Livestock Manure Management for Efficient Crop Production and Water Quality Preservation
Michigan State University Cooperative Extension Service
Water Quality Extension Publications
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Reprinted February 1988
8 pages

Cooperative Extension Service • Michigan State University • Rep. February 1988 Extension Bulletin WQ 12

LIVESTOCK MANURE MANAGEMENT

For Efficient Crop Production And Water Quality Preservation

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Livestock manure is often used to build and maintain soil fertility, but it may also be used to improve soil tilth, increase the soil's water holding capacity and reduce wind and water erosion.

Manure applications, however, may also cause surface and groundwater pollution if mismanaged. Surface runoff from manured land may contain plant nutrients, organic material and sometimes infectious bacteria. Excess nutrients and organic material in surface water often causes algal blooms which increases the turbidity and biological oxygen demand (B.O.D.) of water. The polluted water may also cause odors and even kill fish.

Excessive applications of manure may also cause nitrate nitrogen (NO_3-N) to accumulate in the soil. The excess nitrate nitrogen can reach the surface water through tile drainage or leaching to groundwater. Since groundwater is the largest and most important source of drinking water in Michigan, preventing its contamination is vitally important.

[1]*The authors are members of the Crop and Soil Sciences, Agricultural Engineering and Animal Science Departments, respectively.*

The objective of this bulletin is to provide agronomic information for the efficient use of manure nutrients for crop production and to help preserve surface and groundwater quality. A worksheet is provided for choosing the optimum rate of manure application.

Nutrient Composition of Manure

The nutrient composition of manure varies greatly depending on the kind of livestock, feed ration, manure handling system and whether it has been diluted by water or bedding. Much nitrogen (N) can be lost by ammonia (NH_3) volatilization during handling and storage or by runoff and leaching from open lots. Very little phosphorus (P) or potassium (K) is lost from confined manure systems. However, in open lots 20-30% of the phosphorus and 30-50% of the potassium may be lost by runoff and/or leaching. Table 1 shows average nitrogen losses as ammonia gas during storage and handling.

To make the most efficient use of the nutrients, the manure should be immediately incorporated into the soil after application. Nitrogen is the nutrient of greatest concern because appreciable losses from ammonia volatilization can occur within 24 hours after application. Table 2 shows average nitrogen losses as ammonia for various methods of application, provided no rain occurs within 4 days. Incorporating or injecting manure into the soil also minimizes the problems associated with odors given off by freshly applied manure. Some recent studies, however, report significant denitrification losses (15-30%) from knifed-in manure and subsequent reduced N recovery by corn.

Tables 3 and 4 provide estimates of the nutrient value of manure (wet basis). These values are guidelines only because nutrient composition can vary greatly. More accurate values can be obtained from a laboratory analysis of the manure. The following laboratories are equipped to handle analysis of manure samples. Check with the lab for sampling and shipping procedures before sending in a sample.

Laboratory Address and Telephone Number

A & L Great Lakes Agricultural Laboratories, Inc.
5011 Decatur Road
Fort Wayne, IN 46806-3085
219-456-3545

Research-Extension Analytical Laboratory
Hayden Hall
Gerlaugh Drive
O.A.R.D.C.
Wooster, OH 44691
216-263-3760

Soil and Plant Analysis Lab
University of Wisconsin-Ext.
5711 Mineral Point Road
Madison, WI 53705
608-262-4364

Not all of the nitrogen in manure is readily available for plant use. Inorganic nitrogen such as ammonium (NH_4) or nitrate (NO_3), if incorporated or moved into the soil by rain, is readily available to plants. However, some of the nitrogen in manure is organic nitrogen and must be decomposed before it can be used. Table 5 summarizes the amount of organic nitrogen released (mineralized) from manure during the first cropping season. Organic nitrogen released during the second, third and fourth cropping years is estimated to be 50%, 25% and 12.5% respectively of that released the first year. Nearly all of the phosphorus and potassium in manure is available for plant use in the first year.

Time of Application

Make manure applications on sandy soils as near to planting time as possible to minimize nitrate leaching and to improve plant uptake. Avoid planting directly into freshly applied manure because the high salt content of some manures can cause poor germination and seedling injury. Consider late fall or winter applications of manure only on level, fine textured soils. Although 20-50% of the nitrate nitrogen in manure may be lost due to early application, applying the manure in the fall allows for greater decomposition and release of the organic nutrients for the following season. Less soil compaction of fine textured soils is another major advantage of fall or winter application on these soils. *Do not apply manure to frozen sloping land where runoff can easily enter surface water.* Such applications can contaminate lakes and streams.

Determining the Optimum Rate

Whenever possible, apply manure to land where corn will be grown, particularly where the crop is removed as silage to achieve the greatest nutrient use and economic benefits. Small amounts of manure may be used on small grains, but avoid excessive applications which may cause lodging due to high nitrogen additions.

Manure applied to legumes such as alfalfa or soybeans does not make for efficient use of the nitrogen because legumes fix their own nitrogen. Adding supplemental nitrogen to legumes, however, usually results in inactive root nodules, and allows the legume to utilize some of the nitrogen from manure. Additions of manure to alfalfa may stimulate the growth of grasses and weeds which can reduce the stand and yield of alfalfa. Manure applied to the foliage just prior to harvest may also reduce forage quality and palatability.

Soil testing plus a chemical analysis of the manure are the most important steps in determining the optimum rate of manure application. Many fields previously manured often have high fertility levels and may require little or no manure to meet the phosphorus or potassium requirements of the crop. Do not apply manure to these fields because it represents an inefficient use of nutrients and a potential for environmental degradation. Additional information on soil testing and fertilizer recommendations can be found in Extension Bulletins E-498, E-937 and E-550. See your county Cooperative Extension Service office for these bulletins.

Once you have obtained the soil test information that determines the fertilizer requirements of the crop and the nutrient composition of the manure, you are ready to calculate the optimum application rate. After determining the optimum manure application rate, you can determine any additional fertilizer nutrients that are needed. A worksheet is provided (with an example) to help determine the optimum manure application rate for efficient and economic use of the nutrients.

When soil test information is not available, use estimates of nutrient removal by the crop (Table 6). *Do not exceed the estimated nutrient removal, otherwise nutrient buildup will occur which may ultimately threaten surface and groundwater quality.* Follow this procedure only if you do not have a soil test or do not have time to obtain the necessary information.

The following worksheet is available for use as a microcomputer spreadsheet program. The program requires an IBM or IBM compatible microcomputer with a minimum of 256K memory and a copy of Lotus 1-2-3 software. The program file is available from your county Cooperative Extension Service office or from the authors of this bulletin.

Worksheet to Determine Manure Application Rates

(Adapted from MWPS-18, Livestock Waste Facilities Handbook)

Section A. Manure Composition and Soil Information

1. Manure composition:
   a. Values from chemical analysis of manure.

Composition		Your Farm
Laboratory data are often given in ppm. To convert ppm to percent, divide by 10,000. If composition data are not available, use Table 3 or 4.	Total N	______ %
	Ammonium N	______ %
	Nitrate N	______ %
	P_2O_5	______ %
	K_2O	______ %

   b. Determine the amount of each nutrient per ton of solid manure or per 1,000 gal of liquid manure.
   If nutrient contents are given in percent: percent nutrient in manure x 20 = lb nutrients/ton; or x 85 = lb nutrients/1,000 gal (e.g., 0.5% Total N = 10 lb/ton or 42.5 lb/1,000 gal)

Composition	Example (Table 4)	Your farm
Total N	36 lb/ 1000 gal.	______ lb/ ______
Ammonium N*	26 lb/ 1000 gal.	______ lb/ ______
Nitrate N*	— lb/ —	______ lb/ ______
P_2O_5	27 lb/ 1000 gal.	______ lb/ ______
K_2O	22 lb/ 1000 gal.	______ lb/ ______

*If only total N is determined, assume 50% ammonium N and 5% nitrate N.

2. Soil information:

Soil Information	Example	Your soil
Texture	Sandy Loam	______
Soil pH	6.2	______
Available P	— lb/acre	______ lb/acre
Exchangeable K	— lb/acre	______ lb/acre

Section B. Nutrient Needs of Crop

	Example	Your crop
Crop to be grown	Corn	______
Expected yield/acre	150	______
Nutrients required/acre	N = 180 lb/acre	______ lb/acre
(based on soil test	P_2O_5 = 80 lb/acre	______ lb/acre
report or Table 6)	K_2O = 215 lb/acre	______ lb/acre

Section C. Annual Rate of Manure Application

1. Calculate amount of organic N in manure (either per ton or per 1,000 gal):

   lb total N - (lb ammonium N + lb nitrate N) = lb organic N

Example:

36 - (26 + —) = 10 lb organic N/ 1,000 gal.

Your manure:

________ - (________ + ________) = ________ lb organic N/ ________

2. Calculate amount of organic N in manure made available the first year.

   lb organic N/(ton or 1,000 gal) x mineralization factor (Table 5) = lb available organic N/(ton or 1,000 gal)

Example:

10 x 0.35 = 3.5 lb available organic N/ 1,000 gal.

Your farm:

________ x ________ = ________ lb available organic N/ ________

3. Calculate amount of plant-available N in manure (use either a or b below):
   a. Incorporated application of manure (assume 25% of ammonium N is lost by denitrification if knifed-in; assume no loss if immediately incorporated by other methods):

      Available organic N (sec C.2) + [Ammonium N (Sec A.1.b) x 0.75] + Nitrate N (Sec A.1.b) = lb plant-available N/(ton or 1,000 gal)

Example:

3.5 + [26 x 0.75] + — = 23 lb available N/ 1,000 gal.

Your farm:

________ + [________ x 0.75] + ________ = ________ lb available N/ ________

   b. Surface application of manure (assumes 50% of ammonium N is lost by ammonia volatilization):

      Available organic N (Sec C.2) + [Ammonium N (Sec A.1.b) x 0.50] + Nitrate N (Sec A.1.b) = lb plant-available N/(ton or 1,000 gal)

Your farm:

________ + [________ x 0.50] + ________ = ________ lb available N/ ________

4. Adjust N fertilizer recommendation to account for residual N from manure applications in the last 3 years.
   a. Manure applied to field 1 year ago (if none, proceed to b.):

      lb organic N/(ton or 1,000 gal) of manure x (mineralization factor x 0.50) x tons or 1,000 gal applied/acre = lb residual N/acre

Example:

10 lb./1,000 gal. x (0.35 x 0.50) x 6,000 = 10.5 lb residual N/acre

Your farm:

________ x (________ x 0.50) x ________ = ________ lb residual N/acre

   b. Manure applied to field 2 years ago (if none, proceed to c.):

      lb organic N/(ton or 1,000 gal) of manure x (mineralization factor x 0.25) x tons or 1,000 gal applied/acre = lb residual N/acre

Your farm:

________ x (________ x 0.25) x ________ = ________ lb residual N/acre

(continued next page)

Table 1. Nitrogen loss as ammonia during handling and storage.

System	Nitrogen lost (%)
Solid	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Deep pit (poultry)	15-35
Liquid	
Anaerobic pit	15-30
Above-ground storage	10-30
Earth storage	20-40
Lagoon	70-80

Source: MWPS-18, Livestock Waste Facility Handbook.

Table 2. Nitrogen loss as ammonia within four days after land application.

Application method	Type of waste	Nitrogen lost (%)
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with immediate cultivation	Solid	1-5
	Liquid	1-5
Knifing	Liquid	0-2*
Sprinkler irrigation	Liquid	15-35

Source: MWPS-18, Livestock Waste Facilities Handbook.

*Recent studies in Wisconsin and Illinois indicate significantly higher losses (15-30%) due to denitrification. (Personal communication.)

Table 3. Nutrients in solid manure at the time of land application.

Species	Bedding or litter	Dry matter	Ammonium N	Total N	P_2O_5	K_2O
		%	lb/ton manure			
Swine	No	18	6	10	9	8
	Yes	18	5	8	7	7
Beef	No	15*	4	11	7	10
	No	52+	7	21	14	23
	Yes	50	8	21	18	26
Dairy	No	18	4	9	4	10
	Yes	21	5	9	4	10
Sheep	No	28	5	18	11	26
	Yes	28	5	14	9	25
Poultry	No	45	26	33	48	34
	Yes	75	36	56	45	34
	Deep pit	76	44	68	64	45
Turkey	No	22	17	27	20	17
	Yes	29	13	20	16	13
Horse	Yes	46	4	14	4	14

Source: MWPS-18, Livestock Waste Facilities Handbook.

*Open concrete lot.

+Open dirt lot.

Table 4. Nutrients in liquid manure at the time of land application.

Species	Waste handling	Dry matter	Ammonium N	Total N	P_2O_5	K_2O
		%	lb/1,000 gal manure			
Swine	Liquid pit	4	26	36	27	22
	Lagoon*	1	3	4	2	4
Beef	Liquid pit	11	24	40	27	34
	Lagoon*	1	2	4	9	5
Dairy	Liquid pit	8	12	24	18	29
	Lagoon*	1	2.5	4	4	5
Veal calf	Liquid pit	3	19	24	25	51
Poultry	Liquid pit	13	64	80	36	96

Source: MWPS-18, Livestock Waste Facilities Handbook.

*Includes lot runoff water.

Table 5. Amount of nitrogen mineralized or released from organic nitrogen forms in manure to plant available forms during the growing season.

Manure type	Manure handling	Mineralization factor
Swine	Fresh	0.50
	Anaerobic liquid	0.35
	Aerobic liquid	0.30
Beef	Solid without bedding	0.35
	Solid with bedding	0.25
	Anaerobic liquid	0.30
	Aerobic liquid	0.25
Dairy	Solid without bedding	0.35
	Solid with bedding	0.25
	Anaerobic liquid	0.30
	Aerobic liquid	0.25
Sheep	Solid	0.25
Poultry	Deep pit	0.45
	Solid with litter	0.30
	Solid without litter	0.35
Horses	Solid with bedding	0.20

Table 6. Estimated nutrient requirements for one crop year assuming complete crop removal.

Crop	Yield	N Requirement	P_2O_5 Removal	K_2O Removal
		lb/acre		
Corn	80 bu	80	42	77
	100 bu	110	60	120
	150 bu	180	80	215
	180 bu	220	100	240
Corn silage	16 tons	110	45	102
	32 tons	240	80	245
Soybeans*	30 bu	0	32	52
	40 bu	0	45	80
	50 bu	0	48	120
	60 bu	0	65	145
Grain sorghum	80 cwt	150	90	200
Wheat	40 bu	40	30	50
	60 bu	70	50	110
	80 bu	90	54	162
Oats	80 bu	30	35	95
	100 bu	40	55	150
Barley	65 bu	40	32	63
	100 bu	70	55	150
Alfalfa*	4 tons	0	40	180
	8 tons	0	80	480
Orchardgrass	6 tons	100	100	375
Bromegrass	5 tons	100	66	254
Tall fescue	3.5 tons	100	65	185
Clover-grass*	4.5 tons	0	60	175
	6 tons	50	90	360
Timothy	4 tons	100	55	250
Sorghum-Sudan grass	8 tons	150	122	467

Source: Extension Bulletin E-550 and the Potash and Phosphate Institute.

*Alfalfa, soybeans, and clover get most of their N from the air, so additional N from manure is not needed.

Section C. Annual Rate of Manure Application (continued)

c. Manure applied 3 years ago (if none, proceed to d.):

lb N/(ton or 1,000 gal) of manure x (mineralization factor x 0.125) x tons or 1,000 gal applied/acre = lb residual N/acre

Your farm:

__________ x (__________ x 0.125) x __________ = __________ lb residual N/acre

d. Total residual N:

Sec C.4.a + Sec C.4.b + Sec C.4.c = total lb residual N/acre

Example:

10.5 + — + — = 10.5 total lb residual N/acre

Your farm:

__________ + __________ + __________ = __________ total lb residual N/acre

e. Adjust N requirement of crop:

lb N required by crop (Sec B) - lb residual N (Sec C.4.d) = lb N required/acre

Example:

180 - 10.5 = 169.5 lb N required/acre

Your farm:

__________ - __________ = __________ lb N required/acre

5. Annual manure applications based on amount of N required by crop:

Adjusted N required (Sec C.4.e) ÷ lb available N/(ton or 1,000 gal) (Sec C.3.a or C.3.b) = tons of manure/acre or number of 1,000 gal units of manure/acre

Example:

169.5 ÷ 23 = 7,370 manure/acre

Your farm:

__________ ÷ __________ = __________ manure/acre

6. Annual manure application based on amount of P_2O_5 required by crop:

P_2O_5 required by crop (Sec B) ÷ lb P_2O_5/(ton or 1,000 gal) (Sec A.1.b) = tons manure/acre or number of 1,000 gal units of manure/acre

Example:

80 ÷ 27 lb/1,000 gal = 2,963 manure/acre

Your farm:

__________ ÷ __________ = __________ manure/acre

7. Select annual rate of manure to be applied. If manure is to supply all N and P_2O_5 needs of the crop, select the **higher** of the two values (Sec C.5 or Sec C.6) as your application rate per acre. If your aim is to maximize use of nutrients in animal manure, select the **lower** of the two values, then supplement with commercial fertilizer to supply the remainder of the nutrients required by the crop.

Rate of manure to be applied is:

Example:

2,963 manure/acre

Your farm:

__________ manure/acre

Section D. Additional Fertilizer Required

1. Nitrogen (do not complete if manure rate selected in Sec C.7 supplies all of the required N).
   a. Available N added in manure:

   Tons or 1,000 gal units of manure added/acre (Sec C.7) x lb available N/(ton or 1,000 gal) (Sec C.3.a or C.3.b) = lb available N applied

Example:
2963 x 23 lb/1,000 gal. = 68.1 available N applied

Your farm:
__________ x __________ = __________ available N applied

   b. Additional fertilizer N required:

   Adjusted N requirement (Sec C.4.e) - lb N applied (D.1.a) = lb fertilizer N required

Example:
169.5 - 68.1 = 101.4 lb fertilizer N

Your farm:
__________ - __________ = __________ lb fertilizer N

2. Phosphorus (do not complete if manure rate selected in Sec C.7 supplies all of the required amount of P_2O_5).
   a. P_2O_5 added in manure:

   Tons or 1,000 gal units of manure/acre (Sec C.7) x lb P_2O_5/(ton or 1,000 gal) (Sec A.1.b) = lb P_2O_5 applied

Your farm:
__________ x __________ = __________ lb P_2O_5 applied

   b. Additional fertilizer P_2O_5 required:

   P_2O_5 required by crop (Sec B) - lb P_2O_5 applied (Sec D.2.a) = lb fertilizer P_2O_5 required

Your farm:
__________ - __________ = __________ lb fertilizer P_2O_5 required

3. Potassium:
   a. K_2O added in manure:

   Tons or 1,000 gal units of manure/acre (Sec C.7) x lb K_2O/(ton or 1,000 gal) (Sec A.1.b) = lb K_2O applied

Example:
2,963 x 22 lb/1,000 = 65.2 lb K_2O added

Your farm:
__________ x __________ = __________ lb K_2O added

   b. Additional K_2O required:

   K_2O required by crop (Sec B) - lb K_2O applied (Sec D.3.a) = lb fertilizer K_2O required

Example:
215 - 65.2 = 149.8 lb fertilizer K_2O required

Your farm:
__________ - __________ = __________ lb fertilizer K_2O required

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Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.

Rep. 2-88-5M-KMF-SP, Price 35 cents.