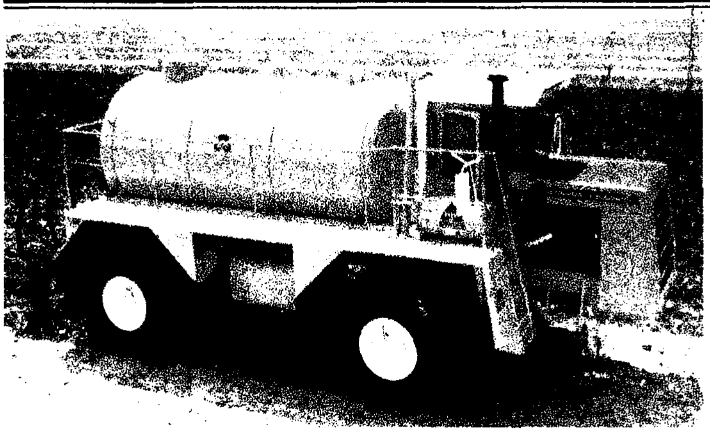

UTILIZATION OF ANIMAL MANURE AS FERTILIZER

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Until a decade or so ago, the manure produced in a livestock enterprise was generally considered a liability. Its value as fertilizer rarely offset the cost of handling, storing and applying it to the land. Therefore, the goal was often to dispose of it as conveniently and cheaply as possible.

Today, significantly higher fertilizer prices and tight profit margins have caused many livestock producers to re-evaluate their manure handling programs. Consequently, manure is being viewed less as a liability to be disposed of by the least cost method, and more as an asset to be stored and applied in a way that maximizes its nutrient value. Land application of animal manure can provide a hedge against the high price and possible short supplies of commercial fertilizers. Proper application is also compatible with recommended pollution control measures.

The purpose of this publication is to provide you, the livestock producer, with information on which to base decisions concerning the handling, storage and use of animal manure as a fertilizer resource. Discussed here are: the factors that affect manure's nutrient content, how to minimize nutrient loss, the kinds and amounts of nutrients used by various crops, how to determine manure application rates and the need for supplementary fertilizer, plus related management suggestions for maximizing manure value. A worksheet (with example) takes you step by step through the process of calculating proper application rates and needed disposal area size.

(Note: Decisions relative to manure handling and disposal involve considerations other than maximizing the nutrient values of manure. Such concerns include: labor availability and cost, type of livestock production system, equipment needs, manure application scheduling, conflicts with other production activities, etc.)

FACTORS AFFECTING THE FERTILIZER VALUE OF ANIMAL MANURE

The types and amounts of nutrients in manure and their eventual uptake by plants will vary considerably from farm to farm. The major determinants of manure nutrient content and availability are: (a) composition of the rations fed to livestock; (b) method of waste collection and storage; (c) amount of feed, bedding and/or water added; (d) method and time of land application; (e) characteristics of the soil; (f) type of crop to which the manure is applied; and (g) the climate. Following is a brief discussion of just how these factors affect animal manure fertilizer value and what might be done to minimize nutrient loss.

Ration Composition

The levels of nutrients and the presence or absence of certain feed additives in livestock rations will be reflected in the nutrient composition of manure. For example, changing the levels of inorganic salts (sodium, calcium, potassium, magnesium, phosphate and chloride) and feed additives (copper, arsenic, sulfa drugs or antibiotics) in rations will change the concentrations of these elements and possibly the rate of decomposition of organic matter in the manure. Changing the kinds and amounts of roughages or concentrates in rations will also likely alter the composition of manure and, thus, its fertilizer value.

Method of Collection and Storage

Type of housing system and the manure handling method used also affect nutrient content in manure. For instance, Table 1 shows that considerable nitrogen (N) will be lost when manure is dried by sun and air movement or exposed to runoff by rain, as would be the case in an open-lot livestock system. On the other hand, little N is lost in a completely covered feedlot when a manure pack, deep compost pit or liquid system with above or below ground storage is used. Loss of N from manure is generally greatest with long-term treatment or storage systems such as lagoons.

Phosphorus (P) and potassium (K) losses are negligible for all but open-lot and lagoon manure handling methods. In an open lot, 20-40 percent of the P and 30-50 percent of the K can be lost to runoff and leaching; however, much of these nutrients could be retained by use of runoff control systems such as settling basins and detention ponds. With a lagoon, 50-80 percent of the phosphorus in manure may settle out in the sludge layer and, thus, be unavailable if the liquid is applied to the land by irrigation.

Bedding and water that get into animal manure dilute its nutrient concentration, thus lessening its value as a fertilizer per unit volume; whereas feed spillage or wastage will increase the manure's nutrient content. In liquid manure systems, however, feed spillage together with inadequate agitation can cause sludge build-up, making removal difficult.

Method of Land Application

Animal manure is generally applied to land either by surface broadcast with plow-down or disking, by broadcast without incorporation, by injection (knifing) under the soil surface, or by irrigation. Maximum nutrient benefit is realized when manure is incorporated into the soil immediately after application (Table 2).

With solid manure, immediate incorporation not only minimizes nitrogen loss to the air, but also allows soil microorganisms to start decomposing the organic matter in manure, thus making nutrients available to the crop faster. With liquid systems, the practice of injecting, chiseling or knifing the manure beneath the soil surface likewise reduces N loss to the air and/or to runoff as well as minimizes odor problems.

Phosphorus and potassium losses during spreading are negligible and, thus, are not affected by method of application. However, incorporation of manure would minimize P and K losses due to runoff from the land.

Nitrogen loss by ammonia volatilization from surface applications is greater on dry, warm, windy days than on days that are humid and/or cold; therefore, loss is generally higher during the spring and summer seasons compared to fall and winter. Also, most ammonia volatilization occurs within the first 24 hours after surface application. Because poultry and veal calf manures are highly alkaline, ammonia N losses are greater than from manures of other livestock. Thus, it is especially important that poultry and veal calf manure be incorporated into the soil as soon as possible.

Also important is uniform application to prevent local concentrations of ammonium or inorganic salts that could otherwise reduce seed germination and yields.

Time of Land Application

The nearer to planting time that liquid manure is applied, the greater the availability of nutrients for plant growth. This would be especially desirable in a high rainfall area having soils from which nitrate N is readily lost by leaching or denitrification. However, on many other soils, planting too soon after heavy manure applications could reduce germination and seedling growth because of high salt concentrations near the soil surface.

By and large, in Minnesota, the best time for land application is still late summer or fall. This is usually when labor is more available and soil more trafficable. And although summer-fall application may result in a 25-50 percent total N loss, soil microorganisms do have more time to break down the manure and release nutrients for the following cropping season. This is especially important for solid manure, which contains high levels of organic matter.

Table 1. Nitrogen Losses from Animal Manure as Affected by Method of Handling and Storage.

Manure handling and storage method	Nitrogen loss[a]
	pct.
Solid systems	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Deep pit (poultry)	15-35
Liquid systems	
Anaerobic deep pit	15-30
Above ground storage	15-30
Earthen storage pit	20-40
Lagoon	70-80

[a]Based on composition of manure applied to the land vs. composition of freshly excreted manure, adjusted for dilution effects of the various systems.

Table 2. Nitrogen Losses from Animal Manure to the Air as Affected by Method of Application.

Method of application	Type of manure	Nitrogen loss[a]
		pct.
Broadcast without incorporation	Solid	15-30
	Liquid	10-25
Broadcast with incorporation[b]	Solid	1-5
	Liquid	1-5
Injection (knifing)	Liquid	0-2
Irrigation	Liquid	30-40

[a]Percent of total nitrogen in manure applied which was lost within 3 days after application; wind and temperature effects may increase losses.
[b]Incorporation within a few hours of application.

Soil Characteristics

Properties of soil, such as water infiltration rate, water-holding capacity, texture and cation exchange capacity, affect how much manure can be efficiently utilized by crops. Organic matter in manure is decomposed more rapidly in coarse-textured soil than in fine-textured soil and more rapidly under warm, moist conditions than under cold, dry conditions. However, fine-textured soils will retain the nutrients longer in the upper profile (where plant roots can get to them).

Because fine-textured soils have slow water infiltration rates, the amount of liquid manure (especially lagoon effluent) applied at any one time should be limited to the point that runoff does not occur. Coarse-textured soils, on the other hand, are quite permeable and can accept higher rates of liquid manure at any one time without danger of runoff. However, because most coarse-textured soils have a low cation exchange (nutrient-holding) capacity, manure applications may have to be restricted to several small doses during the growing season to minimize the chance of soluble nutrients entering and polluting ground water.

An added advantage of applying animal manure on the land is the fact that it enhances soil structure and increases organic matter content, thus improving a soil's tilth and its nutrient- and water-holding capacities. However, soil improvement through manure application is a long-term process; and initially, at least, the amounts that can be applied are restricted by soil characteristics.

Nutrient Removal by the Crop

Animal manure should be applied to soil only to the limit of the growing crop's nutrient needs. This not only insures efficient use of manure nutrients, but also minimizes the chances of nutrients leaching into and polluting ground water.

Table 3 shows the amounts of N, P_2O_5 and K_2O that various crops at various yield levels remove from the soil during a typical growing season. Nitrogen is utilized more effectively by grasses and cereal grain crops than by legumes. Thus, for greatest benefit, apply manure to land in corn, sorghum, small grains and grass for hay or pasture. Application of manure to legume pastures or soybean land should be considered only as a last alternative.

Any cropland scheduled for manuring should first be soil tested to determine its present fertility level. Periodic testing is recommended on land receiving heavy manure applications to monitor both the amounts and balance of nutrients in the soil. The soil test results and subsequent fertilizer recommendations for the crop to be grown are the best data for calculating a given field's manure application rate. However, if such tests and recommendations are not available, Table 3 may be used to approximate nutrient needs of crops.

Table 3. N, P_2O_5 and K_2O Utilization by Various Crops.[a]

Crop	Expected yield	N	P_2O_5	K_2O
			lb./acre	
Corn	80 bu.	121	42	77
	100 bu.	160	60	120
	150 bu.	185	80	215
	180 bu.	240	100	240
Corn silage	16 ton	130	45	102
	32 ton	200	80	245
Soybeans	30 bu.	123[b]	32	52
	40 bu.	180[b]	45	80
	50 bu.	257[b]	48	120
	60 bu.	336[b]	65	145
Grain sorghum	4 ton	250	90	200
Wheat	40 bu.	70	30	50
	60 bu.	125	50	110
	80 bu.	186	54	162
Oats	80 bu.	75	35	95
	100 bu.	150	55	150
Barley	65 bu.	74	32	63
	100 bu.	150	55	150
Alfalfa	4 ton	180[b]	40	180
	8 ton	450[b]	80	480
Orchardgrass	6 ton	300	100	375
Bromegrass	5 ton	166	66	254
Tall fescue	3.5 ton	135	65	185
Bluegrass	3 ton	200	55	180
Clover-grass mixture	4.5 ton	185	60	175
	6 ton	300	90	360
Timothy	4 ton	150	55	250
sorghum-sundan grass	8 ton	319	122	467

[a]Values are from reports by The Potash and Phosphate Institute of America and are for the total aboveground portion of the plants. When only grain is removed, a significant percentage of nutrients is left in the residues; however, these nutrients are temporarily tied up and not readily available for crop use. Thus, for estimating nutrient utilization for any crop year, assume complete crop removal.

[b]Legumes get most of their N from the air; additional N from livestock manure or inorganic N fertilizer is not normally needed.

Soil analyses can be performed by the University of Minnesota Soil Testing Laboratory as well as by a number of commercial laboratories. Contact your county Agricultural Extension Service office for instructions and materials for taking soil samples.

AVAILABILITY OF MANURE NUTRIENTS TO THE CROPS

Table 4 shows the amounts of manure produced annually by various livestock per 1000 pounds of live weight. Table 5 gives the average percent dry matter, pounds-per-ton fertilizer nutrient composition and monetary value of *solid manure* from the different animal species at time of disposal on the land. And Table 6 provides similar data for *liquid manures*, with nutrient composition expressed as pounds per 1000 gallons of raw manure.

The actual fertilizer value of manure from a particular farm might differ considerably from Tables 5 and 6, due to the factors discussed above. Nevertheless, these figures can serve as a guideline in determining land application rates if a nutrient analysis of manure is not available. But for accurate rate calculations, the nutrient content of manure must be determined by laboratory analysis. How to obtain such an analysis is discussed later.

Not all of the nutrients present in manure are readily available to a crop in the year of application. To be utilized by plants, manure nutrients must be

Table 4. Annual Manure Production per Animal Unit for Various Types of Livestock.

Type of livestock	Raw manure production per 1000 lb. animal weight[a] Solid	Liquid
	ton/yr	gal./yr
Dairy cow	15.0	3,614
Veal calf	7.5	1,752
Beef feeder	11.0	2,738
Beef cow	11.5	2,884
Swine feeder	18.0	4,380
Swine breeding herd	6.5	1,533
Sheep	7.5	1,679
Poultry layer	10.0	2,336
Poultry broiler	13.0	3,139
Turkey	11.0	2,592
Horse	8.5	2,044

[a]Raw manure includes feces and urine.

Table 5. Approximate Dry Matter, Fertilizer Nutrient Composition and Dollar Value of Various Types of Animal Manure at Time Applied to the Land—Solid Handling Systems.[a]

Type of livestock	Bedding vs. no bedding	Dry matter	Total N[b]	NH_4^+[c]	P_2O_5[d]	K_2O[e]	Value per ton[f]
		pct.	lb./ton				
Swine	Without bedding	18	10	6	9	8	$ 5.22
	With bedding	18	8	5	7	7	4.16
Beef cattle	Without bedding[g]	15	11	4	7	10	$ 4.69
	Without bedding[h]	52	21	7	14	23	9.57
	With bedding	50	21	8	18	26	11.03
Dairy cattle	Without bedding	18	9	4	4	10	$ 3.65
	With bedding	21	9	5	4	10	3.70
Sheep	Without bedding	28	18	5	11	26	$ 8.33
	With bedding	28	14	5	9	25	7.40
Poultry	Without litter	45	33	26	48	34	$24.51
	With litter	75	56	36	45	34	26.32
	Deep pit (compost)	76	68	44	64	45	36.01
Turkeys	Without litter	22	27	17	20	17	$12.31
	With litter	29	20	13	16	13	9.51
Horses	With bedding	46	14	4	4	14	$ 4.22

[a]Manure spreader capacity: 1 bu. = 40-60 lb.
[b]Ammonium N plus organic N, which is slow releasing.
[c]Ammonium N, which is available to the plant during the growing season.
[d]To convert to elemental P, multiply by 0.44.
[e]To convert to elemental K, multiply by 0.83.
[f]Based on a per-lb. value of 20¢ for available N, 30¢ for P_2O_5 and 13¢ for K_2O.
[g]Open concrete lot.
[h]Open dirt lot.

Table 6. Approximate Dry Matter, Fertilizer Nutrient Composition and Dollar Value of Various Types of Animal Manure at Time Applied to the Land—Liquid Handling Systems.[a]

Type of livestock	Manure storage	Dry matter	Total N[b]	NH_4^+[c]	P_2O_5[d]	K_2O[e]	Value per 1000 gal.[f]
		pct.	lb./1000 gal.				
Swine	Liquid pit	4	36	26	27	22	$ 16.16
	Lagoon[g]	1	4	3	2	4	1.79
Beef cattle	Liquid pit	11	40	24	27	34	$ 18.28
	Lagoon[g]	1	4	2	9	5	3.87
Dairy cattle	Liquid pit	8	24	12	18	29	$ 12.29
	Lagoon[g]	1	4	2.5	4	5	2.44
Veal calf	Liquid pit[h]	3	24	19	25	51	$ 18.28
Poultry	Liquid pit	13	80	64	36	96	$ 37.20

[a]Application conversion factors: 1000 gal. = about 4 tons; 27,154 gal. = 1 acre-inch.
[b]Ammonium N plus organic N, which is slow releasing.
[c]Ammonium N, which is available to the plant during the growing season.
[d]To convert to elemental P, multiply by 0.44.
[e]To convert to elemental K. multiply by 0.83.
[f]Based on a per-lb. value of 20¢ for available N, 30¢ for P_2O_5 and 13¢ for K_2O.
[g]Includes feedlot runoff water and is sized as follows: single cell lagoon—2 cu.ft./lb. animal wt; two-cell lagoon—cell 1, 1-2 cu.ft./lb. animal wt. and cell 2, 1 cu.ft./lb. animal wt.

converted into soluble inorganic ions as a result of microbial decomposition of organic matter.

Most of the nitrogen in animal manure is in ammonium (NH_4^+) and organic forms. All of the ammonium is potentially available to the crop during the first year after manure application. However, if manure is broadcast on the soil surface and not incorporated, about one-third of the added ammonium will be lost to the air as ammonia (NH_3) gas. Very little ammonia loss occurs, however, when manure is injected or incorporated.

Nitrogen in the organic form must be converted into inorganic forms (ammonium and nitrate) before it can be used by plants. The amounts of organic N converted to plant-available forms during the first cropping year after application vary according to both livestock species and manure handling system. Table 7 gives the proportions of organic N released (mineralized) from various types of manure during the first season. The amounts further released during the second, third and fourth cropping years after application are usually about 50, 25 and 12.5 percent, respectively, of that mineralized in the initial season.

Generally, 80-90 percent of the phosphorus and 80-100 percent of the potassium in animal manures are available to plants during the year of application. In most cases, we can assume that all of the P and K in manures is plant-available.

Table 7. Proportions of Organic Nitrogen in Various Manures Mineralized During the First Cropping Season After Application.

Livestock species	Manure handling system	Mineralization factor
Swine	Fresh	0.50
	Anaerobic liquid	0.35
	Aerobic liquid	0.30
Beef cattle	Solid without bedding	0.35
	Solid with bedding	0.25
	Anaerobic liquid	0.30
	Aerobic liquid	0.25
Dairy cattle	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

DETERMINING HOW MUCH ANIMAL MANURE TO APPLY

By knowing both the fertilizer needs of the crops to be grown and the nutrient content of animal manure, you can determine (1) how much manure can safely be applied to how much land, and (2) if additional commercial fertilizer will be needed for efficient crop production. On the following pages is a worksheet for making these application rate calculations. It presents an example situation, using hypothetical manure and soil/crop data, then provides space for inserting the data that reflect your situation.

Remember that soil tests and fertilizer recommendations, along with manure analyses, are necessary to calculate exact application rates. However, if such are lacking, the data in Tables 3, 5 and 6 can be used to calculate approximate rates.

WORKSHEET FOR DETERMINING ANIMAL MANURE APPLICATIONS RATES AND SIZE OF DISPOSAL AREA

Example Situation

A beef cattle feeder has an 800-head finishing operation (average weight 850 pounds per animal) on an open concrete lot. Manure is handled as a solid (no bedding) and surface-applied to the land without immediate cultivation. The area to be manured had received 20 tons last spring and will be planted to corn this spring (150-bushel potential). To maximize use of the manure as fertilizer, what is the proper manure application rate, how much, if any, supplemental commercial fertilizer will be needed, and how many acres of cropland will be required to dispose of the manure?

A. Determine Manure Composition and Soil Information

1. Manure Composition.

a. Values from chemical analysis of manure. (Laboratory data often given in ppm. To convert to pct., divide by 10,000. If composition data not available, go to Step A.1.b. and use appropriate figures from Table 5 or 6.)

	Our example	Your farm
Total N	= — pct.	_____ pct.
Ammonium N	= — pct.	_____ pct.
Nitrate N	= — pct.	_____ pct.
P_2O_5 (P x 2.29)	= — pct.	_____ pct.
K_2O (K x 1.20)	= — pct.	_____ pct.

b. Amount of each nutrient in manure (per ton or per 1000 gal.).

Pct. nutrient (A.1.a) x 20 = lb. nutrient/ton
Pct. nutrient (A.1.a) x 85 = lb. nutrient/1000 gal.

	Our example	Your farm
Total N	= 11 lb./t.	_____ lb./___
Ammonium N	= 4 lb./t.	_____ lb./___
Nitrate N	= — lb./—	_____ lb./___
P_2O_5	= 7 lb./t.	_____ lb./___
K_2O	= 10 lb./t.	_____ lb./___

2. Soil Information (from soil test).

Soil	Our example	Your farm
Texture	= silt loam	____
Soil pH	= 6.2	____
Available P	= — lb./acre	____ lb./acre
Exchangeable K	= — lb./acre	____ lb./acre

B. Determine Nutrient Needs of the Crop.

		Our example	Your farm
1. Crop to be Grown		= corn	____
2. Expected Yield per Acre		= 150 bu.	____
3. Nutrients Needed per Acre from soil test report or Table 3).	N	= 185 lb./acre	____ lb./acre
	P_2O_5	= 80 lb./acre	____ lb./acre
	K_2O	= 215 lb./acre	____ lb./acre

C. Determine Annual Rate of Manure Application.

1. Organic N in Manure (per ton or per 1000 gal.).

Lb. total N (A.1.b) - [lb. ammonium N (A.1.b) + lb. nitrate N (A.1.b)] = lb. organic N

Our example: 11 - [4 + 4] = 7 lb. organic N/t.

Your farm: ____ - [____ + ____] = ____ lb. organic N/____

2. Organic N in Manure (per ton or 1000 gal.) Available the First Year.

Lb. organic N (C.1) x mineralization factor (Table 7) = lb. available organic N

Our example: 7 x .35 = 2.45 lb. avail. organic N/t.

Your farm: ____ x ____ = ____ lb. avail. organic N/____

3. Plant-Available N in Manure (per ton or 1000 gal.). (Use either "a" or "b" below.)

a. Incorporated application of manure.

Lb. avail. organic N (C.2) + lb. ammonium N (A.1.b) + lb. nitrate N (A.1.b) = lb. plant-avail. N

Our example: — + — + — = — lb. avail. N/—

Your farm: ____ + ____ + ____ = ____ lb. avail. N/____

b. Surface application of manure (assumes 1/3 ammonium N lost by ammonia volatilization).

Lb. avail. organic N (C.2) + [lb. ammonium N (A.1.b) x .66] + lb. nitrate N (A.1.b) = lb. plant-avail. N

Our example: 2.45 + [4 x .66] + — = 5.09 lb. avail. N/t.

Your farm: ____ + [____ x .66] + ____ = ____ lb. avail. N/____

4. N Fertilizer Recommendation Adjusted for Residual N from Manure Applications the Last 3 Years.

a. Residual N from manure applied 1 year ago. (If none, proceed to "b".)

Lb. organic N (C.1) x [mineralization factor (Table 7) ÷ 2] x tons or 1000-gal. units manure applied/acre (your records) = lb. residual N/acre

Our example: 7 x (.35 ÷ 2) x 20t. = 24.5 lb. residual N/acre

Your farm: ____ x (____ ÷ 2) x ____ = ____ lb. residual N/acre

b. Residual N from manure applied 2 years ago. (If none, proceed to "c".)

Lb. organic (C.1) x [mineralization factor (Table 7) ÷ 4] x tons or 1000-gal. units manure applied/acre (your records) = lb. residual N/acre

Our example: — x (— ÷ 4) x — = — lb. residual N/acre

Your farm: ____ x (____ ÷ 4) x ____ = ____ lb. residual N/acre

c. Residual N from manure applied 3 years ago. (If none, proceed to "d".)

Lb. organic N (C.1) x [mineralization factor (Table 7) ÷ 8] x tons or 1000-gal. units manure applied/acre (your records) = lb. residual N/acre

Our example: — x (— ÷ 8) x — = lb. residual N/acre

Your farm: ____ x (____ ÷ 8) x ____ = lb. residual N/acre

d. Total residual N from applications over 3 years.

From 1 year ago (C.4.a) + from 2 years ago (C.4.b) + from 3 years ago (C.4.c) = total lb. residual N/acre

Our example: 24.5 + — + — = 24.5 total lb. residual N/acre

Your farm: ____ + ____ + ____ = ____ total lb. residual N/acre

e. Adjusted N requirement of crop.

Lb. N needed by crop (B.3) - lb. residual N (C.4.d) = lb. N still required/acre

Our example: 185 - 24.5 = 160.5 lb. N required/acre

Your farm: ____ - ____ = ____ lb. N required/acre

5. Annual Rate of Manure (per ton or 1000-gal.) to Be Applied.

a. Application rate based on amount of N needed by crop.

Lb. N still required (C.4.e) ÷ lb. avail. N in manure (C.3.a or C.3.b) = tons or 1000-gal. units of manure/acre

Our example: 160.5 ÷ 5.09 = 31.5t. manure/acre

Your farm: ____ ÷ ____ = ________ manure/acre

b. Application rate based on amount of P_2O_5 needed by crop.

Lb. P_2O_5 needed by crop (B.3) ÷ lb. P_2O_5 in manure (A.1.b) = tons or 1000-gal. units of manure/acre

Our example: 80 ÷ 7 = 11.4t. manure/acre

Your farm: ____ ÷ ____ = ________ manure/acre

c. Rate selected. If your aim is to supply all the crop's N and P_2O_5 needs from manure, select the higher of the two values (C.5.a. or C.5.b). If your aim is to maximize use of the nutrients in manure, select the lower of the two values, then supplement with commercial fertilizer to supply the rest of the nutrients required by the crop.

Our example: 11.4t. manure/acre

Your farm: _______ manure/acre

D. Determine Amount of Additional Fertilizer Required.

1. Nitrogen. (Do not complete if manure rate selected supplies the required N.)

a. Available N added by the manure.

Manure rate/acre (C.5.c) x lb. avail. N in manure (C.3.a. or C.3.b) = lb. avail. N applied/acre

Our example: 11.4 x 5.09 = 58 lb. avail. N applied/acre

Your farm: ____ x ____ = ____ lb. avail. N applied/acre

b. Additional fertilizer N required.

Lb. N still required/acre (C.4.e) - lb. N applied/acre (D.1.a) = lb. fertilizer N needed/acre

Our example: 160.5 - 58 = 102.5 lb. fertilizer N needed/acre

Your farm: ____ - ____ = ____ lb. fertilizer N needed/acre

2. Phosphorus. (Do not complete if manure rate selected supplies the required P_2O_5.)

a. P_2O_5 added by the manure.

Manure rate/acre (C.5.c) x lb. P_2O_5 in manure (A.1.b) = lb. P_2O_5 applied/acre

Our example: — x — = — lb. P_2O_5 applied/acre

Your farm: ____ x ____ = ____ lb. P_2O_5 applied/acre

b. Additional fertilizer P_2O_5 required.

Lb. P_2O_5 needed by crop/acre (B.3) - lb. P_2O_5 applied/acre (D.2.a) = lb. fertilizer P_2O_5 needed/acre

Our example: — - — = — lb. fertilizer P_2O_5 needed/acre

Your farm: ____ - ____ = ____ lb. fertilizer P_2O_5 needed/acre

3. Potassium.

a. K_2O added by the manure.

Manure rate/acre (C.5.c) x lb. K_2O in manure (A.1.b) = lb. K_2O applied/acre

Our example: 11.4 x 10 = 114 lb K_2O applied/acre

Your farm: ____ x ____ = ____ lb. K_2 applied/acre

b. Additional fertilizer K_2O required.

Lb. K_2O needed by crop/acre (B.3) - lb. K_2O applied/acre (D.3.a) = lb. fertilizer K_2O needed/acre

Our example: 215 - 114 = 101 lb. fertilizer K_2O needed/acre

Your farm: ____ - ____ = ____ lb. fertilizer K_2O needed/acre

E. Determine Amount of Land Required to Dispose of Annual Manure Production.

1. Average Animal Units (a.u.) per Year in the Livestock Enterprise.

   (Avg. wt./animal x avg. no. animals/yr.) ÷ 1000 lb. = a.u./yr.

   Our example: (850 x 800) ÷ 1000 = 680 a.u./yr.

   Your farm: (____ x ____) ÷ 1000 = ____ a.u./yr.

2. Annual Manure Nutrient Production per Animal Unit, Expressed as Pounds of Nutrient per Animal Unit.

   Tons or 1000-gal. units of manure/a.u. (Table 4) x lb. nutrient in manure (A.1.b and C.3.a or C.3.b) = lb. nutrients/a.u.

   Our example:
   N = 11t. x 5.09 (C.3.a or b) = 56 lb. avail. N/a.u.
   P_2O_5 = 11t x 7 (A.1.b) = 77 lb. P_2O_5/a.u.
   K_2O = 11t x 10 (A.1.b) = 110 lb. K_2O/a.u.

   Your farm:
   N = ____ x ____ (C.3.a or b) = ____ lb. avail. N/a.u.
   P_2O_5 = ____ x ____ (A.1.b) = ____ lb. P_2O_5/a.u.
   K_2O = ____ x ____ (A.1.b) = ____ lb. K_2O/a.u.

3. Annual Manure Nutrient Production from the Livestock Enterprise, Expressed as Pounds Year.

   a.u./yr. (E.1) x lb. manure nutrient/a.u. (E.2) = lb. manure nutrient/yr.

   Our example:
   N = 680 x 56 = 38,080 lb. avail. N/yr.
   P_2O_5 = 680 x 77 = 52,360 lb. P_2O_5/yr.
   K_2O = 680 x 110 = 74,800 lb. K_2O/yr.

   Your farm:
   N = ____ x ____ = ____ lb. avail. N/yr.
   P_2O_5 = ____ x ____ = ____ lb. P_2O_5/yr.
   K_2O = ____ x ____ = ____ lb. K_2O/yr.

4. Total Cropland Area Required for Annual Manure Application, Expressed as Acres Year.

   Lb. manure nutrient/yr. (E.3) ÷ lb. nutrient needed by crop (B.3 or C.4.e) = acres needed/yr.

   Our example:
   N = 38,080 ÷ 160.5 (C.4.e) = 237 acres/yr.
   P_2O_5 = 52,360 ÷ 80 (B.3) = 654 acres/yr.

   Your farm:
   N = ____ ÷ ____ (C.4.e) = ____ acres/yr.
   P_2O_5 = ____ ÷ ____ (B.3) = ____ acres/yr.

   The first line is number of acres required if basing manure application rate on the crop's N needs. The second line is number of acres required if basing manure application rate on the crop's P_2O_5 needs.

Summary of the Worksheet Example

The example shows that the proper manure application rate on 150-bushel corn land would be 31.5 tons per acre if the manure is used to supply all the N and P needed by the crop or 11.4 tons if the fertilizer value is maximized (C.5.c).

The example calculations also determined that this 800-head cattle feeding operation would require a minimum of 236 acres at the 31.5 ton-per-acre manure application rate or a maximum of 654 acres at the 11.4 ton-per-acre rate (E.4).

If manure was applied to maximize its fertilizer value (11.4 tons per acre), calculations indicate that an additional 102.5 pounds of N and 114 pounds of K_2O are needed per acre to meet the corn nutrient requirements (calculations not shown).

OTHER MANAGEMENT CONSIDERATIONS TO MAXIMIZE THE FERTILIZER VALUE OF MANURE

Using Nitrification Inhibitors

Chemical compounds are available called "nitrification inhibitors" that can be added to fertilizers to retard nitrogen losses from soil. These products inhibit the action of certain soil bacteria that convert ammonium N to nitrate N. It is this nitrate form that easily leaches by water movement through the soil or converts to nitrogen gas during denitrification. Nitrification inhibitors are particularly valuable when used with fall applications of manure and/or commercial fertilizer, since N losses can range from 25 to 50 percent due to leaching and denitrification over the wintering period.

Recent research at Purdue has shown that addition of a nitrification inhibitor to liquid swine manure used as the only source of N for corn minimized N losses and increased corn yields. This beneficial effect was more evident with fall manure applications than with spring applications unless soil conditions were extremely wet in spring (favorable for denitrification).

Nitrification inhibitors are added to manure either: (1) through an open hatch prior to manure loading, (2) through a separate aspirator tube with vacuum systems or (3) into a manure pump (on the suction side) at time of loading. Regardless of which method is used, the manure must be injected or immediately incorporated in the soil after application to assure beneficial response, since nitrification inhibitors are volatile compounds.

Maximum benefit from a nitrification inhibitor is realized when the rate of N added to the soil equals the crop's needs. Therefore, manure sample analysis is highly recommended to insure that proper amounts of N are being applied.

Developing a Fertilizer/Manure Application Plan

Many producers are already applying enough manure on the land to meet crop nutrient needs and then are unnecessarily adding commercial fertilizer. This practice not only wastes money and much of the manure's fertilizer value, but also can cause nutrient imbalance in the soil as well as heighten the chances of nutrient leaching or runoff into water courses. Repeated applications of high amounts of manure result in a buildup of the P and K contents of soils.

Livestock and poultry producers should develop a fertilizer application plan that first maximizes the use of manure nutrients then supplements with commercial fertilizers *only* if additional nutrients are needed for the crop. The major elements of such a plan include: (1) periodic analysis of the manure produced in the livestock operation, (2) a routine soil testing program, (3) keeping good records of fields manured and the application rates used, and (4) rotating fields for manure application every 2-3 years or as a soil test dictates to avoid nutrient buildup.

Applying Manure to the Land

Here are some suggestions to help insure safe and effective application of animal manure to cropland. (Additional suggestions are found in the publications listed at the end.)

- Unless immediately incorporated into the soil, surface apply manure at reasonable distances from streams, ponds, open ditches, residences and public buildings to reduce runoff and odor problems and to avoid neighbor complaints.
- To minimize farmstead odor problems, spread raw manure frequently, especially during the summer. Spread early in the day when the air is warming

up and rising rather than later when the air is cooling and settling. Do not spread on days when the wind is blowing toward populated areas or when the air is still and seems to hang.

- During periods of the year when the soil is frozen, apply manure only to relatively level land.
- Agitate liquid manures thoroughly in pits to insure removal of settled solids. This is important for uniform application of the nutrients and for obtaining accurate, representative analysis samples.
- Consider irrigating diluted manures (lagoon or runoff liquids) during dry weather to supply needed water as well as nutrients to growing crops.
- If irrigating manure on growing crops, do it at a time other than during the heat of the day. After manure application, irrigate with clean water to wash the plants off, thereby avoiding leaf burn.
- Don't spread liquid manure on water-saturated soils where runoff is likely to occur.
- Make safety your first priority when removing manure from tanks or pits. That includes removing animals or increasing ventilation to maximum in slatted floor areas over manure pits during agitation because of oxygen deficiency or toxic gas accumulation. If animals are left in buildings during agitation, monitor their behavior carefully. Don't enter manure storage structures without life-support equipment (preferably oxygen tank and mask).

HOW TO OBTAIN AN ANIMAL MANURE ANALYSIS

Laboratory analysis is the most accurate way to ascertain the nutrient value of the manure from your livestock enterprise. The analysis report will include information on dry matter, ammonium N, total N (ammonium plus organic N), phosphorus and potassium content. For the names of commercial laboratories providing this service, contact your county Extension office.

Keys to the accuracy of a manure analysis are thorough agitation of the manure and proper sampling. A considerable amount of nitrogen can be lost if a sample is not correctly taken, handled and preserved. Here is how to collect both liquid and solid samples.

For liquid manure, agitate the contents of a manure pit to obtain a well-mixed specimen. Place the sample in a quart-sized plastic container with a screw-on lid and tighten well. Preserve the liquid sample immediately either by freezing or by adding 2-3 drops of muriatic acid to lower its pH. Muriatic acid can be applied with an inexpensive medicine dropper, but be extremely careful when doing so and wear goggles.

For solid manure, obtain samples from several parts of the manure source. Place the composite sample in a plastic bag, twist and tie tightly. For added safety, place in a second plastic bag. Preserve immediately by freezing.

Deliver the liquid or solid manure sample to the laboratory personally or package well in a strong, insulated container and ship the fastest way possible. Insist that the sample be kept frozen or refrigerated at the laboratory until tested.

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