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Estimating Plant-available Nitrogen from Manure

Oregon State University
Extension Service

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Prepared by Dan M. Sullivan, Extension soil scientist, Oregon State University.

Nutrient management plans for crops require estimates of plant-available nitrogen (PAN) provided by application of manure or compost. Recent developments have stimulated interest in utilizing manure nitrogen (N) as a resource. These factors include the following:

- Increased cost of N fertilizers
- Increased value of PAN from manure on farms using certified organic methods to produce crops or animal products
- Greater concern for the environmental effects of ammonia and nitrate loss
- Development of manure application equipment that can reduce ammonia loss (increase retention of PAN)
- Federal cost-share programs (usually administered by the Natural Resources Conservation Service) that pay producers to adopt practices that reduce N loss to the environment
- Efforts to reduce phosphorus buildup in manure-fertilized soils (when manure N is used more efficiently, the manure application rate to meet P needs can be reduced)

How to Use This Publication

This publication focuses on how to estimate PAN provided by manure. We do not address management of other nutrients or other aspects of manure management, such as manure sampling, calibration of application equipment, record-keeping, or post-application monitoring. See "For More Information" (page 19) for resources on these topics.

This publication is primarily designed for use by planners (agricultural professionals that assist farmers with nutrient management). We focus primarily on cropping systems west of the Cascades in Oregon and Washington.

This publication has two main parts:

1. Worksheet for calculating available nutrients supplied by manure application
2. Management practices that increase crop N utilization

The Worksheet can be used to do the following:

- Determine the manure application rate needed to supply a target amount of PAN
- Estimate the dollar value of PAN from the current year's manure application
- Estimate the value of additional PAN retained by immediate tillage or direct application (injection, banding, etc.)
- Assess the balance between PAN, P, and K supplied by manure
- Get a rough, long-term (10-year) estimate of PAN availability from manure
- Evaluate management options to increase crop N utilization

Management practices discussed in the second section of this publication can help farmers reduce N loss to the environment (water and air) and may provide economic benefit to some farmers.

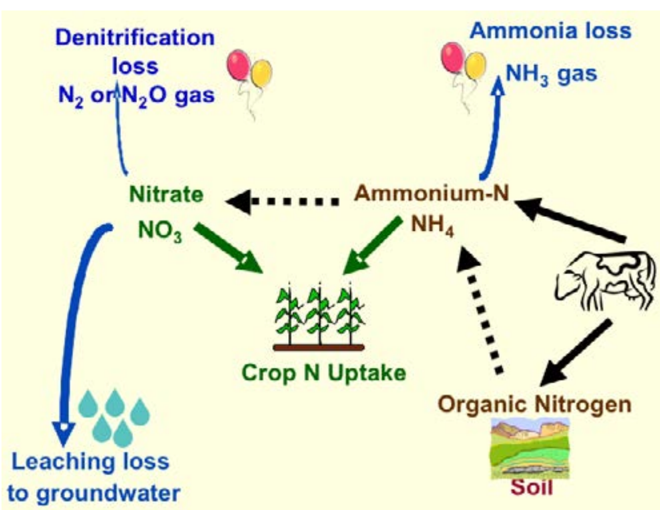


Figure 1. Where does manure N go? It can be taken up by the crop (green arrows) or lost to air or water (blue arrows). Organic N in the soil is converted to different forms by microbial activity (dotted arrows).

Nitrogen Forms and Cycling

The goal of N management is to efficiently deliver plant-available N (PAN) to a crop by maximizing crop utilization and minimizing losses to the environment. Plant roots take up nitrate and ammonium-N. Major losses of N to the environment occur when ammonia gas (NH_3) is lost to the air or nitrate (NO_3) is leached to groundwater. Losses of N via denitrification as N_2 or N_2O gas can be important under some conditions, but are generally small enough to be ignored in estimating PAN from manure.

Manures that contain mostly ammonium-N contain much PAN that is subject to volatilization (loss to the atmosphere) shortly after manure application. Manures that contain mostly organic N release much less PAN in the short term, and must be managed as a long-term investment in soil building.

Efficient manure N management matches N supply to crop needs. Management can reduce ammonia loss to the atmosphere and nitrate leached to groundwater.

Introduction to the Worksheet

The Worksheet estimates:

- Nutrients supplied this year and their dollar value
- Ammonia-N lost and its value
- Amount of organic N stored in the soil from this year's manure application

The Worksheet uses manure N analyses for ammonium-N (NH_4-N) and organic N as starting points for calculations (instead of a "total N" book value). This approach allows site-specific adaptation of calculations.

To use the Worksheet, you will need:

- This year's manure analysis
- Planned manure application rate for this year
- Manure application rate and manure N analyses from previous years

If you don't have manure analysis data, you can still use the Worksheet, but the results will not be customized for your farm.

The Worksheet does have some limitations.

- It is not a complete planning tool for long-term nutrient management. The Worksheet is most useful for quick, "ballpark" estimates. It can be used by farm managers to adjust in-season application rates based on manure analyses.
- It is not a nitrogen recommendation or nitrogen budget (N budgets are used to estimate crop N need). You need to know how much PAN the crop needs before using the Worksheet.
- It allows input for only one kind of manure for the current year. If two types of significantly different manure will be applied, you can use the Worksheet twice and add the results together. (Take credit for manure applied in previous years only one time.) For complicated scenarios, the calculation method presented here is compatible with several software packages that are available for nutrient management planning.
- Worksheet estimates of PAN from manure should be regarded as rough estimates. Post-application monitoring (crop yield, plant tissue tests, soil tests) are needed before adjusting manure management practices to fit site-specific conditions.

Nutrient Analysis of Manure

Typical values for manure nutrient content (book values) can be used for a general comparison of the nutrient content of different manure sources (e.g., chicken vs. horse manure). Manure nutrient composition depends on management practices, such as:

- Source and quality of livestock feed
- Water added to manure
- Type and amount of livestock bedding
- Manure storage method and length of storage

Because management practices vary substantially among farms, it is important to sample and test manure to determine its nutrient content.

For livestock farms that utilize manure on their own acreage, we recommend that you sample and analyze manure several times a year to develop a "running average" of manure nutrient content. Usually, it takes 2 to 4 years to develop a reliable estimate of average manure nutrient content and of the variability of nutrient content during the year.

The best time to sample manure is at the time of field application, because:

- Manure is well-mixed, so the sample is representative.
- The analysis will reflect changes in manure N concentration that occur during storage (volatilization) or in preparation for field application (agitation, mixing, and dilution with water).

For Worksheet input, you may choose to separate manure test results into two or more different groups (instead of averaging test results over the entire year). For example, you may want to average early-spring manure tests separately from midsummer tests.

Consult *Sampling Dairy Manure and Compost for Nutrient Analysis* (PNW 673, catalog.extension.oregonstate.edu/pnw673) for sampling and testing recommendations.

Ask the laboratory to perform these analyses:

1. **Nitrogen:** total N and ammonium-N (NH_4-N). For compost only, also request an analysis for nitrate-N (NO_3-N). Other manures contain insignificant amounts of NO_3-N. To obtain an accurate

value for manure NH_4-N, make sure the laboratory determines NH_4-N on a fresh sample (not a dried sample). Most of the manure NH_4-N is lost when samples are oven-dried.

2. **Phosphate and potash:** total P and total K. You will need analyses of P_2O_5 and K_2O for the Worksheet. Some labs report values in these units. If the lab reports only P, multiply P x 2.29 to calculate P_2O_5. If the lab reports only K, multiply by 1.2 to calculate K_2O.
3. **Manure dry matter (DM) or total solids.** The laboratory determines this value by oven-drying manure. This value enables you to express manure nutrient content on a dry weight or wet weight basis. Also, if manure analyses using wet weight fluctuate over time, manure DM can be used to determine whether the variation is due to changes in moisture or changes in nutrient content.

Manure N Availability Values

The worksheet estimates plant-available N (PAN) as:

PAN = NH_4-N retained after application
+ N mineralized from manure organic N in soil

The amount of manure NH_4-N retained is determined within the first week after application. In contrast, PAN is released from mineralization of manure organic N over a much longer period (Figure 2, page 7).

Estimating PAN from manure NH_4-N

Under some conditions, ammonium (NH_4) is readily transformed to ammonia (NH_3) and is lost as a gas (Figure 1, page 3). Nitrogen lost as ammonia reduces PAN supplied by manure.

Management practices affect the amount of ammonium-N retained after manure application (Table 1):

- **Time to manure incorporation.** The sooner manure is incorporated into soil, the more ammonium-N is retained. After manure is in contact with soil, it is held as non-volatile ammonium-N (NH_4-N).
- **Manure dry matter (DM).** When manure is not incorporated or injected, the proportion of dry matter in manure determines the amount of ammonium-N retained. Solid manures remain on the soil surface, where most of the NH_4-N is lost to the atmosphere. Lagoon water, on the other hand, infiltrates soil rapidly, retaining almost all of its manure NH_4-N. With slurries, some of the NH_4-N infiltrates into the soil, and some remains with manure solids on the soil surface. The thicker the slurry, the less ammonium-N is retained.

  Composting. The pH value of finished compost is near 7 (usually 6.5 to 7.5). At pH values below 7.5, N remains in the ammonium form and is not subject to loss as ammonia gas.

Table 1 estimates the amount of ammonium-N retained after field application. To use this table, you will need information on:

- Manure dry matter
- Method of application
- Number of days before manure is incorporated

To use Table 1, find the column representing the kind of manure (lagoon water, slurry, solid, or compost) you will apply. Use the “lagoon water” column for water pumped from secondary lagoons, even if the dry matter content is above 1 percent. Use the “thick slurry” column if manure has greater than 5 percent dry matter, but can still be pumped as a liquid. Use the “solid” or “solid poultry” column for manures that are applied with a solid manure spreader. Use the “compost” column for well-composted materials that have an earthy odor with no discernable ammonia odor. If you smell ammonia in a material sold as compost, use the “solid” manure column in Table 1.

Next, find the “time to incorporation” (left column in Table 1) that best describes the typical time elapsed between manure application and tillage. Because ammonia is lost rapidly after application, immediate shallow incorporation often conserves NH_4-N more effectively than more intensive tillage the next day. When manure is broadcast, subsequent application of a half-inch of water via sprinkler irrigation or rainfall is considered as effective as tillage for moving NH_4-N into soil (provided the soil is not saturated).

If you use a directed application method (injection or banding), choose one of the application options at the bottom of Table 1. See “Conserve NH_4-N at application” (page 13) for additional information on directed incorporation methods.

Table 1. Estimated fraction of manure ammonium-N retained after application.
Use the appropriate value from this table in Worksheet Step 3, "PAN from NH_4-N."

	Manure type and dry matter (DM) content					
Time to incorporation[a]	**Lagoon water (< 1% DM)**	**Thin slurry (1–5 % DM)**	**Thick slurry (5–10% DM)**	**Solid (> 10% DM)**	**Compost**	**Solid poultry (> 10% DM)**
	--------------------------Fraction of manure NH_4-N retained[b]---------------------					
Immediate incorporation (1 hr)	0.95	0.95	0.95	0.95	1.00	0.95
Incorporation 1 day after	0.95	0.70	0.60	0.50	1.00	0.70
Incorporation 2 days after	0.95	0.60	0.45	0.30	1.00	0.50
Incorporation 7 days after	0.95	0.55	0.40	0.20	1.00	0.40
Directed application methods:						
Subsurface injection		0.95	0.95			
Surface band (partial incorporation)		0.85	0.70			
Surface band (no incorporation)		0.75	0.60			

[a] Tillage with harrow, cultivator, plow, etc. to incorporate manure, or overhead sprinkler irrigation (0.5 inch) after manure application.

[b]Ammonium-N retention estimates for lagoon water, slurry, solid manure, and compost apply to all livestock manures except solid poultry.

Table 2. Estimating PAN from manure organic N. Use the appropriate value in Worksheet Step 3, "PAN from organic N."

			Organic N applied in previous years			
Manure	**Manure dry matter (as applied)**	**Organic N applied this year**	**1 year ago**	**2 years ago**	**3 years ago**	**4 to 9 years ago**
		-------------Fraction mineralized to PAN---------------------				
Dairy cattle or other livestock						
Lagoon water	< 1% DM	0.40	0.15	0.07	0.03	0.02 per year
Thin slurry	1 to 5 % DM	0.40	0.15	0.07	0.03	0.02 per year
Thick slurry	5 to 10% DM	0.30	0.15	0.07	0.03	0.02 per year
Solid	> 10% DM	0.30	0.15	0.07	0.03	0.02 per year
Separated dairy solids or horse manure[a]		0.10	0.05	0.05	0.03	0.02 per year
Compost[b]		0.10	0.05	0.05	0.03	0.02 per year
Solid poultry	> 10% DM	0.50	0.15	0.07	0.03	0.02 per year

[a]PAN for dairy solids from a mechanical separator. If separated solids come from gravity separation (settling basin or evaporation basin), use PAN values for the type of manure (lagoon water or slurry) that flows into the settling basin.

[b]Stable or finished compost. A finished compost does not smell like ammonia, has a pile temperature less than 95°F (35°C), and often contains significant amounts of nitrate-N. Not all materials sold as compost meet these criteria.

Estimating PAN from mineralization of manure organic N

PAN is released from manure organic N through microbial activity in soil in a process called mineralization. This process is more rapid in soils that are warm and moist, and it is slower in soils that are cold or dry. Table 2 estimates the fraction of manure organic N that is released as PAN by mineralization.

Organic N mineralizes most rapidly during the first months after manure application. With time, the manure N mineralization rate slows. Figure 2 shows cumulative N mineralization for a variety of manures. The amount of N mineralized during the first year is strongly affected by the composition of manure (see "How Manure Composition Affects N Mineralization"). Mineralization rates for residual organic N (1 or more years after application) from many manures and composts are similar. However, it takes much longer for all of the manure organic N to mineralize from compost than from other manures.

The Worksheet (pages 11–12) tracks PAN from manure organic N over a 10-year period (Table 2). For the current year and for 1, 2, and 3 years ago, annual mineralization estimates are given. Long-term mineralization (4 to 9 years ago) is estimated at 2 percent per year and summed over the number of years (years manure applied x 0.02 per year). Table 3 shows examples of estimated N mineralization for manure (page 8) applied 4 to 9 years ago.

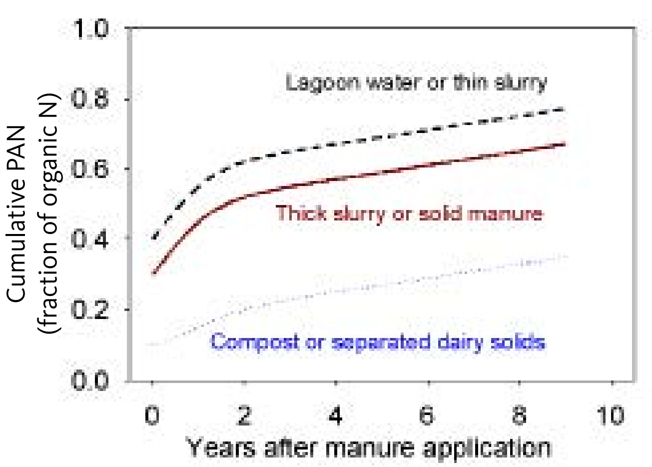


Figure 2. Cumulative PAN supplied by manure organic N, using the mineralization factors presented in Table 2. For this example, manure was applied in Year 0, with no subsequent manure applications. Slow release of PAN from mineralization continues beyond the 10-year period shown in the graph.

How Manure Composition Affects N Mineralization

The rate of mineralization in soil depends upon the "digestibility" of manure organic matter and its carbon:nitrogen (C:N) ratio. Separation of whole manure into liquids and solids segregates coarse and fine manure particles that have different organic composition and different mineralization rates. Fine particles in manure contain organic compounds with low C:N ratios (high protein) and are rapidly decomposed in soil. Coarse particles have higher C:N ratios (lower protein) and are more slowly decomposed in soil.

Because thin slurry and lagoon water contain the finest organic particles, these materials have the most rapid N mineralization rate. Thick slurry and solid manures contain a mixture of fine and coarse particles, so they have a lower N mineralization rate.

Solids separated from liquid manure by a mechanical separator (separated dairy solids) contain mostly coarse particles (bedding plus undigested feed). These solids have a unique pattern of mineralization over time in soil. Separated solids typically have negative N mineralization rates (PAN in soil decreases) for 4 to 8 weeks after application. After that, PAN is mineralized very slowly. Cumulative PAN from separated solids is much lower than for other fresh manures. The timing and amount of PAN release from horse manure is similar to that from separated dairy solids.

Separation of solids from liquid manure by gravity separation (settling basin or evaporation basin) does not change PAN, because the fine organic particles in the manure are recovered from the basin.

Composting manure reduces manure volume by 50 percent or more. During composting, some of the manure N is lost as ammonia gas, and some is transformed to more stable organic compounds. Compost organic matter decomposes very slowly in soil. Cumulative PAN for compost organic matter is similar to that of separated dairy solids.

Fresh poultry manure or broiler litter contains some organic N in the form of uric acid (similar to urea). In soil, uric acid is converted to PAN in 1 to 2 weeks. Most broiler litter sold as "compost" in western Oregon contains uric acid and behaves more like fresh litter than compost in terms of N availability. If you can smell ammonia in broiler litter, it probably is not thoroughly composted. Dry-stacking of broiler litter does not provide adequate moisture for composting.

Table 3. Examples: Mineralization factors for estimating PAN from manure applied 4 to 9 years ago.

Manure application frequency	Calculation	Mineralization factor to use for "4 to 9 years ago" in Worksheet
Annual (6 out of 6 years)	0.02 per year x 6 years	0.12
5 out of 6 years	0.02 per year x 5 years	0.10
3 out of 6 years	0.02 per year x 3 years	0.06
1 out of 6 years	0.02 per year x 1 year	0.02

Worksheet Instructions and Example Data Inputs

Input your data in the yellow worksheet cells. The Worksheet automatically calculates the values in the green cells.

The Worksheet shows "example" calculations for dairy slurry. The example is provided to help you follow the steps in the calculation. It is **not** a recommendation for manure application rate.

The mini-worksheets below include only the input data. You can use these mini-worksheets to assemble your manure and field management data before using the Worksheet. **The Worksheet has six steps.**

Step 1. Enter manure data.

Instructions

- Enter the kind of manure and the measurement units used for manure application. The Worksheet is not designed for use with more than one kind of manure for "this year." If you will apply more than one kind of manure this year, repeat the process with additional blank Worksheets.
- Enter analysis values for manure on an "as-is" or wet weight basis. If laboratory analysis units are different than field application units, see Table 5 (page 18) for conversion factors. For compost only: enter the compost NH_4-N + NO_3-N analysis value in the Worksheet "NH_4-N" box.
- Enter solids fraction in manure: 5% DM (dry matter) = Solids fraction of 0.05

Example input data (Step 1)

	Example	Your information
Kind of manure	Thin dairy slurry	
Field application units (choose one)		
Per ton (solid or semi-solid manure)		
Per 1,000 gallons (slurry)	X	
Per acre-inch (lagoon or holding pond effluent)		
This year's manure analysis [a, b, c]		
Total N	10 lb/1,000 gal	
Ammonium-N (NH_4-N)	6 lb/1,000 gal	
Phosphate (P_2O_5)	7 lb/1,000 gal	
Potash (K_2O)	16 lb/1,000 gal	
Manure solids fraction (dry matter percentage ÷ 100)	0.03	

[a] Input "as-is" or wet weight manure analysis data.

[b]Enter only "lb nutrient" if the manure analysis is in units of "lb nutrient per 1,000 gallons." For example, you would enter total N of "8" for a manure analysis of "8 lb/1,000 gallons."

[c] If laboratory analysis units are different than field application units, see Table 5 for conversion factors.

[d]The Worksheet calculates this figure automatically for this year's manure application.

Step 2. Calculate manure N applied.

Instructions

- Enter the manure application rate planned for this year and this year's manure organic N analysis.
- Enter manure application rate and organic N analyses for manure applied in previous years.

Example input data (Step 2)

This year's manure application:
Rate = 20,000 gal/acre
Manure organic N applied in previous years:

	Example	Example	Your information	Your information
	Manure application rate	Manure organic N analysis[a]	Manure application rate	Manure organic N analysis
Year	(units/acre)	(lb/unit)	(units/acre)	(lb/unit)
1 year ago	25,000 gal/acre	9 lb/1,000 gal		
2 years ago	15,000 gal/acre	5 lb/1,000 gal		
3 years ago	10,000 gal/acre	7 lb/1,000 gal		
4 to 9 years ago	15,000 gal/acre	6 lb/1,000 gal		

[a]Estimate from past manure analyses. Organic N = total N - NH_4-N.

Step 3. Estimate plant-available N (PAN) supplied by manure.

Instructions

Enter appropriate fractions for NH_4-N retention (Table 1, page 6) and fraction of organic N mineralized (Table 2, page 6).

Example input data (Step 3)

- Method of manure application: surface broadcast (splash plate)
- Time to incorporation by tillage or by 0.5 inch overhead sprinkler application: no incorporation within 7 days
- Fraction NH4-N retained at application (Table 1) = 0.55
- Fraction of organic N mineralized (Table 2)

Fraction of NH_4-N retained at application	
Example	**Your information**
0.55	

	Fraction of organic N mineralized	
Year	**Example**	**Your information**
This year	0.40	
1 year ago	0.15	
2 years ago	0.07	
3 years ago	0.03	
4 to 9 years ago (application every year)	0.02 per year x every year (6 years) = 0.12	

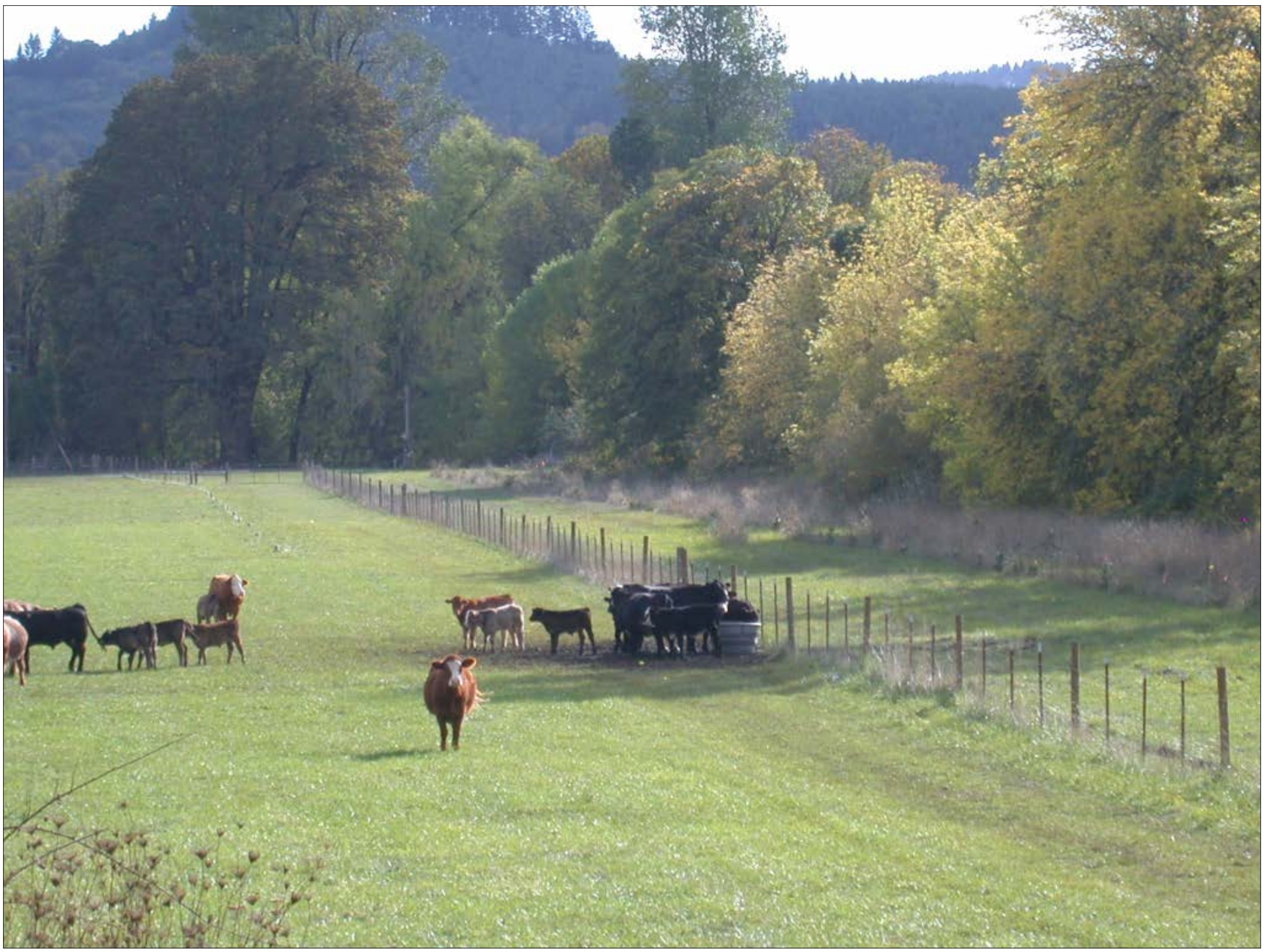
Steps 4–6. Plant available nutrients and their values.

Instructions

These steps show plant-available N, P, and K provided at the selected manure application rate. You can enter local values for cost of nutrients from commercial fertilizer to get an estimate of the value of manure nutrients. Because manure is an excellent source of P and K, it has the greatest value when applied to soils that test "low" or "medium" in plant-available P and K. If your soil test values are "high" or "excess," adding additional P or K will not have economic benefit.

Example input data

	Example	Your information
Nutrient	**Nutrient price ($/lb nutrient)**	**Nutrient price ($/ lb nutrient)**
Phosphate (P_2O_5)	$0.40/lb	
Potash (K_2O)	$0.24/lb	
Nitrogen (N)	$0.50/lb	



Worksheet: Estimating plant-available N from manure

Input cells are yellow.

Calculations are done for you in green boxes. (These cells contain equations.)

Final results for total PAN, P_2O_5, and K_2O are highlighted in blue text.

Note: The yellow cells contain example data. Replace the information in these cells with your own data. Before entering your data in the yellow cells, we recommend entering "0" in all yellow cells (to make sure you don't accidentally use the "example" data).

Note: We recommend turning off the following options in Acrobat Reader:
- Show border hover color for fields
- Auto-complete

To turn off these options, choose Preferences from the

Edit menu (PC) or File menu (Mac). In the Preferences dialog box, chose Forms from the left-hand menu. Then make sure the buttons for these options are clicked OFF.

Step 1. Enter manure data

Instructions: Choose the manure application units that will be used througout this worksheet.

	Your information	Example
Kind of manure	thin dairy slurry	Thin dairy slurry

Choose manure application unit

Is wet manure measured in :

- ○ ton (solid or semisolid manure)?
- ◉ 1000 gallons (slurry or liquid)?
- ○ acre-inches (lagoon or holding pond effluent)?

Instructions: Enter "as-is" or "wet weight" manure analysis. If units are "lb nutrient/1000 gal," enter only "lb nutrient" in the boxes below.

This year's manure analysis
Nitrogen (N), lb/unit

	Your values	Example
Total N	10	10 lb/1000 gal
NH_4-N	6	6
Organic N	4	4

This year's manure analysis
Phosphate (P_2O_5) and potash (K_2O), lb/unit

	Your values	Example
P_2O_5	7	7 lb/1000 gal
K_2O	16	16

This year's manure analysis
Manure solids and moisture

Fraction	Your values	Example
Solids or DM	0.03	0.03
Moisture	0.97	0.97
Total	1.00	1.00

Step 2. Calculate manure N applied.

Instructions: Enter manure application rate for this year. Use application units chosen in Step 1.

	Your value units/acre	Example
Application rate selected	20	20,000 gallons

Ammonium-N applied this year

Manure rate (units/ac)		NH_4-N analysis (lb/unit)		NH_4-N applied (lb/acre)
20,000 gal	×	6 lb/1000 gal	=	120
20		6		120

From manure analysis (this year):

6 lb NH_4-N per 1000 gallons

Organic N applied this year

Manure rate (units/ac)		Organic-N analysis (lb/unit)		Organic-N applied (lb/acre)
20,000 gal	×	4 lb/1000 gal	=	80
20		4		80

From manure analysis (this year):
4 lb organic N/1000 gal

Instructions: Enter manure rate and manure analysis for 1–9 years ago.

Organic N applied in previous years

Year	Manure rate (units/ac)		Organic N analysis (lb/unit)		Organic N residual (lb/acre)
1 year ago	25,000 gal	×	9 lb/1000 gal	=	225
	25		9		225
2 years ago	15,000 gal	×	5 lb/1000 gal	=	75
	15		5		75
3 years ago	10,000 gal	×	7 lb/1000 gal	=	70
	10		7		70
4 to 9 years ago	15,000 gal	×	6 lb/1000 gal	=	90
	15		6		90

Manure organic N analysis (lb/1000 gal):
9 (1 year ago), 5 (2 year ago), 7 (3 year ago)
Estimated manure organic N 4 to 9 years ago = 6 lb/1000 gal

Step 3. Estimate plant-available N (PAN) supplied by manure

Instructions: Consult Tables 1 and 2, and choose appropriate values for manure NH_4-N retained and organic-N mineralized.

PAN (from NH_4-N)

NH_4-N applied (lb/acre)		Fraction retained (Table 1)		PAN (lb/acre)
120	×	0.55	=	66
120		0.55		66

Surface applied

not incorporated

PAN (from organic N applied this year)

Organic N applied (lb/acre)		Fraction mineralized to PAN (Table 2)		PAN (lb/acre)
80	×	0.4	=	32
80		0.40		32

Thin dairy slurry

PAN (from residual organic N)

Year	Organic N residual (lb/acre)		Fraction mineralized to PAN (Table 2)		PAN (lb/acre)
1 year ago	225	×	0.15	=	34
	225		0.15		34
2 years ago	75	×	0.07	=	5
	75		0.07		5
3 years ago	70	×	0.03	=	2
	70		0.03		2
4 to 9 years ago	90	×	0.12	=	11
	90		0.12		11

4 to 9 years ago: manure applied annually

Years 4 to 9, fraction mineralized = 0.02/year x 6 years = 0.12

Step 4. Sum plant-available N (PAN) supplied by manure application

(PAN from this year + PAN from residual manure organic N)

PAN from NH_4-N (lb/acre)		PAN from this year's organic-N (lb/acre)		PAN from residual organic N (lb/acre)		Total PAN (lb/acre)
66	+	32	+	52	=	150
66	+	32	+	52	=	**150**

Step 5. Phosphate (P_2O_5) and potash (K_2O) supplied by this year's manure application, and its fertilizer value

Instructions: Enter local $ value for phosphate (P_2O_5) and potash (K_2O).

Note: Manure P and K have value when soil test values are "low" or "medium." When P and K soil test values are "high" or "excess," value of P and K is zero or negative.

Phosphate (P_2O_5)

Manure rate (?/ac)		P_2O_5 analysis (lb/unit)		P_2O_5 applied (lb/acre)		Phosphate fertilizer price (\$/lb P_2O_5)		Manure P_2O_5 value (\$/acre)
20,000 gal	×	7 lb/1000 gal	=	140	×	\$0.40	=	\$56
20		7		**140**		\$0.40		\$56

Potash (K2O)

Manure rate (?/ac)		K_2O analysis (lb/unit)		K_2O applied (lb/acre)		Potash fertilizer price (\$/lb K_2O)		
20000 gal	×	16 lb/1000 gal	=	320	×	\$0.24	=	\$77
20		16		**320**		\$0.24		\$77

Step 6. Estimated fate of this year's manure N, and its fertilizer value

Instructions: Enter local $ value for fertilizer N.

PAN this year, and its value

Total N applied (lb/acre)	PAN (lb/acre)		Nitrogen Fertilizer price (\$/lb N)		Manure PAN value (\$/acre)
200	98	×	\$0.50	=	\$49
200	98		\$0.50		\$49

NH_4-N lost, and its value

Manure NH_4-N lost at application (lb/acre)		Fertilizer N price (\$/lb N)		Value of Manure NH_4-N lost (\$)
54	×	\$0.50	=	\$27
54		\$0.50		\$27

N stored in soil

Residual soil organic N from this year's manure (lb/acre)
48
48

Management to Increase Crop N Utilization

Conserve manure NH4-N at application

Directed application methods reduce exposure of slurry to the atmosphere, which reduces ammonia loss. When properly done, directed application increases NH_4-N retention, reduces odor, decreases the risk of manure runoff from the field, and allows for greater manure application uniformity. Directed application methods do not require a separate tractor trip across the field for slurry incorporation. Directed application methods (Figures 3 and 4) include:

- Injection below the soil surface
- Surface banding; placement of slurry in a line (band) on the soil surface
- Surface banding with partial incorporation of slurry into soil with a tillage implement

Many equipment configurations are available. Slurry is supplied to tractor-mounted application equipment through a drag hose or from a tanker. Many directed application methods are suitable for use with no-till or reduced tillage cropping systems.

Because surface banding does not completely cover slurry with soil, it does not increase NH_4-N retention as much as does injection (Table 1). However, surface banding methods require less power, are faster, and cause less damage to established grass than injection.

Equipment alternatives are discussed below and illustrated in Figures 3 and 4.

Preplant or side-dress for row crops (Figure 3). With this kind of equipment, one injection slot is made for each crop row. Options include:

- Deep injection (4 to 8 inches) into soil with a hose mounted on a knife or chisel (Figure 3a).

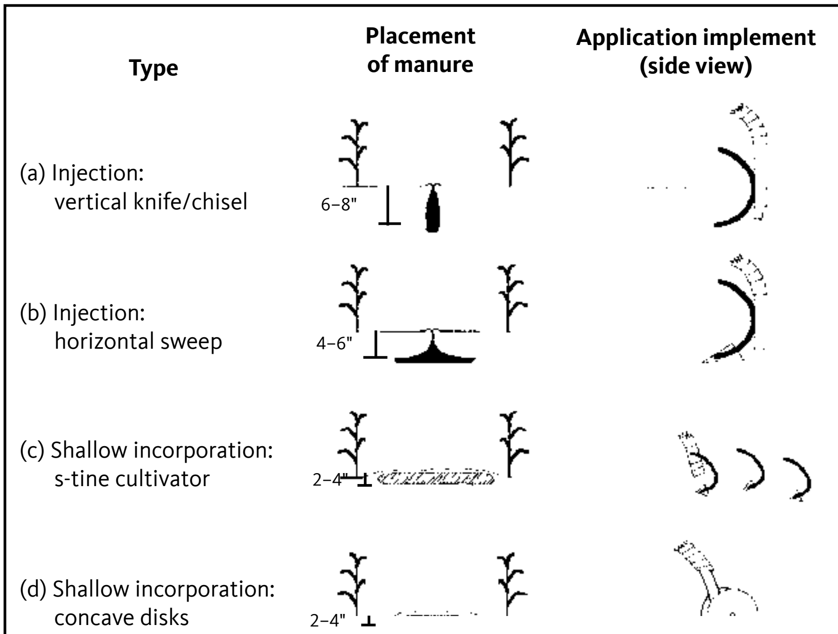


Figure 3. Directed application methods for row crops. Source: Jokela, W.E. and D. Côté. 1994. In NRAES-79. Natural Resource, Agriculture, and Engineering Service (NRAES), Ithaca, NY. www.nraes.org

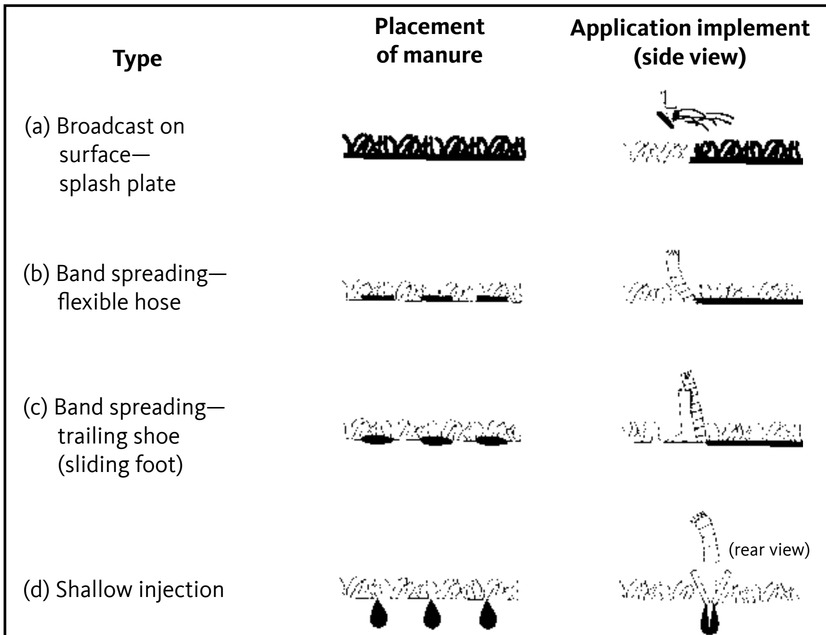


Figure 4. Directed application methods (b, c, d) for grasses or cereal crops vs. traditional broadcast manure application (a). Source: Jokela, W.E. and D. Côté. 1994. In NRAES-79. Natural Resource, Agriculture, and Engineering Service (NRAES), Ithaca, NY. www.nraes.org

- Injection with a sweep (4 to 6 inches depth)—this kind of injection has a wider application zone (Figure 3b).
- Shallow injection (2 to 4 inches) into soil, followed by shallow tillage with tines or discs (Figure 3c and 3d).

Surface band application in established grass (Figure 4). Slurry is placed in a line (band) on the soil surface. For best results, surface bands need to be close together (3 to 6 inches apart) and placed under crop residues. A "sleigh foot applicator" is one type of surface banding implement that has been tested extensively in coastal British Columbia. (The "sleigh" is pulled across the soil surface like Santa in his sleigh.) The "sleigh foot" applicator is similar to a "trailing shoe" or "sliding foot" applicator (Figure 4c). A recent innovation has combined aerator tines with sleigh foot application (Bittman and Kowelenko, 2004). The aerator tines make small holes or slots that encourage rapid slurry infiltration and improve NH_4-N retention.

Limitations of directed application methods include:

- More labor, fuel, equipment, and expertise are required than for broadcast surface application.
- Requires driving on the field, which may be impractical during wet spring months.
- When manure is supplied by a tanker, row length must be matched to tanker volume to avoid "driving empty."
- Requires closely spaced bands (3 to 6 inches between bands) when application is made to grass.
- When injection slots are spaced far apart, injected slurry may move deeper than desired, or may move to the soil surface. This problem can be overcome by limiting the slurry application rate.
- If manure is supplied by a tanker, an equipment turn-around area usually is needed at the top and bottom of the field.
- Injection may increase N loss from leaching and denitrification in some situations.
- Injection slots may channel runoff, causing increased erosion.

Schedule manure applications to minimize N leaching loss

The manure application date affects the efficiency of crop uptake of PAN supplied by manure (Table 4, page 15). The PAN values estimated in the Worksheet (pages 11–12) assume that manure is applied during months when crop N utilization is "medium" to "high." When crop utilization is "low" or "very low" (Table 4), a substantial portion of PAN is likely to be lost by leaching before it can be utilized by the crop. Crop N utilization estimates given in Table 4 assume that:

- Manure application rate is not excessive.
- Manure application does not cause significant damage to soil (compaction) or crop (smothering).

Most crops have the greatest ability to take up N before it can be lost by leaching below the root zone when manure is applied in spring or summer. Nitrate-N already present in the soil in the fall usually is sufficient to support winter cover crop establishment, so applying manure to cover crops in the fall generally is not an efficient use of manure N. However, winter crops often can utilize manure N applied in early spring (February–March). Crop utilization of manure PAN is lowest when manure is applied in fall to fallow ground or corn stubble.

Crop N utilization values given in Table 4 do not apply to well-composted manures or to dairy solids removed by a mechanical separator. These materials release PAN slowly and in small amounts, reducing the importance of season of application.

Although crop N utilization is "medium" for fall or winter application to grass, manure or compost application may cause excessive runoff of phosphorus or bacteria from the field.

Table 4 does not specify a method of manure application. At times of the year when crop N utilization is "medium," "high," or "very high," you can gain the most benefit from manure application methods that conserve NH_4-N. When crop N utilization is "low" or "very low" (Table 4), changing the manure application method will **not** improve crop N utilization.

Table 4. Effect of the timing of manure application on crop N utilization for crops grown west of the Cascades.[a] Best utilization of manure N = "high."

	Manure application date				
	March	April–June	July	August	September–February[b]
Crop	Crop N uptake utilization of first-year PAN[c, d]				
Corn for silage	Medium	High	Medium	Low	Very low
Grass pasture or grass for silage	High	High	High	Medium	Medium
Cereal or grass winter cover crop	High	Medium (April), very low (May–June)			Low
Grass seed crop	High	Medium (April), very low (May–June)	Medium (postharvest)	Medium	Medium
Summer annual forage crop (e.g., sudangrass)	Medium	High	High	Medium	Very low

[a] Excludes mechanically separated dairy solids and composts. These materials have "medium" or "high" crop N utilization because they release PAN slowly and in small amounts.

[b] September–February applications are not recommended where significant surface runoff is expected.

[c] PAN = First-year plant-available N from manure application.

[d] PAN utilization estimate given assumes that manure application rate is adequate, but not excessive, and that manure application does not cause significant damage to soil (compaction) or crop (smothering).

Take advantage of increased soil N mineralization rates

Repeated manure applications gradually increase the amount of PAN supplied from mineralization of residual organic N (manure organic N applied 1 or more years ago). This process is part of "soil building." The annual quantity of N mineralized from manured soils (in the absence of current-season manure application) typically is 1.5–2 times greater than from unmanured soils with similar soil and crop management regimes. This boost in soil N mineralization is accounted for in the Worksheet (pages 11–12) as "PAN from residual organic N."

Studies of soil biota (soil animals, nematodes, fungi, bacteria, etc.) show adaptation to repeated manure application. Biota communities adapted to manured soil typically have greater capacity to break down organic N compounds in manure that generally are resistant to decomposition. The proliferation of soil biota in manured soils also often improves soil tilth, which can increase root growth and crop N utilization. These changes in soil biota and tilth also contribute to "residual" manure effects (increasing PAN supply for the crop).

The rate of PAN release from residual organic N (1 or more years after manure application) is strongly affected by soil moisture and soil temperature, but it is not affected much by the kind of manure or compost applied the previous year. With irrigation, N mineralization rates are 2 to 4 times faster during the summer than during the cool season (October–March). Because soil is moist but not frozen for most of the winter at sites west of the Cascades, a small, but significant, amount of N mineralizes between October and March.

To take full advantage of PAN from soil organic matter mineralization, the field must have vegetative cover during the October–March period. Otherwise, nitrate-N released via mineralization during this period is likely to be lost by leaching. On fields with a history of frequent manure application, perennial grass growth typically continues for several weeks longer in the fall, and begins earlier in the spring, than on unmanured fields (even if manure was not reapplied in the early spring). The most significant long-term impact of manure application is evident in early spring (February and March) grass growth.

Crop rotation strongly affects PAN release from residual organic N. When rotating from perennial

The Environment and N Loss from Manures—Why Do We Care?

Plant-available N (PAN) losses from the soil represent lost fertilizer value. Nitrogen can be lost as ammonia, nitrate, or nitrous oxides (Figure 1, page 3). Besides losing a valuable resource, the lost PAN can contribute to off-site problems.

Ammonia lost to the atmosphere is an air pollution problem in some areas of the western U.S., particularly in winter when atmospheric inversions prevent air mixing. In the atmosphere, ammonia can react with dust and other compounds to reduce visibility and to acidify rain or fog. Ammonia emissions may contribute to:

- Human health problems (inhalation hazard)
- Changes in natural plant communities in forests and rangeland. (Nitrogen deposited in N-poor ecosystems can alter the balance between adapted species and N-loving invasive species.)
- Acid fog or rain damage to limestone buildings or cultural artifacts (for example, petroglyphs on limestone)
- Reduction in visibility (haze)

Nitrate moves with soil water. Nitrate lost from soil enriches groundwater or surface water and can contribute to:

- Human health problems (blue baby syndrome, elevated cancer risk)
- Algae blooms in lakes or other slow-moving bodies of water
- Reduced survival and reproduction of some amphibians

Nitrous oxides lost to the atmosphere through denitrification can contribute to:

- Human health problems (inhalation hazard)
- Global warming (A molecule of nitrous oxide (N_2O) traps approximately 300 times more heat than a molecule of carbon dioxide.)
- Increased N deposits in sensitive ecosystems, resulting in soil acidification or change in plant communities
- Reduction in visibility (haze)

grass or alfalfa to a row crop, a large amount of PAN is mineralized during the first 6 months following tillage. Tillage aerates the soil and breaks up soil aggregates that protect organic N from soil biota. Lower rates of PAN addition are required for most row crops following plow-down of a perennial grass sod. When grass sod is plowed down in the fall, a substantial amount of N is lost over the winter through leaching.

Supply only a portion of crop N need from manure

One of the most efficient N management strategies for row crops is to supply only 50 to 70 percent of planned crop N need with manure. Then, side-dress with N fertilizer at midseason if needed (based on soil nitrate test results). This practice improves crop N utilization by:

- Supplying PAN when the crop needs it
- Minimizing the accumulation of PAN at the end of the growing season
- Allowing some margin for error in estimating PAN release from manure

Because less manure is applied, this practice will also reduce accumulation of manure P and K in soil. See OSU Extension publication EM 8832 (listed in "For More Information") to learn how to collect and interpret data from a midseason soil nitrate test.

Questions and Answers

Should denitrification loss estimates be included in N budgets for manure utilization?

The denitrification process (Figure 1, page 3) requires:

- Anaerobic soil conditions (lack of oxygen)
- Microbial activity
- Soil nitrogen in the nitrate form

Research conducted west of the Cascades has demonstrated that N loss via denitrification is typically less than 10 percent of N applied. Nitrate-N loss in the fall and winter is caused mainly by leaching. In spring, denitrification is limited by low concentrations of soil nitrate. In western Oregon and Washington, denitrification loss is not necessarily related to soil drainage class because seasonal high water tables usually occur in winter and spring when soil nitrate-N is low (e.g., it has already been leached out).

Because the amount of PAN lost by denitrification is generally small relative to other processes that affect PAN (timing and rate of manure application, NH_4-N retained at application, organic-N mineralized, nitrate-N leached) it is ignored in the Worksheet.

If manure is applied in fall, does it count as manure applied "this year" in the Worksheet?

The Worksheet allows you to define a "year" any way you wish. If you apply manure in the fall to perennial grasses, you may want to begin your "manure application year" after the last forage cut in the fall, since this manure N will be utilized by grass the following spring.

For crops other than perennial grasses, it is best to avoid fall application of manure because crop N utilization is low (Table 4, page 15). Most of the first-year PAN is lost from manure applied in the fall when crop N utilization is "low" or "very low" (Table 4).

Is the Worksheet a nitrogen budget or nitrogen recommendation?

The Worksheet provided in this publication is **not** a complete nitrogen budget or recommendation. The Worksheet focuses only on N supplied by manure application. A nitrogen recommendation considers other factors, including:

- N uptake/removal by crops
- N supplied from other sources (irrigation water, fertilizer, legumes)
- Typical mineralization rate for soil organic matter (unmanured soil)

Conversion Factors

Nutrient concentrations in manure can be expressed in different units or in different chemical forms. Use the unit conversion table on the next page to convert laboratory analysis units to field application units. Carefully examine your laboratory report to determine whether nutrient concentration is expressed on an "as-is" basis (moist manure) or on a dry matter basis (no moisture).

Table 5. Conversion factors. To convert from units in column 2 (blue) to those in column 5 (orange), multiply by the conversion factor in column 4. To convert from units in column 5 to units in column 2, divide by the conversion factor. For example, to convert P2O5 to P, divide by 2.29.

Measurement	Unit	Symbol	Multiply by	To obtain	Symbol
Volume	acre-inch	ac-in	27000	gallon	gal
	gallon	gal	8.35	pound	lb
Concentration	parts per million	ppm or mg/kg	0.002	pound/ton	lb/t
	parts per million	ppm or mg/L	0.00835	pound/1,000 gallon	lb/1,000 gal
	parts per million	ppm or mg/L	0.227	pound/acre-inch	lb/ac-in
	percent	%	20	pound/ton	lb/t
	percent	%	83.5	pound/1,000 gallon	lb/1,000 gal
	percent	%	2,266	pound/acre-inch	lb/ac-in
	percent	%	10,000	parts per million	ppm
	pound/1,000 gallon	lb/1000 gal	27	pound/acre-inch	lb/ac-in
Dry or wet	percent dry matter (total solids)	% DM	0.01	solids fraction	DM
	percent moisture	% moisture	0.01	moisture fraction	MF
	manure, dry wt. basis		100/(%DM)	manure, "as-is" basis	
Nutrients	phosphorus	P	2.29	phosphate	P_2O_5
	potassium	K	1.20	potash	K_2O
	nitrogen in nitrate form	NO_3-N	1	nitrogen	N
	nitrogen in ammonium form	NH_4-N	1	nitrogen	N
	nitrogen in organic form	org-N	1	nitrogen	N

For More Information

OSU Extension publications

Manure nutrient analyses

Sampling Dairy Manure and Compost for Nutrient Analysis. 2015. PNW 673. https://catalog.extension.oregonstate.edu/pnw673

Interpreting Compost Analyses. 2018. EM 9217. https://catalog.extension.oregonstate.edu/em9217

Choosing manure application rates

Nutrient Management for Pastures: Western Oregon and Western Washington. 2019. EM 9224. https://catalog.extension.oregonstate.edu/em9224

Manure Application Rates for Forage Production. 2007. EM 8585. https://catalog.extension.oregonstate.edu/em8585

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Record keeping and monitoring

Post-Harvest Soil Nitrate Testing for Manured Cropping Systems West of the Cascades. 2003. EM 8832. https://catalog.extension.oregonstate.edu/em8832

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