MANAGING ANIMAL MANURES

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For centuries farmers have spread animal manures on the land as a way to increase soil productivity. Once applied to the soil, manure is decomposed by microorganisms, forming humus and releasing essential elements for plant growth. The economic value of manure is related to its fertilizer replacement value, its organic matter content, and probably some unknown factors that enhance crop production.

Management is the key to efficient use of nutrients by a crop. Proper management will increase economic crop returns and reduce the potential for polluting surface and ground waters. This chapter discusses the basic principles regarding the use of manure in a soil fertility program and presents general guidelines for managing manure for optimum crop production.

Nutrient Content

Depending on the species, approximately 70-80% of the nitrogen, 60-85% of the phosphorus, and 80-90% of the potassium fed to animals are excreted in the manure. The high nutrient return in manure permits a recycling of plant nutrients from crop to animal and back to the crop again.

The amount of nutrients contained in manure and their eventual uptake by plants will vary considerably from farm to farm. The major factors determining nutrient content and availability are (I) composition of the feed ration, (2) amount of bedding and water added or lost, (3) method of manure collection and storage, (4) method and timing of land application, (5) characteristics of the soil and the crop to which manure is applied, and (6) the climate.

Table 8 shows the wide range in nutrient composition of manures sampled from numerous farms. Because of the large amount of variation, it is not advisable to use the average nutrient contents often seen in publications. Average values are very misleading. The best way to determine the nutrient content of manure is by laboratory analysis. The minimum analysis should include the percentage of dry matter,

Table 8. Range in nutrient analysis of manure for various handling systems

	Nonliquid systems			Liquid systems		
Type	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	Ib/ton			Ib/1000 gal		
Dairy	5-16	2-16	2-31	3-51	2-21	2-58
Beef	4-20	1-13	3-29	6-37	1-29	5-30
Swine	3-27	1-62	2-18	1-65	1-63	1-49
Poultry	4-111	1-96	2-55	35-75	13-91	13-39

Source: Adapted from T. Bates and E. Gagnon, 1981, Nutrient content of manure, University of Guelph, Guelph, Ontario, Canada.

ammonium nitrogen (NH_4), total nitrogen (ammonium N + organic N), phosphorus (P or P_2O_5), and potassium (K or K_2O).

The key to an accurate manure analysis is proper sampling. Samples should be taken just before spreading to account for losses during handling. Storages should be sampled each time they are emptied, and daily spread operations should be sampled several times throughout the year to obtain a good average nutrient value. When the results become reasonably consistent, sampling can be done less frequently. Samples should be taken from representative loads to give the nutrient content at the time of application. Be sure liquid storages are agitated thoroughly before unloading. Place a composite sample in a plastic bottle, seal tightly, and freeze immediately Freezing is to preserve the sample, because a considerable amount of nitrogen can be lost by improper handling.

Nutrient Availability

The nutrients in manure cannot be substituted for the nutrients in commercial fertilizer on a pound-for pound basis. A portion of the nutrients are not as readily available, nor can they be as accurately applied as those in fertilizer. How efficiently they are used by a crop depends on management of the land application program, as well as the rate of biological breakdown of the organic material and release of plant-available nutrients. The following sections describe how nutrient availability can be estimated.

NITROGEN

There is no quick soil test procedure to determine the N supply from organic matter. Therefore, the N supply from manure in the soil must be estimated from research studies and applied to individual farm conditions.

Because of its chemical nature, manure N is more difficult to manage than other nutrients.

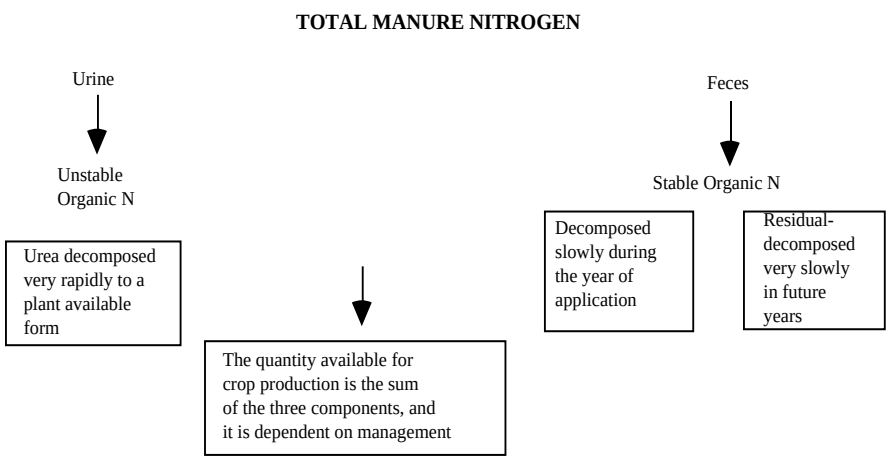

Figure A. Form and degree of nitrogen availability in manure.

There are two forms of N in manure, namely the unstable and stable organic N (Fig. A). In either form, the organic N must be decomposed by microorganisms to an inorganic N form before it can be used by plants. The resulting inorganic N is available for crop growth as nitrate (NO_3) and ammonium (NH_4).

The unstable organic N is present in urine as urea or uric acid and may account for more than 50% of the total N. Urea in manure is no different from urea in commercial fertilizer. It decomposes very rapidly to ammonium (NH_4)

and, in turn, converts very quickly to ammonia (NH_3) as the pH increases and the manure begins to dry.

All the ammonium in manure is immediately available for plant growth. Ammonia is extremely volatile, however, so exposure of manure on the barn floor, in the feedlot, in storage, or after spreading increases the N loss. At every step between production and its use by the crop, ammonia is the most valuable and most easily lost component. It is also the most variable component between management systems, and therefore, an analysis of the manure is useful to determine how much ammonia has been conserved before spreading.

Table 9 shows a typical field loss of ammonia after spreading. The more stable organic N is present in the feces and is a more slowly released form of organic N than urea. The decomposition of stable organic N to a plant-available form occurs at two rates. The less-resistant organic N decomposes during the year of application, whereas the more-resistant organic N decomposes very slowly in future years. Repeated application to the same field results in an accumulation of a slow-release manure N source.

Table 9. Loss of ammonia by volatization after a surface application of dairy manure.

Days after application	Ammonia N loss, %
1	20
2	40
3	50
4	60
10	75
15	90

A decay, or decomposition, series is commonly used to estimate the rate of N availability from stable organic N. A decay series of .35-.12-.05-.02 is used to estimate the rate of decomposition of organic N in fresh manure in New York. The sequence of numbers means that 35% of the organic N is decomposed during the year applied, 12% of the initial organic N application is decomposed during the second year, 5% is decomposed the third year, and 2% the fourth year. The last three numbers in the decay series are the annual rates of decomposition of the residual organic N from past applications.

There is some evidence that manure containing large amounts of bedding may decompose at a slower rate than fresh manure. Therefore, the estimated availability of N during the year applied is reduced from 35 to 25% when the dry matter content exceeds 18%.

The amount of N available during the growing season is equal to the ammonium N + decomposed organic N from the present application + decomposed organic N from past applications. An estimate of N availability in New York is shown in Figure B. The quantity that is available can vary from year to year and from farm to farm because the rate of microbiological breakdown depends upon soil characteristics and climatic conditions. Other factors affecting availability are animal species, moisture content, bedding, and method of manure storage. However, the guidelines in Figure B are reasonable estimates.

At the present time, there is not enough research data to determine N availability from manure when left on the surface throughout the growing season. The value of N in manure spread for no-till crops or for top-dressings on hayfields or pastures will have to be based on your past experiences.

A work sheet is provided to make it easier for you to estimate N availability from present and past applications. Transfer the values in figure B to work sheet 1 to determine availability based on your management practice. The example in work sheet 1 shows that the amount of available N will be low when manure is spread during the fall of the year. The nitrogen value increases

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TOTAL MANURE NITROGEN

Urine — Feces

Ammonium N

Time of application	% available
During the growing season as a sidedress injection for row crops	100
Spring season. Reduce number by 15 for each day incorporation is delayed	65
All other conditions	0+

Organic N-decomposed during year applied

Dry Matter content	% available
Less than 18%	35
Greater than 18%	25

Organic N (residual) decomposed from past applications

From manure applied	% available
1 year ago	12
2 years ago	5
3 years ago	2

Figure B. Estimated availability of the different forms of nitrogen in manure.

considerably by applying and immediately incorporating manure in the spring.

Work sheet 1 is also available in computer program form at your Cooperative Extension office. If you do not have a manure analysis, the work sheet or computer program will not be very helpful.

PHOSPHORUS AND POTASSIUM

Manure is an excellent source of P and K. When manure is applied at a rate to supply the N needed, P and K will most likely be applied in excess of crop needs.

Not all the P in manure is immediately available for plant use. Some of the P is in an organic form that has to decompose before it is available. P is not very mobile in the soil. Therefore, broadcasted manure is not an efficient method of applying P when establishing a crop. Some P will be recommended in a band-placed starter fertilizer except when the soil test level is extremely high. For top-dressing hayfields, the P in broadcasted manure is probably as efficiently used as P in broadcasted fertilizer.

Essentially all the K in manure is available for plant growth during the year applied. K can be used efficiently by a crop as either a band or broadcast application.

The fertilizer requirements for P and K on manured fields can be determined by soil testing. The soil test levels are a reflection of how much P and K have been applied from past manuring; and these values should be used to determine the amount of fertilizer needed.

If manure was applied before the soil test was taken, follow Cornell's P_2O_5 and K_2O fertilizer recommendations. The P and K applied will be reflected in the soil test values. If manure will be applied after the soil test is taken, the following guidelines are offered.

Table 10. Corn yields on a manured field with various rates of fertilizer

Manure Input, lb/A		Cornell Soil Test	
N = 149	P2O5 = 59	pH = 6.4	K = 375 (H)
K20 = 149		P = 16 (H)	Mg = 320 (H)

Fertilizer applied N	P2O5	K2O, lb/A	Corn silage, T/A
0	0	0	19.3
20	40	20	19.0
40	40	20	20.7
80	40	20	19.3
120	40	20	19.3
120	40	80	20.1

NOTE: Manure was spring applied at 4500 gal/A and plowed down within 8 hr.

Phosphorus *For crop establishment or top-dressing:*

a. If the fertilizer recommendation is less than 40 lb/acre, apply the entire amount as fertilizer.

b. If the fertilizer recommendation exceeds 40 lb/acre, apply 40 lb and use the P in manure to supply the rest.

Potassium *For crop establishment:*

a. If the fertilizer recommendation is less than 20 lb/acre, apply the entire amount as fertilizer.

b. If the fertilizer recommendation exceeds 20 lb/acre, apply 20 lb and use the potassium in manure to supply the rest.

For top-dressing:
The potassium in manure can be used to supply the entire amount.

MICRONUTRIENTS

Manure contains small quantities of micronutrients; hence, micronutrient deficiencies on manured fields are not very common. Because of the slow availability of micronutrients in manure, a micronutrient deficiency should be corrected with a commercial fertilizer source.

Economics

The effectiveness of manure as a fertilizer is based on the nutrients it contains that are not supplied in adequate amounts by the soil. Thus, the fertilizer dollar value of manure is equal to the cost of the fertilizer that has to be purchased if manure is not applied. In fields where the soil test levels for P and K indicate these nutrients are in adequate supply, only the fertilizer nitrogen value of the manure should be considered.

When contemplating capital investments for manure handling, make a careful economic analysis of the change in your management. For instance, an expenditure that produces nutrient surpluses is not economical unless the surplus can be sold; on the other hand, an expenditure that markedly improves nutrient recycling, environmental quality, or your management ability is a good investment.

The results of several field trials (Tables 10 and 11) illustrate the effectiveness of manure as a

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Work Sheet 1. Estimating the amount of nitrogen available for crop production

Example: A dairy manure sample was taken from a nonliquid storage facility and analyzed. The following calculations show how to estimate the amount of nitrogen that will be available during the growing season from the current manure application and from previous applications. Assume that 25 tons/acre, having an organic N content of 6 Iblton, were applied in each of the past 3 years.

Calculations

A. Insert the percentage of dry matter and the nitrogen value of the manure from the analysis in Ib per ton for a nonliquid system or Ib per 1000 gal for a liquid system. Organic N = Total N - Ammonium N.

	Example	Your Farm
Dry Matter	15%	_____
Total N*	10 lb/ton	_____
Ammonium N	4 lb/ton	_____
Organic N*	6 lb/ton	_____

B. Determine the availability of nitrogen during the first year. Available N = Ib of ammonium N or organic N in item A x the percentage of availability from Figure B.

	Time of Application	Quantity Available From: Ammonium N (Ib x %)		Organic N (Ib x %)		Available N
Examples:	Fall	4 X 0	+	6 X .35	=	2.1 lb/ton
	Spring Incorp. delayed 2 days	4 X .35	+	6 X .35	=	3.5 lb/ton
	Spring immed. incorp.	4 X .65	+	6 X .35	=	4.7 lb/ton
Your Farm:	_____	_____		_____		_____

C. Determine the availability of nitrogen from previous applications. Omit those years when manure was not applied. Available N per acre = application rate from previous records in tons or 1000s of gal x Ib of organic N per ton or per 1000 gal x percentage of availability from Figure B.

Quantity available from residual organic N from:

	1 year ago (rate x N x %)		2 years ago (rate x N x %)		3 year s ago (rate x N x %)		Residual N Availability
Example:	25x6x.12	+	25x6x.05	+	25x6xl02	=	28.5 lb/A
Your Farm:	_____	+	_____	+	_____	=	_____

*Some laboratories may report their nitrogen results under the heading "nitrogen" and "ammonium or ammonia N." The larger of the two numbers is total N. Many laboratories do not report organic N simply because it is the difference between total N and ammonium N.

Table 11. Corn yields on a manured field with various rates of fertilizer

Manure Input, lb/A		Cornell Soil Test	
N = 342	P2O5 = 56	pH = 6.3	K = 320 (H)
K20 = 294		P = 11 (H)	Mg = 360 (H)

Fertilizer applied N	P2O5	K2O, lb/A	Corn silage, T/A
0	0	0	20.8
20	40	40	22.5
40	40	40	23.4
80	40	40	23.0
120	40	40	23.3
120	80	80	23.7

NOTE: Manure was spring applied at 30 T/A and plowed down within 6 hr.

fertilizer. The corn yields shown in Table 10 are typical of those found on farms where manure has been applied uniformly at a high rate for many years. Under these conditions, nutrients accumulate in the soil, the soil test levels increase, and the need for commercial fertilizer decreases. When corn is in rotation with hay, some additional N will be supplied by the previous sod crop. On this farm there was no economic advantage to applying fertilizer.

The yields shown in Table 11 were on a field in continuous corn that did not receive much manure in the past; therefore, N availability may be low because of little or no supply from previous application. Although this year's manure application supplied plenty of P and K, it was economical to add a starter fertilizer containing up to 40 pounds of N. Even at high rates of manure there is an advantage to using a band-placed starter fertilizer with the planter, especially with the cold, wet springs experienced in New York.

Land Application

The goal of a well-managed land application program is to develop a soil fertility program that uses manure to supply as much of the needed plant nutrients as possible, with commercial fertilizer providing only what is additionally needed.

A particular kind of manure-handling system does not, in itself, increase or decrease nutrient use by a crop; management does!

Table 12. A nutrient balance on a typical dairy farm in New York

Nutrients produced in manure	Nutrient requirements from soil testing
75 cows + 53 heifers	Soil = silt loam, 228 A
Manure, T = 1,830	Soil test = medium
Analysis, lb/T = 10-5-9	Rotation = 4 yr. corn 4 yr. alfalfa
N = 18,300 lb	N = 11,800 lb
P_2O_5 = 9,100 lb	P_2O_5 = 7,300 lb
K_2O = 16,400 lb	K_2O = 11,100 lb

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The first step in developing a land application program is to determine the amount of nutrients collected in manure; the second is to soil test to determine of nutrient requirements of the crop rotation; the third is to estimate nutrient availability in manure; and the fourth is to calculate a compatible rate of application.

The quantity of nutrients produced should be compared with the total nutrient requirement of your crop rotation. Table 12 shows a typical nutrient balance for a 75-cow dairy in New York. With similar information for your farm, a management program can be developed to ensure that manure will supply a major portion of the nutrient requirement.

If your crops require more nutrients than are available in manure, you should consider changing your management practices to conserve more. On the other hand, if the availability of nutrients in manure exceeds crop requirements, there is no advantage in changing management to conserve more unless (a) you can sell the excess, (b) the convenience or environmental concerns outweigh the economic returns, and (c) the change enables you to manage other areas more effectively.

The example in work sheet 2 showed that a 120-pound-per-acre N requirement for corn could be met by a combination of residual N from past applications, applying 30 tons of manure, and adding 30 pounds of N in the starter fertilizer at planting. Thirty tons per acre will also contain 150 pounds of P_2O_5 and 270 pounds of K_2O. For the spreader being used, it took 44 loads to apply 30 tons per acre to a 15-acre field.

The amount of liquid manure applied by irrigation can be measured by placing cans in the field to record the depth of water applied. There are 27,150 gallons in 1 acre-inch.

To save a lot of tedious calculations, contact your extension office. It has a computer program that will calculate annual manure production on your farm, the amount of nutrients (from a manure analysis) collected, the nutrient requirements of your crop rotation, and estimates N availability for various management practices. From the computer printout a compatible rate of application can be determined.

After determining the rate for each field, add the total amount of manure needed and compare this to the amount collected. If there is an excess, divide it among those fields having the highest nutrient demand.

Excessive rates of manure will oversupply nutrients that may affect plant growth and animal nutrition. Excessive rates of application as well as accumulations of manure around barn lots will eventually cause water pollution. Examples include aquatic growth in lakes and high nitrate levels in groundwater. Preventing such problems calls for a combination of appropriate soil and water conservation practices and proper management of the rate, timing, and method of manure application. In extreme cases additional land must be used to lower the application rate.

MAXIMIZING THE VALUE OF MANURE

The timing and method of manure application determine the efficiency of nutrient recycling. Some important points follow:

- Incorporating manure immediately minimizes odors and ammonia loss. If manure supplies more N than is needed, some ammonia loss is unimportant as far as the crop is concerned. Ideally, ammonia should be conserved so that N can be applied to a larger number of acres. Incorporation of manure too far in advance of crop needs will result in N losses. Spring or early summer incorporations are best.

Table 13. Approximate manure spreader capacities

Nonliquid system

Spreader volume (Measure all dimensions in feet and tenths of feet.)

Box spreader: cubic feet = length x width x average depth.

Barrel spreader: cubic feet = 0.393 x d^2 (diameter squared) x length.

Irregular shapes: Use manufacturer's rated capacity. Estimate the percentage of a full load.

Spreader capacity

Tons per load = cubic feet x 62 Ib per ft^3 (Use 55 Ib per ft^3 2000 lb per ton for extremely dry manure.)

Liquid system

Tank spreader: Use manufacturer's data to determine gallon capacity. Estimate the percentage of a full load. There are approximately 8,300 lb in 1,000 gal.

- Surface runoff and erosion must be controlled. Using tillage to incorporate manure on erosive soils in the fall may result in unacceptable soil losses. Applying manure as close to planting as feasible reduces the potential for nutrient loss.

- As is the case with commercial fertilizer, manure must be spread uniformly to get consistent results.

- Amounts of commercial fertilizer should be reduced according to the nutrient value of the manure and the accumulation of nutrients in the soil from past manuring. Avoid over-applications.

The recommendations from Cooperative Extension should be followed to ensure a proper balance of plant nutrients. Keep a record of nutrient levels in fields and use this information as the basis for adjusting your manure management and soil fertility program.

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Work Sheet 2. Estimating a Rate of Application

Example: A dairy operator will apply manure to a 15-acre cornfield in the early spring and incorporation will be delayed for 1 week. From the manure analysis and available N calculations in work sheet 1, determine the rate of application to meet the N requirement, the amount of P_20_5 and K_20 added, the amount of commercial fertilizer needed, and the number of spreader loads needed to apply the desired application rate.

Calculations	Example	Your Farm
A. Determine the nutrient needs of the crop.		
1. Crop to be grown	Corn	_____
2. Nutrient requirements from the Cornell soil test	N = 120 lb/A	_____
	P_2O_5 = 30 lb/A	_____
Soil Test P = 8 (med), K = 150 (high)	K_2O = 20 lb/A	_____
B. Determine the nutrient value of manure. Express as pounds per ton for a nonliquid system or pounds per 1000 gallons for a liquid system		
1. Available N from item B in work sheet 1	N = 2.1 lb/A	_____
2. P_20_5 from recent analysis	P_2O_5 = 5 lb/A	_____
3. K_20 from recent analysis	K_2O = 9 lb/A	_____
C. Determine the rate of application.		
1. Nutrient having the highest priority	= N	_____
a. Amount to be supplied by manure. Express as pounds needed in item A.2 minus amount of fertilizer applied. 120 lb - 30 lb at planting	= 90 lb/A	_____
b. If nitrogen, subtract residual N availability from item C in work sheet 1. 90 lb - 28 lb/A residual	= 62 lb/A	_____
2. Rate of manure needed to supply highest priority nutrient (item C. 1 . item B). Express in tons per acre for a nonliquid system or as 1000s of gallons per acre for a liquid system. 62 lb/A / 2.1 lb/ton.	= 30 ton/A	_____
3. Pounds of N, P_20_5, and K_20 applied per acre with manure.		
a. N value from item B. 1 times manure rate from item C.2 plus residual N availability from item C in work sheet 1. (2.1 lb/ton x 30 tons) + 28 lb.	N = 90 lb/A	_____
b. P_20_5 value from item B.2 times manure rate from item C.2. (5 x 30)	P_2O_5 = 150 lb/A	_____
c. K_20 value from item B.3 times manure rate from item C.2. (9 x 30)	K_2O = 270 lb/A	_____

Work sheet 2 (continued)

D. Determine the amount of commercial fertilizer needed
-- 30 lb N based on 90 lb from manure.
-- P_2O_5 and K_2O based on soil test recommendation

N = 30 lb/A _____

P_2O_5 = 30 lb/A _____

K_20 = 20 lb/A _____

E. Determine the number of manure spreader loads required to apply the application rate in C.2.

1. Spreader capacity (use equations from Table 13).

a. Liquid System:
(Express in units of 1000s of gal. per load) = _____ _____

b. Nonliquid system

cu ft of spreader = 16.9" x 6.3" x 3.2' = 340 ft^3 _____

tons per load = 340 ft^3 x 62 lb/ft^3 / 2000 = 10.5 tons/ load _____

2. Number of loads needed.

a. Loads per acre = manure rate in C.2 / spreader capacity from E.1 (30 / 10.5) = 2.9 loads/ acre _____

b. Loads per field = loads per acre x acres.
(2.9 x 15) = 44 loads _____

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