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Calculating the fertilizer value of manure from livestock operations

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Livestock producers know that manure can be applied to croplands as a soil amendment as well as a fertilizer. This publication outlines a method for calculating appropriate manure application rates for particular crops and soil conditions. It also identifies losses of nutrients that can occur at different stages in the management and application system—from collection, through storage, to land application.

The values represent the best available knowledge that we can suggest over a statewide area. Where you have specific values, such as from manure or soil analyses, you're encouraged to use them. A worksheet and example are included for your use (pages 6-7).

Benefits

Increased crop production can result when you add the nutrients contained in manure. A manure slurry will also provide some water to the soil. Adding manure to soil can lessen wind and water erosion, improve soil aeration and tilth, increase soil organic matter, and promote the growth of microorganisms that are beneficial to crops.

Hazards

On the other hand, excess applications of manure can be harmful to crops, soil, surface and ground water quality. In some cases (most commonly with fresh poultry manure) manure with high nitrogen content can burn crops. Heavy applications of manure also can cause excess accumulation of soluble salts in the soil, especially in some of eastern Oregon's arid regions, where little or no leaching occurs.

High salt content in soil can decrease water availability, which inhibits plant growth. In addition, a large volume of manure in one application can cause temporary soil sealing, particularly in low spots. Soil sealing increases the potential hazard of manure runoff with any subsequent rainfall.

Plant nutrient content of manure

A laboratory analysis of a representative manure sample will determine its nitrogen, phosphorus, and potassium (N-P-K) content. You can then calculate the economic value of the manure according to its plant nutrient content. Although other nutrients and trace elements in the manure are beneficial to crops, it's difficult to determine the value of that benefit.

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Sample the manure to determine the concentration of nutrients in storage. In liquid tanks, mix thoroughly before sampling or sample at different places in the storage unit to get a representative value. Mix these together and put a sample in a plastic jug or jar with a screw lid.

Keep the sample in a cool location to prevent gas buildup and rupture of the container. A local feed store, county health department, or your county Extension agent can help you locate a laboratory that will analyze the sample.

Some studies have been conducted on the production and nutrient content of fresh manures from farm animals (table 1). To find the total weight originally available, multiply the nutrient value from table 1 times the number of animals times the number of days the manure has been collected and stored.

For a portion of the year, the animals may spend part of a day in an area where the manure will be collected, and the rest of the day out on pasture. When this applies, adjust the production values accordingly. For that period when the animals are pastured, use the grazing option to account for the nutrients handled in that way. Be sure to account for the manure produced for 365 days.

Nutrient losses during collection and storage

Nutrient losses from manure occur in collection, during storage, while spreading, and after land application. These losses vary widely—under some conditions, up to 70 or 80% of the initial concentration will be lost. Table 2 lists the percentage of original nutrient concentrations retained by various collection and storage methods. These values represent a range of values, and yours could be higher or lower, depending on several factors.

In addition to the frequency and method of manure collection, the type of animal housing and handling system affects the final nutrient composition by influencing the addition of bedding, wastewater, and other materials.

The duration, type, and location of storage also affect the final concentrations of nutrients in manure. Covered storage units generally are cooler and have less biological activity than open units. This usually means smaller losses from these units. Open storage units are subjected to precipitation, resulting in leaching and runoff. Less nitrogen, for example, is lost from deep pits and roofed areas that are protected from high temperatures and rainfall.

From the animal source through field application, nitrogen is subject to the greatest losses of all the plant nutrients contained in manure. About 50% of the nitrogen in fresh manure is in the organic form and appears as partially digested feed and microorganisms. The other 50% is inorganic, usually as ammonia, and it's subject to significant losses during collection, storage, and application.

In most manure management systems, 5 to 15% of the original phosphorus and potassium is lost in handling. In open lots, however, as much as 50% of the phosphorus and 40% of the potassium can be lost through runoff, leaching, and mixing with the soil on the lot surface.

In lagoon systems, up to 80% of the phosphorus and nitrogen can be lost. Much of the phosphorus is in the sludge along the bottom—and very difficult to remove in normal emptying operations.

Table 1.—Total production and nutrient content of manure from various farm animals

Animal	Animal size (lb)	Total manure production lb/day	cu ft/day	gal/day	% water	Nutrient content N lb/day	P lb/day	K lb/day
Dairy	150	13	0.19	1.5	88	0.06	0.011	0.04
	250	22	0.32	2.4	88	0.11	0.023	0.07
	500	43	0.66	5.0	88	0.22	0.047	0.15
	1000	89	1.32	9.9	88	0.45	0.094	0.29
	1400	120	1.85	13.9	88	0.59	0.131	0.41
Beef								
Cattle	500	30	0.50	3.8	91	0.17	0.051	0.12
	750	45	0.75	5.6	91	0.26	0.079	0.19
	1000	60	1.0	7.5	91	0.34	0.109	0.24
	1250	65	1.2	9.4	91	0.43	0.12	0.31
Cow		63	1.05	7.9	91	0.36	0.11	0.26
Swine								
Nursery pig	35	2.9	0.038	0.27	89	0.018	0.0052	0.01
Growing pig	65	5.3	0.070	0.48	89	0.034	0.0099	0.02
Finishing pig	150	12.4	0.16	1.13	89	0.078	0.023	0.045
	200	16.6	0.22	1.5	89	0.104	0.036	0.059
Gestate sow	275	11.3	0.15	1.1	89	0.069	0.023	0.04
Sow and litter	375	15	0.21	1.4	89	0.1	0.031	0.054
Boar	350	14	0.19	1.4	89	0.081	0.023	0.051
Sheep	100	4	0.062	0.46	87	0.045	0.0066	0.032
Poultry								
Layers	4	0.26	0.0035	0.027	84	0.0034	0.0012	0.0012
Broilers	2	0.17	0.0024	0.018	78	0.0024	0.0006	0.0008
Horse	1000	51	0.75	5.6	85	0.31	0.072	0.25

Table 2.—Percentage of original nutrient content of manure retained by various storage systems

	Beef			Dairy			Horse			Poultry			Sheep			Swine		
Method	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Daily spread				80	90	90	75	90	90	65	90	90	75	90	90			
Dry (with roof)				70	90	90	70	90	90	60	90	90	65	90	90			
Earthen storage	65	80	85	55	60	70										60	60	70
Lagoon/flush	30	40	60	30	40	60				25	40	60				30	40	60
Open lot	60	70	60	60	70	65	60	70	65				55	70	60	60	70	65
Pits (slats)	75	95	95	75	95	95				70	95	95	75	95	95	75	95	95
Scrape/ storage tank	70	85	90	70	90	90												
None (grazing)	100% of nutrients retained																	

You'll notice that earthen storage losses of nitrogen are much less than those from a lagoon. The basic reason is that a treatment lagoon is never emptied and is constantly undergoing biological breakdown, but an earthen storage unit will be emptied several times a year and applied to land.

Nutrients removed in solids

Some operators use a liquid-solid separator to remove solids from the manure/wastewater slurry. If you remove the solids (or any other part of the manure) off farm, subtract that fraction from the amount of nutrients left to be applied to your crop land. A separator is capable of removing solids containing about 22% of the nitrogen, and 20% of both phosphorus and potassium. Don't use this calculation if you field-apply the solids to your land.

Nutrient losses during field application

Nitrogen can volatilize when manure is spread on cropland (fresh manure odor is mostly volatilized ammonia). Essentially all the phosphorus and potassium applied will be available for the crop. Runoff can remove a portion of all three nutrients; however, this type of loss is very site-specific and is not included in these calculations.

Table 3 outlines the percentage of original nutrient content delivered and available for plant use by various application methods. These figures represent both application and field losses before plant use (preutilization).

Table 3.—Percentage of original manure nutrient content delivered to cropland and available for plant uptake (these figures reflect application and preutilization losses)

Application method	%N	%P	%K
Injection	95	100	100
Broadcast	80	100	100
Broadcast with immediate cultivation	95	100	100
Sprinkling	75	100	100
Grazing	85	100	100

Denitrification losses in the field

Nitrogen may also be lost by denitrification (loss of inorganic nitrogen by biological conversion to nitrogen gas). Anaerobic bacteria, which work in the absence of oxygen, break down nitrate nitrogen to release nitrogen gas; thus the more oxygen in the soil, the less nitrogen that is lost. This loss is related to the soil type and the rainfall pattern.

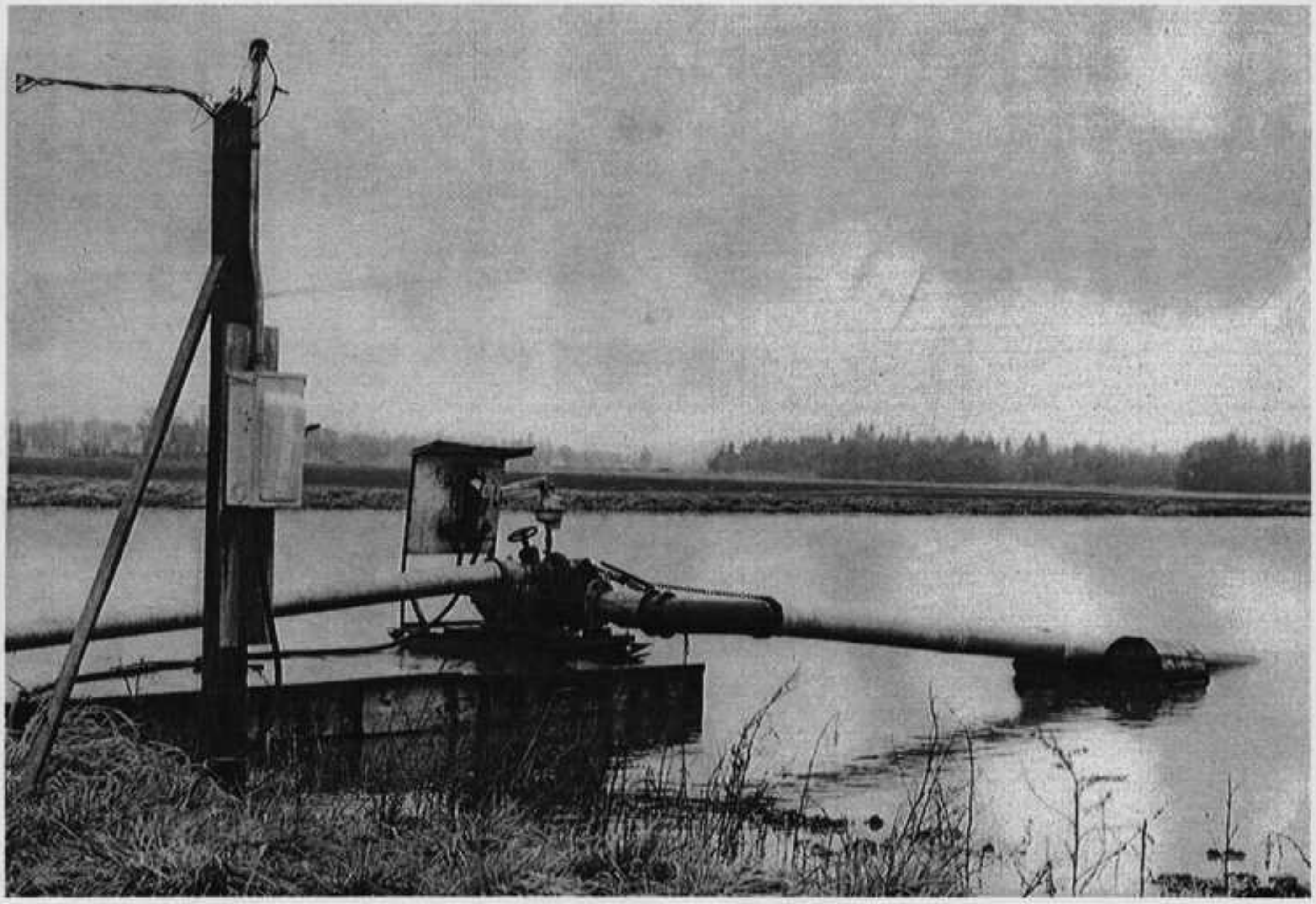
Heavy, wet soils provide the ideal condition for maximum nitrogen loss through denitrification. Soil drainage rate is one of the factors used to calculate denitrification losses.

For denitrification to occur, the nitrogen must first be oxidized to nitrate and then reduced to nitrogen gas or nitrous oxide gas. The rather complex processes that govern these transformations depend on the cycle of aeration and saturated (anaerobic) conditions.

Denitrification coefficients range from 5% loss in well-drained soils to 50% loss in poor drainage conditions. The wide rainfall patterns and diverse soil types make a complex set of values for Oregon. The values shown in table 4 indicate average expected nitrogen available to plants after denitrification losses.

Table 4.—Percentage of field-applied manure nitrogen available to plants after denitrification losses, by region

Location	%N available
Coast	80
Willamette Valley and southern Oregon	
Irrigated	87
Nonirrigated	92
Eastern Oregon	95



Leaching loss of nitrate nitrogen is caused by percolating water moving below the root zone. Once below the root zone, this nitrate is a potential ground water pollutant. Again, soil type and rainfall are the major influencing factors. Soil permeability can range from less than 0.06 inch per hour for clay soils to greater than 20 inches per hour for gravelly sandy soils.

The amount of nutrients (nitrogen, primarily) that are lost to deep leaching depends on physical conditions and on the rate and season of manure application.

Availability of nutrients for crops

Nitrogen is a vital nutrient, and its availability influences both microbial activity and plant growth. The carbon-nitrogen ratio (C/N) of applied wastes affects this availability and, therefore, affects plant growth.

If a material with a high C/N ratio, such as manure with a lot of bedding, is added to a soil, organisms that decompose the organic matter grow until limited by available minerals and nitrogen.

All the immediately available nitrogen may be bound by the microorganisms; for the short run, you may have to add more commercial fertilizer to the soil than before you applied the manure. The nitrogen bound by the microorganisms will become available to the plant, but it will take a longer time.

Inorganic nitrogen is the form that is taken up by the plant root system and used for growth. The organically bound nitrogen in the soil breaks down with time to form inorganic nitrogen. With enough time, the organic nitrogen present in manure will be converted to plant-usable inorganic nitrogen.

The exact percentage will vary, but researchers agree that from 4 to 25% of the nitrogen in manure will contribute to the organic matter of the soil. This means that a fraction of the added manure won't be available for plant uptake.

This nonavailable fraction is sometimes referred to as the *recalcitrant* fraction. For the calculations in this publication, we've classified a value of 10% of the manure nitrogen as recalcitrant. This means you can add 10% more nutrients than your crop will use, and we've included this value in the suggested application rates in tables 5 and 6. This fraction won't add to surface or ground water pollution problems.

The breakdown process of manure is called *mineralization*. Since livestock feeds have various particle sizes and compositions, manures have different mineralization rates, and some of the manure may be in the soil 2 years before all the organic nitrogen is converted to plant-usable inorganic nitrogen. Therefore, not all the nitrogen contained in manure that has been incorporated into the soil can be used by the plants during the first year after manure application.

Table 5.—Rates of nutrients used by NCALC

Crop	Unit	Rate (lb) N	P	K
Alfalfa hay, immature and early bloom	per ton	65.0	5.3	42.0
Alfalfa hay, midbloom to mature	per ton	45.0	4.5	36.0
Canarygrass hay	per ton	40.0	7.3	63.0
Orchardgrass	per ton	38.4	6.1	37.6
Cereal grain hay	per ton	24.0	3.4	10.0
Grass hay	per ton	25.0	3.6	19.4
Barley/oats	per ton	34.0	5.0	7.2
Alfalfa/grass silage	per ton, wet	22.0	2.9	19.0
Red clover silage	per ton, wet	14.5	2.0	12.0
Corn silage	per ton, wet	7.0	2.5	6.6
Corn earlage	per ton, wet	25.5	4.6	5.6
Grazed grass (by region, range indicated)	per acre	50-165	19-24	87-110
Harvested grass (by region, range indicated)	per acre	80-220	20-28	92-132

Table 6.—Suggested nutrient application rates for pastures, by location, harvested and grazed (lb/acre[a])

Location	Harvested N	Harvested P	Harvested K	Grazed N	Grazed P	Grazed K
Coast	220	28	132	165	24	110
NW valleys						
irrigated	200	25	120	150	22	100
nonirrigated	110	21	95	80	20	92
So. Oregon						
irrigated	180	24	110	75	20	90
nonirrigated	80	20	92	50	19	87
E. Oregon	200	25	120	120	21	96

[a]These values include a fraction of the nutrients in addition to the plant uptake values, to account for the portion that is unavailable to the plant and contributes to an increase in soil organic matter. *Note:* 1 lb P_2O_5 = 0.44 lb P; 1 lb K_2O = 0.83 lb K.

The rate of mineralization depends on the soil moisture content, organic matter level, and temperature. However, most animal manure is spread on the same fields year after year. Therefore, except for the recalcitrant component, the exact mineralization rate is unimportant because the plant will receive the same amount of nutrients each year after the first year—some from the current year's application, some from last year, and so on. This will be exactly the same amount next year.

For efficient use of nutrients, apply manure so nutrients added do not greatly exceed those removed by crops on an annual basis. Table 5 lists nutrient application rates for crops common on livestock operations in Oregon. Table 6 lists two levels of fertilization for pastures.

For example, if a beef operator grazes the animals full time on the pasture and cuts no hay, all the nutrients that leave this field must go in the beef produced. A lower fertilization rate is recommended for this type of operation.

Harvesting by cutting of hay (green chopping) is the most efficient harvest and removes all of the grass. The amount of applied fertilizer should be reflected in the nutrients that are removed from the field.

Management of the animals and crop is very important in determining proper application and use values. It's impossible to place a numerical value on the management factor, but tables 5 and 6 reflect the values suggested under a good management program.

There are also different values for four different regions in the State. Table 6 includes these to represent differences in growing degree days and general soil types.

Because moisture availability is critical to grass production, the irrigated and nonirrigated choices reflect these levels of production. Manure nutrients, especially nitrogen, are used more efficiently by grasses and cereals than by legumes. Inoculated legumes can get most of their nitrogen from the air, so additional nitrogen is not normally needed.

Get your soil tested to determine specific fertilizer requirements for your land. See EC 628 for the procedure, and ask if your county Extension office has the OSU Extension videotape, *How to Take a Soil Sample*. Adjust manure application rates for your soil conditions to balance crop nutrient needs with the soil test results.

In most cases, if you apply manure at a rate to satisfy the nitrogen requirements, you'll overapply phosphorus or potassium. Apply manure to satisfy the requirements of the least-needed nutrient and supplement the other two.

The worksheet and example on pages 6-7 will let you follow the process and insert the values for your livestock operation.

A computer program called *NCALC* has been developed using these same values and procedures. See your county Extension agent about access to this program.

For further reading

Gardner, E. Hugh, and John Hart, *How to Take a Soil Sample... and Why*, Oregon State University Extension Service Circular 628 (Corvallis, reprinted 1991). No charge for single copy.

Calculating land application rates

The following example and worksheet will help you use all the information in this publication to determine how much nitrogen, phosphorus, and potassium from manure you should use on your cropland.

Example

1. Operator in the Willamette Valley has 100 milking cows (1400 lb each) with a liquid flush/lagoon system with a separator. Annually sprinkles this on cropland to grow 31 tons of corn silage. How much land should he utilize to receive his manure?

No. animals	Animal wt.	Storage
100	1400 lb	365 days

2. Nutrient production rate (from table 1)

N: 0.59 lb/cow/day
P: 0.131 lb/cow/day
K: 0.41 lb/cow/day

3. Total nutrient production
No. animals × Days × Rate = Total produced

N: 100 × 365 × 0.59 = 21,535
P: 100 × 365 × 0.131 = 4,781
K: 100 × 365 × 0.41 = 14,965

4. Use of a separator and off-farm use of solids

	Yield (lb)	×	% Held	=	Total from storage
N:	21,535	×	0.78	=	16,797
P:	4,781	×	0.80	=	3,825
K:	14,965	×	0.80	=	11,972

5. Storage losses (from table 2)

	To storage	×	Retained	=	Total from storage
N:	16,797	×	0.30	=	5,039
P:	3,825	×	0.40	=	1,530
K:	11,972	×	0.60	=	7,183

1. ______________________________
____
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____
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No. animals	Animal wt.	Storage
________	________	________

2. Nutrient production rate (from table 1)

N: ______________________________
P: ______________________________
K: ______________________________

3. Total nutrient production
No. animals × Days × Rate = Total produced

N: ______________________________
P: ______________________________
K: ______________________________

4. Use of a separator and off-farm use of solids

Yield × % Held = Total to storage
N: ______________________________
P: ______________________________
K: ______________________________

5. Storage losses (from table 2)

To storage × Retained = Total from storage
N: ______________________________
P: ______________________________
K: ______________________________

6. Application losses (from table 3)

From storage	×	Retained	=	Total applied
N: 5,039	×	0.75	=	3,779
P: 1,530	×	1.00	=	1,530
K: 7,183	×	1.00	=	7,183

7. Nutrient availability after denitrification

Total lb applied	×	Retained	=	Lb available
N: 3,779	×	0.87	=	3,287
P: 1,530	×	1.00	=	1,530
K: 7,183	×	1.00	=	7,183

8. Nutrients used by crop

Lb available	÷	Amount needed/A	=	No. of A available
N: 3,287	÷	220 lb	=	14.9
P: 1,530	÷	40 lb	=	38
K: 7,183	÷	220 lb	=	32.6

9. Largest acreage needed (from #8 above)

38 A for Phosphorus

10. Acres needing supplemental nutrients

Acres served	−	Satisfied	=	Total
N: 38	−	14.9	=	23.1 A
P: 38	−	38	=	0 A
K: 38	−	32.6	=	5.4 A

11. Additional nutrients needed

Area (A)	×	Rate (lb/A)	=	Bought
N: 23.1	×	220	=	5,082 lb
P: 0	×		=	0 lb
K: 5.4	×	220	=	1,188 lb

6. Application losses (from table 3)

From storage × Retained = Total applied

N: ______________________________

P: ______________________________

K: ______________________________

7. Nutrient availability after denitrification

Total applied × Retained = Lb available

N: ______________________________

P: ______________________________

K: ______________________________

8. Nutrients used by crop

Lb available ÷ Amount needed/A = No. of A available

N: ______________________________

P: ______________________________

K: ______________________________

9. Largest acreage needed (from #8 above)

____

10. Acres needing supplemental nutrients

Acres served − Satisfied = Total

N: ______________________________

P: ______________________________

K: ______________________________

11. Additional nutrients needed

Area (A) × Rate (lb/A) = Bought

N: ______________________________

P: ______________________________

K: ______________________________

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Since then, we have reprinted a number of titles that may be of interest to you. Some, however, are permanently out of print. For a current catalog of available publications, contact us at:

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