The Most Important Tool in the Nitrogen Management Toolbox

Wisconsin Crop Management Conference
January 11, 2011

Carrie Laboski

DEPARTMENT OF SOIL SCIENCE
University of Wisconsin-Madison

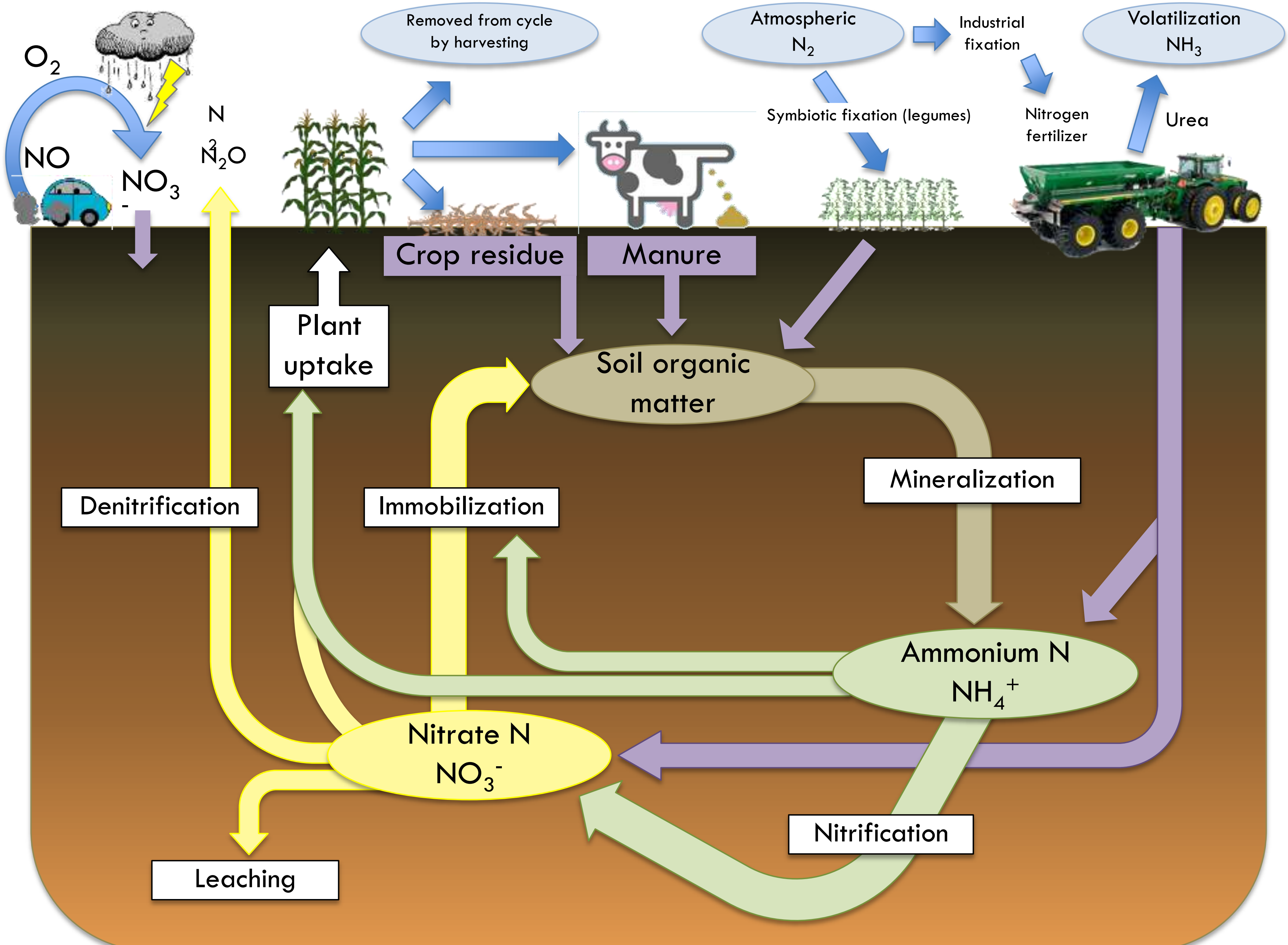
UW Extension

N management continues to be a challenge

- High fertilizer prices
- Typical and unusual weather challenges
- Confusion about N fertilizer technologies
- Uncertainty regarding manure and legume N credits
- Fear of economic yield loss

Most important tool

Solid understanding of N cycle



O2
NO
NO3-
N2O
Removed from cycle by harvesting
Atmospheric N2
Industrial fixation
Volatilization NH3
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH4+
Nitrate N NO3-
Nitrification
Leaching

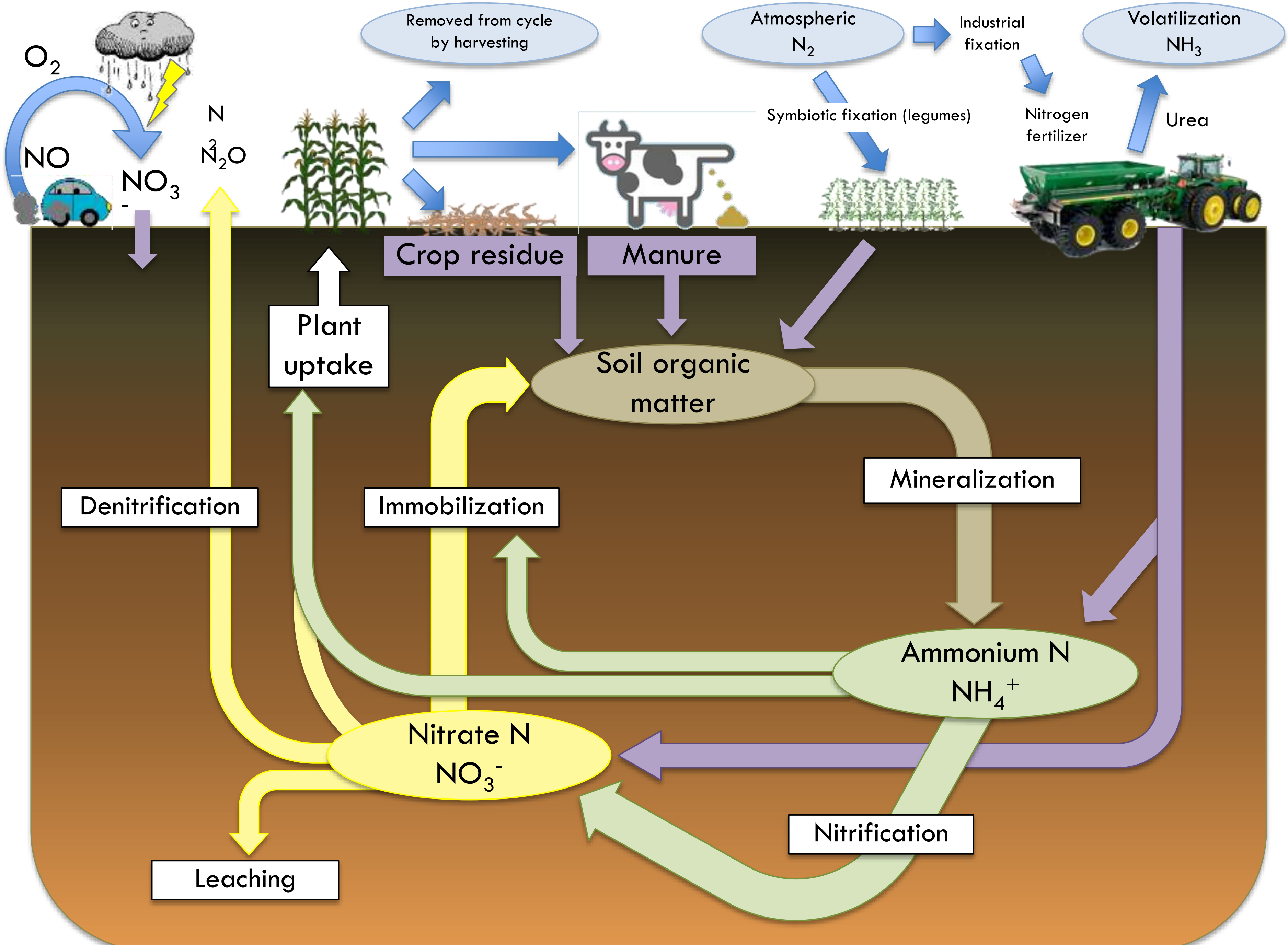
Using the N cycle to make decisions in five situations

1. Manure and forage legumes in rotation
2. Excessive rainfall on medium- & fine-textured soils
3. Topdressing in notill corn or grass pasture
4. Fall N applications
5. Sandy soils

Manure and forage legumes in rotation

- Biggest concern – N credits in years with cool temperatures and/or excessive rainfall

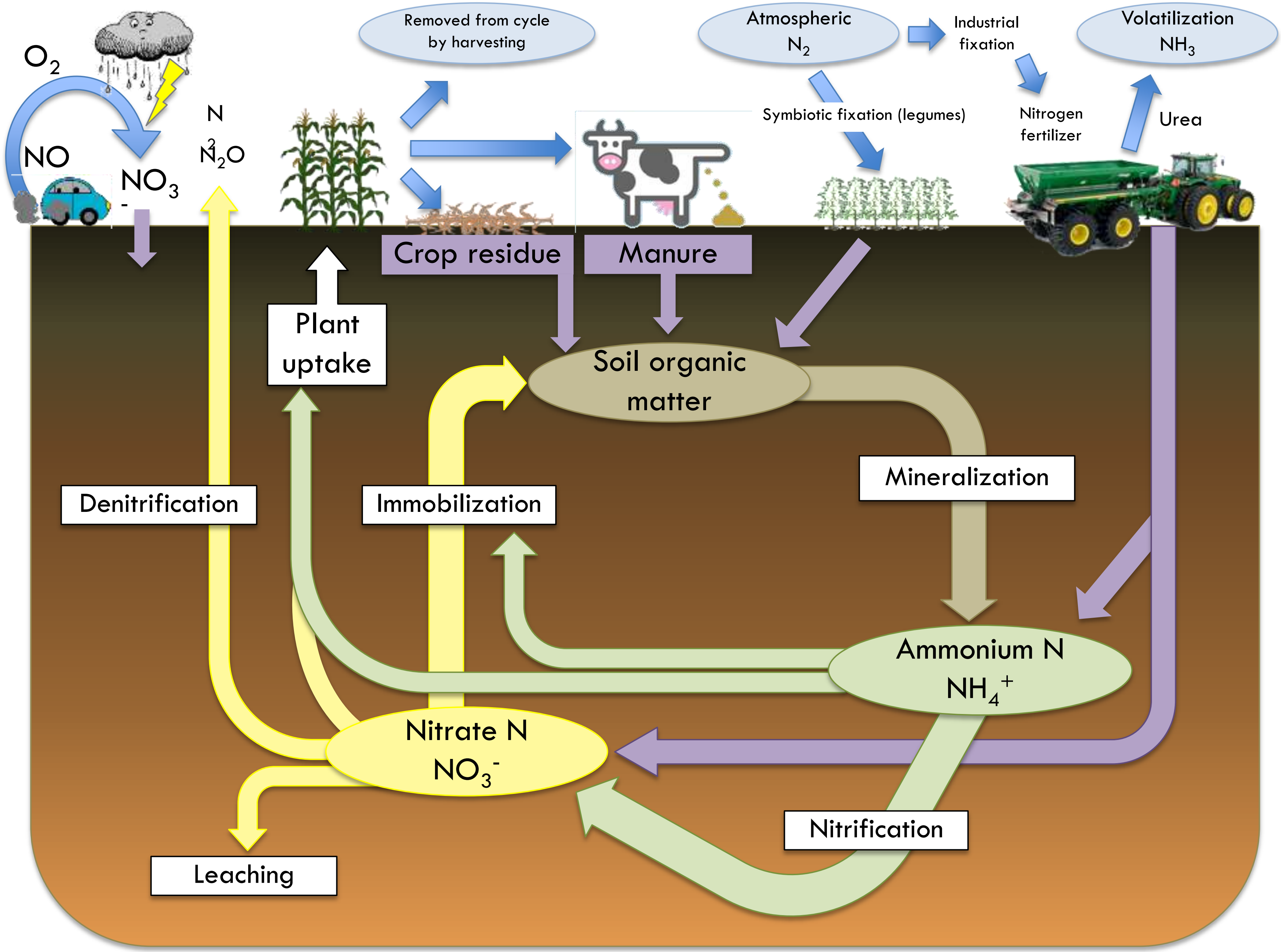
DEPARTMENT OF SOIL SCIENCE
University of Wisconsin-Madison



Removed from cycle by harvesting
Atmospheric N2
Industrial fixation
Volatilization NH3
O2
NO
NO3 -
N2O
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH4+
Nitrate N NO3-
Nitrification
Leaching

Mineralization

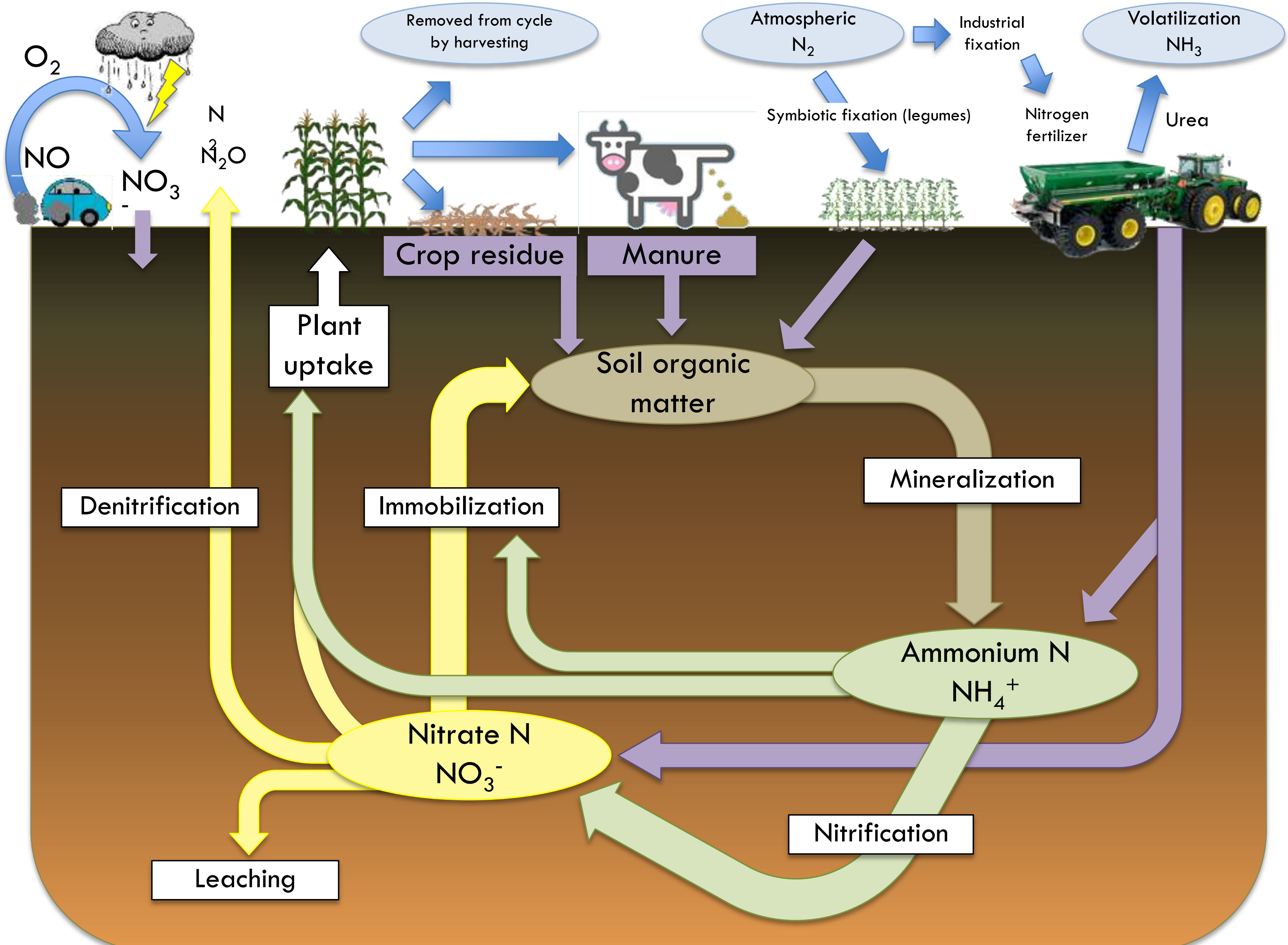
- Organic N $\longrightarrow$ NH_4^+
- Bacteria & fungi in control
  - Temperature
    - Peak activity between 75°F and 95°F
  - Oxygen
    - occurs to much greater extent in aerobic soils compared to anaerobic soils
  - Moisture
    - Max. activity between 50% and 70% water-filled pore space



Removed from cycle by harvesting
Atmospheric N2
Industrial fixation
Volatilization NH3
O2
NO
NO3 -
N2O
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH4+
Nitrate N NO3-
Nitrification
Leaching

Nitrification

- $NH_4^+ \longrightarrow NO_2^- \longrightarrow NO_3^-$
- Controlled by
  - Supply of NH_4
  - Temperature & moisture (similar to mineralization)
  - Population of nitrifying organisms
  - Soil pH (4.5 to 10.0, 8.5 is ideal)
  - Oxygen is required



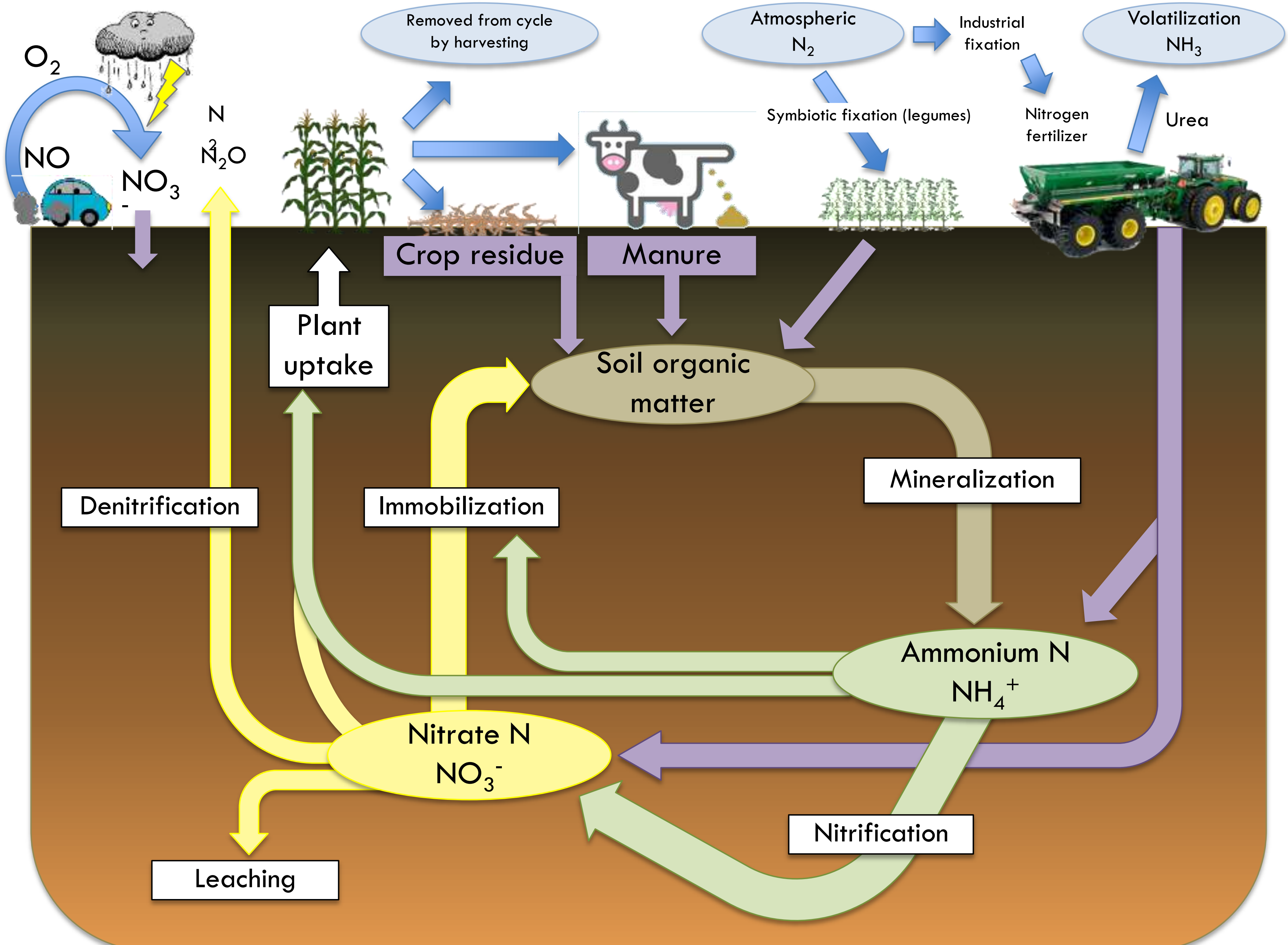
Removed from cycle by harvesting
Atmospheric N_2
Industrial fixation
Volatilization NH_3
O_2
NO
NO_3^-
N_2O
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH_4^+
Nitrate N NO_3^-
Nitrification
Leaching

Can PSNT be useful?

- If July–August temperatures ≥ average after a cool spring, the total amount of organic N mineralized with be close to expectations
  - PSNT will underestimate available N
- If manure was applied in early fall, PSNT may better estimate N needs rather than using manure N credits
  - Assuming that some N may have been lost

Excessive rainfall on medium- and fine-textured soils

- Biggest concern – denitrification



Removed from cycle by harvesting
Atmospheric N_2
Industrial fixation
Volatilization NH_3
O_2
NO
NO_3^-
N_2O
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH_4^+
Nitrate N NO_3^-
Nitrification
Leaching

Denitrification

- $NO_3^- \longrightarrow N_2$ or N_2O
- Need organic matter (carbon)
- Need nitrate
- Wet soils with low O_2 content
  - Greater saturation periods results in more denitrification
- Temperature (bacteria prefer > 75°F)
- pH (bacteria prefer >5.0)

Estimated N losses from denitrification as influenced by soil temperature and number of days the soil is saturated

Soil temperature (°F)	Days saturated	N loss (% of applied)
55 to 60	5	10
	10	25
75 to 80	3	60
	5	75
	7	85
	9	95

From Shapiro, University of Nebraska

Approximate time until fertilizer N is in the nitrate form

Fertilizer material	Approximate time until NH_4^+	Approximate time until NO_3^-
Ammonium sulfate, 10-34-0, MAP, DAP	0 weeks	1 to 2 weeks
Anhydrous ammonia		3 to 8 weeks
Urea	2 to 4 days	1.25 to 2.5 weeks
Ammonium nitrate	50% is NH_4^+, 0 weeks	50% is NO_3^-, 0 weeks 50% in 1 to 2 weeks
UAN	25% is NH_4^+, 0 weeks 50% is urea, 2 to 4 days	25% is NO_3^-, 0 weeks 25% in 1 to 2 weeks 50% in 1.25 to 2.5 weeks

Effect of Instinct applied preplant with 28% UAN at Arlington in 2008-2010

Year	N rate	Instinct Without	Instinct With	*P* value
	lb N/a	Yield (bu/a)		
2008	mean of 80 & 120	173	178	0.25
2009	mean of 40 & 80	196	196	0.91
2010	mean of 40 & 80	196	201	0.14

Year	May	June	July
	Rainfall departure from normal (inches)		
2008	-0.2	9.6	1.0
2009	0.3	0.3	-1.7
2010	0.7	3.6	5.4

Year	Preplant	Sidedress
	$EONR_{0.10}$ (lb N/a)	
2008	144	113
2009	69	59
2010	96	57

Instinct costs ~$10/a

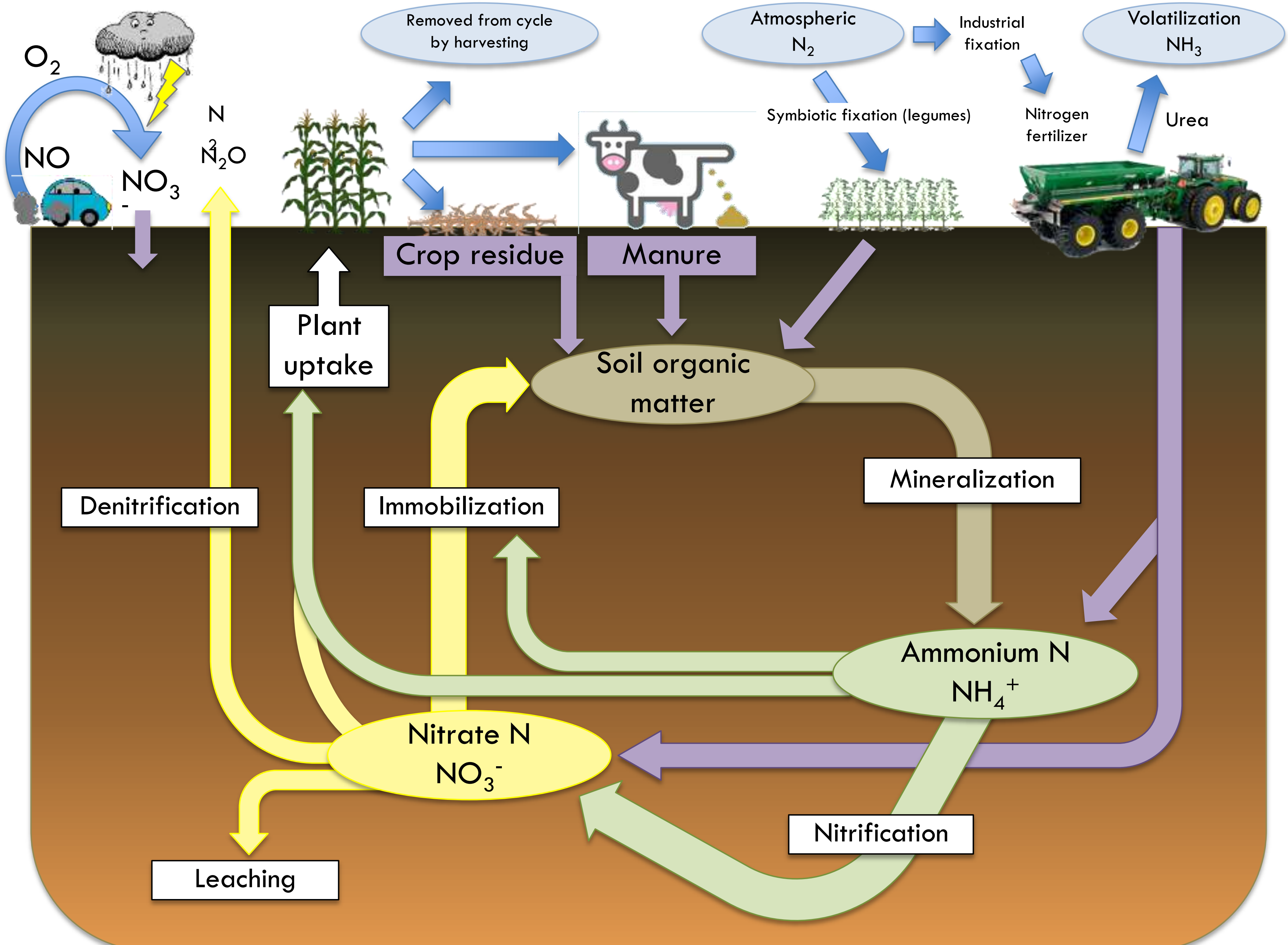
Relative probability of increasing corn yield using a nitrification inhibitor

Soil type	Time of nitrogen application		
	Fall	Spring preplant	Spring sidedress
Sands & loamy sands	Not recommended	Good	Poor
Sandy loams & loams	Fair	Good	Poor
Silt loams & clay loams			
Well drained	Fair	Poor	Poor
Somewhat poorly drained	Good	Fair	Poor
Poorly drained	Good	Good	Poor

Note: Table was developed based on data collected in Wisconsin and the upper Midwest.

Fall N applications

- Biggest concern – leaching and denitrification



O_2
NO
NO_3^-
N
N_2O
Removed from cycle by harvesting
Atmospheric N_2
Industrial fixation
Volatilization NH_3
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N NH_4^+
Nitrate N NO_3^-
Nitrification
Leaching

Fall N applications

- Should be avoided on:
  - Sandy soils
  - Other soils that have a high probability of leaching N to ground water
    - With the exception of fall seeded crops
- On silt loam soils, nitrate-containing fertilizers should be avoided

Fall N applications

- Wait to apply fertilizer until soil is < 50°
  – Nitrification processes are dramatically reduced at low soil temperatures
- Nitrification inhibitors may be beneficial at reducing the potential for nitrate losses
  – However, likely provide a lower economic return than spring applications

Impact on N application timing and use of NServe on corn yield, seven-year average on a poorly drained Mollisol in Waseca, MN (Randall et al., 2003)

N Timing†	NServe‡	Yield	Income*	N Cost	NServe Cost	Return
		bu/a	$/a	$/a	$/a	$/a
Fall	No	131	655	67.50		597.50
Fall	Yes	139	695	67.50	8	619.50
Spring	No	139	695	67.50		627.50
Split	No	145	725	67.50		657.50
LSD (0.01)		4				

† 135 lb N/a was applied as anhydrous ammonia in all treatments. Split application had 40% of the N applied in the spring and 60% sidedressed at V8.

‡ NServe was applied at a rate of 2 pt/a.

* Calculations were based on $5.00/bu corn, $0.50/lb N, and $32/gal of NServe.

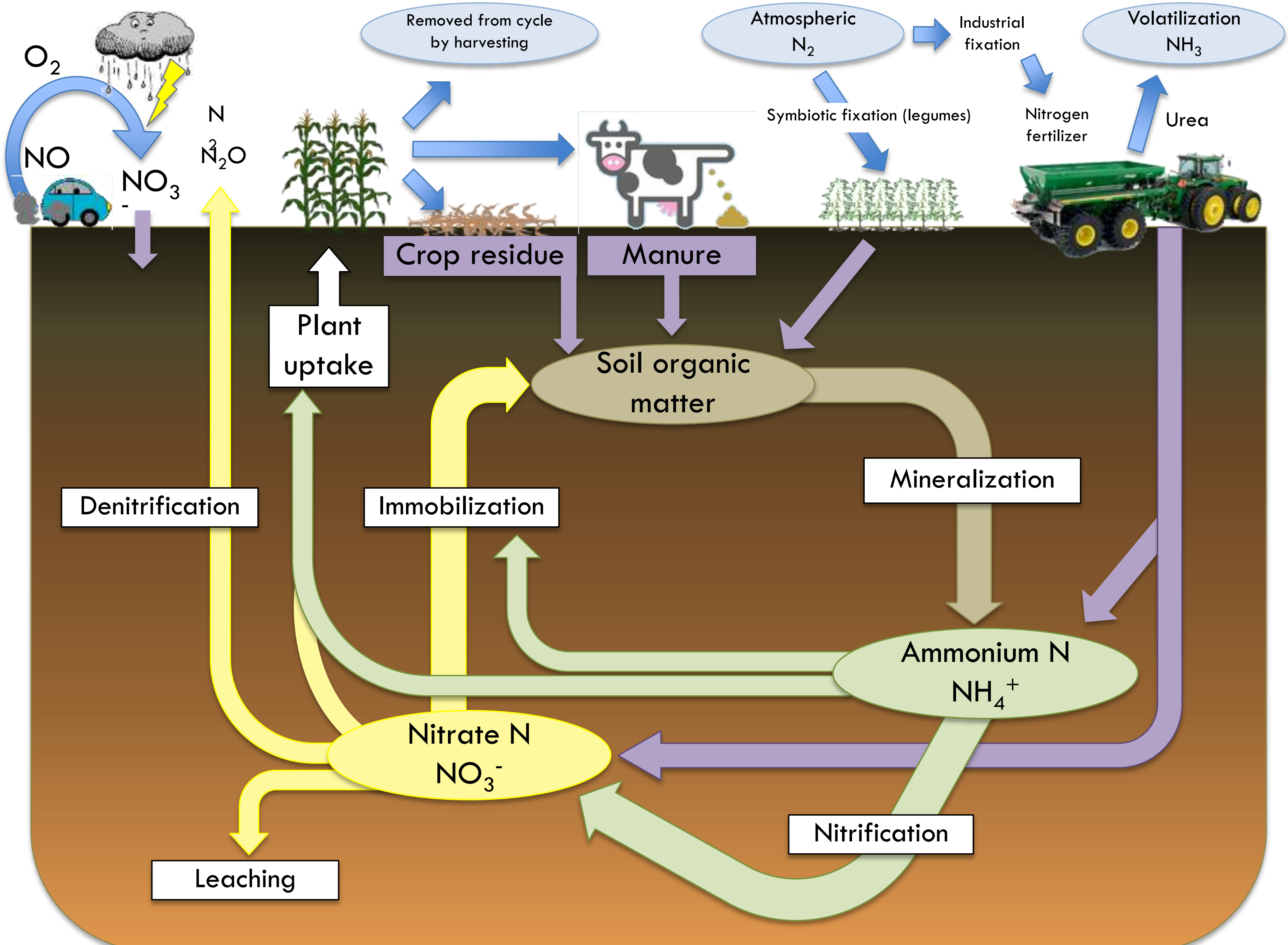
Relative probability of increasing corn yield using a nitrification inhibitor

Soil type	Time of nitrogen application		
	Fall	Spring preplant	Spring sidedress
Sands & loamy sands	Not recommended	Good	Poor
Sandy loams & loams	Fair	Good	Poor
Silt loams & clay loams			
Well drained	Fair	Poor	Poor
Somewhat poorly drained	Good	Fair	Poor
Poorly drained	Good	Good	Poor

Note: Table was developed based on data collected in Wisconsin and the upper Midwest.

Topdressing in notill corn or grass pasture

- Biggest concern – ammonia volatilization



O2
NO
NO3
-
N
2
N2O
Removed from cycle
by harvesting
Atmospheric
N2
Industrial
fixation
Volatilization
NH3
Symbiotic fixation (legumes)
Nitrogen
fertilizer
Urea
Crop residue
Manure
Plant
uptake
Soil organic
matter
Mineralization
Denitrification
Immobilization
Ammonium N
NH4+
Nitrate N
NO3-
Nitrification
Leaching

Urea hydrolysis and N volatilization

$$(NH_2)_2CO + 2H_2O \xrightarrow{\text{urease}} (NH_4)_2CO_3$$

urea ammonium carbonate

$$(NH_4)_2CO_3 + 2H^+ \longrightarrow 2NH_4^+ + CO_2\uparrow + H_2O$$

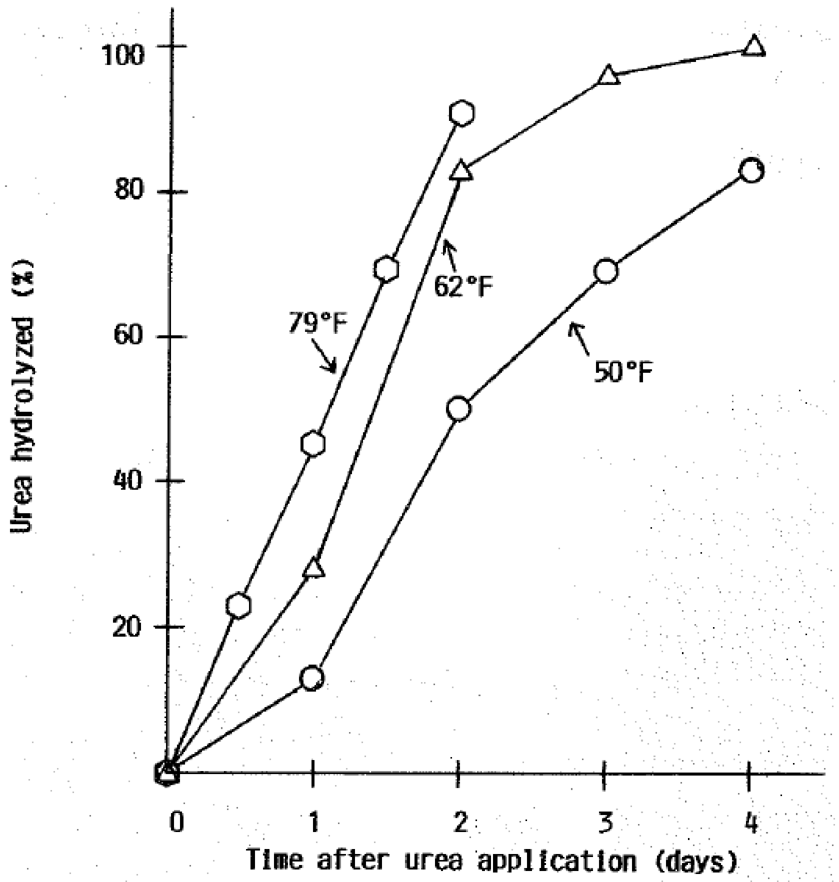
$$NH_4^+ + OH^- \longrightarrow NH_3\uparrow + H_2O$$

DEPARTMENT OF SOIL SCIENCE
University of Wisconsin-Madison

Soil & climatic condition favoring high NH_3 loss from surface-applied urea

- No rainfall after application
  - Significant N loss if no rainfall within 5 days of application
- High temperatures

Urea hydrolysis is relatively quick and temperature dependent



Soil & climatic condition favoring high NH_3 loss from surface-applied urea

- No rainfall after application
  - Significant N loss if no rainfall within 5 days of application
- High temperatures
- High soil pH (≥8.0)
- Intermediate humidity (50-90%)
- Low soil clay and organic matter
- Crop residue on soil surface

Effect of NH_3 volatilization from surface-applied N fertilizer on corn and grass pasture yields

Crop	N Source*	% of added N lost as NH_3**	Yield
		%	bu/a or T/a
Corn	None	--	83
	Urea	16	122
	UAN (28%)	12	125
	Ammonium nitrate	2	132
Grass pasture	None	--	0.74
	Urea	19	1.09
	Ammonium nitrate	1	1.30

* N sources surface applied at 50 & 100 lb N/a for corn and 60 lb N/a for grass pasture. Corn yields are averages of both N rates.

** NH_3 loss determine by field measurement.

From Oberle and Bundy, 1984.

Management considerations

- Is a non-urea based N source available?
- Is 0.25" of rain forecast within the next 2 days?
  - Or do you have the ability to irrigate?
- Is a urease inhibitor economical?

Cost-benefit of urease inhibitor with surface applied urea

N rate	Yield	Net Return to N
lb N/a	bu/a	$/a
140	214	1000
115	213	1007
100	211	1005
90	208	995

- Used actual corn yield response data
  - Agrotain was not a treatment; High yield potential soil
  - Previous crop = soybean; Max yield (214 bu/a) achieved at 120 lb N/a
- Price of corn is $5.00/bu; Price of N is $0.50/lb N
- Agrotain application rate of 5 qt/T urea; $65/gal
- When Agrotain applied, no N loss
  - Yield the same as when no Agrotain and no N loss
    - Realistically may not occur in all fields

Cost-benefit of urease inhibitor with surface applied urea

N rate	Yield	Net Return to N
lb N/a	bu/a	$/a
140	214	1000
115	213	1007
100	211	1005
90	208	995

20% N Loss	Yield	Net Return to N
lb N/a	bu/a	$/a
28	212	990
23	209	987
20	205	975
18	201	960

- Used actual corn yield response data
  - Agrotain was not a treatment; High yield potential soil
  - Previous crop = soybean; Max yield (214 bu/a) achieved at 120 lb N/a
- Price of corn is $5.00/bu; Price of N is $0.50/lb N
- Agrotain application rate of 5 qt/T urea; $65/gal
- When Agrotain applied, no N loss
  - Yield the same as when no Agrotain and no N loss
    - Realistically may not occur in all fields

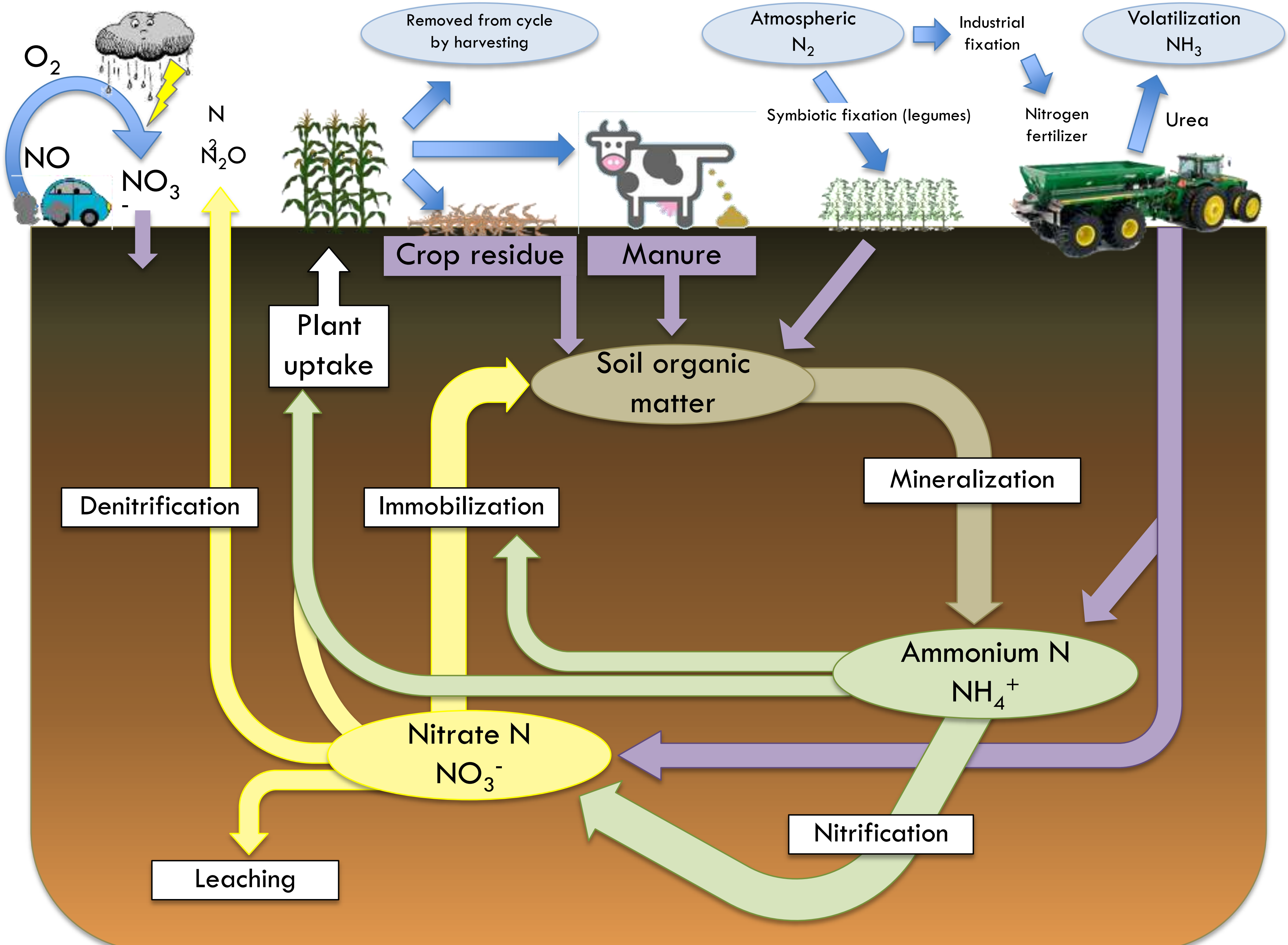
Cost-benefit of urease inhibitor with surface applied urea

N rate	Yield	Net Return to N	20% N Loss	Yield	Net Return to N	Agrotain Cost	Net Return to N & Agrotain
lb N/a	bu/a	$/a	lb N/a	bu/a	$/a	$/a	$/a
140	214	1000	28	212	990	5.60	994
115	213	1007	23	209	987	4.60	1003
100	211	1005	20	205	975	4.00	1001
90	208	995	18	201	960	3.60	991

- Used actual corn yield response data
  - Agrotain was not a treatment; High yield potential soil
  - Previous crop = soybean; Max yield (214 bu/a) achieved at 120 lb N/a
- Price of corn is $5.00/bu; Price of N is $0.50/lb N
- Agrotain application rate of 5 qt/T urea; $65/gal
- When Agrotain applied, no N loss
  - Yield the same as when no Agrotain and no N loss
    - Realistically may not occur in all fields

Sandy soils

- Biggest concern – NO_3^- leaching



Removed from cycle by harvesting
Atmospheric N_2
Industrial fixation
Volatilization NH_3
O_2
NO
NO_3^-
N_2O
Symbiotic fixation (legumes)
Nitrogen fertilizer
Urea
Crop residue
Manure
Plant uptake
Soil organic matter
Mineralization
Denitrification
Immobilization
Ammonium N
NH_4^+
Nitrate N
NO_3^-
Nitrification
Leaching

Managing to reduce leaching

- Time of application
- Fertilizer materials
- Use of inhibitors

Effect of timing of UAN application on corn grain yield & N recovery at Hancock, WI

Timing				Year 1		Year 2	
PP	SD	SD+4	SD+8	Yield	Recovery	Yield	Recovery
% N applied				bu/a	%	bu/a	%
100	0	0	0	140	44	129	26
0	100	0	0	139	56	143	30
50	50	0	0	--	--	149	41
0	50	25	25	140	49	138	35
17	50	17	17	143	65	141	56

All plots received 210 lb N/a as UAN.
PP = preplant
SD = sidedress
SD+4 = sidedress + 4 weeks
SD+8 = sidedress + 8 weeks

Effect of nitrification inhibitors on corn yield and N recovery, 4-year average at Hancock, WI

Inhibitor	Timing	Yield	Recovery
		bu/a	%
No	PP	116	37
	SD	134	63
Yes	PP	121	51
	SD	134	65

All treatments received 140 lb N/a

PP = preplant

SD = sidedress

Sidedress applications are preferred to nitrification inhibitors on sandy soils.

Fertilizer materials

- NH_4^+ forms preferred
- Urea must be incorporated
  - Tillage or ¼” rain/irrigation within 2 days
- Polycoated urea (eg ESN)

N source & timing effects on corn grain yield at Hancock, WI

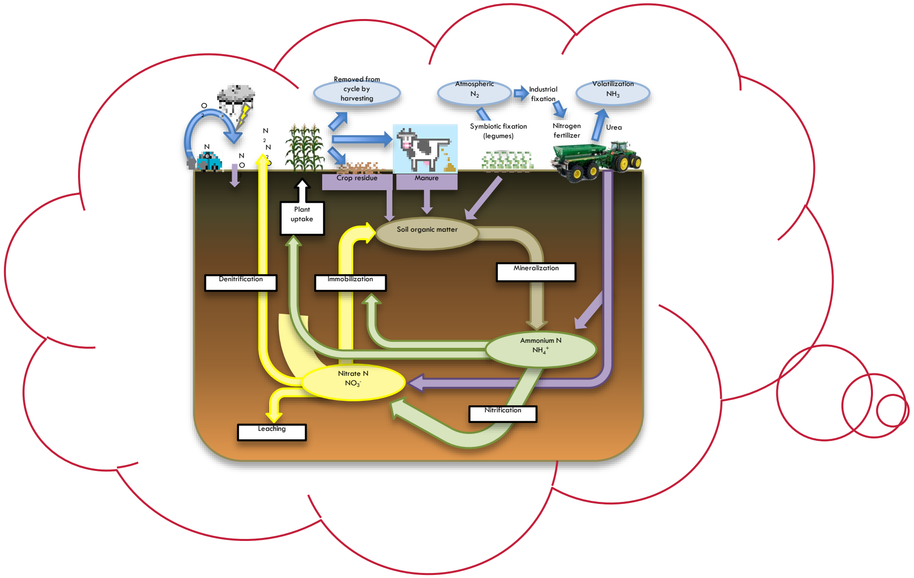
N Source	N Timing	Year 2003	2004	2005
		Yield, bu/a		
Control	--	107	115	96
PCU (ESN)	PP	204NS	167 c	186 ab
	PP+4 wk	205	180 b	189 a
Amm. Sulf.	PP	196	132 e	175 b
	PP+DCD	202	136 e	183 ab
	4 wk & 8 wk	194	181 b	180 ab

Yields are the average of 150 and 200 lb N/a rates.
PP = preplant
PP + 4 wk = split applications at preplant & 4 wk
PP + DCD = preplant + DCD nitrification inhibitor
4 wk & 8wk= split applications at 4 wk & 8 wk after planting

Years with normal or < normal rainfall, ESN is = or > SD or split amm. sulf. or urea

Years with excessive early rainfall:

- DCD provided no benefit
- ESN preplant > other N sources preplant
- Split amm. sulf > preplant ESN



Thanks for your attention.

Any questions?