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Best Management Practices for Nitrogen Use in SOUTHEASTERN MINNESOTA

BEST MANAGEMENT PRACTICES FOR NITROGEN APPLICATION

Best Management Practices for Nitrogen Use in Southeastern Minnesota

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Introduction

Nitrogen (N) is an essential plant nutrient that is applied to Minnesota crops in greater quantity than any other fertilizer and contributes greatly to the agricultural economy of Minnesota crop producers. In addition, vast quantities of nitrogen are contained in the ecosystem, including in soil organic matter. Biological processes that convert nitrogen to its mobile form, nitrate (NO_3), occur continuously in the soil system. (For greater detail see "***Understanding Nitrogen in Soils*" AG-FO-3770**.) Unfortunately, nitrates can be leached from the root zone of the soil. Management guidelines have been developed to assist crop producers manage their nitrogen in ways that optimize profitability, reduce risk, and minimize losses of nitrate to surface and ground water.

What Are the Best Management Practices (BMP's)?

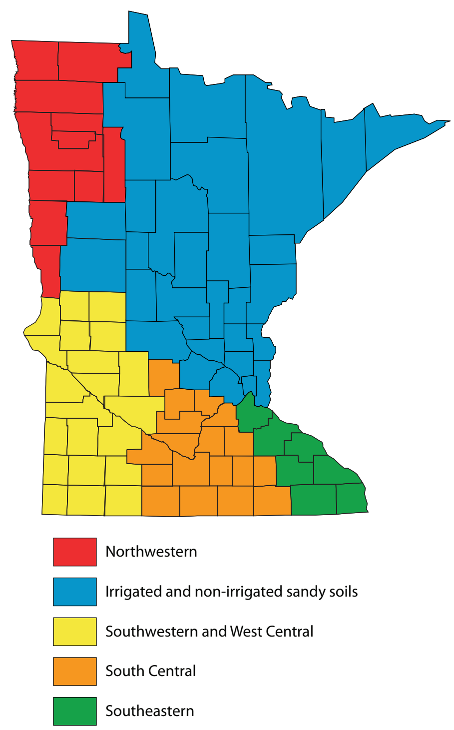
There's general agreement that BMP's are voluntary practices that are capable of minimizing nutrient contamination of surface and ground water. The BMP's recommended herein are based upon research conducted by the University of Minnesota from over 40 site-years of field research in southeastern Minnesota and upon practical considerations.

The BMP's are based, in part, upon the concept of total nitrogen management, which accounts for all forms of on-farm nitrogen in the development of crop management plans. BMP's were developed to be adopted on a statewide as well as a regional basis. Those developed for the unique soil and climatic conditions of southeastern Minnesota refine the recommendations of the statewide BMP's.

BMP's for Southeastern Minnesota

Southeastern Minnesota is characterized by permeable, silt loam soils with underlying fractured limestone bedrock. This "karst" region is very susceptible to ground water contamination. Average annual precipitation in the region is greater than 32 inches. Crops include corn, forages, oats and soybeans. Livestock production consists primarily of dairy, beef and hogs. BMP's for the counties shown in Figure 1 (Dakota, Goodhue, Fillmore, Houston, Olmsted, Wabasha and Winona) have been developed based on field research conducted in these counties.

The BMP's in this publication focus on nitrogen use for corn production. They are divided into three categories described as, 1) recommended, 2) acceptable but with greater risk, and 3) not recommended. With respect to N management, risks can be either economic or environmental. Economic risk can be a consequence of added input costs without additional yield or a reduction in yield. Environmental risks pertain to the potential for loss of nitrogen to either ground water or surface waters.



The nitrogen BMP's for southeastern Minnesota include:

1) Recommended

- Select an appropriate N fertilizer rate using U of M guidelines ("***Fertilizing Corn in Minnesota***" **FO-3790,** 2006 or newer) which are based on current fertilizer and corn prices, soil productivity and economic risks.
- Total N rate should include any N applied in a starter, weed and feed program, and contributions from phosphorus fertilizers such as MAP and DAP.
- Spring preplant applications of ammonia and urea or split applications of ammonia, urea, and UAN are highly recommended. (See Tables 2, 8, 9 and 10).
- Incorporate broadcast urea or preplant UAN within three days. (See Table 9).
- Under rain fed (non-irrigated) conditions, apply sidedress N before corn is 12 inches tall. (V7 stage).
- Take appropriate credit for previous legume crops and any manure used in the rotation.

- Inject or incorporate sidedress applications of urea or UAN into moist soil to a minimum depth of three inches.
- Minimize direct movement of surface-water to sinkholes.
- When soils have a high leaching potential (sandy texture), nitrogen application in a split-application or sidedress program is preferred. Use a nitrification inhibitor on labeled crops with early sidedressed N.

2) Acceptable, but with greater risk

- Spring preplant application of UAN (see Table 10)
- Spring preplant application of ESN

3) Not recommended

- Fall application of ammonia, urea, and UAN, with or without a nitrification inhibitor (N-Serve). (See Table 2).
- Sidedressing all N when corn follows corn.
- Fall application of N to coarse-textured (sandy) soils.
- Application of any N fertilizer including MAP or DAP on frozen soils.

Nitrogen Management Research in Southeastern Minnesota

Nitrogen management research for corn primarily involves determining the effects of rate and time of fertilizer N application, source of N, application methods, and additives (nitrapyrin, N-Serve) on corn production. In addition to measuring crop yield responses to various N treatments, many studies also evaluate crop quality (protein), economic return to N, carryover residual nitrate in the soil profile, and N use efficiency. In the following section, emphasis is placed on crop yield, economic return, and residual soil nitrate-N to determine economically and environmentally sound BMP's for southeastern Minnesota.

Rate of N Application

Using the correct amount of N optimizes crop yield while minimizing loss of N to the environment. Using excessive rates reduces profitability for the farmer and can result in excess nitrate being delivered to ground and surface water resources.

Determining the correct amount of fertilizer N to apply for a crop means first estimating how much N is available from the soil and second adding fertilizer N to meet the crop's total N need. Because uncontrollable factors like precipitation and temperature affect the release of N from the soil as well as the amount of N needed by the crop, the optimum amount of fertilizer N can change from area to area and year to year.

Dozens of field research studies have been conducted by University scientists in southeastern Minnesota to determine optimum N rates for corn. Data from 128 Minnesota sites were included in a massive effort to arrive at N recommendations for seven Corn Belt states (Iowa State Univ., PM 2015, 2006). Yield goal was found not to be a good predictor of the N rate needed. Instead, the recommended rate of N to apply was determined to be within a range of N rates, depending on the productivity of the soil, previous crop, manure applications, and the ratio of price of fertilizer N to corn price.

For southern Minnesota, the range of N rates for corn after corn and corn after soybeans is found in Table 1. Thus, for corn following soybeans, when N costs $0.25/lb and corn sells for $2.50/bu (a ratio of 0.10), the optimum N rate ranges from 90 to 125 lb N/A with the maximum economic return to N (MRTN) achieved at a rate of 110 lb N/A. In southeastern Minnesota, a rate of 110 to 120 lb N/A is recommended on those soils with the highest productivity and yield potential (Port Byron, Mount Carroll, Seaton, etc.), whereas, the 90-lb rate would be suitable for those soils of lower productivity where the yield potential is less due to limited water holding capacity (Frankville, New Glarus, Rockton, etc.).

A continuous corn study conducted in Olmsted County beginning in 1987 clearly demonstrates that nitrogen should not be applied above recommended rates and definitely not in the fall (Table 2). Highest four-year average yields occurred with the 150-lb N rate as ammonia; however, NO_3-N concentrations in the soil water at 5 feet also began to climb rapidly at this rate.

There may be fields in the region where production potential is limited by factors such as poor drainage, low water holding capacity, severe compaction and/or other restrictions to root and/or crop growth. For these fields or portions of fields, it is suggested that the rates listed to achieve MRTN and the N rates in the acceptable ranges listed in Table 1 be reduced by 20 lb. per acre.

Table 1. Nitrogen rate fertilization guidelines for highly productive soils in southern Minnesota based on N: corn price ratios and economic return for corn after corn and corn after soybean.

Price ratio	Previous Crop	
	Corn	Soybean
$/lb N: $/bu corn	- - - - - - - - - - - lb N/A[1]	- - - - - - - - - - -
0.05	130-180 (155)[2]	100-140 (120)
0.10	120-165 (140)	90-125 (110)
0.15	110-150 (130)	80-115 (100)
0.20	100-140 (120)	70-100 (85)

[1] N rates are to be reduced 20 lb/A on soils considered to have a medium yield potential due to yield-limiting factors.
[2] N rate that maximizes economic return to N (MRTN)

Table 2. Corn yield and NO_3-N concentration in the soil water at 5 feet as affected by rate and time of application in Olmsted Co., 1987-90.

Nitrogen Treatment		Grain Yield		Nitrate-N Conc. in Soil Water[1]
Rate	Time/Method	1990	1987-90	
lb N/A		---- bu/A ----		ppm
0	--	76	84	1
75	Spr., preplant	145	156	11
150	"	155	172	29
225	"	156	167	43
150	Fall	145	169	43
150	Fall + N-Serve	148	169	50
75 + 75	Spr. + SD (V7)	154	168	47

[1] Fall, 1990

Additional studies to define the optimum rate for continuous corn were conducted from 1992-2004 (Table 3). Corn grain yields were optimized at the 150-lb N rate during this 13-year period. Residual NO_3-N left in the soil profile in October greatly increased at N rates of 150 lb N/A and greater. These data clearly indicate the reduced profitability and increased potential for ground water contamination by nitrate when fertilizer N was applied at rates greater than needed.

Table 3. Continuous corn grain yield and residual NO_3-N in the soil profile in October in Olmsted Co., 1992-2004.

N Rate	Corn Yield		Residual NO_3-N in 0-7' profile[1]
	1992-2004	2002-2004	
lb N/A	------ bu/A ------		lb/A
0	71	90	23
60	124	126	38
90	137	143	52
120	146	156	62
150	150	161	158
180	--	161	173

[1] October, 2003.

To determine if "extra-high" continuous corn yields could be achieved on a very high yielding Port Byron soil, very high fertilizer and seeding rates were used in an Olmsted Co. study in 2003-2005. Corn grain yields were increased about 6 bu/A with the very high fertilizer rates, but economic return was reduced by more than $120/A (Table 4). Moreover, potential nitrate leaching losses were increased by about 300 lb NO_3-N/A with the additional N that carried over in the soil profile after harvest from the 300-lb N rate. These results illustrate the negative consequences of very high total N rates for corn, which also can occur if N credits from legumes and manure are not properly taken and fertilizer N is applied.

Table 4. Influence of very high N rates and plant populations on continuous corn yield, economic return, and residual NO_3-N in the soil profile in Olmsted Co., 2003-2005.

N Rate	Final population	3-Yr. Average		Residual[1] NO_3-N in soil
		Yield	Return to Fert. & Seed	
lb N/A	plants/A	bu/A	$/A	lb/A
180[2]	31,000	183	326	129
180[2]	41,900	184	313	167
300[3]	31,900	188	201	473
300[3]	41,900	192	192	420

[1] 0-5' profile in Oct. 2005.
[2] no additional P or K
[3] plus 200 lb P_2O_5 and 300 lb K_2O/A/yr

Nitrogen rate experiments for corn after soybeans were conducted on seven farmers' fields without a recent (10-yr) manure history from 1989-1999 (Table 5). The average economic optimum N rate (EONR), using a N price of $0.25/lb and a corn value of $2.50/bu—a 0.10 ratio) was 97 lb N/A for the six sites that responded to N. No fertilizer N was required to produce the 150 bu/A yield at the non-responding Dakota Co. site. Corn yield at the EONR averaged across all seven sites was 173 bu/A. Yield for the zero N treatment averaged across all seven sites was 147 bu/A, indicating that soil N supplied 85% of the N needed to optimize yield and profit while fertilizer N supplied 15% (26 bu/A). These results suggest that rates slightly lower than the MRTN rates shown in Table 1 can be used for corn after soybeans on highly productive soils in southeastern Minnesota.

Table 5. Corn yields for the zero N rate and for the economic optimum N rate (EONR) for seven sites following soybeans in southeastern Minnesota, 1989-1999.

Year	County	Corn grain yield at		EONR
		Zero N rate	EONR	
		----- bu/A -----		lb N/A
1989	Dakota	150	150	0
1989	Olmsted	163	188	126
1992	Dodge	105	140	105
1992	Goodhue	115	147	92
1998	Dodge	175	202	89
1998	Dodge	175	200	82
1999	Olmsted	146	183	86
	Avg.	147	173	97[1]

[1] Six responding sites.

Nitrogen From Previous Legume Crops

Nitrogen can be supplied from legume crops used in the rotation. Nitrogen credits from these crops are listed in Tables 6 and 7 and should be subtracted from the nitrogen guidelines for corn following corn Table 1. The N credit for the soybean crop is 40 lb. per acre and has been accounted for in Table 1. The N credit for a corn crop in the second year following a forage legume is summarized in Table 7.

Table 6. Nitrogen credits for legumes preceding corn in the crop rotation.

Previous Crop	1st Year Nitrogen Credit
	---- lb. N per acre ----
Harvested alfalfa	
4 or more plants/ft^2	150
2-3 plants/ ft^2	100
1 or less plants/ ft^2	40
Red clover	75
Edible beans	20
Field peas	20

Table 7. Nitrogen credits for some forage legumes if corn is planted two years after the legume.

Previous Crop	2nd Year Nitrogen Credit
	---- lb. N per acre ----
Harvested alfalfa	
4 or more plants/ft^2	75
2-3 plants/ ft^2	50
1 or less plants/ ft^2	0
Red clover	35

Nitrogen in Manure

Nitrogen in livestock manure is just as important as nitrogen applied in commercial fertilizers. Therefore, any available N in manure should be used as a credit when determining the total amount of fertilizer N needed for corn. The process of determining the amount of N supplied by manure is described in other publications that are listed on page 6 of this bulletin. As with credits from legumes, manure N credits should be subtracted from the guideline values in Table 1 for corn following corn.

Nitrogen from Other Sources

When determining the total amount of fertilizer N needed, N supplied in other fertilizers cannot be ignored. This is true whether pre-emergence or post emergence herbicides are applied using 28-0-0 as a carrier or applying high rates of phosphate fertilizers using sources containing N (11-52-0, 18-46-0, 10-34-0). This N must be taken into consideration when the rate of fertilizer N to be applied for corn is determined.

Time of N Application and N-Serve

Fall application of nitrogen produces a greater risk of nitrate leaching in southeastern Minnesota because of high average annual precipitation, the well-drained and permeable nature of the soil, and the presence of fractured limestone (karst geology). Spring preplant or sidedress nitrogen applications provide more efficient use of nitrogen than fall application.

Fall application (Nov. 13) of anhydrous ammonia with and without N-Serve gave yields in 1990 that were 7 to 10 bushels per acre (bu/A) less than with the same nitrogen rate applied in the spring before planting (Table 2). Moreover, NO_3-N concentrations in the soil water were 50 to 70 percent higher with the fall applications. Nitrate-N concentrations in the soil water in October 1988 were also highest for the fall applications; however, yields were not affected that year. Examination of the four-year yield average does not show consistent yield decreases with fall-applied nitrogen, but in seasons with above-normal rainfall lower yields can be encountered with fall application of nitrogen.

Spring preplant (PP) applications of ammonia or urea have been found to yield as well as split and sidedress (SD) applications. Continuous corn studies conducted on Port Byron silt loam in 1987-90 in Olmsted Co. (Table 2) and Goodhue Co. (Table 8) showed no yield advantage for either split (PP + SD) or a single sidedress application of ammonia. Soil water obtained from a 5-foot depth after harvest in 1990 showed a significantly higher NO_3-N concentration with the split application in Olmsted Co. and the sidedress application at V5 in Goodhue Co.

Table 8. Effect of nitrogen application time and rate on corn yield and NO_3-N concentration in the soil water at a 5-foot depth in Goodhue Co., 1987-90.

Nitrogen Treatment		4-yr Average Yield	Nitrate-N Concentration in Soil Water[1/]
Rate	Time/Method		
lb N/A		bu/A	ppm
0	--	89	6
50	Preplant (PP)	129	ND[2/]
100	PP	143	22
150	PP	147	39
200	PP	148	ND
50+50	PP+SD (V5)	142	ND
50+100	PP+SD (V5)	146	ND
100+50	PP+SD (V5)	148	ND
100	SD (V5)	140	ND
150	SD (V5)	146	62

1/ Fall 1990
2/ ND-not determined

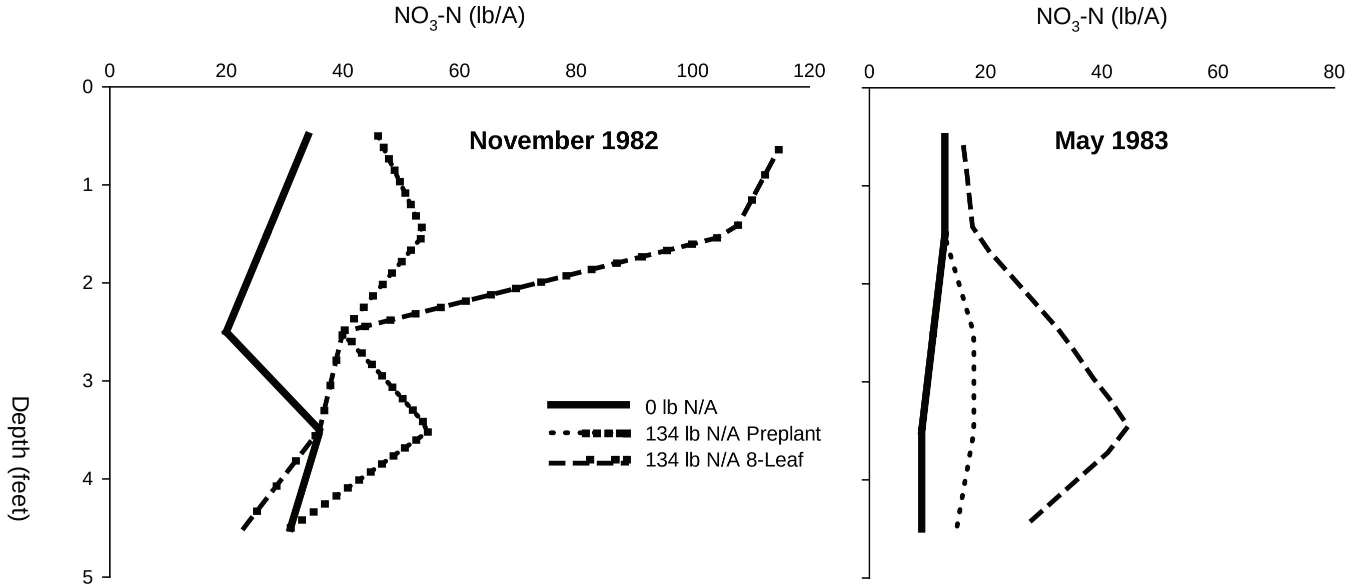


Figure 2. Effect of nitrogen rate and time of application on the NO_3-N in the soil profile in 1982-83.

Nitrogen not absorbed by plants often remains in the soil after harvest and thus is highly susceptible to leaching loss before the next year's crop can use it. Strong evidence of this occurred on a Mount Carroll silt loam in Goodhue Co. in 1982 and 1983 where substantial amounts of NO_3-N remained in the soil after harvest when the sidedress nitrogen was band-applied 2 inches deep at the 8-leaf stage (Figure 2). Most of this residual nitrate was not found in the 5-foot profile the following May. Excess levels of residual soil nitrate similar to those shown in Fig. 2 can also occur when preplant-applied N rates are greater than needed as shown in Tables 3 and 4.

Limiting sidedress applications to corn shorter than 12 inches will help ensure that nitrogen is available when the plants need it most, from late June through mid-August. This strategy also improves the chances that nitrogen will be available to the crop during extended dry weather. An Olmsted Co. study clearly showed that delayed nitrogen applications can result in significant yield reduction. On a Port Byron soil that had only received a 60-lb N rate the previous year, second year corn was grown to compare split application (PP + SD, V10) with preplant N application (Table 9). Grain yields of 194 bu/A were obtained at the 200-lb rate of preplant N at this "N-starved" site. Interestingly, yields for the split-applied 160-lb treatment were 19 bu/A lower than for the preplant treatment (166 vs. 185 bu/A). The sidedress urea treatments were applied on July 5 (V10 stage) and no precipitation occurred until after July 20 (R1). The roots did not take up the sidedressed N until after R1 as shown by the lower relative chlorophyll levels for the sidedress treatments.

Table 9. Corn grain yield and relative leaf chlorophyll content at R1 as influenced by N rate and time of application in Olmsted Co, 2005.

Time of Application		Total N Rate	Grain Yield	Rel. Leaf Chlorophyll
Preplant	V10			
------------ lb N/A		------------	bu/A	%
0	0	0	75	68
40	0	40	115	78
80	0	80	142	86
120	0	120	174	94
160	0	160	185	98
200	0	200	194	99
40	40	80	145	75
40	80	120	164	76
40	120	160	166	77

Time of Application and Source of N

For preplant applications, use ammonium forms of nitrogen fertilizer such as anhydrous ammonia and urea to reduce the potential for early-season nitrate loss. Urea-ammonium nitrate (UAN) contains 25% nitrate, which is immediately susceptible to leaching. Under normal spring conditions anhydrous ammonia and urea will take from two to six weeks to nitrify from ammonium to nitrate. This delay decreases the potential for leaching of nitrate during the last part of April and in May, when precipitation is highest and crop demand for nitrogen and water is low.

Urea broadcast on the surface should be mixed into the soil (incorporated) soon after application to reduce potential loss by volatilization and surface runoff. Volatilization is generally accelerated by crop residue and high soil pH. High soil pH is uncommon in southeastern Minnesota, but large amounts of surface residue are common because conservation tillage is used with continuous corn. In addition, fertilizer N injected or incorporated to a 4-inch depth is more likely to reach roots under dry conditions. Surface-applied fertilizers are less likely to reach roots under dry conditions, and yields may suffer.

Preplant-applied urea gave significantly greater continuous corn yields in a 3-year study on a Port Byron soil than did preplant-applied UAN (28%N) (Table 10). Yields for a split application of UAN were not significantly different from the preplant urea treatment.

Table 10. Continuous corn grain yield as affected by source and time of N application in Olmsted Co., 2002-2004

N Treatment		Corn Yield*
Source	Time	
		bu/A
Urea	Preplant	152
UAN	"	146
UAN	Split**	150

* Averaged across 60, 90, 120, 150, and 180-lb N rates.
** 30 lb N/A preplant and rest injected at V4 stage.

Urea and other fertilizers and manures left on the soil surface can easily be washed toward streams and sinkholes during intense rains. When nutrient-laden surface water runs directly into sinkholes, water quality over a large region can be harmed. Movement of those nutrients can be minimized through erosion control, berms, and filter strips around sinkholes. Incorporating fertilizer and manure into the soil, rather than leaving them on top, greatly reduces chances that they will wash into sinkholes and contaminate the groundwater.

Potential Helpful Products

There is general recognition that nitrogen can be lost from soils. Responding to that recognition, products have been developed that, when used, could reduce the potential for loss. N-Serve is a nitrification inhibitor used for the purpose of delaying the conversion of ammonium (NH_4-N) to nitrate (NO_3-N). The use of this product for corn production in southeastern Minnesota has been discussed previously in this publication.

Agrotain is a urease inhibitor designed to be used in no-till or other production systems where urea remains on the soil surface without incorporation. It reduces the potential for N loss due to volatilization. This product could be used in southeastern Minnesota where corn is planted using the no-till system.

ESN is a product that consists of urea coated with a polymer and, thus, is intended for use as a slow release nitrogen fertilizer. It is acceptable to use this product in the spring before planting in southeastern Minnesota. However, there is a risk. The cost is substantially higher than the cost of N supplied as urea. Mixtures of ESN and urea might be appropriate. However, mixtures have not been evaluated.

Summary

Effective and efficient management of nitrogen fertilizers is important for profitable corn production in southeastern Minnesota. The research based Best Management Practices (BMP's) described in this publication are agronomically, economically, and environmentally sound. They are voluntary. If these practices are followed, agriculture can be more profitable without the threat of regulation.

Related Publications

08560 (revised, 2008) - Best Management Practices for Nitrogen Use in Minnesota

08554 (revised, 2008) - Best Management Practices for Nitrogen Use in South-Central Minnesota

08558 (revised, 2008) - Best Management Practices for Nitrogen Use in Southwestern and West-Central Minnesota

08555 (revised, 2008) - Best Management Practices for Nitrogen Use in Northwestern Minnesota

08556 (Revised, 2008) - Best Management Practices for Nitrogen Use on Coarse Textured Soils

AG-FO-5880 - Fertilizing Cropland with Dairy Manure

AG-FO-5879 - Fertilizing Cropland with Swine Manure

AG-FO-5881 - Fertilizing Cropland with Poultry Manure

AG-FO-5882 - Fertilizing Cropland with Beef Manure

AG-FO-3790 - Fertilizing Corn in Minnesota

AG-FO-3770 - Understanding Nitrogen in Soils

AG-FO-3774 - Nitrification inhibitors and Use in Minnesota

AG-FO-2274 - Using the Soil Nitrate Test for Corn in Minnesota

AG-FO-2392 - Managing Nitrogen for Corn Production on Irrigated Sandy Soils

AG-FO-0636 - Fertilizer Urea

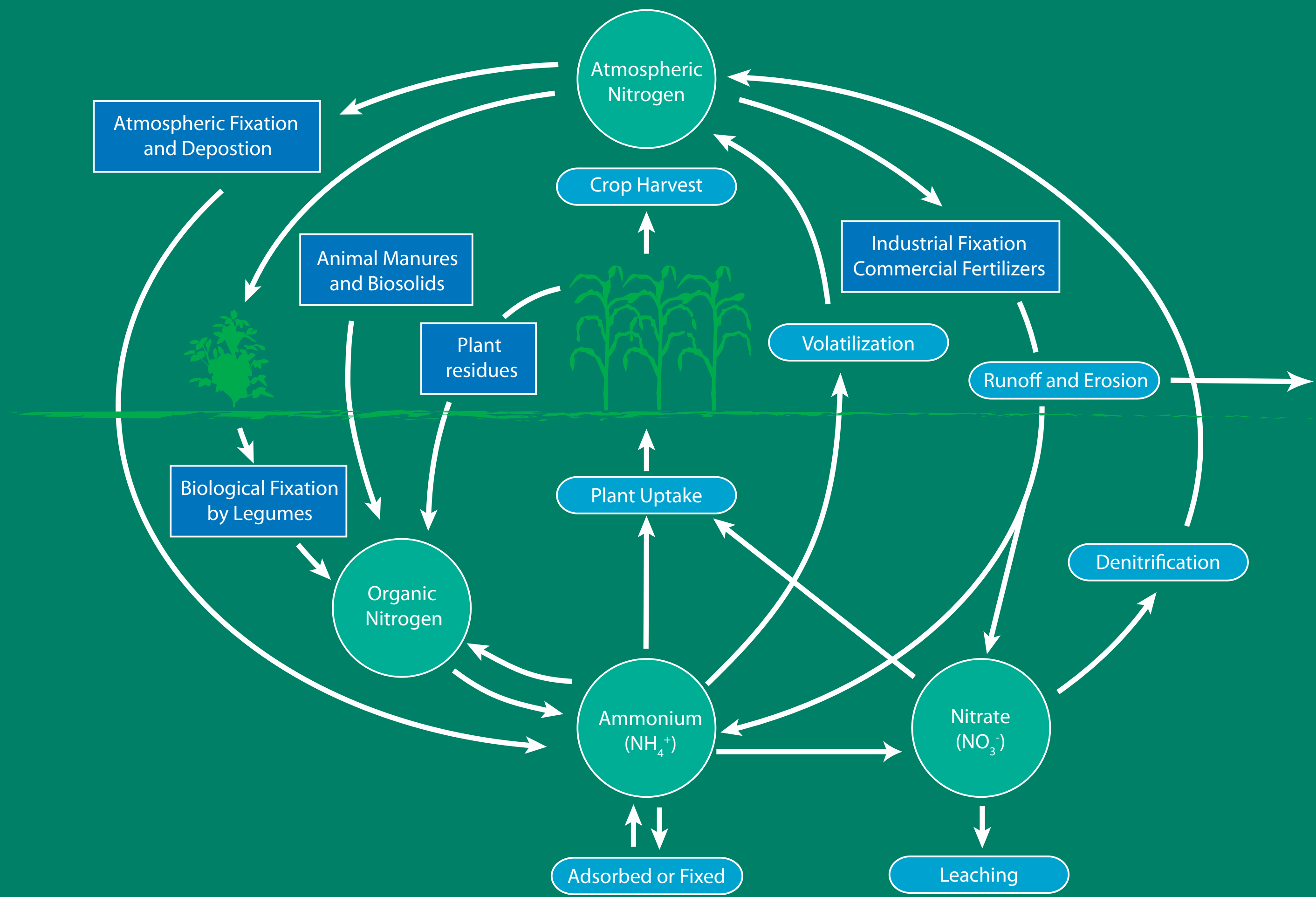
AG-FO-3073 - Using Anhydrous Ammonia in Minnesota

AG-FO-6074 - Fertilizer Management for Corn Planted in Ridge-till or No-till Systems

AG-FO-3553 - Manure Management in Minnesota

BU-07936 - Validating N Rates for Corn

Iowa State Univ. PM 2015 - Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn



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