, 5, and 8 and multiply by the relevant factor describing your manure management system.

	N			P_2O_5			K_2O		
1. Manure Storage/Treatment System	**2. N Produced (Table 31-1)**	**3. Multi-plication Factor[1]**	**4. Available N After Losses**	**5. P_2O_5 Produced (Table 31-1)**	**6. Multi-plication Factor[1]**	**7. Available P_2O_5 After Losses**	**8. K_2O Produced (Table 31-1)**	**9. Multi-plication Factor [1]**	**10. Available K_2O After Losses**
Example: Storage (liquid manure,									
Open lot or feedlot		X 0.6 =			X 0.95 =			X 0.7 =	
Manure pack under roof		X 0.70 =			X 1.0 =			X 1.0 =	
Bedded pack for swine (e.g., hoop building)[1]		X 0.50 =			X 1.0 =			X 1.0 =	
Bedded pack & compost for swine (e.g., hoop building)[1]		X 0.35 =			X 1.0 =			X 1.0 =	
Solid/semi-solid manure & bedding held in roofed storage		X 0.75 =			X 1.0 =			X 1.0 =	
Solid/semi-solid manure & bedding held in unroofed storage		X 0.65 =			X 0.95 =			X 0.9 =	
Liquid/slurry storage in covered storage		X 0.90 =			X 1.0 =			X 1.0 =	
Liquid/slurry storage in uncovered storage		X 0.75 =			X 1.0 =			X 1.0 =	
Storage (pit beneath slatted floor)		X 0.85 =			X 1.0 =			X 1.0 =	
Poultry manure stored in pit beneath slatted floor		X 0.85 =			X 1.0 =			X 1.0 =	
Poultry manure on shavings or sawdust held in housing		X 0.70 =			X 1.0 =			X 1.0 =	
Compost		X 0.70 =			X 0.95 =			X 0.9 =	
1-Cell anaerobic treatment lagoon		X 0.20 =			X 0.35 =			X 0.65 =	
Multi-cell anaerobic treatment lagoon[1]		X 0.10 =			X 0.35 =			X 0.65 =	

[1]Multiplication factor is portion of nutrients retained in the manure. Remaining N volatilizes into air as ammonia and remaining phosphate settles to lagoon bottom as solids or is lost as runoff in open lot. Actual losses for individual situations may vary substantially from listed values.

Table 31-4. Phosphorus retained as settled solids by an anaerobic treatment lagoon.[1] To complete the calculation, enter quantity of total manure P estimated from Table 31-1 and interval (years) between when settled solids are removed.

	Total Pounds Produced Annually from Table 31-1	1-Cell & Multiple Cell Treatment Lagoon		
		Years Between Solids Removal	Portion Retained in Lagoon	Total P_2O_5 in Settled Solids
Phosphate		x	x 0.65 =	

[1]This applies to an anaerobic treatment lagoon with a permanent liquid pool and no agitation at the time of effluent removal.

Table 31-5. Potential N available after accounting for ammonia volatilization during land application.

Manure Source	A. Available N after Storage/Treatment Losses (value from Table 31-3)	B. Fraction of N Remaining after Land Application (see Table 31-2)	Potential N Available after Storage and Land Application Losses Total = A x B
1.			
2.			
3.			

The nutrient value of manure can also fluctuate. Factors that affect the nutrient levels include

- The application method used (see Table 31-2).
- The animal diet (ration composition).
- The handling/treatment of the manure between animal excretion and land application (Table 31-3).
- Time of year (season, temperatures).
- Length of time of manure in storage structure and level of sludge buildup.

All of these reasons help to justify a regimen of routine manure sampling for nutrient value.

Other nutrient sources

When developing a manure utilization plan, consider all sources of nutrients on your farm. Sources of nutrients include nutrients already in the soil, commercial fertilizers, crop residues, and other manure or byproduct applications. To account for these nutrients, you can use manure and soil analysis. For example, legumes can leave many pounds of PAN for the following crops (see Table 31-6). Manure and soil analysis will be covered in other sections. When planning manure applications, the producer should account for all of these nutrient sources before determining manure application rates to fields.

When developing a manure utilization plan, consider all sources of nutrients on your farm.

Table 31-6. Nitrogen residual following some legume crops.

Crop Type	Pounds of N Available for Next Crop, Per acre
Peanuts	20-40
Clover	40-100
Alfalfa	50-125
Soybeans	30-45
Hairy vetch	80-100

A strategy of applying sufficient nutrients for crop growth, without overapplying nutrients, is called *nutrient sufficiency strategy,* or *agronomic rate.*

Amount

Nutrient sufficiency strategy

A strategy of applying sufficient nutrients for crop growth, without overapplying nutrients, is called *nutrient sufficiency strategy*, or *agronomic rate.* In a manure utilization system, you must know the crops to be grown, their nutrient requirements, and when they are actively taking up nutrients. You will also need to estimate and document realistic yield expectation (R.Y.E.). From this information, one is able to calculate the amount of manure that can safely be applied.

Insufficient applications will result in nutrient deficiencies, which can reduce crop yield and quality as well as decrease utilization of manure nutrients. Excessive applications can negatively affect both the plant and the environment. The effect of too much fertilization on plant growth depends on the crop and nutrients involved. In most cases, too much P and K have little effect on plant growth and yield unless so much is applied that salt injury results. However, too much P in the soil may have negative environmental consequences with P leaving the site.

Too much N can reduce yields by making plants more susceptible to diseases and insects, increasing lodging, and stimulating vegetative growth at the expense of fruit or grain production. Excess metals, such as copper and zinc, can be toxic to plants. In extreme cases, soil concentrations of these metals can be high enough to limit or prevent the growth of certain crops. Soil levels of nutrients should be regularly checked (recommend annually) with a soil test for each field receiving manure.

Soil test results give recommendations for nutrient applications for major plant nutrients (N, P, K), secondary plant nutrients (calcium, magnesium, sulfur), and micronutrients. Most manure utilization plans target N and P; therefore, they are the major nutrients on which to base manure application rates. Because P is not a highly mobile nutrient in the soil, soil testing for P gives a relatively accurate assessment of P availability in the soil and P needs for subsequent crops.

Nitrogen, however, is highly mobile in the soil and is constantly going through transformations such as mineralization, leaching, volatilization, and immobilization. Therefore, soil testing for N results in less accuracy. Some areas in the United States use soil nitrate testing for pre-plant or pre-sidedress N recommendations. Where sample results can be obtained quickly, this test is valuable and can assist the farmer with nutrient (fertilizer or manure) applications. However, with N application, using crop data and R.Y.E. results are generally a better tool than soil testing to determine N application rates.

Crop selection and nutrient requirements

To determine the amount of manure to apply, you must know the nutrient requirements of the crops to be planted. Crops are an integral part of the system. In a manure management system, the function of the crop is to

- Use the applied nutrients.
- Prevent soil erosion.
- Take up water.
- Provide food and habitat for organisms in the soil that further break down and use the manure.
- Provide economic return.

Without a crop to actively utilize nutrients and prevent erosion, nutrients applied in manure could be washed directly into surface streams or leached into the groundwater. The vegetative cover reduces the potential for runoff and erosion from an area. The root system in a cover crop holds soil together and provides a network of openings, or pores, for water to infiltrate (move into) soil rather than run off.

When selecting a crop, there are numerous considerations other than nutrient requirement. Two such considerations are ease of management and economic value of the crop. Ease of management varies with cropping system. Other factors to be considered include

- Adaptation to the local climate.
- Ability to use nutrients when manure applications must be made.
- Harvest requirements.
- Marketability and profitability.
- Yield.
- Suitability to soil conditions.

Crops vary in their ability to use nutrients. Some examples of the nutrient uptake by common crops are shown in Table 31-7. Please note that this table is generalized for the United States, and specific data for your region should be obtained from local experts with the NRCS, Cooperative Extension Service (CES), or land-grant university.

Realistic Yield Expectations (R.Y.E.)

Final crop yields are not determined by soil fertility alone. Other factors such as soil management, climate, plant population, timing, pest control, and variety selection are also important. Because the amount of nutrients required by a crop usually varies directly with the yield, expected yields must be estimated on different fields. Yields vary with weather conditions, soils, cultivars, pest pressure, level of management, and many other factors; therefore, the best way to estimate yield potential is to use existing production records. Where records are available, you can average the three highest yields in five consecutive crop years for the field. Increased yields due to the use of new, improved varieties and hybrids should be considered when yield goals are set for a specific field. Realistic yield expectations is the estimated crop yield for a given field.

Where records are not available, as with most new operations, some method of estimating yield is needed. The NRCS, in conjunction with state Agricultural and CES specialists, put together R.Y.E. values for agricultural soils. These values are based on inherent soil properties and long-term observations. They are intended to represent high levels of management but

To determine the amount of manure to apply, you must know the nutrient requirements of the crops to be planted. Crops are an integral part of the system.

When selecting a crop, there are numerous considerations other than nutrient requirement.

Table 31-7. Plant nutrient uptake by specified crop and removed with the harvested part of the crop.

Crop	N	P_2O_5	K_2O	Units
Grain Crops				
Barley (Grain)	0.87	0.37	0.25	lbs/bu.
(Straw)	15.00	5.04	30.12	lbs/ton
Buckwheat (Grain)	0.79	0.34	0.26	lbs/bu.
(Straw)	15.60	2.29	54.46	lbs/ton
Corn Grain (Grain)	0.90	0.36	0.27	lbs/bu.
(Stover)	22.20	9.16	32.29	lbs/ton
Oats (Grain)	1.27	0.51	0.38	lbs/bu.
(Straw)	12.60	7.33	40.00	lbs/ton
Rice (Grain)	0.63	0.25	0.12	lbs/bu.
(Straw)	12.00	4.12	27.95	lbs/ton
Rye (Grain)	1.16	0.33	0.33	lbs/bu.
(Straw)	10.00	5.50	16.63	lbs/ton
Sorghum (Grain)	0.94	0.46	0.28	lbs/bu.
(Stover)	21.60	6.87	31.57	lbs/ton
Wheat (Grain)	1.25	0.85	0.38	lbs/bu.
(Straw)	13.40	3.21	23.37	lbs/ton
Oil Crops				
Flax (Grain)	2.29	0.71	0.57	lbs/ton
(Straw)	24.80	5.04	42.17	lbs/ton
Peanuts (Grain)	36.00	3.89	6.02	lbs/1,000 lbs
(Vines)	46.60	10.99	42.17	lbs/ton
Rapeseed (Grain)	1.80	0.90	0.46	lbs/bu.
(Straw)	89.60	19.69	81.20	lbs/ton
Soybeans (Grain)	3.75	0.88	1.37	lbs/bu.
(Stover)	45.00	10.08	25.06	lbs/ton
Sunflower (Grain)	35.70	39.16	13.37	lbs/1,000 lbs
(Stover)	30.00	8.24	70.36	lbs/ton
Fiber Crops				
Cotton	26.70	13.28	10.00	lbs/1,000 lbs
(Seed Stalk)	17.50	5.04	17.47	lbs/1,000 lbs
Pulpwood	0.12	0.05	0.07	%
(Bark & branches)	0.12	0.05	0.07	%
Forage Crops				
Alfalfa	45.00	10.08	45.06	lbs ton
Bahiagrass	25.40	5.95	41.69	lbs/ton
Big bluestem	19.80	38.93	42.17	lbs/ton
Birdsfoot trefoil	49.80	10.08	43.86	lbs/ton
Bluegrass-pastd.	58.20	19.69	46.99	lbs/ton
Bromegrass	37.40	9.62	61.45	lbs/ton
Clover-grass	30.40	12.37	40.72	lbs/ton
Dallisgrass	38.40	9.16	41.45	lbs/ton
Guineagrass	25.00	20.15	45.54	lbs/ton
Bermudagrass	37.60	8.70	33.73	lbs/ton
Indianagrass	20.00	38.93	28.92	lbs/ton
Lespedeza	46.60	9.62	25.54	lbs/ton
Little bluestem	22.00	38.93	34.94	lbs/ton
Orchardgrass	29.40	9.16	52.05	lbs/ton
Panagolagrass	26.00	21.53	45.06	lbs/ton
Paragrass	16.40	17.86	38.31	lbs/ton
Red clover	40.00	10.08	40.00	lbs/ton
Reed canarygrass	27.00	8.24	–	lbs/ton
Ryegrass	33.40	12.37	34.22	lbs/ton
Switchgrass	23.00	4.58	45.78	lbs/ton

Table 31-7. (continued)

Crop	N	P_2O_5	K_2O	Units
Forage Crops (continued)				
Tall fescue	39.40	9.16	48.19	lbs/ton
Timothy	24.00	10.08	38.07	lbs/ton
Wheatgrass	28.40	12.37	64.58	lbs/ton
Silage Crops				
Alfalfa haylage	27.90	7.56	27.95	lbs/ton
Corn silage	7.70	4.01	9.19	lbs/ton
Forage sorghum	8.64	2.61	7.37	lbs/ton
Oat haylage	12.80	5.13	9.06	lbs/ton
Sorghum-sudan	13.60	3.66	17.47	lbs/ton
Sugar Crops				
Sugarcane	3.20	1.83	8.92	lbs/ton
Sugar beets	4.00	1.37	3.37	lbs/ton
Sugar beet tops	8.60	1.83	24.82	lbs/ton
Tobacco				
All types	37.50	7.56	60.00	lbs/1,000 lbs
Vegetable Crops				
Bell peppers	8.00	5.50	11.81	lbs/ton
Beans, dry	62.60	20.61	20.72	lbs/ton
Cabbage	6.60	1.83	6.51	lbs/ton
Carrots	3.80	1.83	6.02	lbs/ton
Cassava	8.00	5.95	15.18	lbs/ton
Celery	3.40	4.12	10.84	lbs/ton
Cucumbers	4.00	3.21	7.95	lbs/ton
Lettuce (heads)	4.60	3.66	11.08	lbs/ton
Onions	6.00	2.75	5.30	lbs/ton
Peas	73.60	18.32	21.69	lbs/ton
Potatoes	6.60	2.75	12.53	lbs/ton
Snap beans	17.60	11.91	23.13	lbs/ton
Sweet corn	17.80	10.99	13.98	lbs/ton
Sweet potatoes	6.00	1.83	10.12	lbs/ton
Table beets	5.20	1.83	6.75	lbs/ton

Source: NRCS Agricultural Waste Management Field Handbook 1992.

should be viewed as estimates only, since they may not reflect irrigation, new cultivars, and improved management tools. Information on your soils may be obtained through the NRCS county field office. Local farmers, fertilizer dealers, and custom harvest companies may also be able to provide yield data.

Once a R.Y.E. is determined for a soil type, the required amount of N to apply can be determined. Table 31-7 can be used to determine the N requirement.

Knowing your manure application rate allows you to calculate the total acreage you need for manure application.

EXAMPLE 3

How much N should be applied when growing corn (for grain) where the R.Y.E. is 140 bushels/acre?

From Table 31-7, the N requirement is 0.90 lb N/bushel of grain.

N application rate =

140 bu/acre x 0.90 lb N/bushel = 126 lbs N/acre

EXAMPLE 4

What is the manure application rate for the above cornfield if you are surface broadcasting dairy manure slurry without incorporation? The recent manure analysis shows 10.4 pounds of available N per 1,000 gallons of slurry (Note: Without a manure analysis, this number is generated from Tables 31-1 and 31-2).

Manure Application rate (gal/acre) =

$$\frac{\text{crop nutrient (N) requirement (lb/acre)}}{\text{pounds of N from manure analysis}}$$

Manure Application Rate (gal/acre) =

$$\frac{\text{126 lbs N/acre}}{\text{10.4 lbs N/1,000 gal}} = \text{12,115 gal/acre}$$

Knowing your manure application rate allows you to calculate the total acreage you need for manure appplication. This is determined by

Acres needed for manure application =

$$\frac{\text{gal (or tons) of manure produced annually}}{\text{manure application rate, gallons (or tons)/acre}}$$

EXAMPLE 5

If your dairy operation generates approximately 80 tanker loads of manure slurry per year, at 4,000 gallons per tanker (total of 320,000 gallons per year), how many acres of corn (for grain) are required to handle the manure application (based on N)?

Acres needed for manure application =

$$\frac{320{,}000 \text{ gal/year}}{12{,}115 \text{ gal/acre}} = 26.4 \text{ acres}$$

Of course, if you are using several crop types, this must be done for each crop type (see summary worksheets at the end of the lesson).

EXAMPLE 6

Farmer Ortiz uses 50 acres of bermudagrass for manure application and grazes cattle on the land in a rotational sequence. He expects to produce 5 tons of hay per acre based on the soil type. How much PAN per acre must he apply to meet his needs for grazing?

To find the amount of plant-available N per acre to be applied,

Application rate (lbs PAN/acre) =

$$\frac{\text{realistic yield (lbs, tons, or bushels)}}{\text{acre}} \times \frac{\text{lbs PAN}}{\text{unit of yield}}$$

$$\text{Application rate (lbs PAN/acre)} = \frac{5 \text{ tons}}{\text{acre}} \times \frac{37.6 \text{ lbs PAN}}{\text{ton of yield}}$$

$$= 188 \text{ lbs PAN/acre}$$

Current guidelines show that the PAN rate for grazed land is 60% to 75% of the hay PAN rate. The 188 pounds PAN per acre rate above must be adjusted for the grazing as follows:

Application rate (lbs PAN/acre) =
188 lbs PAN/acre × 0.7 = 132 lbs PAN/acre*

*Note: 70% factor used for pasture.

Manure application rates

With values for plant-available nutrient content of the manure (from sampling or from Tables 31-1 and 31-2) and R.Y.E.s for the crop, we can now determine the manure application rate for the field. If you have a plan (or state regulations) that requires both N- and P-based limits for manure application, then you must determine which nutrient limits the manure application volume. Let's look at a specific example.

As you can see, the manure application will be restricted by the crop's P needs. Compared to the application rate required by N, about 2.5 times the land area will be required (assuming this same crop) to handle the manure generated at the farm. Worksheets in Appendix C may be used to summarize acreage needs for manure utilization plans based on N and P. In the above case, if the manure were applied to meet the crop's P needs, supplemental N from another source would be required. See Example 8 to determine how this is calculated.

EXAMPLE 7

If Farmer Jones' manure analysis shows 2.0 pounds N per 1,000 gallons of lagoon liquid and 3.5 pounds of P_2O_5 per 1,000 gallons, what is his manure application rate to apply 125 pounds of N per acre?

Manure application rate (gal/acre) =

$$\frac{\text{crop N requirement (lbs/acre)}}{\text{Lbs of N from manure analysis}}$$

Manure application N rate (gal/acre) =

$$\frac{\text{125 lbs N/acre}}{\text{2.0 lbs N/10,000 gal}} = \text{62,500 gal/acre}$$

This will supply the proper amount of N to the corn crop. Now let's determine the manure application rate based on P. The application rate based on P then is as follows:

Manure application rate (gal/acre) =

$$\frac{\text{crop P requirement (lbs/acre) from soils test}}{\text{Lbs of P from manure analysis}}$$

Manure application N rate (gal/acre) =

$$\frac{\text{80 lbs P/acre}}{\text{3.5 lbs P/10,000 gal}} = \text{22,857 gal/acre}$$

EXAMPLE 8

How much supplemental N is required in the previous example?

Farmer Jones applies 22,857 gal/acre based on the crop's P needs. This will supply

22,857 gal/acre x 2.0 #N/1,000 gallons manure = 45.7 #N/acre

Since the target rate for N is 125 #/acre, the supplemental N needed is

125 #N/acre - 45.7 #N/acre = 79.3 #N supplemented

Manure typically provides more P than the crop needs when applying to meet N needs. Crop uptake of N and P is in a ratio ranging from 4 to 9 pounds of N per pound of P. Manure is generally excreted at an N to P ratio of 2 or 3 to 1. This often causes a buildup of P in the soil, leading to high or very high soil test P levels. Because of this, where manure utilization plans are based on N, fields receiving livestock manure require regular soil testing with close monitoring of P levels. If you do not have enough land to handle the manure produced, several options and explanations are provided in Lesson 25, Manure Treatment Options.

Soil test recommendations

No one plant nutrient is more important than any other. All are essential for plant growth and expected yields. While we focus on N and P in nutrient management plans, a complete nutrient balance is needed for a crop to complete its growth cycle. Many of the micronutrients, for example, boron, copper, zinc, manganese, and molybdenum, are adequately supplied by the soil's natural reserves. However, a representative soil test (and sometimes plant tissue analysis) is necessary to verify the adequacy of all plant nutrients. Producing a healthy, productive crop is crucial to sustained use of manure in agricultural systems.

While we focus on N and P in nutrient management plans, a complete nutrient balance is needed for a crop to complete its growth cycle. …a representative soil test…is necessary to verify the adequacy of all plant nutrients.

Figure 31-4 Crop stress due to nutrient deficiency or toxicity is costly to the producer and the environment.

With the exception of N, soil testing is a means of determining soil levels and recommended application amounts of most other plant nutrients. Soil testing for N was mentioned above. To assess soil N levels, some growers use a pre-sidedress nitrate test prior to planting or fertilizer sidedressing. Soil testing is also necessary to determine soil pH and to obtain lime recommendations that adjust the soil pH to a range suitable for crop growth. Most soil test labs will give a nutrient recommendation for N, P, K, and the secondary nutrients and micronutrients, if needed. These recommendations are typically in pounds per acre.

Many labs use some type of index or reference value for plant nutrients. These indexes may be categorized as low, moderate, high, and very high, and are based on the "expected" plant response to additional nutrients. They correspond to a recommendation for a nutrient application. If a manure utilization plan is based on P, for example, and the soil test level of P is high (no recommendation for additional P), then the operator should consider other options for manure utilization. These options include

- Applying manure to another field or farm.
- Applying manure based on P removal for the subsequent crop, and supplement the crop with commercial N and K for additional needs, as required.
- Reducing the nutrients in your manure by further treating the manure prior to application.
- Allowing crops to "mine" existing P from the soil before adding more.

One of the most important pieces of information to be gathered from the soil test is the recommendation for lime to obtain proper soil pH. Nutrient availability in soils is very dependent on proper soil pH. If soil pH is not closely monitored (recommend annually for fields receiving manure applications), nutrient availability and uptake may be very different from expected results.

Placement

Application method

Manure placement affects a crop's ability to utilize most of the applied nutrients and the likelihood of manure runoff from the site.

Manure placement affects a crop's ability to utilize most of the applied nutrients and the likelihood of manure runoff from the site. Application to the soil surface typically results in greater potential for N loss through volatilization (escape as a gas) and runoff than where manures are incorporated (mixed with the topsoil) or injected. Uniformity of nutrient applications and distance from the root system can also influence crop response to nutrient applications. The method of application can also affect odor. Careful placement also means irrigating at rates that prevent runoff.

Nutrient losses

Manure placement can affect the efficiency of crop use and the likelihood of nutrient loss from the soil. Surface-applied nutrients are more subject to loss by erosion from heavy rains, and under dry conditions, will remain on the soil surface and be unavailable to plant roots. Surface-applied lagoon liquids contain ammonium-N, which can escape as ammonia gas. Incorporation into the soil improves crop utilization. Solid manures such as feedlot pen manure contains very little ammonium-N, making incorporation less critical for conserving N. Surface-applied P is easily lost in runoff unless

Figure 31-5. Uniformity of manure application is critical for proper nutrient management.

Figure 31-6. Nutrients applied unevenly affect both your crops and the environment.

adequate erosion control is achieved. Incorporation within the root zone increases plant availability of P.

The method of application can also affect nutrient availability. Placement often depends on the type of application equipment that is available or the method that is most cost or time effective. You should also review your farm conservation plan to see if crop residue should be conserved. Many growers choose broadcast nutrient application because of fewer time constraints and lower cost. Broadcast applications can be made by a tank spreader or by irrigation. Where nutrient utilization is a prime consideration, the handling system may dictate the application method. For example, solid or semisolid materials cannot be effectively injected into the soil or applied through an irrigation system, while lagoon liquids are most economically applied through an irrigation system. The application rate of the irrigation equipment will also determine if the manure moves into the soil or runs off. The operator

Figure 31-7. Buffer strips along ditches and streams reduce the risk of nutrient transport into surface waters.

should review the specifications of the irrigation equipment and make adjustments if necessary to ensure that applied manure does not run off from the application site.

The manager of the land application system must be familiar with the required buffers or setbacks for manure application.

Site considerations

The manager of the land application system must be familiar with the required buffers or setbacks for manure application. Typically, there are setbacks from property lines, homes, surface waters, wells, road right of ways, and public use areas. These considerations are addressed in Lesson 30, Soil Utilization of Manure.

Timing

It has been said, with respect to nutrient management, that timing is everything. While there are certainly other factors that affect crop yields and nutrient management, timing is very important. If crops have access to nutrients when they are needed, quality and yields are higher. If, however, nutrients are supplied at times when crop need is low or nonexistent, then these nutrients pose a greater environmental risk, especially in regions with higher rainfall. Also, applications when the soil is saturated may lead to nutrient movement.

Some common crops grown to use nutrients in manure are shown in Table 31-8. A cropping system with a variety of crops offers the most flexibility for manure application during the seasons of the year.

Crop growth rates and application conditions are not uniform throughout the year and neither are crop nutrient requirements.

Scheduling manure applications

Crop growth rates and application conditions are not uniform throughout the year, and neither are crop nutrient requirements. Realizing this fact, you need to understand when it is or is not appropriate to land apply manure. All nutrient sources should be applied at times that will maximize crop use and minimize loss. Ideally, manure nutrients should be applied to an actively growing crop or within 30 days of planting a crop. If crops for human consumption are to be grown, consult your state's health agencies for specific requirements. Timing is most important for nutrients applied to soils with a high leaching potential. Applying N to a sandy soil when there is no crop to remove it will almost certainly result in N loss to the shallow groundwater.

Recommendations that are used in your local area for fertilizer N conservation (reduced leaching) should also be used for manure N. Manures that have primarily organic N can be successfully applied in the fall, prior to spring planting, if erosion and runoff control measures are in place.

Storage factors

In some cases, manure storage capacity dictates the frequency of manure applications. Low manure storage capacity will require frequent applications and year-round cropping systems, while larger storage volumes may allow less frequent applications to a single crop. Many storage structures are designed for 180 to 270 days of temporary storage. If the same fields are to be used, this means an actively growing crop must be present in both summer and winter. Double cropping or overseeding of perennial forages can be used to accomplish this, but a higher level of management is required to make this system work properly. For existing facilities, the temporary storage volume should be known, or can be calculated, and used to determine the number of days of temporary storage. Because manure production and storage capacity determine the maximum amount of time between manure applications, these factors strongly influence crop selection.

As seen in Figure 31-8, there are several months during the year when most crops are dormant. For example, bermudagrass is dormant in January and February, and growth is "slow" during March, November, and December. If the crop is not actively growing, there is little or no nutrient uptake. In this situation, any N applied to the bermudagrass field could leach through the soil and move down toward the water table. Consequently, land application is not generally recommended during dormant periods.

The risk of encountering an emergency situation can be significantly reduced by utilizing a flexible cropping system that permits manure application throughout most of the year.

Table 31-8. Crops useful for manure utilization and their maximum uptake period in the southeastern United States.[1]

Crop	Uptake Period[2]
Corn (grain)	April–July
Corn (silage)	April–July
Sorghum (grain)	April–July
Small grains (grain)	Feb.–April
Small grains (hay, pasture)	Feb.–April
Soybean	July–Sept.
Cotton	June–August
Bermudagrass (hay, pasture)	April–Sept.
Tall fescue (hay, pasture)	Sept.–Nov. & Feb.–April
Alfalfa (hay)	May–August
Annual ryegrass (hay, silage, pasture)	Feb.–April & Sept.–Oct.
Millet (hay, silage)	May–August

[1] Relevant crop growth periods for your local area should be substituted in this table.
[2] Application should occur no more than 30 days before planting or greenup of perennial forages.

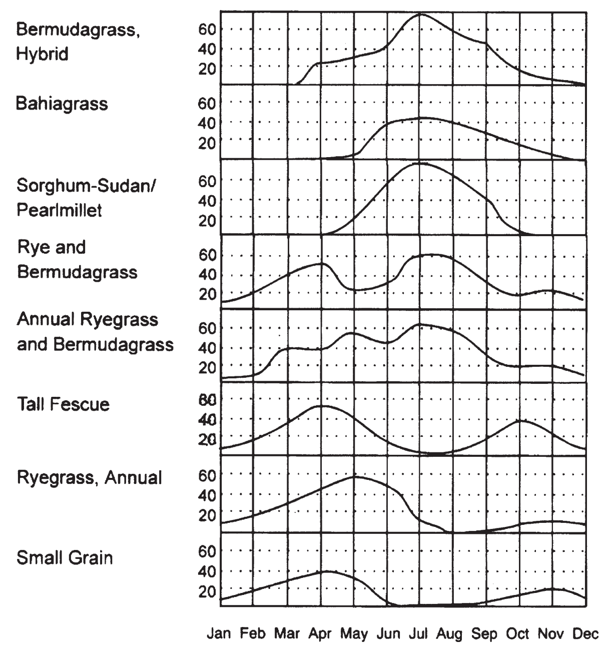


Figure 31-8. Growth rate of selected forage crops. Growth is expressed as pounds of forage produced per day per acre.

The risk of encountering an emergency situation can be significantly reduced by utilizing a flexible cropping system that permits manure application throughout most of the year. For example, if bermudagrass is overseeded with rye in the winter, you have a cropping system in place that can accept some manure during every month in most years. There may still be one or two consecutive months when fields are too wet to apply manure. In a bermudagrass/rye cropping system, the peak storage duration in the lagoon is only for the wet weather period, rather than the five months or longer required if only bermudagrass is being grown.

Following is a planning calendar that can be used as a checklist for items relevant to manure applications to fields. This checklist is meant to serve as a guide only. Individual topics may or may not be relevant to your specific situation, and timing issues may be different depending on your location and length of growing season.

Manure Utilization Planning Calendar

December – February
- ❑ Review manure utilization plan and make changes, if necessary
- ❑ Perform service on manure application equipment
- ❑ Review manure utilization plan, best management practices, and application rates
- ❑ Review crop yields and overall productivity
- ❑ Adjust plan with assistance from technical specialist with NRCS, Cooperative Extension Service, Soil and Water Conservation District, or university
- ❑ Make records of carryover nutrients from previous crops/fall manure applications

March
- ❑ Soil test (if testing for N) each field that receives manure applications*
- ❑ Sample all sources of manure
- ❑ Calculate manure application rates for each crop and each field in the plan
- ❑ Apply lime or other soil pH amendments
- ❑ Make manure applications to cool season grasses/forages

April
- ❑ Make pre-plant manure applications
- ❑ Supplement with commercial fertilizer as per soil test
- ❑ Calibrate manure application equipment
- ❑ Scout for pests and other crop stresses-plant sample, if necessary

May
- ❑ Make manure application to warm season grasses/forages
- ❑ Sidedress row crops with manure/commercial fertilizer
- ❑ Hay harvest as appropriate-maintain yield records

June – August
- ❑ Scout for pests and other crop stresses-plant sample, if necessary
- ❑ Manure applications to pastures/hayland
- ❑ Sample all sources of manure
- ❑ Hay harvest as appropriate-maintain yield records
- ❑ Harvest silage/grain-maintain yield records

September
- ❑ Sample all sources of manure
- ❑ Calculate manure application rates for each crop and each field in the plan
- ❑ Pre-plant manure applications for fall/winter crops
- ❑ Plant winter annuals and cover crops
- ❑ Manure applications to cool season grasses/forages

October – November
- ❑ Soil sample all fields (unless sampling in spring to include N from soil)
- ❑ Manure applications to cool season grasses/forages
- ❑ Complete harvest of soybeans/cotton/etc.
- ❑ Maintain yield records
- ❑ Plant winter cover crops to all fallow fields

Monthly
- ❑ Monitor manure storage ponds, lagoons, and tanks for manure level
- ❑ Monitor manure pumps and piping to ensure proper operation
- ❑ Monitor rainwater diversions and runoff prone areas to ensure no loss of manure from the farm
- ❑ Complete manure application records and compare to manure utilization plan

*This window will vary with region of the United States. Check with local experts.

Best Management Practices (BMPs)

Best management practices refer to those management practices that can be used to generate maximum utilization of on-farm nutrients while protecting the environment. In addition to the practices discussed throughout this lesson, erosion control and water management play an important role in responsible nutrient management. Lesson 32, Land Application Best Management Practices, will offer some detailed examples of common BMPs used in manure utilization systems.

Summary

This lesson focuses on land application as the primary component of the manure utilization plan. This is most often the case. However, where manure nutrients are utilized in other ways, such as removal from the farm, the producer should take these situations into account and modify the manure utilization plan and nutrient budget balance sheets (see Lesson 2, Whole Farm Nutrient Planning) accordingly.

By managing the amount, source, placement, and timing of nutrients, you will achieve both optimum crop production and water quality goals. These practices apply to all nutrient sources including commercial fertilizers, organic manure, and crop residues. Appropriate application rates, timing, and placement will minimize surface water and groundwater pollution, supply adequate nutrients for plant growth and development, improve the crop's nutrient efficiency, and assist in maintaining good soil conditions to reduce runoff and soil erosion.

By managing the amount, source, placement, and timing of nutrients, you will achieve both optimum crop production and water quality goals.

Your job as the operator of the manure management system is to follow the manure utilization plan, all local and state rules and buffers that apply, and manage the manure application volumes, placement, and timing to gain maximum benefit from the nutrients and minimize adverse environmental impacts. To do this, you must be familiar with the manure utilization plan, specifically

- The maps and fields receiving manure applications, including buffers.
- The cropping patterns and growth pattern of these crops (peak nutrient demands).
- Appropriate manure application rates to meet crop needs and how to calculate this.
- Be able to calibrate your equipment.
- Be able to complete appropriate records.

Appendix C contains summary tables that can be used to both plan manure applications to fields as well as track annual nutrient applications. These worksheets can help with the annual planning and manure utilization plan modification. They review N, P, and K balances in fields and provide easy recordkeeping of nutrient applications. To be most effective, matters such as cropping systems and management techniques must be kept flexible in a manure utilization plan. Items such as manure production rates, manure nutrient values, and crop R.Y.E.s will need to be revisited periodically, ensuring that the manure utilization plan is properly implemented to gain the maximum nutrient value from the manure and to minimize the possibility of negative environmental impacts associated with manure-handling practices. Using average manure nutrient values or average manure generation rates can lead to manure applications that do not match crop requirements.

APPENDIX A
Environmental Stewardship Assessment: Manure Utilization Plans

Does your current level of planning manure utilization present any specific environmental risks? This assessment tool will help you confidentially evaluate current manure utilization planning efforts. For each issue listed in the left column, read across to the right and circle (or check) the statement that best describes management practices implemented on your farm.

Issues	High Risk	Moderate Risk	Low Risk
Accuracy and Availability of Information for a Manure Utilization Plan			
	Incomplete or no information is available.	Most information is available.	All information is available.
Map Availability			
Aerial photos of all fields, identifying soil types, highly erodible sites, and wetlands? Topo maps showing surrounding topography and surface waters? Cultural maps showing residences, public facilities, etc? Tax or property maps showing property boundaries, individual fields, and crop acres? Maps identifying wells and drainage systems?			
Manure System Information			
Storage volume, estimated days of storage, cleanout schedule? Application equipment volumes and daily application capacity? Calibration records for all application equipment including application rates and uniformity of distribution?			
Farm Management Planning			
Farm conservation (including erosion control) plan? Crop plan identifying crops to be grown, realistic yield goal, and past yield records? Record of recent soil test results? Records of recent waste analysis results?`			
Manure Nutrient Planning			
Strategic Plan: Has an assessment been completed to estimate the land requirements for managing manure nutrients?	No OR Yes, and insufficient land land is available for managing both manure-N and P.	Yes, sufficient land is available for managing manure-N, but insufficient land is available for managing manure-P.	Yes, sufficient land is available for managing both manure-N and P.
Annual Plan: Has an annual plan identifying manure and fertilizer application rates for individual fields been developed?	No		Yes

APPENDIX B
Regulatory Compliance Assessment: Manure Utilization Plan

Regulatory Issue	Is this issue addressed by regulations? If "Yes," summarize those regulations.	Is my livestock/ poultry operation in compliance?
What agency (ies) is (are) involved in administering regulations relating to manure (waste) utilization plans?	___ U.S. EPA ___ State ___ Local List Name, Address, and Phone No.:	
What agencies, organizations, or individuals are qualified to write manure utilization plans?	List Name, Address, and Phone No.:	
Is a manure utilization plan required for your farm?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
What nutrients must be addressed in your manure utilization plan?	___ Yes ___ No If Yes, summarize: ___ N ___ P ___ Cu ___ Zn	___ Yes ___ No ___ Not applicable ___ Don't Know
Are limits set for residual soil nutrients, including	N? ___ Yes ___ No P? ___ Yes ___ No C? ___ Yes ___ No Zn? ___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Is documentation of available land base required for managing manure nutrients?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Is manure sampling required for nutrient concentration?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Is soil sampling required on manure application sites?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are manure generation rates part of the manure utilization plan, or are you required to keep records of manure generation?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are you required to account for supplemental nutrients such as legume residual, commercial fertilizer, etc. as part of your manure utilization plan?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are you required to maintain crop yield records to support your manure application rates?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Other:	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know

APPENDIX C
Developing a Manure Utilization Plan

(1) Maps
- ❏ Aerial photographs of the farm and all fields, with highly erodible land fields and wetlands identified
- ❏ Topographic maps showing surrounding topography and surface waters
- ❏ Cultural maps showing neighboring homes, churches, schools, parks, etc.
- ❏ Tax or property maps showing property boundaries
- ❏ Location of all wells, buried utilities, drainage systems

(2) Type of facility
- ❏ Type of animals that are raised
- ❏ Total animal head capacity
- ❏ Type of manure-handling system(s)
- ❏ Storage volume and estimated days of storage
- ❏ Typical cleanout schedule

(3) Equipment
- ❏ Type of manure-handling equipment
- ❏ Volume of spreaders/tankers
- ❏ Calibration records
- ❏ Capability for surface vs. subsurface application

(4) Farm management plan
- ❏ Farm conservation plan (erosion control plan)
- ❏ Fields and acreage available for manure application
- ❏ Soil types
- ❏ Crops to be grown and acreage of each
- ❏ Crop rotation patterns
- ❏ Yield records
- ❏ Recent soil test results
- ❏ Recent waste analysis results

This appendix summarizes the worksheets in this lesson. Several additional worksheets are introduced that are useful in summarizing total nutrient applications to fields. Each worksheet is explained along with some basic instructions for completing the worksheet.

(1) Manure Excretion. Table 31-1 is used to estimate total manure nitrogen (N), phosphorus (P), and potassium (K) excreted by a group of livestock or poultry. This approach uses standard values for nutrient excretion. Significant variation is possible depending upon feed ration. To use Table 31-1, you must provide the average one-time animal population and the average weight for each species and animal group. If a facility has animals for only part of a year, the average animal population should be adjusted down to reflect the time during which the facility is not occupied.

(2) Livestock Manure Nutrient First-Year Availability Coefficients (Table 31-2). Table 31-2 is used to reduce total manure nutrients to plant-available nutrients based on losses that occur during application. You must select the manure type and application method, then multiply total manure nutrients from Table 31-1 by the Table 31-2 factor (coefficient).

(3) Nutrients Remaining After Storage Losses. Nitrogen, P, and K can be lost during the storage or treatment phases of manure handling. Table 31-3 enables you to develop a "ballpark" estimate of the nutrients remaining after these storage losses. You must identify the manure storage or treatment system that most closely approximates your manure management facility, enter the nutrients production numbers (estimated in Table 31-1) into Table 31-3, and complete the appropriate calculations. Then use Table 31-2 to determine plant-available nutrients.

(4) Phosphorus Accumulation in Lagoons. If an anaerobic lagoon (storage that includes a permanent pool, typically at least one-third of the structures volume) is used and the structure is not agitated as it is pumped out, most of the P may remain in the sludge layer accumulating in the bottom of the lagoon. This accumulation of P can be determined in Table 31-4 by entering the P excretion estimates from Table 31-1, calculating the time between sludge removal events, and completing the appropriate calculations.

(5) Nitrogen Losses due to Volatilization. Ammonia volatilization losses during land application are deducted from available manure N. The magnitude of these losses depends upon the application method. Table 31-2 can be used.

(6) Total Remaining N Available. Table 31-5 is used to summarize remaining manure N after calculating losses. Data from Tables 31-1, -2, and -3 are used to calculate the PAN remaining after all losses.

(7) Nutrient Requirements of Cropping System. Nitrogen (Table 31C-1) and P (Table 31C-2) utilization by cropping systems are balanced against the available manure nutrients after losses to determine if sufficient land is available for agronomic application of manure. Typical cropping programs, yields, and nutrient requirements are entered for individual fields available for land application. The nutrient requirements of these fields are balanced against previous estimates of available manure nutrients to determine the adequacy of the land base for managing manure. Table 31C-3 provides a similar accounting of land base to utilize the P that has accumulated in the settled solids of an anaerobic lagoon.

(8) Summary Worksheet 31-1 for Manure Nutrient Generation Based on Producer Records of Manure Handling and Manure Analyses. Enter annual manure generation, manure analysis data, and availability coefficients from the tables to calculate total N, P, and K for the year's cropping systems.

(9) Worksheet 31-2: Field summary for manure utilization plan. This worksheet allows you to budget the manure nutrients from Worksheet 31-1 across the fields that receive manure. Insert a N recommendation based on R.Y.E. and on P_2O_5 and K_2O recommendations from a soil test. Each field is assigned a crop and the total nutrient budget for the year is calculated.

Table 31C-1. Land requirement for manure N.

Available Manure N (Table 31-5) = _________lbs N

B. Field ID	C. Acres	D. Crop	E. Yield Units	F. Crop N Requirement[1]	G. N Credits[2]	H. Manure N Requirement (= F - G)	I. Manure N Use by Field (= C x H)	J. Remaining Manure N (A – I)[3]
Example	*160*	*Corn*	*170 lbs/bu.*	*150 lbs/acre* lb./acre	*30 lbs/acre* lb./acre	*120 lbs/acre* lb./acre	*19,200 lbs*	
				lb./acre	lb./acre	lb./acre		
				lb./acre	lb./acre	lb./acre		
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				lb./acre	lb./acre	lb./acre		

[1] Crop N Requirements should be based upon historical soil tests and/or recommendations. If this information is not available, crop N removal rates are an alternative. For the corn example, Crop N Removal equals 170 bu./ac. x 0.9 lb N/acre or 153 lbs of N/acre.

[2] Nitrogen credits should include commercial fertilizer use, legume credit, or residual soil N credit (if not already discounted by soil test recommendation).

[3] Remaining Manure N is calculated for the first field by subtracting "Manure N Use by Field" from "Available Manure N." For all remaining fields, it is calculated by subtracting "Manure N Use by Field" from the "Manure N Remaining" results of the previous field.

Table 31C-2. Land requirement for manure P.

Available Manure P (Table 31-3) = _________lbs P

B. Field ID	C. Acres	D. Crop	E. Yield Units	F. Crop P Requirement[1]	G. P Credits[2]	H. Manure P Requirement (= F - G)	I. Manure P Use by Field (= C x H)	J. Remaining Manure P (A – I)[3]
Example	*160*	*Corn*	*170 lbs/bu.*	*61 lbs/acre* lb./acre	*0 lbs/acre* lb./acre	*61 lbs/acre* lb./acre	*9,760 lbs*	
				lb./acre	lb./acre	lb./acre		
				lb./acre	lb./acre	lb./acre		
				lb./acre	lb./acre	lb./acre		
				lb./acre	lb./acre	lb./acre		
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				lb./acre	lb./acre	lb./acre		

[1] Crop N Requirements should be based upon historical soil tests and/or recommendations. If this information is not available, crop N removal rates are an alternative. For the corn example, Crop N Removal equals 170 bu./ac. x 0.9 lb N/acre or 153 lbs of N/acre.
[2] Nitrogen credits should include commercial fertilizer use, legume credit, or residual soil N credit (if not already discounted by soil test recommendation).
[3] Remaining Manure N is calculated for the first field by subtracting "Manure N Use by Field" from "Available Manure N." For all remaining fields, it is calculated by subtracting "Manure N Use by Field" from the "Manure N Remaining" results of the previous field.

Table 31C-3. Land requirement for anaerobic lagoon sludge P.

Available Manure P (Table 31-4) = ________lbs P

B. Field ID[1]	C. Acres	D. Crop	E. Yield Units	F. Crop P Requirement[2]	G. Years of Crop P Needs to be Supplied[3]	H. Sludge P Use by Field (= C x F x G)	I. Remaining Sludge P (A – H)[4]
Example	*160*	*Corn*	*170 lbs/bu.*	*61 lbs/acre* lb./acre	*0 lbs/acre* lb./acre	*9,760 lbs* lb./acre	
				lb./acre	lb./acre	lb./acre	
				lb./acre	lb./acre	lb./acre	
				lb./acre	lb./acre	lb./acre	
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				lb./acre	lb./acre	lb./acre	
				lb./acre	lb./acre	lb./acre	

[1] Fields not receiving regular manure applications should be selected for sludge application.

[2] Crop P Requirements may be based upon historical soil tests and/or recommendations or crop P removal rates (select larger value). For the corn example, Crop P Removal equals 170 bu./ac. times 0.36 lb N/acre or 61 lbs of N/acre.

[3] If soil P levels are near or below agronomic rates, it may be desirable to build soil P levels by applying sufficient P to supply several years of crop needs.

[4] Remaining Manure P must be calculated for the first field by subtracting “Sludge P Use by Field” from “Available Sludge P.” For all remaining fields, it is calculated by subtracting “Sludge P Use by Field” from the “Sludge P Remaining” results of the previous field.

SUMMARY WORKSHEET 31-1 FOR MANURE NUTRIENT GENERATION

Use this worksheet when you know the volume of manure that is handled based on cleanout or pumping records.

Manure generation, tons or gallons/year ______________________

	N	P_2O_5	K_2O
Manure analysis, lb/ton or lb/1,000 gallons			
Manure nutrient availability coefficients*			
Corrected manure analysis* (multiply above two columns)			
Total manure nutrients to handle (manure generation x corrected manure analysis)			
Total other nutrients on the farm** (includes starter fertilizer, residual N credits, other waste sources, N from recent soil test. Note: These are on a field-by-field basis.)			
Total nutrients to handle in cropping system			

*These are needed if lab results are not in plant-available nutrients. If lab results are plant-available nutrients, skip this part.
** Based on 25 acres of soybeans at 25 pounds residual N per acre

COMPLETED SUMMARY WORKSHEET 31-1 FOR MANURE NUTRIENT GENERATION

You operate a swine-finishing operation with a 4,000-head capacity. Your manure-handling system is a slurry system, and the manure analysis shows 25.2 pounds of N, 23.7 pounds of P_2O_5, and 16.8 pounds of K_2O per 1,000 gallons of manure. Your application system is a honeywagon with incorporation.

Manure generation, tons or gallons/year: 4,000 head x 751 gal/animal = 3,004,000 gal

	N	P_2O_5	K_2O
Manure analysis, lbs/ton or lbs/1,000 gallons	25.2	23.7	16.8
Manure nutrient availability coefficients*	0.7	0.8	0.8
Corrected manure analysis*(multiply above two columns)	17.64	18.96	13.44
Total manure nutrients to handle, (manure generation x manure analysis)	52, 990	56,956	40,374
Total other nutrients on the farm ** (includes starter fertilizer, residual N credits, other waste sources, N from recent soil test. Note: These are on a field-by-field basis.)	625	0	0
Total nutrients to handle in cropping system	53,615	56,956	40,374

* These are needed if lab results are not in plant-available nutrients. If lab results are plant-available nutrients, skip this part.

** Based on 25 acres of soybeans at 25 pounds residual N per acre

WORKSHEET 31-2. FIELD SUMMARY FOR MANURE UTILIZATION PLAN

Use this worksheet to combine all information, determining total nutrients produced and whether adequate acreage exists to handle the manure nutrients.

					Crop Nutrient Recommendation			Total Crop Nutrients per Field		
Field Name	Field Size, acres	Soil Type	Crop	R.Y.E.	N[1] lb/acre[2]	P_20_5 lb/acre[2]	K_20	N	P_20_5	K_20
Total of All Fields										

[1] From R. Y. E. worksheets
[2] From soil test recommendations

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References

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Glossary

Agronomic rate. *See* **Nutrient sufficiency strategy.**

Ammonia volatilization. Loss of ammonia, derived from ammonium, to the atmosphere.

Annual plan. Actual implementation of the strategic plan, which 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.

Best management practice (BMP). Management practices that can be used to generate maximum utilization of on-farm nutrients while protecting the environment.

Manure utilization plan. Plan that addresses manure production on a farm and how the manure nutrients are utilized, describing all manure nutrients and the ultimate end use of all manure (crops, local landowners, composted and bagged, re-feeding blends, incineration, etc.). Tool that helps you define the number of acres and types of crops to be grown on the basis of the volume of manure produced and the nutrient requirements of your crops.

Mineralization. Nutrient conversion over time by soil microbes from an organic form to an inorganic form so that nutrients become plant available.

Nutrient sufficiency strategy. Applying sufficient nutrients for crop growth, without overapplying nutrients.

Plant-available nitrogen (PAN). Portion of the total nitrogen that is available for crop uptake.

Realistic yield expectation (R.Y.E.). Estimated crop yield for a given field.

Soil pH. The relative acidity or alkalinity of the soil, based on a scale of 1 (extremely acidic) to 14 (extremely basic or alkaline) with 7 being neutral.

Strategic plan. 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.

Wet basis. Determining manure nutrient contents as they naturally exist, without a conversion for percent solids of the manure.

Index (Page numbers highlighted in green are linked to corresponding text.)

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Click on road map to return to Contents.

Reviewers

Many colleagues reviewed drafts of the Livestock and Poultry Environmental Stewardship curriculum and offered input over a two-year period. Thus, it is impossible to list all reviewers; however, certain reviewers provided in-depth reviews, which greatly improved the curriculum's overall quality, and pilot tested the curriculum within their state. These reviewers, also members of the Review and Pilot Team, are listed below.

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Livestock and Poultry Environmental Stewardship Curriculum: Lesson Organization

This curriculum consists of 27 lessons arranged into six modules. Please note that the current lesson is highlighted.

Module A. Introduction

1. Principles of Environmental Stewardship
2. Whole Farm Nutrient Planning

Module B. Animal Dietary Strategies

10. Reducing the Nutrient Excretion and Odor of Pigs Through Nutritional Means
11. Using Dietary and Management Strategies to Reduce the Nutrient Excretion of Poultry
12. Feeding Dairy Cows to Reduce Nutrient Excretion
13. Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle

Module C. Manure Storage and Treatment

20. Planning and Evaluation of Manure Storage
21. Sizing Manure Storage, Typical Nutrient Characteristics
22. Open Lot Runoff Management Options
23. Manure Storage Construction and Safety, New Facility Considerations
24. Operation and Maintenance of Manure Storage Facilities
25. Manure Treatment Options

Module D. Land Application and Nutrient Management

30. Soil Utilization of Manure
31. **Manure Utilization Plans**
32. Land Application Best Management Practices
33. Selecting Land Application Sites
34. Phosphorus Management for Agriculture and the Environment
35. Land Application Records and Sampling
36. Land Application Equipment

Module E. Outdoor Air Quality

40. Emission from Animal Production Systems
41. Emission Control Strategies for Building Sources
42. Controlling Dust and Odor from Open Lot Livestock Facilities
43. Emission Control Strategies for Manure Storage Facilities
44. Emission Control Strategies for Land Application

Module F. Related Issues

50. Emergency Action Plans
51. Mortality Management
52. Environmental Risk and Regulatory Assessment Workbook