Improve Nitrogen Management by Considering the Source

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DEPARTMENT OF SOIL SCIENCE
University of Wisconsin-Madison

UW Extension

N management continues to be a challenge

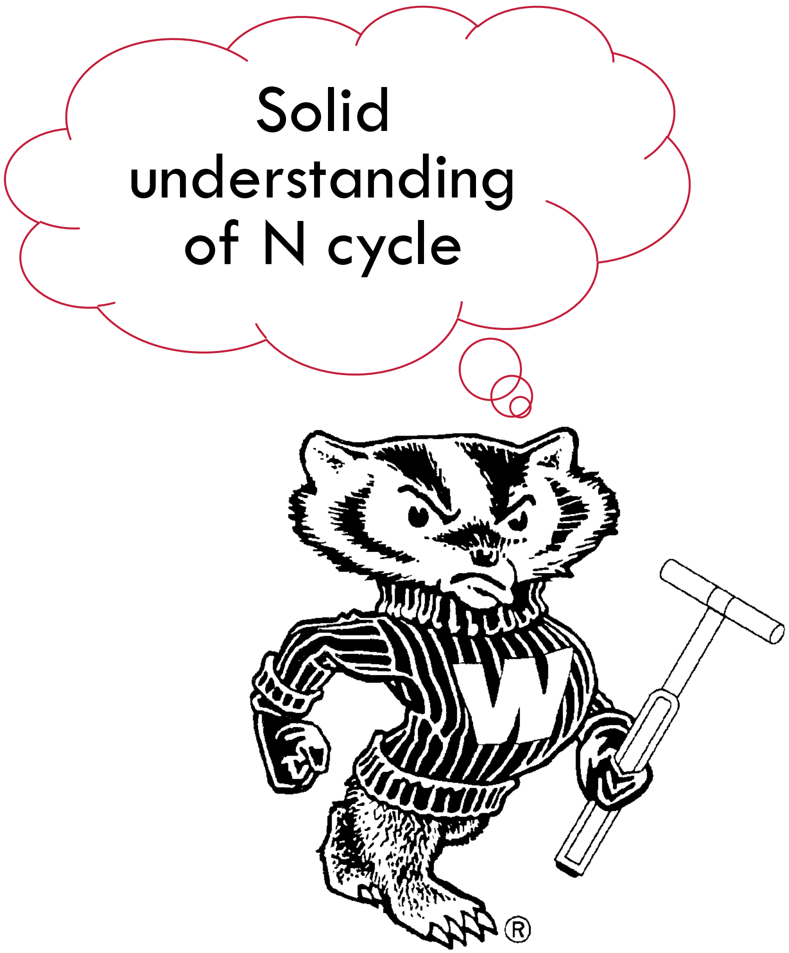
- High fertilizer prices
- Land application of manure
- Typical and unusual weather challenges
- Confusion about N fertilizer sources & technologies
- Uncertainty regarding manure and legume N credits
- Fear of economic yield loss

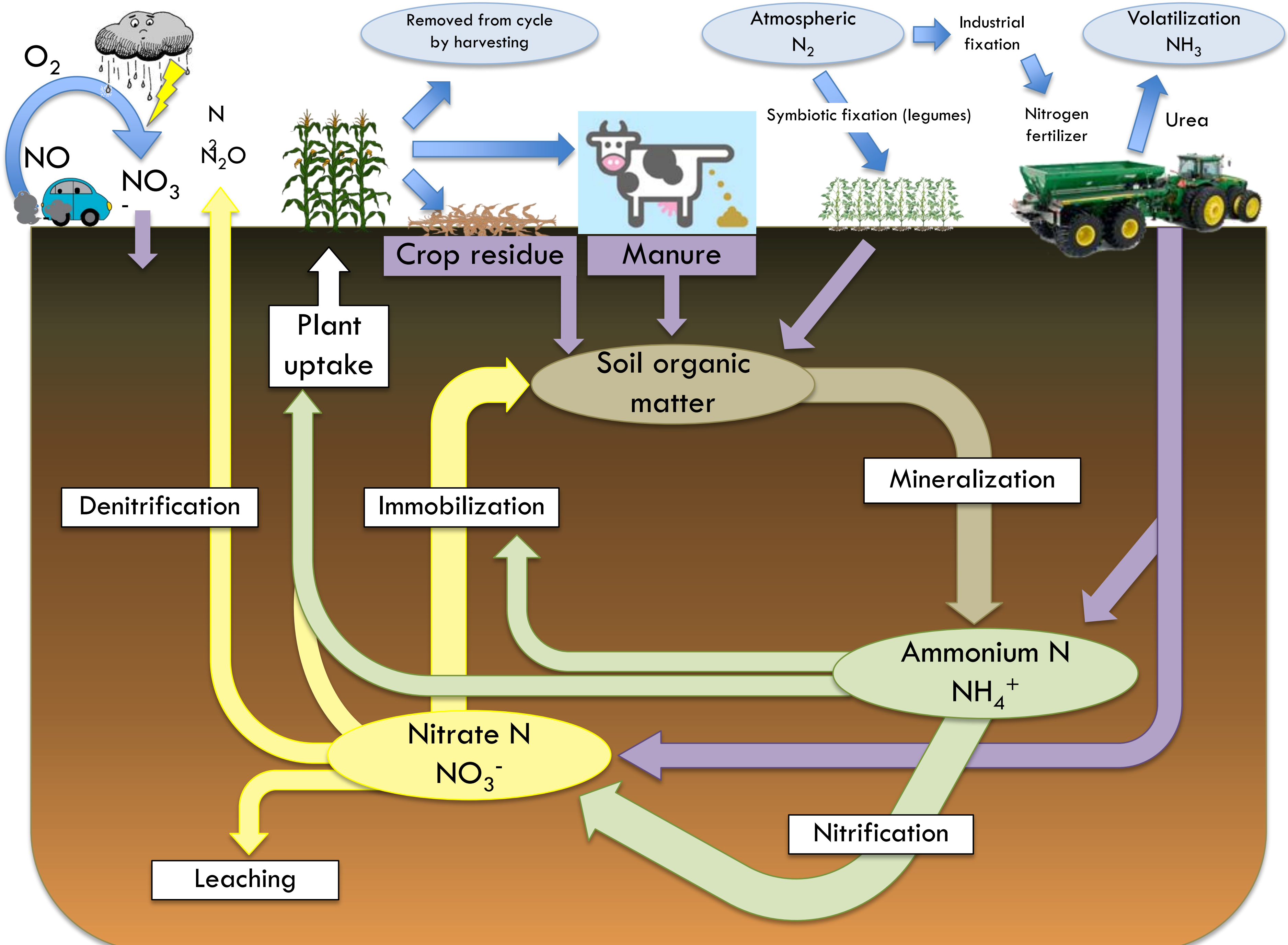
INTERNATIONAL PLANT NUTRITION INSTITUTE

4 Rs of Nutrient Stewardship

- Right nutrient Source at the
- Right Rate, at the
- Right Time and in the
- Right Place

Most important tool





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Leaching

Common Sources of Fertilizer N in the Upper Midwest

- Urea
  - must breakdown to NH_4^+ to be plant available
- Ammonium sulfate
- Ammonium nitrate
- Urea ammonium nitrate (UAN, 28%, 32%)
- Anhydrous ammonia

Organic Sources of N

- Manure
- Forage legumes
- Green manures (cover crops)
- Biosolids
- Other wastes

What you need to know about manure N availability

- All manure is not created equally
- All manure nutrients are not available
  - Total nutrient content = inorganic + organic
- Some nutrients can be lost
- Nutrient credit is dependent upon
  - Amount of manure applied among other things

Average nutrient & dry matter content of manure

Species – Storage	DM	N	P_2O_5	K_2O
	%	lb/T or lb/1000gal		
Dairy – Solid	24	10	5	9
Dairy – Liquid	6	24	9	20
Swine – Solid	20	14	10	9
Swine – Liquid indoor	7	50	42	30
Swine – Liquid outdoor	4	34	16	20
Chicken – Solid	60	40	50	30
Turkey – Solid	60	40	40	30
Poultry – Liquid	3	16	10	12

Nitrogen Availability

- Total N = NH_4-N + organic N

Available, but can be lost thru volatilization

Not available until mineralized

- Available N = NH_4-N that isn't lost

  +

  Mineralized N from organic N

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Variability in N Content of Dairy Manures

Manure type	DM	TN	NH_4	NH_4/TN	Total C: Total N
	%	lb/T or 1000 gal		%	
Farm 1					
Raw liquid	6.7	21.0	9.0	43	11.4
Digest liquid	4.7	20.0	9.8	49	7.6
Digested separated liquid	3.1	18.4	9.9	54	5.4
Digested separated stored liq.	3.3	18.4	9.9	54	5.7
Digested separated solid	32.6	10.2	0.3	3	29.9
Digested separated cured solid	32.3	14.0	1.1	8	20.5
Farm 2					
Raw liquid	4.9	16.2	8.4	52	9.7
Digested liquid	2.6	17.2	11.4	66	4.6
Digested separated liquid	7.5	24.0	12.7	53	8.3
Digested separated solid	26.2	11.4	2.8	25	19.9

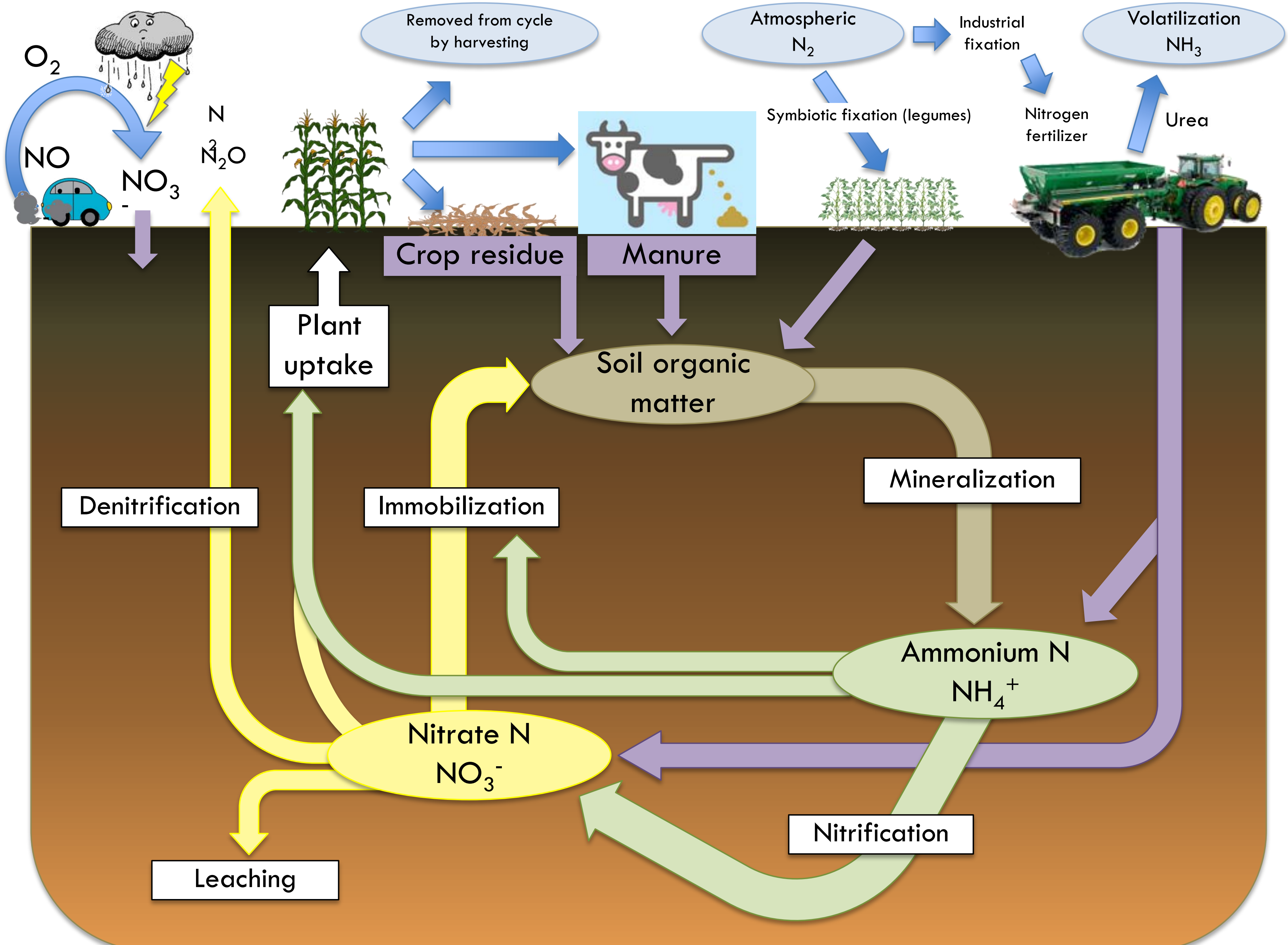
Variability in N Content of Dairy Manures

Manure type	DM	TN	NH_4	NH_4/TN	Total C: Total N
	%	lb/T or 1000 gal		%	
Farm 3					
Separated liquid	1	9.5	7.3	76	3
Separated stored liquid	2.8	26.1	7.5	29	5.2
Separated solid	16.7	5.2	0.9	18	30.3
Separated composted solid	24.7	14.0	0.6	4	14.9
Farm 4					
Compost bedded pack 0-1'	39.7	15.7	0.5	3	23.4
Compost bedded pack 0-2'	37.7	17.4	4.1	23	18.7
Compost bedded pack 0-3'	38.3	16.3	3.5	22	18
Farm 5					
Raw solid-Scrape alley	13.8	8.5	4.1	49	2.2
Raw solid-Approachment	24.3	7.8	2.4	31	7.4

Manure Nitrogen Availability Estiamtes

- Calculation/estimation varies by University
  - Experiments conducted, manure types, etc
  - Follow the guidelines for U of MN

How does organic N in manure become available?



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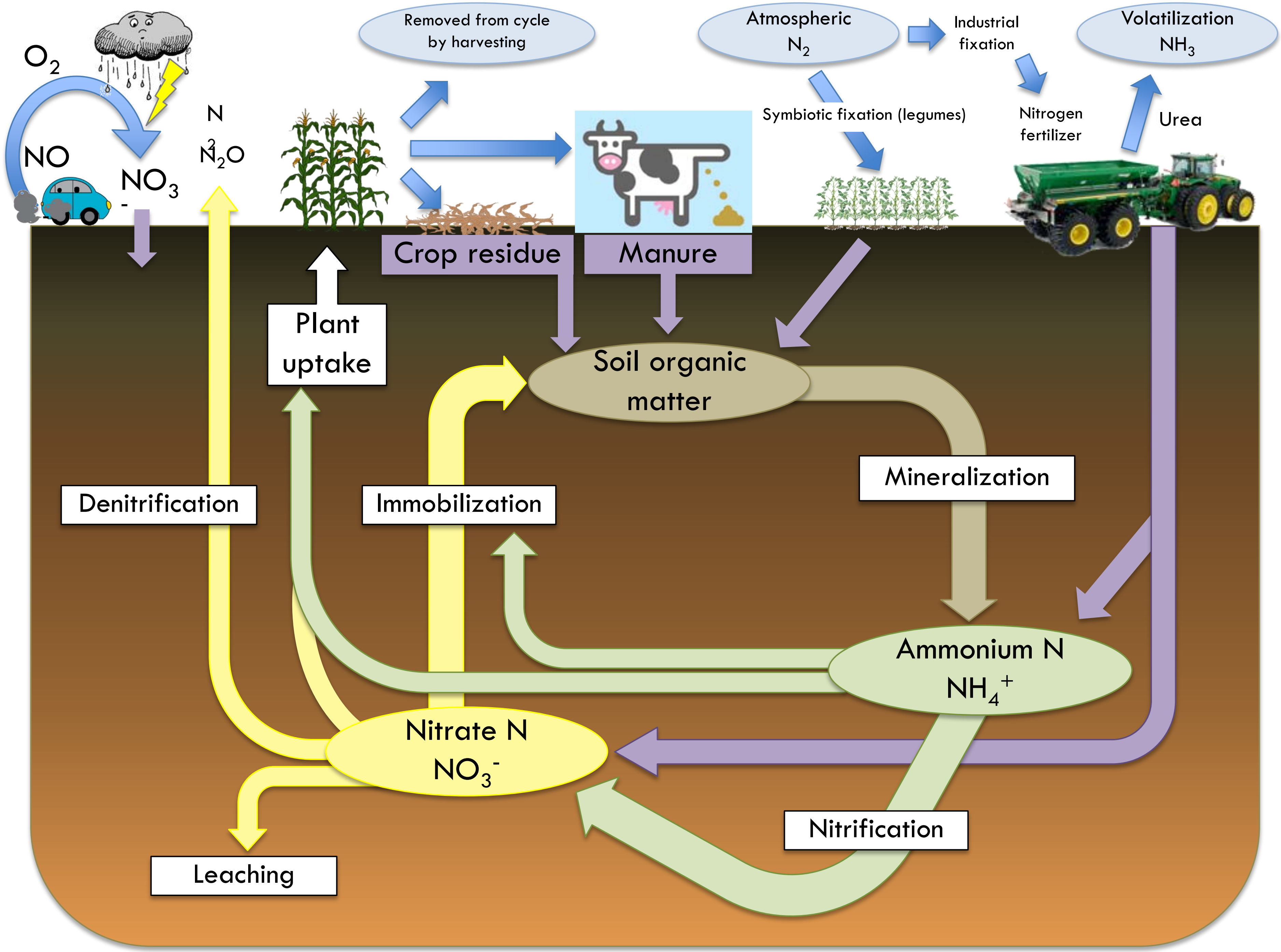
Mineralization

- Organic N ⟶ 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



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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

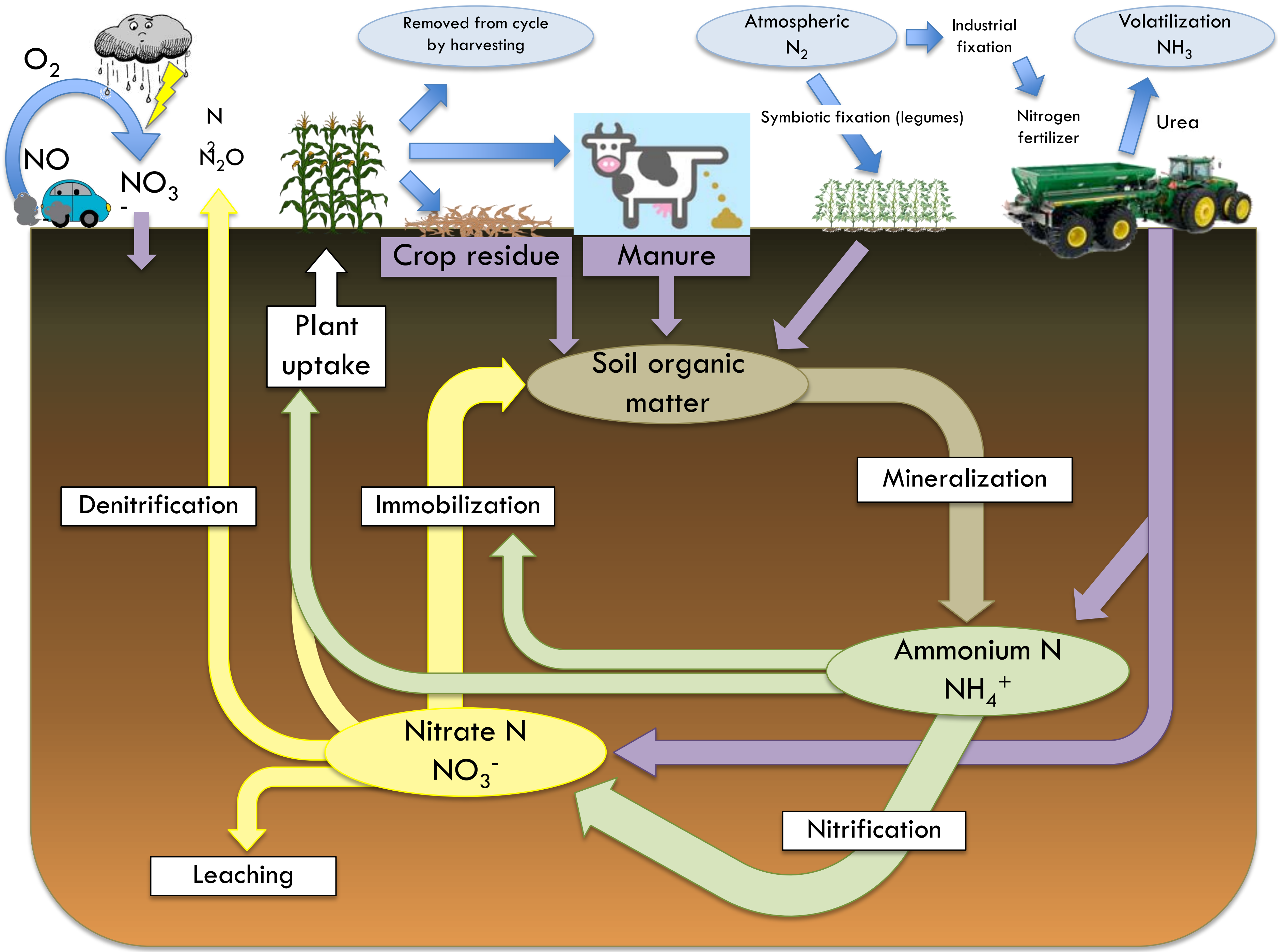
Fertilizer N forms are also governed by the N cycle

Estimates of time needed for N to convert to different forms

Process	Time
NH_4^+ to NO_3^-	1 to 2 weeks
Urea to NH_4^+	2 to 4 days
Organic N to NH_4^+	??? Generally an extended time frame

Plant Available N Forms & Loss Mechanisms

- NH_4^+
  - Held on soil's CEC
- NO_3^-
  - Subject to loss (leaching & denitrification)



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Denitrification

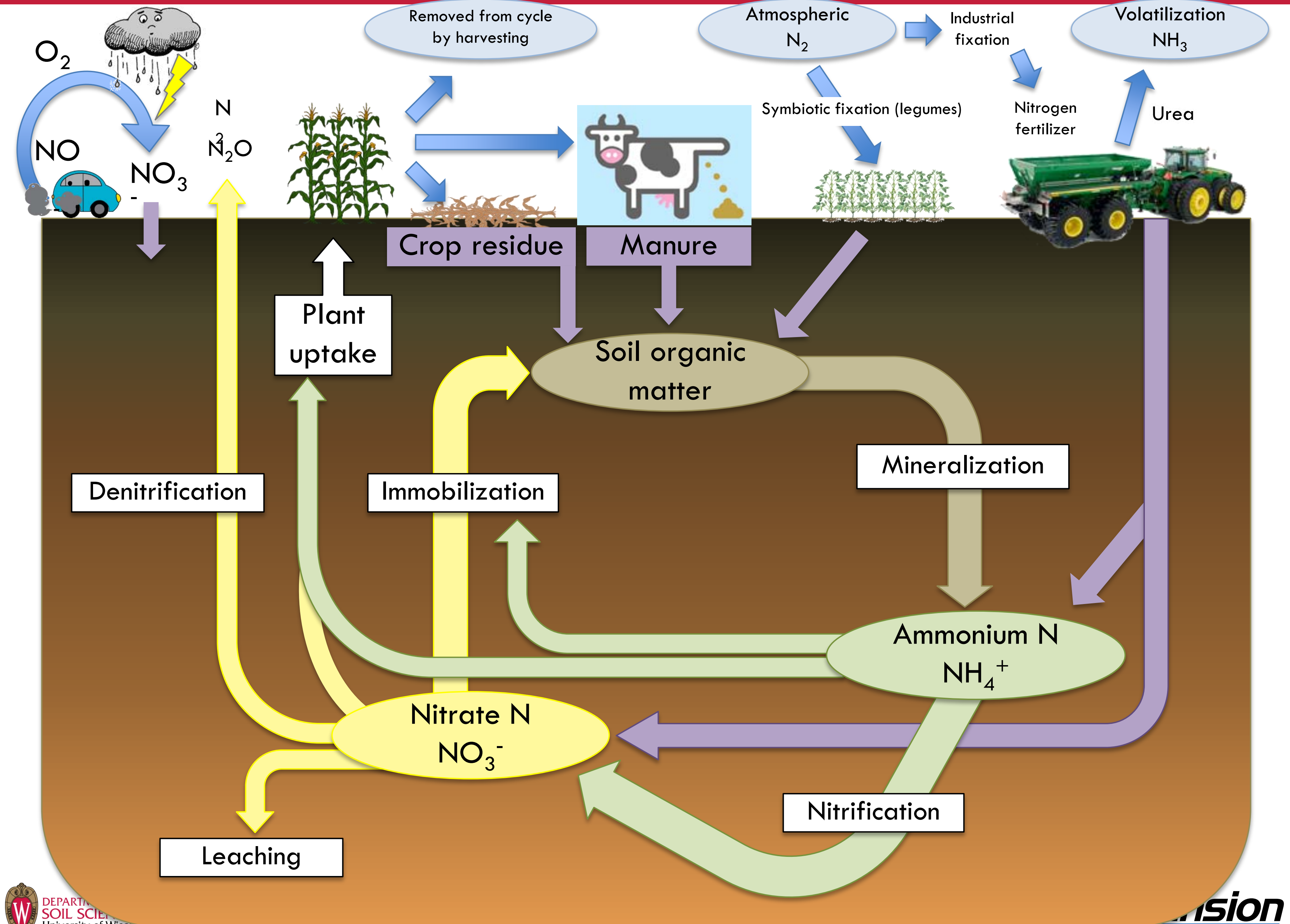
- NO_3^- → N_2 or N_2O
- Need organic matter (carbon)
- Need nitrate
- Wet soils with low O_2 content
  - Greater saturation periods results in more denitrification
- Temperature (bacteria prefer > 75°F)
- pH (bacteria prefer >5.0)

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



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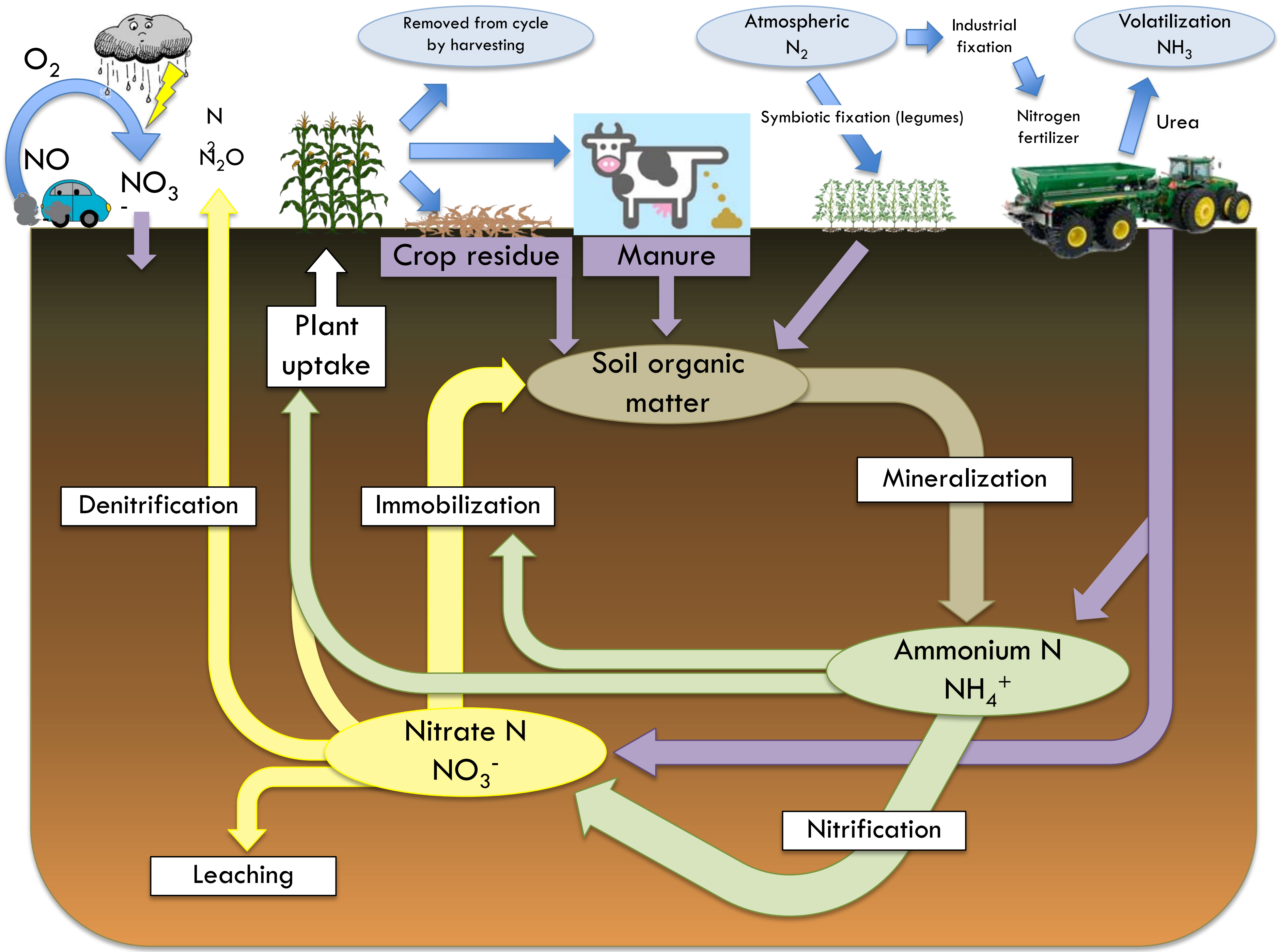
Can PSNT be useful?

- 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



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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

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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

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

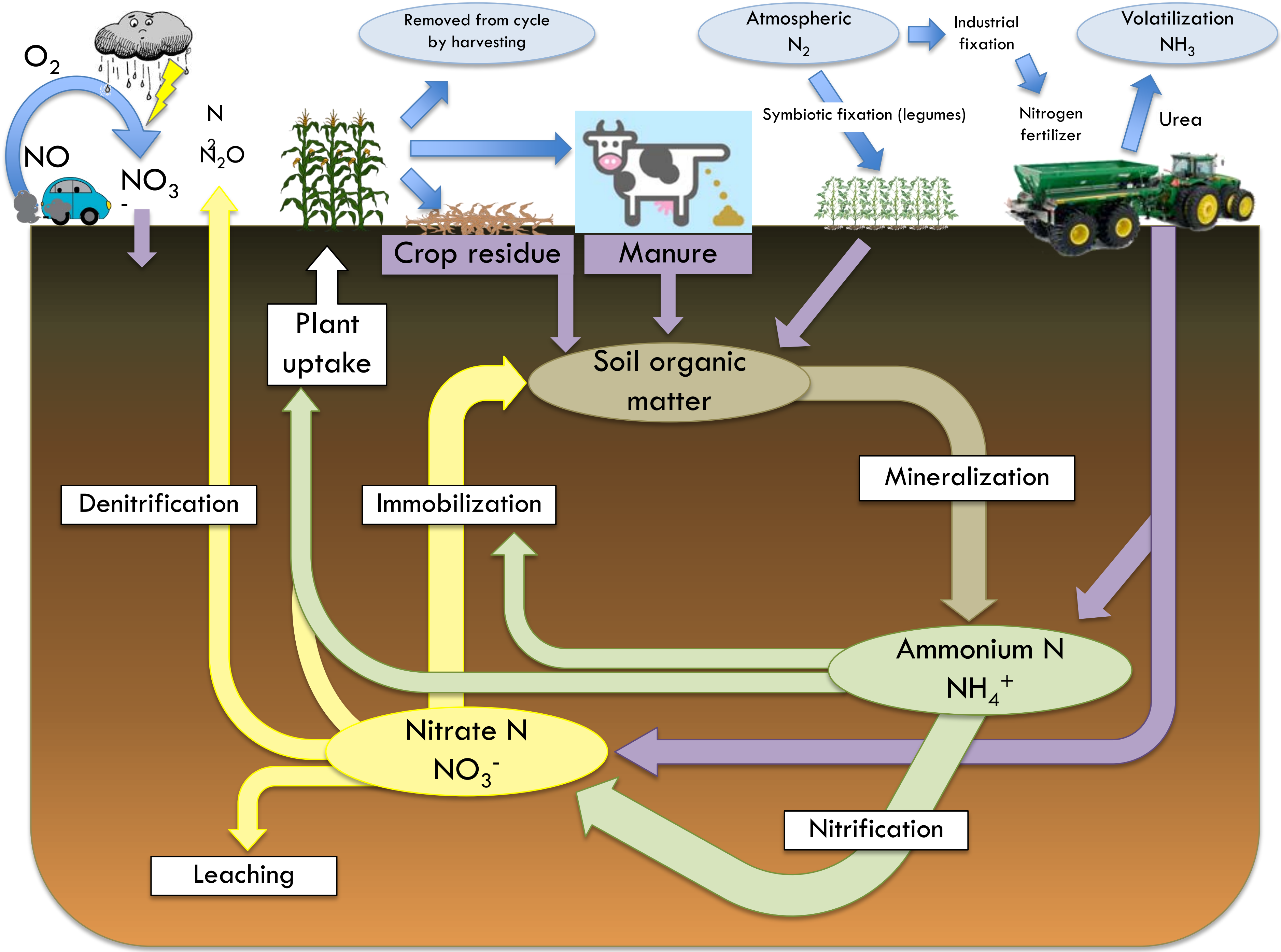
Relative probability of increasing corn yield using a nitrification inhibitor

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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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.

Effect of Instinct and time of urea (100 lb N/a) application on corn grain and silage yield at Arlington, WI, 2011

Timing	Instinct		Instinct	
	No	Yes	No	Yes
	Grain Yield, bu/a		Silage Yield, T DM/a	
Fall 2010	139	160	7.23	7.84
Spring 2011	149	161	7.57	8.65
Mean	144	161	7.40	8.25
ANOVA				
Source of variation	*p*	LSD (0.10)	*p*	LSD (0.10)
Timing (T)	0.53	ns	0.24	ns
Instinct (I)	0.09	16	0.10	0.84
TxI	0.65	ns	0.62	ns

Effect of Instinct and time of manure application on corn grain and silage yield at Arlington, WI, 2011

Timing	Instinct		Instinct	
	No	Yes	No	Yes
	Grain Yield, bu/a		Silage Yield, T DM/a	
Fall 2010	135	141	7.25	7.54
Spring 2011	135	156	7.15	8.40
Mean	135	149	7.20	7.97
		ANOVA		
Source of variation	*p*	LSD (0.10)	*p*	LSD (0.10)
Timing (T)	0.36	ns	0.33	ns
Instinct (I)	0.11	ns	0.07	0.67
TxI	0.33	ns	0.23	ns

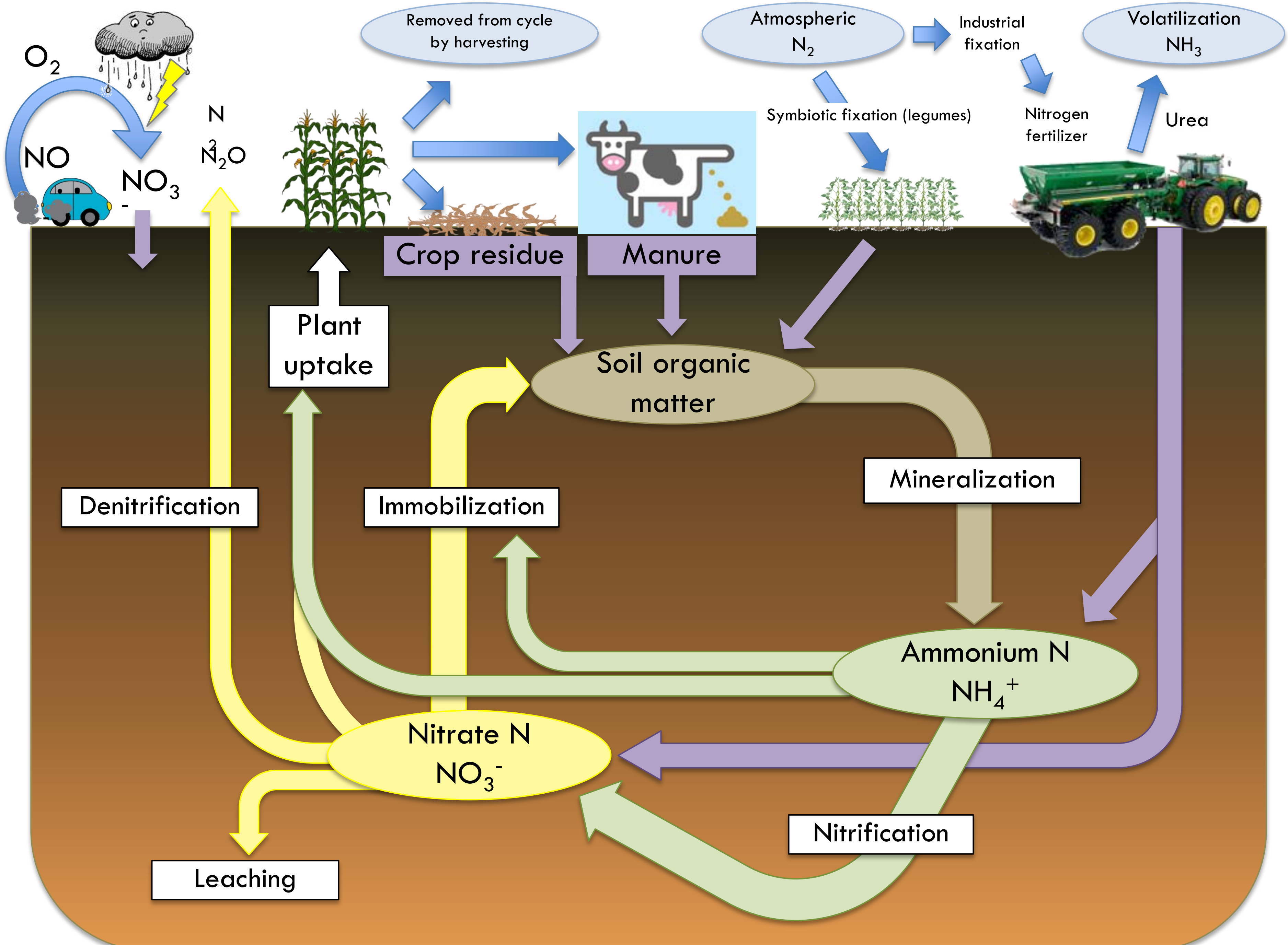
Relative probability of increasing corn yield using a nitrification inhibitor

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



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Urea hydrolysis and N volatilization

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

urea → ammonium carbonate

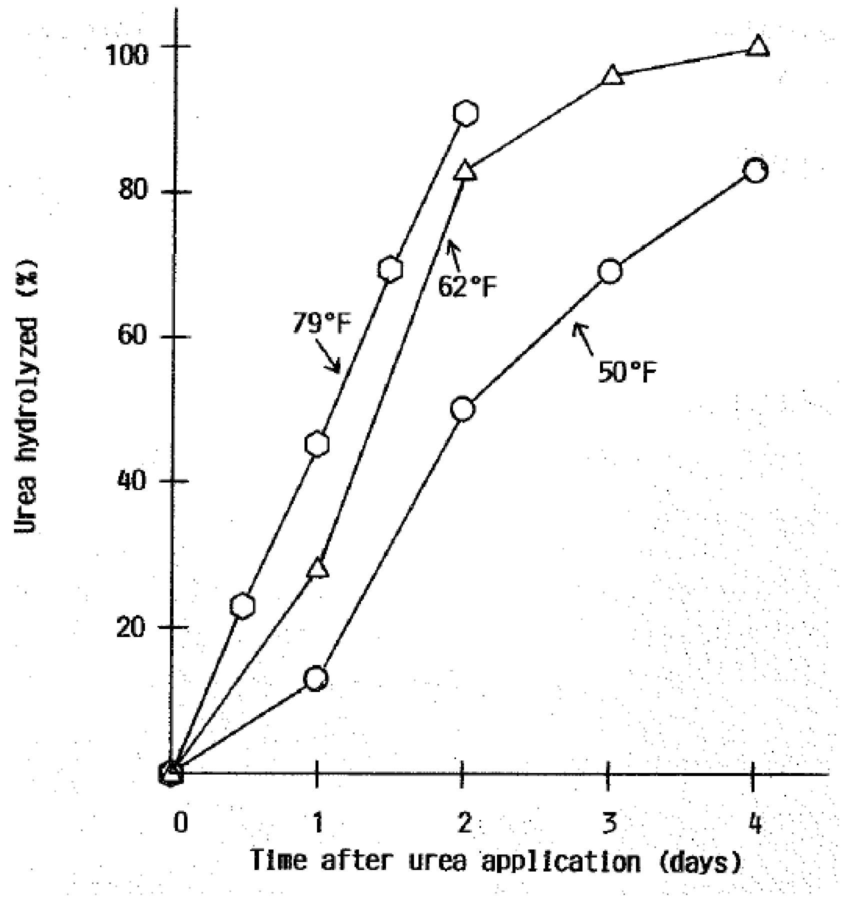
$$(NH_4)_2CO_3 + 2H^+ \longrightarrow 2NH_4^+ + CO_2\uparrow + H_2O$$

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

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.

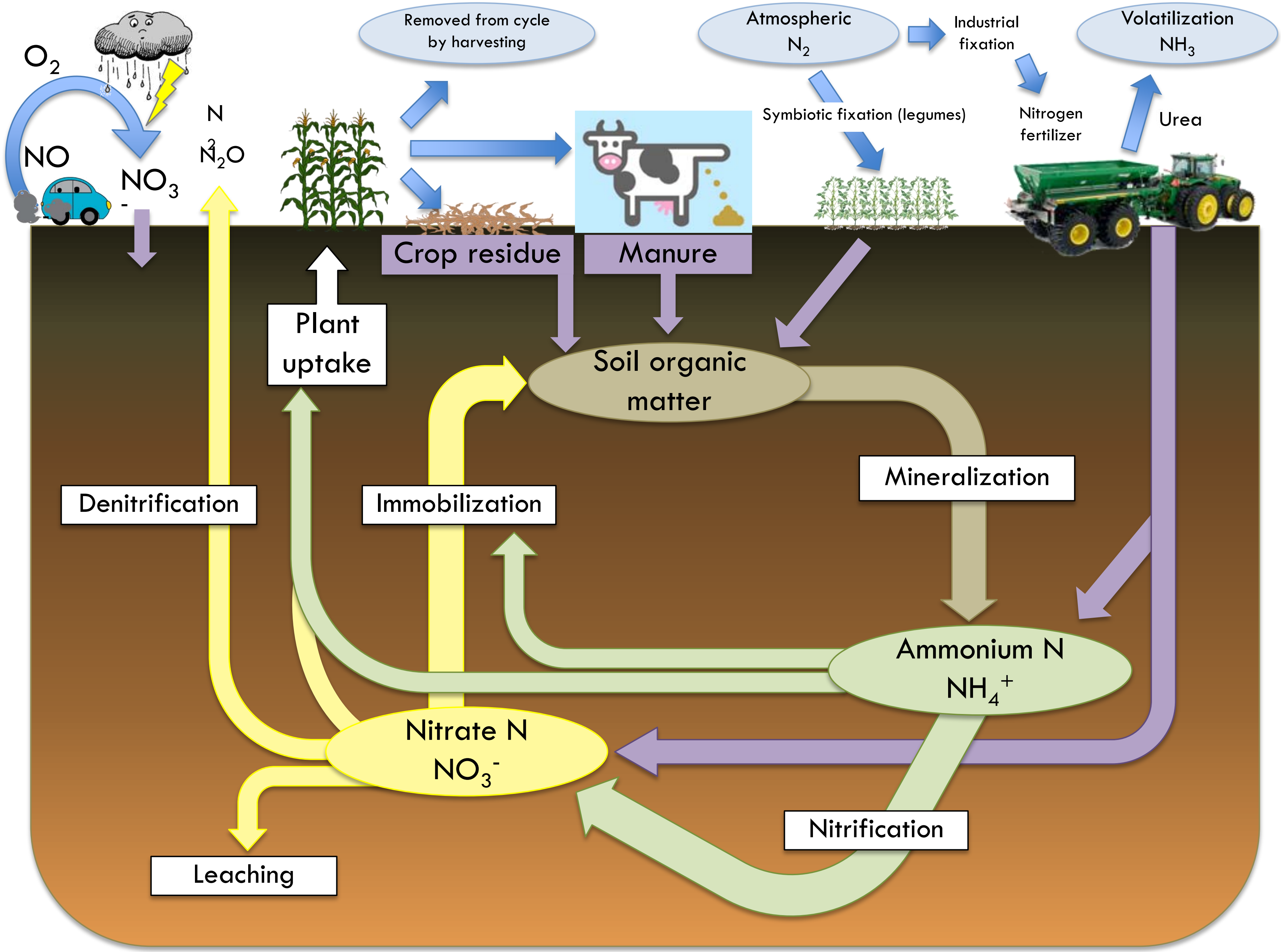
From Oberle and Bundy, 1984.

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?

Sandy soils

- Biggest concern – NO_3^- leaching



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Managing to reduce leaching

- Time of application
- Fertilizer materials
- Use of inhibitors

Effect of timing and use 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

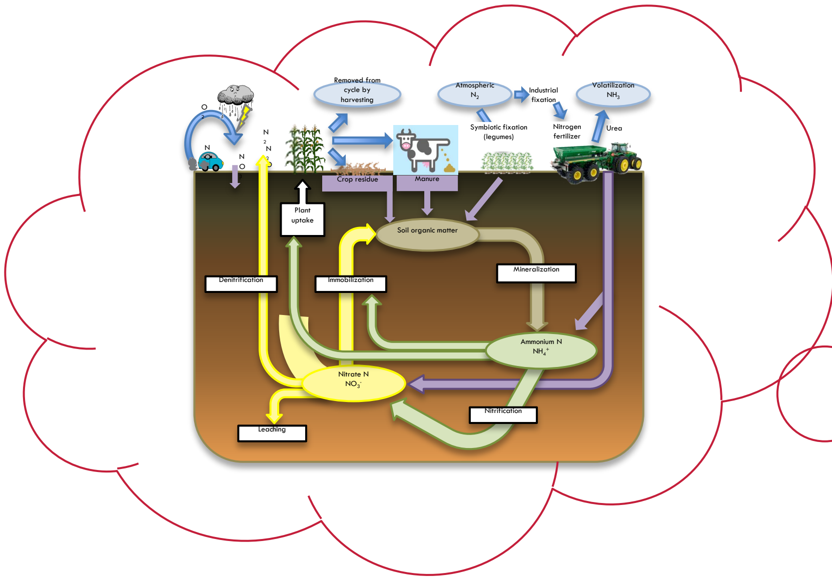
N Source	N Timing	Year 2003	2004	2005
		Yield, bu/a		
Control	--	107	115	96
PCU (ESN)	PP	204NS	167 c	186 ab
	PP+4 wk	205	180 b	189 a
Amm. Sulf.	PP	196	132 e	175 b
	PP+DCD	202	136 e	183 ab
	4 wk & 8 wk	194	181 b	180 ab

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



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