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Determining Crop Available Nutrients from Manure

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Determining Crop Available Nutrients from Manure

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This NebGuide discusses the availability and use of manure nutrients for field crop production.

When managed correctly, nutrients in livestock manure can be a valuable resource. When managed improperly, however, these same nutrients represent a potential environmental pollutant. Accurate crediting of manure nutrients within a total crop nutrient program is fundamental to utilizing manure as a resource. This NebGuide illustrates how to estimate the crop available manure nutrients *(part c, Figure 1)* and calculate an agronomically based manure application rate. There are other tools available that do the calculations for you. This NebGuide will explain each step of the process. After understanding how and why these calculations are made, the tools offer fast and accurate ways to work with multiple fields and manure sources. To illustrate the calculations, an example calculation is provided and a worksheet is included, allowing you to determine manure availability for your situation.

To accurately credit crop available manure nutrients, three pieces of information are needed:

1. Manure nutrient of concentration at time of land application—the concentration of individual nutrients in manure measured as pounds of nutrient per unit of manure (ton, 1,000 gallons, or acre-inch).
2. Manure application rate—the rate at which manure is applied to the land measured as tons, 1,000 gallons, or acre-inches.
3. Manure nutrient availability factors—the percentage of nutrients in manure available to the crop in a given year.

Estimating Manure Nutrient Concentration

Knowing the concentration of nutrients in manure is as crucial as knowing those facts about commercial fertilizer. *Table 1* provides estimates of typical manure nutrient concentrations. Because manure nutrient content can vary with livestock species, manure moisture, livestock diet, and collection and storage losses, a manure analysis is preferable to using table values for an accurate estimate. Where manure is stored outdoors, sampling on a seasonal basis (when significant quantities of manure are land applied) is recommended.

Figure 1. Three key estimates needed to use manure nutrients as a resource.

Table 1. Typical nutrient content of manure. Because of variability between farms, individual manure analysis is preferable to the estimates below.

	% Dry Matter	Nitrogen			
		Ammonium-N	Organic-N	P_2O_5	K_2O
Slurry Manure		**(lb of nutrient per 1,000 gallons of manure)**			
Dairy	8	12	13	25	40
Beef[†]	10	21	24	24	36
Swine (finisher, wet-dry feeder)	9	42	17	40	24
Swine (slurry storage, dry feeder)	6	28	11	34	24
Swine (flush building)	2	12	5	13	17
Layer[¥]	—	42	20	59	37
Dairy (lagoon sludge)[*]	10	4	17	20	16
Swine (lagoon sludge)	10	6	16	48	7
Solid Manure		**(lb of nutrient per ton of manure)**			
Beef (dirt lot)	67	2	22	23	30
Beef (paved lot)[*]	29	5	9	9	13
Beef (bedded pack barn) [†]	30	1	17	11	14
Swine (hoop barns)[‡]	40	6	20	15	18
Dairy (scraped earthen lots)	46	—	14	11	16
Broiler (litter from house)	69	15	60	27	33
Layer	41	18	19	55	32
Turkey (grower house litter)	70	—	44	15	30
Liquid Effluent from lagoon or holding pond		**(lb of nutrient per acre-inch)**			
Beef (runoff holding pond) [†]	5	44	5	20	109
Swine (lagoon)	0.40	91	45	104	192
Dairy (lagoon)	2	181	—	83	302

Values are based upon ASABE, 2005, D384.2; *Manure Production and Characteristics* with exception of those noted with the superscripts described below. Please note that these values have not been updated by the ASABE since 2005 and, therefore, might not accurately reflect manure produced by livestock systems that are feeding distillers grains.

[†] Values based upon Iowa State publication PM1867, revised 2015.

Empty spaces indicate we do not have reliable numbers for this specific manure compound.

[¥] Values based upon North Carolina State University publication AG-439–5, revised 1997.

[‡] Values based upon University of Missouri publication EQ 352, revised 2003.

A manure analysis should include:

- *Both ammonium-nitrogen and organic-nitrogen* (or total nitrogen). Knowing two of the three values means you can calculate the third.

  Total-N = Ammonium-N + Organic-N

  Nitrogen is excreted in two forms *(Figure 2)*. About one-half of the excreted nitrogen is a stable organic-nitrogen present in the feces. The other half is excreted as urea in urine, which decomposes rapidly to ammonium-N (NH_4+).

- *Phosphorus and potassium as P_2O_5 and K_2O equivalents.*

- *Nutrients in the same units of measure as you calibrate your manure application system.* If manure application is measured by tons per acre, request the analysis be reported as pounds of nutrient per ton.

- *Nutrients on a "wet" or "as is" basis* since you are calibrating application equipment on a wet manure basis. Because laboratories may use different methods to determine nutrient availability on a "wet" basis, using the "as-is" values on your manure analysis report to calculate nutrient availability, using the method in this publication is recommended. Storage and handling methods may affect the moisture content, which makes the manure appear more variable than it is. When comparing repeat samples, the dry matter basis analysis might give more insight into any changes over time.

Additional information on manure sampling is available in *Manure Testing for Nutrient Content* (NebGuide G1450).

Estimating Manure Application Rate

If manure nutrients are to be managed as a nutrient resource, the application equipment must be managed as a fertilizer applicator. Knowledge of manure application rate, like knowledge of fertilizer application rate, is key to managing nutrients applied to crops. Manure application rate can be estimated by one of the following:

1. Using one of the calibration methods detailed at *go.unl.edu/calibration.*

2. Maintaining a record of total manure applied to a field (i.e., total number of loads × average capacity ÷ the field's area). The Nutrient Management Record Keeping Calendar is a helpful tool for record keeping. More information about the calendar can be found at: *go.unl.edu/ec136.*

Estimating Crop Available Nutrients

Manure application rate and a manure analysis provide the information needed to estimate total manure nutrients applied. The "total manure nutrients," however, is less important than "crop available nutrients." The process for estimating crop available nutrients is illustrated in *Figure 2.* A worksheet for completing the calculations *(Table 2)* will assist in making this estimate.

Some manure nutrients become available slowly through mineralization in the soil. Mineralization is a process by which soil microorganisms decompose organic nutrients into a mineral inorganic, or plant available form. An estimate of crop available phosphorus and potassium is reasonably simple. Seventy percent of the phosphorus and 70 to 90 percent of the potassium is available to the crop during the year it is applied. Many production fields in Nebraska are not deficient in these two nutrients, so the manure application is more of a maintenance application. When the soil does not test low, all phosphorus and potassium can be credited since the rest becomes available in the subsequent years.

Determining nitrogen availability, however, is more complex. The availability of ammonium and organic-nitrogen for specific livestock species, application methods, and other factors can be found in *Figure 2*. Ammonium and organic-nitrogen originate from the urine and feces, respectively. The ammonium fraction's availability to the crop (Box I, *Figure 2*) depends upon both the time between manure application and incorporation into the soil and the environmental conditions. If manure is surface applied, ammonium (NH_4) is converted over several days to ammonia (NH_3) and lost by volatilization. Warmer temperatures accelerate this loss. If manure is mixed into the soil, the ammonium either is directly available to the plants or converts to another plant available form, nitrate-nitrogen (NO_3).

Organic-nitrogen is mineralized to ammonium over several years at a rate affected by soil temperature, soil water content, the characteristics of the manure, and other factors. During the cropping season following application, between 15 and 45 percent of the organic-nitrogen is typically available (Box II, *Figure 2*). Over the next several years, additional organic-nitrogen is mineralized to crop available forms in decreasing amounts (bottom right of box II, *Figure 2*). For example, as a general rule, mineralization of stored swine manure will be approximately 40 percent, 20 percent, 10 percent, and 5 percent of the organic-nitrogen during the year manure is applied, one year later, two years later, and three years later, respectively.

Calculating Crop Available Nutrients

At this point, information should have been collected for 1) nutrient concentration of the manure, 2) manure application rate for the current year and the past three years, and 3) availability of organic-nitrogen, ammonium-nitrogen, phosphorus, and potassium. *Table 2* can now be used to complete a calculation for crop available nutrients. For determining crop available nitrogen in *Table 2*, follow these steps:

1. Select the units used to measure manure application rate. Replace all "?" within the calculations with either tons, 1,000 gallons, or acre-inches of manure or effluent.
2. Enter the manure application rate and nutrient concentration and calculate total nitrogen application.
3. Enter the total nitrogen application and manure nutrient fraction available, and calculate the available nitrogen for ammonium, organic-N, and organic-N from past applications separately.
4. Sum the estimated available nitrogen from ammonium, organic-N, and organic-N from past applications.

An example is presented in *Table 2* for cattle feedlot manure applied at a rate of 20 ton/ac this year and two years ago. Manure is disked into the soil within 24 hours. The producer's manure analysis indicates nutrient concentrations of 5 lb of NH_4/ton, 13 lb of organic-N/ton, 12 lb of P_2O_5/ton, and 21 lb of K_2O/ton. When manure was applied 2 years ago, there was 11 lb of organic-N/ton.

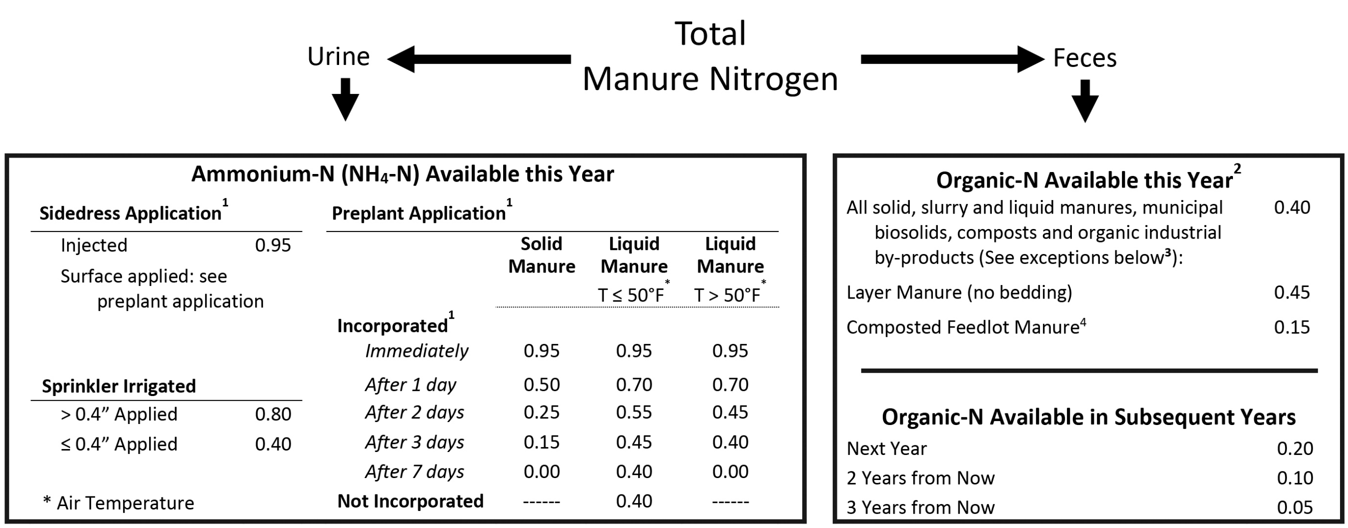
A much simpler estimate of crop available phosphorus and potassium can also be completed in Step 5. The results of these calculations can be summarized in Step 6.

Soil Testing and Crop Monitoring

The previous procedures have provided a "calculated" estimate of nutrient availability from manure. Soil testing provides a "field measurement" of residual nutrients. For a producer who regularly soil tests, is this calculated nitrogen availability in subsequent years estimate necessary? Yes, it is. The reasoning follows:

A deep soil test measures soil nitrate-N at the time of sampling. The above calculations estimate organic and ammonium nitrogen accessible to the crop during the growing season and in future years. Although most manure nitrogen will eventually be converted to nitrate nitrogen, this has not happened at the time soil samples are typically taken (fall, winter, or early spring). A soil test for nitrate nitrogen **will not** account for the future nitrogen available from manure. Thus, the "field measured" and "calculated" values are independent sources of nitrogen and should be added together. In the future we might have soil tests that accurately predict "mineralizable nitrogen," but to date these have not been proven to be accurate under all field conditions.

Phosphorus and potassium application needs can be



1 Incorporation can be accomplished by tillage or rainfall of 0.3 inch or greater.
2 Organic-N availability assumes spring seeded crops such as corn and soybeans. For fall seeded crops such as wheat, multiply organic-N availability factor by 0.7.
3 Mineralization rates are slower under dry conditions. Organic N availability of 30% should be assumed in dryland (or non-irrigated) fields west of US Highway 183 (or regions experiencing drought).
4 Wortmann's research with dairy municipal biosolids composts suggests N availability similar to above values. Previous USDA ARS research in Nebraska with feedlot manure compost suggests N availability closer to 15% which will remain our recommendation.

Figure 2. UNL Extension recommendations for availability factors for manure nitrogen. These values represent average availability and will vary with weather and management factors. Sidedressing of nitrogen based upon in-season fertility checks is recommended to account for variability.

NOTE: Use your Adobe Reader® to fill in the blanks in the following form and print out the results. Use the Tab key on the computer keyboard to move through the form. The form will automatically calculate equation solutions. The file cannot be saved to your computer, but can be completed and printed to create a record.

Step 1. Is manure measured in:

_____ ton (solid or semi solid manure)?
_____ 1,000 gallons (slurry or liquid)?
_____ acre-in (lagoon or holding pond effluent)?
(**Replace "?" with appropriate unit of measure**.)

Check one.

Step 2. Calculate total manure nitrogen applied.

Total Ammonium-N

Manure Rate (?/acre) (lb/acre)	X	NH_4 From Analysis (lb./?)	=	Total (lb/acre)
20 t/ac	X	5 lb/t	=	100

From Manure Analysis: 5 lb. NH_4 /ton

Total Organic-N from Present Application

Manure Rate (?/acre)	X	Organic-N From Analysis (lb./?)	=	Total (lb/acre)
20 t/ac	X	13 lb/t	=	260

From Manure Analysis
13 lb. organic N/ton (this year)
11 lb. organic N/ton (2 years ago)

Total Organic-N from Past Applications

	Manure Rate (?/acre)	X	Organic-N From Analysis (lb./?)	=	Total
1 year ago:	0	X		=	0
2 years ago:	20 t/ac	X	11 lb/t	=	220
3 years ago:	0	X		=	0

Step 3. Calculate crop available nitrogen applied.

Crop Available Ammonium-N

Total (lb/acre)	X	Fraction Available[a]	=	Available (lb/acre)
100	X	0.5	=	50

[a]Box I in *Figure 2*

Incorporated within 24 hours of application

Part 2. Crop Available Organic-N From Present Application

Total (lb/acre)	X	Fraction Available[b]	=	Available (lb/acre)
260	X	0.40	=	104

[b]Box II in *Figure 2*

Beef feedlot manure

Part 2. Crop Available Organic-N From Past Applications

	Total (lb/acre)	X	Fraction Available[c]	=	Available (lb/acre)
1 year ago:	0	X	0.20	=	0
2 years ago:	220	X	0.10	=	22
3 years ago:	0	X	0.05	=	0

[c]Bottom right of Figure 2

Step 4. Sum crop available nitrogen applied

Crop Available Manure Nitrogen Applied

Ammonium	+	Organic-N	+	Residual Organic-N	=	Crop Available Nitrogen
50	+	104	+	22	=	176 lbs. N/acre
						lbs. N/acre

Step 5. Calculate available phosphate and potash in year 1 at known manure application rate.

P_2O_5 concentration in manure: 12 lb/t ____ lb/?

K_2O concentration in manure: 21 lb/t ____ lb/?

lb P_2O_5/?	X	?/acre	X	% available	=	lb P_2O_5/acre
12 lb/t	X	20 t/ac	X	0.7	=	168

lb K_2O/?	X	?/acre	X	% available	=	lb K_2O/acre
21 lb/t	X	20 t/ac	X	0.8	=	336

Step 6. Summarize crop available manure nutrients for year 1 for selected application rate: 20 t/ac ____ **?/ac.**

Available Manure Nitrogen	Available Manure P_2O_5	Available Manure K_2O
176 lb/acre	168 lb/acre	336 lb/acre
lb/acre	lb/acre	lb/acre

Table 2. Procedure for estimating crop available nutrients from animal manures.

determined by soil testing. Regular soil testing of fields receiving manure will document phosphorus and potassium status.

Managing for Manure's Nutrient Variability

The amount of nitrogen provided by the manure nitrogen credit is an estimate based on average conditions. There is much variation field-to-field and year-to-year in crop response to manure-N. For example, Figure 2 availability factors can be influenced by soil conditions and management factors. Therefore, in-season application of some fertilizer-N or liquid manure-N in response to crop need is advised as an alternative profitable fertilizer and manure fertility program. In addition, research reviews of several hundred manure versus fertilizer research trials have reported that the highest yields result from complementary use of manure and fertilizer N.

Corn can be monitored to determine if a nitrogen deficiency is developing by use of a chlorophyll meter or other canopy sensor. For fields managed with the aid of a crop canopy sensor, the following manure and fertilizer program is recommended:

1. Apply manure to meet up to 100% of crop nitrogen requirements. Reduce manure nitrogen to account for planned nitrogen applications in steps 2 and 7 below.
2. Apply less than 65 lb/ac commercial fertilizer-N preplant to allow expression of in-season-N need in corn crop canopy reflectance. This is less critical following high ammonium manure applications (e.g. swine or dairy manure) and more important following low ammonium manure applications (e.g. open lot beef manure or broiler litter).
3. Create a high N reference area in a typical part of the field which can be less than 0.1 acre.
4. Sense the reflectance from the corn crop canopy to determine the NDRE (red edge normalized difference vegetative index).
5. Calculate the in-season N rate:

$$In - season\ N\ rate\ \left(\frac{lb}{ac}\right) = 320\sqrt{0.98 - SI}$$

$$\text{Where SI (sufficiency index)} = \frac{NDRE}{NDRE\ for\ the\ reference\ strip}$$

6. The in-season application can be:
   a. Uniform for a whole field with the average N rate determined from aerial sensing or from 8-12 point readings with a hand-held sensor,
   b. Uniform for management zones within fields following similar procedures discussed in 5a, or
   c. Variable rate based on continuous canopy reflectance sensing during application. For such variable rate application, apply a minimum of 30 lb/ac N in-season even if the calculated rate is less than 30 lb/ac for some parts of a field.
7. Nitrogen fertigation for manured fields should also be guided by canopy reflectance with 30-40 lb/ac applied with fertigation or sidedressing to corn when needed. Check canopy reflectance again at 2 weeks after the fertigation to determine if additional fertilizer-N is needed.

An alternative strategy is the presidedress nitrate test (PSNT). By this time of the growing season, manure nitrogen is mineralizing to nitrate, and this test will help determine if there is enough nitrogen available. In Iowa and other states, a soil nitrate level of over 25 ppm is usually sufficient for maximum corn production. Nebraska has not published recommendations for this test but refers people to the Iowa recommendations. For fields managed with the aid of Pre-Sidedress Nitrate Test (PSNT), the following manure and fertilizer program is recommended:

1. Follow steps 1 and 2 above.
2. Follow Iowa State University validated procedures for a PSNT by collecting a 0-12" soil sample when corn is six to twelve inches in height (typically late May through early June). This test works best if you avoid previous fertilizer application bands, including starter and anhydrous ammonia bands. Take 15-20 cores per sample.
3. Subtract the soil nitrates from 25 ppm (critical level) and multiplying the difference by 8. For example, with a soil test of 18 ppm nitrate-N, the nitrogen recommendation would be: 25-18 = 7, then 7 x 8 = 56 lb N/acre deficit. The in-season application can be uniform for a whole field or for management zones within field. Apply fertilizer-N or liquid manure-N to meet this deficit.

4. See Using the PSNT for Spring Testing of Nitrogen Availability | CropWatch | University of Nebraska–Lincoln for additional details. (https://cropwatch.unl.edu/using-psnt-spring-testing-nitrogen-availability-unl-cropwatch-may-23-2012)

Using any one of these techniques or a combination will allow more accurate crediting of manure nutrients with confidence. The "calculated" estimate of manure nitrogen will remain an important pre-growing season planning tool for manure nutrient sources.

Once the available nutrients are determined, the next step is to fit this information into a nutrient management plan. Extension Circular EC117, *Fertilizer Suggestions for Corn*, details how to determine the total nutrient needs based on soil tests and yield expectation. The *Nutrient Management for Agronomic Crops in Nebraska, EC155 (revised 2014)* provides nutrient recommendations for many Nebraska crops. Calculating the Value of Manure for Crop Production*, G1519* assists in calculating the fertilizer value of the nutrients to be applied to a particular field.

Additional Resources

All University of Nebraska—Lincoln resources for manure nutrient management planning can be found online at *manure.unl.edu* and soil testing and nutrient recommendations can be found at *cropwatch.unl.edu/soils.* The manure website contains software tools, sample records, regulatory information, and other tools associated with nutrient management planning.

This publication has been peer-reviewed.
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