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Estimating Manure Application Rates

Managing manure to optimize its economic returns and at the same time minimize its potential environmental impact is critical. All farmers in the state must manage their manure in compliance with the requirements of the Clean Streams Law. Concentrated animal operations also are required, under the more recent Nutrient Management Act, to have a formal, approved nutrient management plan. The best guides for developing a nutrient management plan are the DEP publication *Manure Management for Environmental Protection* (Manure Manual) and the Penn State Agronomy Guide. These publications provide detailed information about determining agronomically and environmentally sound manure application rates. They also provide information about many other best management practices (BMPs) related to manure management. This fact sheet briefly outlines the approach used to determine manure application rates and includes a simple worksheet for making the calculations. Management practices are included, as well as tables of application rates for some common manure types. *Please refer to the publications listed above for more detailed guidance on making application rate calculations and developing a nutrient management plan.*

CALCULATING MANURE APPLICATION RATES

The main factors that must be considered when determining the amount of manure to apply to a field are the crop nitrogen (N) requirement, the manure history of the field, any fertilizer N that may be applied, the manure N content, and the availability of the manure N, as determined by the time of year and whether it is incorporated. These factors are discussed below and are included in Worksheet 1 on page 3. *The numbers below refer to the numbered calculations in the worksheet.* An example has been included on the worksheet to illustrate the calculation instructions.

1. Crop N Requirement

The soil test report provides a nitrogen recommendation for the expected yield of the crop to be grown. This is the starting point for determining an appropriate manure application rate. Typical N requirements for some common agronomic crops are given in Table 1.

2. Fertilizer N Applications

Any amount of fertilizer N that will be applied regardless of the manure application, such as starter fertilizer, should be subtracted from the soil test N recommendation amount.

Table 1. Typical N recommendations for some common agronomic crops.

Crop	N/unit yield	Typical yield	N Requirement for given yield (lb N/A)
Corn Silage	9 lb/ton	20 ton/A	180
Sorghum Silage	9 lb/ton	15 ton/A	135
Corn Grain	1 lb/bu	125 bu/A	125
Wheat	1.5 lb/bu	60 bu/A	90
Oats	1.1 lb/bu	80 bu/A	88
Barley	1.4 lb/bu	75 bu/A	105
Soybeans*	3.2 lb/bu	40 bu/A	152
Alfalfa Hay*	50 lb/ton	5 ton/A	250
Clover Hay*	40 lb/ton	3.5 ton/A	140
Grass Hay	40 lb/ton	4 ton/A	160

* For legumes, no N is required. This is the amount of N that will be used by the crop.

3. Crop Rotation History of the Field

The base N recommendation may need to be adjusted to account for residual nitrogen from previous legume crops in the rotation. Legume N credits can be found in Table 2. Note that if you are using a Penn State soil test and you provided the previous crop information, the legume credit is already deducted. If this deduction is indicated on the soil test report, do not make this adjustment again.

Table 2. Residual nitrogen contributions from legumes for corn production.[1]

Previous crop	% Stand	Nitrogen credit (lb/A)
Alfalfa		
First year after alfalfa	>50% stand	80 - 120
	25% - 49% stand	60 - 80
	<25% stand	40
Red clover and trefoil		
First year after clover or trefoil	>50% stand	60 - 90
	25% - 49% stand	50 - 60
	<25% stand	40
Soybeans		
First year after soybeans harvested for grain		1 lb N/bu soybeans

[1] When a previous legume crop is checked on the Penn State Soil Test Information Sheet, the residual nitrogen for the year following the legume is taken into account in the recommendation. This is noted on the soil test report; therefore, no further adjustment is necessary.

4. Manure History of the Field

The basic N recommendation from the soil test or from Table 1 above also may need to be adjusted to account for residual nitrogen from previous manure applications. This calculation is made by multiplying the typical annual manure application rate, the typical manure N analysis (see Table 3), and an availability factor from Table 4. If you have taken a legume credit, do not also take a manure history credit.

5. Net N Requirement

The net N requirement that can be met with the planned manure application is the crop N requirement minus any fertilizer N applications minus the residual N from previous legume crops in the rotation minus the residual N from past manure history.

6. Manure N Content and Availability

The manure analysis indicates the amount of total N in the manure. If an analysis is not available, book values such as those in Table 3 can be used as an estimate of the manure nitrogen content. You should recognize, however, that although these book values are good as an average of many manure analyses, there is considerable variation among the individual analyses that make up this average.

Table 3. Average total nutrient content of manure.

Animal type		N (lb/ton)
Dairy cattle	Solid	10
	Liquid (lb/1,000 gal)	28
Veal		8
Beef cattle		11
Swine	Pigs	14
	Gestating sow	14
	Sow and 8 pigs	14
	Boar	14
	Liquid (lb/1,000 gal)	35
Sheep		23
Horse		12
Poultry	Layer	37
	Pullet	43
	Broiler	73
	Turkey (tom)	52
	Turkey (hen)	73

Note: When possible, have manure analyzed. Actual values may vary over 100% from the averages in the table.

Table 4. Residual manure N availability factors.

	N availability factor	
Historical frequency of manure application on the field	**Poultry manure**	**Other manure**
Rarely received manure in the past	0	0
Frequently received manure (4-8 out of 10 yrs)	0.07	0.15
Continuously received manure (>8 out of 10 yrs)	0.12	0.25

Manure N availability

Not all of the N in manure is immediately available to the crop. The main factors that affect manure N availability are time of year and incorporation. Table 5 provides factors that should be multiplied times the manure total N analysis to calculate the amount of the N in the manure that will be available to the planned crop.

7. Calculated Manure Application Rate

The calculated available manure N then is divided into the net crop N requirement to determine the manure application rate that balances the N needs of the crop. These balanced rates usually are rounded to a few practical application rates for the farm based on your manure spreader capabilities. Any rate less than or equal to this balanced rate would be consid-

ered environmentally safe. If the actual rate to be applied is significantly less than this balanced rate, additional N fertilizer will be required to meet the needs of the crop. A spreading rate significantly greater than this balanced rate should not be used because excess N will be applied and will represent a potential environmental threat.

MANURE APPLICATION RATE WORKSHEET

The worksheet at the bottom of this page can be used to estimate a manure application rate that will approximately balance the nitrogen needs of the crop. The numbers in the worksheet refer back to the numbered calculation steps in the previous section of this fact sheet.

Table 5. Percentage of total manure nitrogen available to crops after storage and handling.

Time of application and incorporation	N availability factor	
	Poultry manure	**Other manure**
Manure applied for corn or summer annuals the following year:		
Applied in spring		
incorporation the same day	0.75	0.50
incorporation within 1 day	0.50	0.40
incorporation within 2-4 days	0.45	0.35
incorporation within 5-6 days	0.30	0.30
incorporation after 7 days or no incorporation	0.15	0.20
Applied previous fall or winter with no cover crop[1]	0.15	0.20
Applied previous fall or winter with cover crop harvested for silage[2]	0.15	0.20
Applied previous fall or winter with cover crop as a green manure	0.50	0.40
Manure applied for winter or spring small grains:		
Applied previous fall or winter	0.50	0.40

[1]The potential exists for significant nitrogen loss to the environment when manure is applied in this manner.
[2]These low availability factors do not indicate a net loss of N. A large amount of N is removed in the cover crop silage.

Worksheet 1. Calculating a nitrogen–balanced manure application rate.

Field or Crop Group Identification	**Example**				
Crop	Corn (130 bu/A)				
1. Soil Test N Recommendation (or Table 1)	130 lb/A				
2. Other Fertilizer N to be applied	10 lb/A				
3. Residual N from previous legume (Table 2)	0				
4. Residual N from manure =	30 lb/A				
Typical rate	20 ton/A				
x Typical analysis (Table 3)	10 lb/ton				
x Residual N factor (Table 4)	.15				
5. Net N requirement (1) - (2) - (3) - (4)	**90 lb/A**				
6. Available manure N =	3.5 lb/ton				
Manure N analysis (or Table 3)	10 lb/ton				
x N Availability Factor (Table 5)	.35				
7. Balance Manure N Rate (5) ÷ (6)	**25.7 ton/A**				
Actual Planned Rate	***25 ton/A***				

OTHER CONSIDERATIONS

Several other important considerations exist in addition to applying the appropriate rate of manure. These include winter spreading of manure, soil conservation practices, phosphorus and potassium balance, manure spreader calibration, and record keeping.

MANURE MANAGEMENT ON ENVIRONMENTALLY SENSITIVE AREAS

Farmers should bear in mind that they are responsible for any pollution caused by the spreading of manure. Some special environmental considerations for field application of manure, as specified in the Nutrient Management Act regulations, include:

1. Do not spread manure within 100 feet of an open sinkhole where surface water flow is toward the sinkhole, unless the manure is mechanically incorporated within 24 hours of application.
2. Do not spread manure within 100 feet of active private drinking water sources such as wells and springs where surface flow is toward the water source, unless the manure is mechanically incorporated within 24 hours of application.
3. Do not spread manure within 100 feet of an active public drinking water source, unless other State or Federal laws or regulations require a greater isolation distance.
4. Do not spread manure within concentrated water flow areas in which vegetation is maintained, such as ditches, waterways, gullies, and swales, during times when soil is frozen, snow covered, or saturated.
5. Do not spread manure within concentrated water flow areas in which vegetation is not maintained, such as intermittent streams, gullies, and ditches.
6. Do not spread manure within 100 feet of streams, springs, lakes, ponds, intakes to agricultural drainage systems (such as in-field catch basins and pipe outlet terraces), or other types of surface water conveyance, where surface flow is toward the identified area, during times when soil is frozen, snow covered, or saturated.
7. Do not spread manure within 200 feet of streams, springs, lakes, ponds, intakes to agricultural drainage systems (such as in-field catch basins and pipe outlet terraces), or other types of surface water conveyance, where surface flow is toward the identified area and where the slope is greater than 8% as measured within the 200 feet, during times when soil is frozen, snow covered, or saturated.

Otherwise, if it is necessary to spread manure on frozen ground, apply it to your most level fields, to those farthest from streams, and to those that have a vegetative cover or crop residue with the lowest runoff potential. Apply manure to distant or limited-access fields in early winter, then to nearer fields later in the season, when mud and snow make access and spreading more difficult. The use of conservation practices that reduce or slow runoff will help reduce the adverse effects of winter-applied manure. If it is necessary to spread manure on soils subject to flooding, do so only at times when flooding is least likely to occur.

CONSERVATION PRACTICES

An up-to-date, implemented farm conservation plan is an important component of farm management. Not only do conservation practices reduce soil and water loss, but they also can reduce the potential for nutrient loss. Practices such as using a cover crop or crop residue management, as well as contour stripcropping, contour farming, cropland terraces, diversions, grassed waterways, and filter strips can effectively reduce the surface loss of soil and manure nutrients. It is critical that the practices in the farm conservation plan be integrated into the nutrient management plan. This is not always simple and may require some compromise. For example, incorporating manure is recommended to reduce N loss by volatilization; however, incorporating manure also incorporates crop residues, which are critical to soil conservation.

PHOSPHORUS AND POTASSIUM BALANCE

Most of the emphasis of nutrient planning efforts has been placed on balancing nitrogen. It is important to recognize that phosphorus (P) also is a potential pollutant and to make every attempt to maintain adequate but not excessive P levels in the soil. When manure nutrient applications are balanced based only on N, an excess of P often will be applied. If only some of the crops in a typical crop rotation receive manure, this excess may be balanced out over the cycle of the rotation. Continuous manure application, however, may result in excessively high P levels in the soil. Although potassium (K) usually is not considered an environmental problem, excessive K levels in soils can lead to nutritional imbalances in crops that can affect the health of animals. For example, high forage K levels have been linked to an increase in milk fever in dairy cows. A regular soil testing program should be followed to monitor the status of P and K in your fields. The goal should be to maintain the P and K levels within the optimum range on the soil test report.

RECORDS

Records of manure applications should be kept both as a management tool and as a verification that sound nutrient management practices are being followed, in case of a complaint related to nutrient applications on the operation. It is difficult to make decisions about what practices to change in a farm's nutrient management program without having records such as soil tests, manure analyses, and crop yields. Simple records of which fields manure was applied to, when manure was applied, how much was applied, and any other nutrient applications will meet most needs.

ESTIMATING MANURE APPLICATION RATES

Certain situations require rough estimates of manure application rates. These estimates can be especially helpful in planning a new or modified operation where soil tests and manure analyses do not exist. The accompanying tables can be used to estimate manure application rates for these purposes. For existing operations, although a nutrient management plan should be based on soil tests and manure

analyses, using book values to develop a crude plan is better than having no plan at all. *Note, however, that a plan based exclusively on these tables would not meet the requirements for a nutrient management plan developed under the Pennsylvania Nutrient Management Law.* Whenever possible, manure rates should be determined based on soil test recommendations and manure analysis adjusted for actual incorporation and field history. A simple worksheet for making this calculation is included in this fact sheet. See the Manure Management Manual or the Penn State Agronomy Guide for more information about making these calculations.

To use the following tables, you must know at least the type of manure and the crop to be grown. Additional information that will help to improve the estimated application rate includes the actual expected crop yield, the anticipated time between spreading and incorporation, and some sense of the fields' manure history. In these tables, an estimated N-balanced manure application rate is given for most crops commonly grown in Pennsylvania for an average yield. This base application rate then can be adjusted for a different yield and for the field's manure history. Guidance for making these adjustments follows:

Incorporation: Tillage or approximately 1/2 inch of soaking rainfall will incorporate manure N. In the spring, even without mechanical incorporation, manure likely will be incorporated by rainfall. Consequently, the rates in the "No Incorporation" column in these tables will be applicable only under extreme circumstances.

Yield Adjustment: These rates can be adjusted proportionally higher or lower based on your actual expected yield.

Manure History Adjustment: If the field has a history of frequent manure applications, these rates can be reduced 20 to 30% depending on the frequency and extent of these manure applications.

Adjustment for other nutrient sources: These rates assume that manure will be used to satisfy the entire N requirement or utilization for the crop. If other sources of N, such as starter fertilzer, legume N, etc. meet a portion of the N needs of the crop, the manure rate should be adjusted accordingly. For example, if 10% of the N needs of the crop are met by the starter fertilizer, then the manure rates in the tables should be reduced by 10%.

Notes on high rates: Exercise caution in situations where these tables indicate very high rates of manure (gray boxes). These rates should be split into two or more separate applications. With liquid manure, these rates may exceed the capacity of the soil to absorb the applied liquid. Large applications can result in direct runoff of manure applied to slopes. Heavy rates of manure applied to established forage crops can result in damage to the plants. Even at the lowest rates in these tables, excess P usually will be applied; thus, at the high rates, large excesses of P likely will occur, resulting in pollution problems from P. Use of soil tests to monitor P balance is critical.

Estimated manure application rates for *solid cattle* manure. (Rates in tons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1]Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	25	40	60	60	30
Corn Silage	20	30	40	70	70	35
Sorghum Silage	15	30	40	70	70	35
Grass Hay	4	30	45	80	80	40
Wheat	60	20	25	45	45	25
Oats	80	20	25	45	45	20
Barley	75	20	30	55	55	25
Alfalfa Hay	5	50	70	125	125	65
Clover Hay	3.5	30	40	70	70	35
Soybeans	40	30	45	75	75	40

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 10 lb N/ton of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

Estimate manure application rates for *liquid cattle* manure. (Rates in gallons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1] Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	9,000	13,000	22,000	22,000	11,000
Corn Silage	20	10,000	14,000	25,000	25,000	13,000
Sorghum Silage	15	10,000	14,000	24,000	24,000	12,000
Grass Hay	4	11,000	16,000	29,000	29,000	14,000
Wheat	60	6,000	9,000	16,000	16,000	8,000
Oats	80	6,000	9,000	16,000	16,000	8,000
Barley	75	8,000	11,000	19,000	19,000	9,000
Alfalfa Hay	5	18,000	26,000	45,000	45,000	22,000
Clover Hay	3.5	10,000	14,000	25,000	25,000	13,000
Soybeans	40	11,000	16,000	27,000	27,000	14,000

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 28 lb N/1,000 gal. of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

Estimate manure application rates for *solid swine* manure. (Rates in tons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1] Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	20	25	45	45	20
Corn Silage	20	20	30	50	50	25
Sorghum Silage	15	20	30	50	50	25
Grass Hay	4	25	35	55	55	30
Wheat	60	15	20	30	30	15
Oats	80	15	20	30	30	15
Barley	75	15	20	40	40	20
Alfalfa Hay	5	35	50	90	90	45
Clover Hay	3.5	20	30	50	50	25
Soybeans	40	20	30	55	55	25

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 14 lb N/ton of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

Estimate manure application rates for *liquid swine* manure. (Rates in gallons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1] Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	7,000	10,000	18,000	18,000	9,000
Corn Silage	20	8,000	11,000	20,000	20,000	10,000
Sorghum Silage	15	8,000	11,000	19,000	19,000	10,000
Grass Hay	4	9,000	13,000	23,000	23,000	11,000
Wheat	60	5,000	7,000	13,000	13,000	6,000
Oats	80	5,000	7,000	13,000	13,000	6,000
Barley	75	6,000	9,000	15,000	15,000	8,000
Alfalfa Hay	5	14,000	20,000	36,000	36,000	18,000
Clover Hay	3.5	8,000	11,000	20,000	20,000	10,000
Soybeans	40	9,000	12,000	22,000	22,000	11,000

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 35 lb N/1,000 gal. of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

Estimate manure application rates for *solid poultry layer* manure. (Rates in tons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1] Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	5	8	23	23	8
Corn Silage	20	5	8	25	25	9
Sorghum Silage	15	5	8	24	24	9
Grass Hay	4	6	10	29	29	11
Wheat	60	3	5	16	16	6
Oats	80	3	5	16	16	6
Barley	75	4	6	19	19	7
Alfalfa Hay	5	9	15	45	45	17
Clover Hay	3.5	5	8	25	25	9
Soybeans	40	5	9	27	27	10

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 37 lb N/ton of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

Estimate manure application rates for *solid poultry broiler* manure. (Rates in tons per acre)

Crop	Yield (ton/A for silage and hay, bu/A for grains)	Spring Applied Manure			Fall Applied Manure	
		[1] Manure Rate Immediate Incorporation	[1]Manure Rate Incorporated 2-5 Days After Application	[1]Manure Rate No Incorporation	[1]Manure Rate No Cover Crop or Cover Crop Harvested	[1]Manure Rate With Green Manure Cover Crop
Corn Grain	125	2	4	11	11	4
Corn Silage	20	3	4	13	13	5
Sorghum Silage	15	2	4	12	12	5
Grass Hay	4	3	5	15	15	5
Wheat	60	2	3	8	8	3
Oats	80	2	3	8	8	3
Barley	75	2	3	10	10	4
Alfalfa Hay	5	5	8	23	23	9
Clover Hay	3.5	3	4	13	13	5
Soybeans	40	3	5	14	14	5

[1]Manure application rate, calculated using the listed expected yield, book values for crop N requirement or utilization, a book value of 73 lb N/ton of manure, and incorporation as noted.
High rates are indicated by the gray boxes.

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