Exercises 4, 5, 7, and 9

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MONTANA STATE UNIVERSITY EXTENSION

Questions

- How many of you are certified crop advisers?
- How many of you have made manure management recommendations?

Goals Today

- Focus on nitrogen and phosphorus cycling and differences in their plant-availability
- Introduce fertilization concepts of sufficiency vs. build/maintenance
- Show how to use Fertilizer Guidelines and soil lab results to estimate fertilizer and/or manure needs for a variety of crops.
- Have you determine fertilizer rates given soil test data
- Leave time for questions (I'll be asking some too)

Nutrient Reactions and Cycling

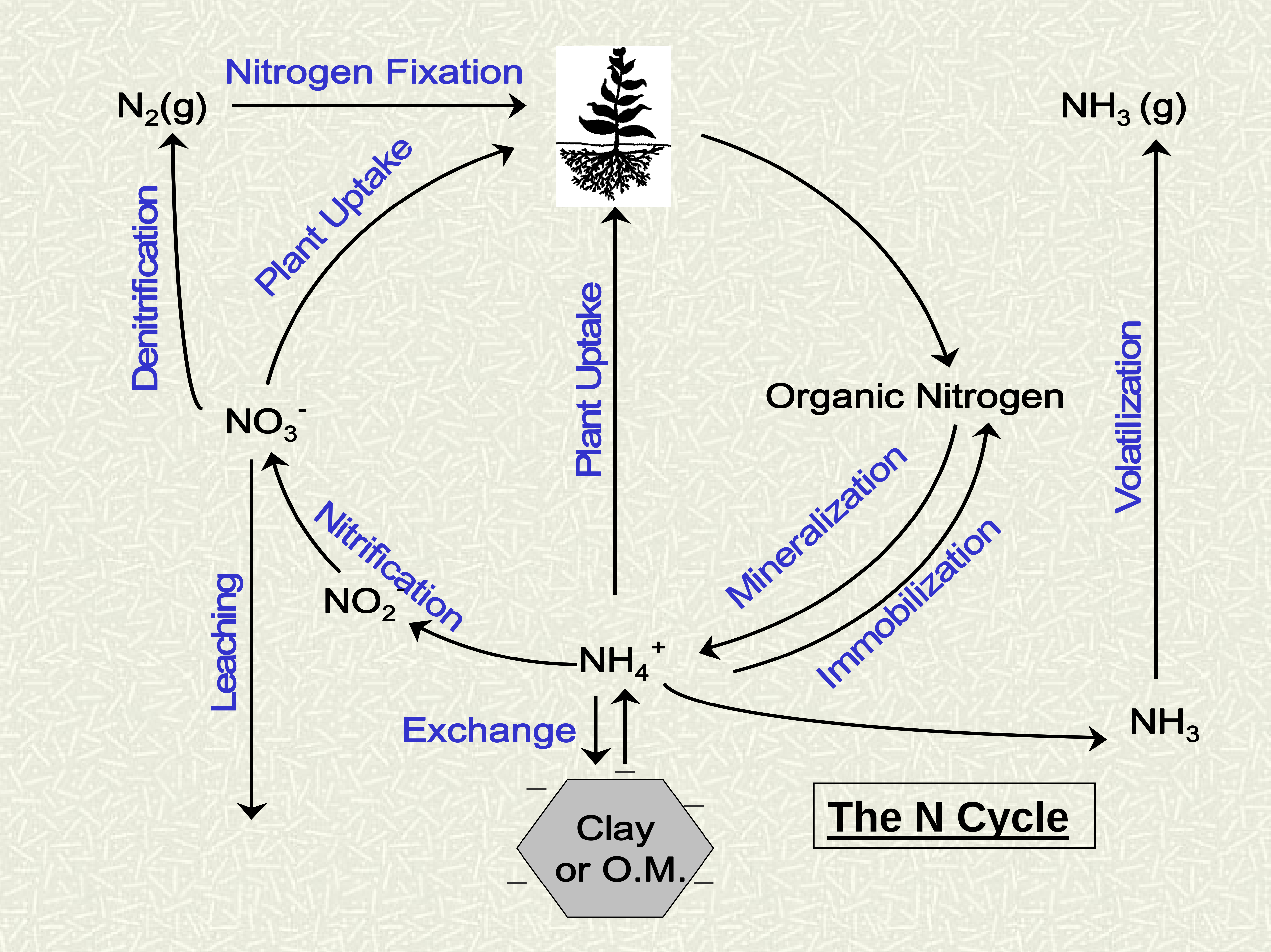
- Will focus on N and P because

  1) These have best chance of limiting yield and quality

  2) Rates of both are stipulated in Nutrient Management Plans, whereas most other nutrients are not. Why?

Exercise 4:
Nitrogen (N) Cycling

Nitrogen form	Molecular formula	Notes
Nitrogen gas	N_2 (g)	Represents about 80% of the air we breathe but not available to plants
Ammonia gas	NH_3 (g)	Volatilizes from animal manures; toxic at high concentrations
Ammonium	NH_4^+	Plant available, attracted to exchange sites on clay particles
Nitrate	NO_3^-	Plant available, very mobile, requires more energy by plant than NH_4^+
Nitrite	NO_2^-	Mobile, generally low concentrations, toxic to young mammals
Organic N	-	Generally highest pool of N in manure-slowly produces available N



Nitrogen Fixation
N2(g)
NH3 (g)
Plant Uptake
Denitrification
Plant Uptake
Organic Nitrogen
Volatilization
NO3-
Mineralization
Immobilization
Nitrification
Leaching
NO2-
NH4+
Exchange
NH3
Clay
or O.M.
The N Cycle

Mineralization

Release of mineral N as organic matter (O.M.) is oxidized, releasing available N

Organic-N → Plant-Available N

Increased by:

- Higher moisture, temperature, and O.M.

MSU Fertilizer Guidelines assume 2% O.M.

Soil O.M.	N fertilizer rate
> 3%	- 20 lb N/ac
< 1%	+ 20 lb N/ac

Immobilization

Incorporation of available N into microbial cells or plant tissue

Plant-Available N → Organic-N

Occurs more with high C:N stubbles (ex: small grains) and less with low C:N stubbles (ex: legumes)

If leave more than ½ ton grain stubble, increase N by 10 lb/ac per ½ ton stubble.

How many work with producers applying manure to small grains?

N Fixation

- Nitrogen gas → Plant-available N
- Performed by *Rhizobia* on legumes, such as alfalfa
- Increased with
  - -Good inoculation
  - -Moderate moisture
  - -Low soil N
  - -High soil P and K

N credits from legumes

Previous crop	N credit (lb N/ac)
Alfalfa, sweet clover	40
Chickpeas, lentils, peas	0-20

Ammonia Volatilization

- $NH_4^+ \rightarrow NH_3$(gas)

- Volatilization of ammonia from manure depends on:
  - Type of animal
  - Storage (stacked, lagoon, time, etc.)
  - Environmental Conditions (next slide)

Rick will cover how to account for this loss in manure calculations.

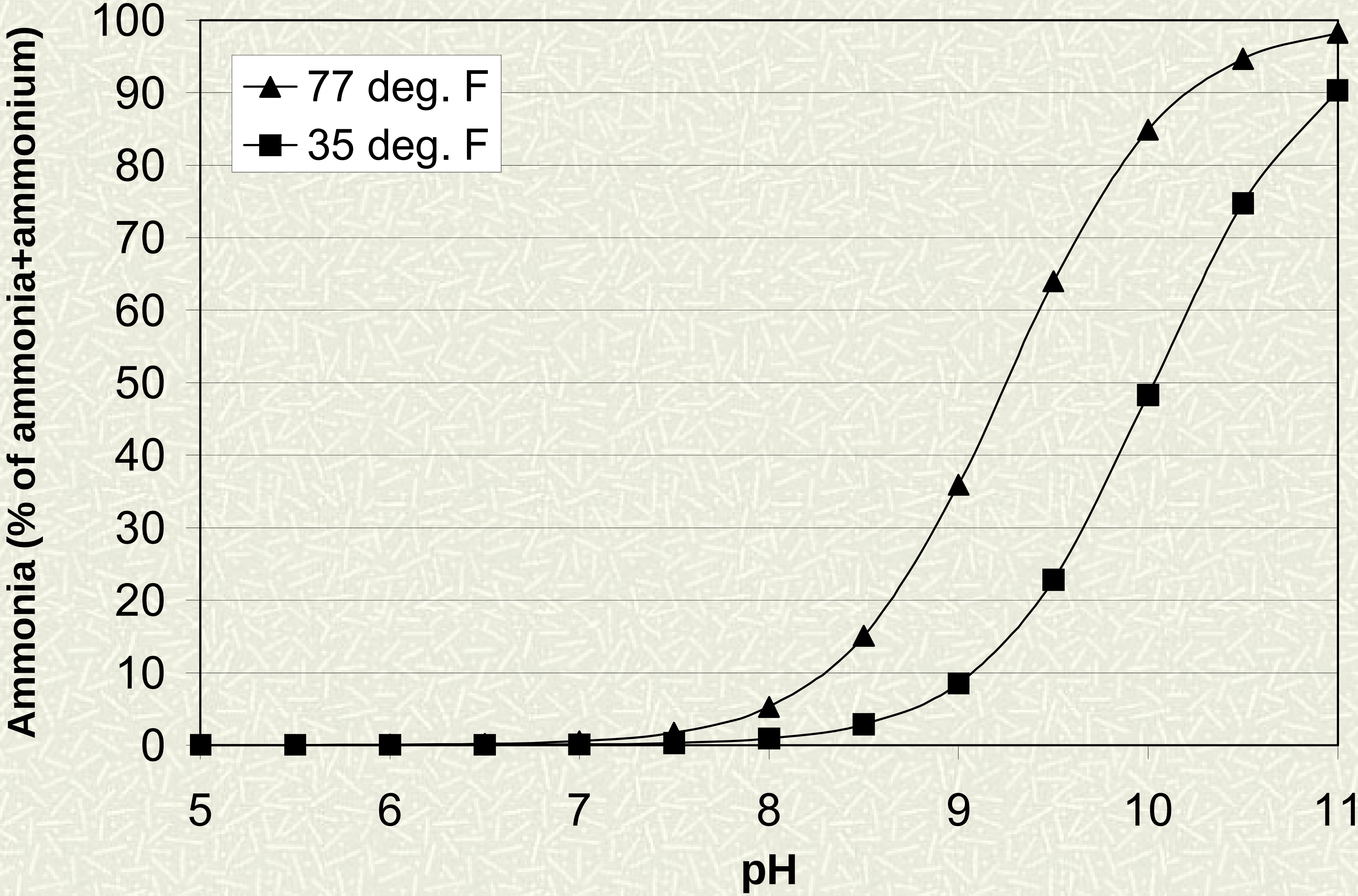
IF want more information on ammonia volatilization from UREA, see Management of Urea Fertilizer to Minimize Volatilization (http://landresources.montana.edu/soilfertility) under Ammonia Volatilization

Factors Affecting Volatilization

1. **Soil pH and Temperature**
2. **Wind**
3. **Cation Exchange Capacity (CEC). WHY?**
4. **Buffering capacity (resistance to pH change)**
5. **Soil moisture/humidity**
6. **Broadcast vs Incorporated**
7. **Ground cover/vegetation/residue. WHY?**
8. **Soluble and Exchangeable Calcium**

Bottom line: Large number of factors make volatilization amounts VARIABLE and difficult to predict.

Soil pH and Temperature Effects on Relative Amount of Ammonia in Soil Solution



Nitrification

- $NH_4^+ \rightarrow NO_3^-$
- Relatively fast (generally less than 2 weeks if greater than 50 deg. F)
- Only occurs under aerobic conditions
- Why important?

Denitrification

- $NO_3^- \rightarrow N_2O \rightarrow N_2$(gas)

Occurs only under anaerobic conditions, though can occur in unsaturated surface soils, especially when manure is present. Why?

Phew! Enough chemistry!

QUESTIONS?

If you want more information on N cycling, go to MSU Extension’s publication on the topic at:

http://landresources.montana.edu/nm

Exercise 5:
Nitrogen Rates and Recommendations

Need to know:

- Yield potential (Rick has covered)
- Soil nitrate-N in top 2 feet
- Previous crop, esp. if a legume

Soil N (lb/ac) = 2 x NO_3-N (ppm) x # of 6 in. depth increments

Depth (in.)	NO_3-N (ppm)
0-6	10
6-24	4

Soil N (lb/ac) = 2 x 10 x 1 +
2 x 4 x 3

= 20 + 24

= 44 lb N/ac

Manure or Fertilizer available N = Needed available N – Soil N – N credit +/- N to account for O.M. if different than 2%

- Needed available N levels from MSU Guidelines (EB 161) for commercial fertilizers can be adjusted based on region, and knowledge of specific field.
- Can N rates for manure be adjusted if part of a CAFO's CNMP?

How much N should be applied to grass?

Fertilizer Guidelines for Montana Crops (EB 161):

GRASS	
Yield Potential (t/a) *	Available N (lbs/a) **
1	25
2	50
3	75
4	100
5	125

Need to divide total N need by fraction of available N in manure and/or fertilizer to find total fertilizer need

http://www.montana.edu/wwwpb/pubs/eb161.html

- Rick will show how to determine how much manure N is plant-available.

<u>Your turn</u> to calculate N need

Crop: Orchard Grass, Irrigated
Yield potential = 3 t/ac
O.M.= 3.1%

Soil N data:

Depth (in.)	NO_3-N (ppm)
0-6	6
6-24	2

Soil N (lb/ac) =

N need (lb/ac) =

QUESTIONS?

What are available N needs for alfalfa-grass stands?

Fertilizer Guidelines for Montana Crops (EB 161)

ALFALFA/GRASS				
Yield Potential (t/a)*	80/20	60/40	40/60	20/80
	———N fertilizer (lbs/a)———			
1	5	10	15	20
2	10	20	30	40
3	15	30	45	60
4	20	40	60	80
5	25	50	75	100
6	30	60	90	120

Dilemma or problem with using alfalfa for manure application?

What if want to apply more manure, to the point of essentially stopping N fixation?

- Use N uptake figures in Table 21:

- Ex: 100% alfalfa, 4 ton/ac:
- N uptake = (48 lb N/ton)(4 ton/ac)

  = 192 lb N/ac

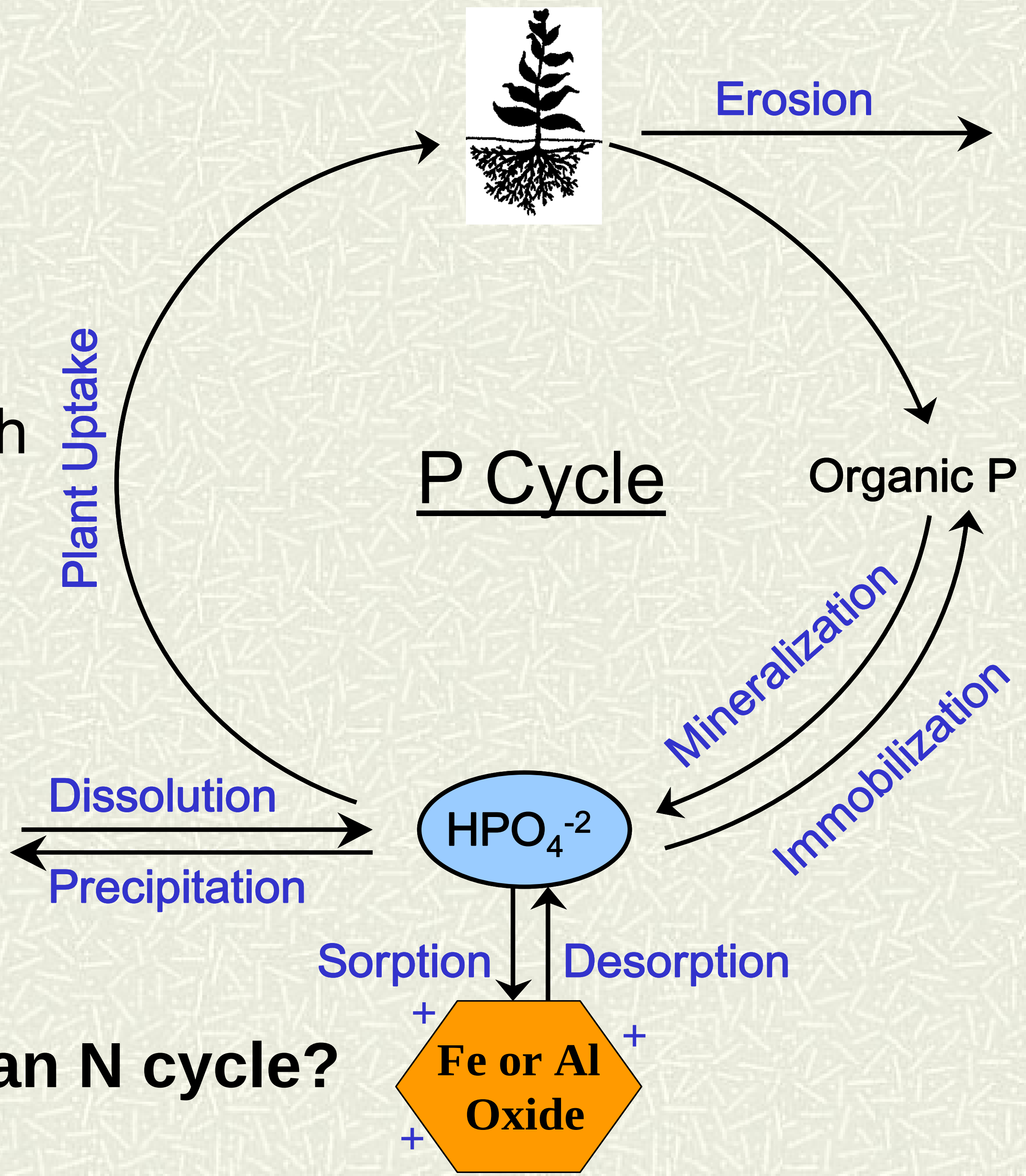
If manure application is ‘Phosphorus-based’, what else might you need to add to maximize crop growth?

Your turn again

- Crop: Feed barley
- Yield potential: 80 bu/ac
- Previous crop: alfalfa (depleted stand)
- O.M. = 1%
- Soil N = 24 lb N/ac
- N needed from manure?

Exercise 7: Phosphorus Cycling

Movement of P
is largely through
erosion/runoff,
NOT leaching.
Why?



Why simpler than N cycle?

Precipitation/Dissolution

- Precipitation: The binding of two dissolved ions (ex: HPO_4^{2-} and Ca^{2+}) to form a solid mineral (ex: monocalcium phosphate)
- Dissolution: The opposite of precipitation

What factors affect the amount of P precipitation?

Sorption/Desorption

- Sorption: The binding of an ion (HPO_4^{2-}) to a soil surface.
- Desorption: The reverse of sorption

What factors increase the amount of P sorption?

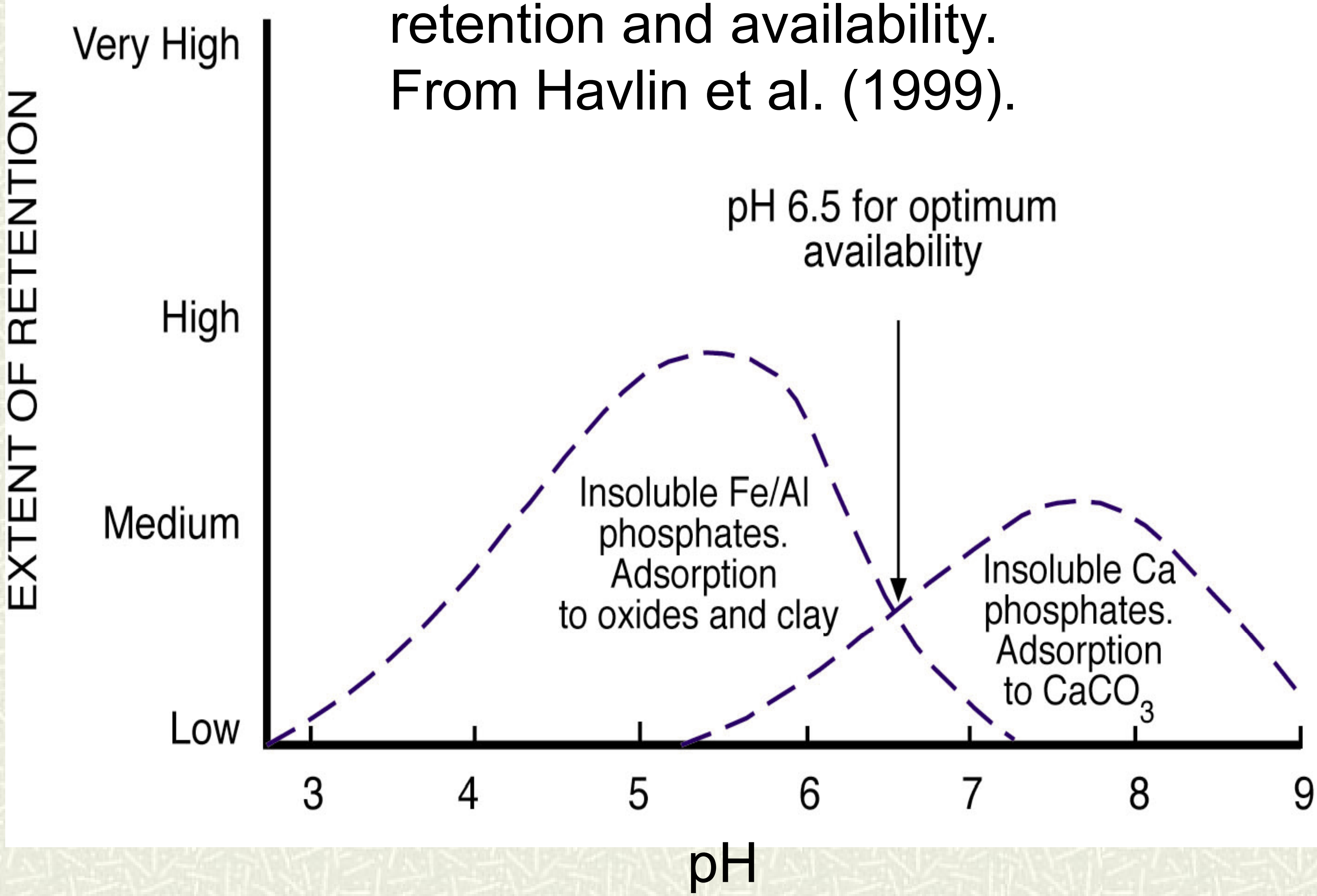
Soluble P concentrations in soil are generally very low (0.01 – 1 mg/L) due to:

1. Precipitation and low solubility of calcium phosphate minerals. This is very relevant in our region due to high pH, calcareous soils.

2. Strong sorption to aluminum, and iron oxides and hydroxides (example: rust). This process increases at low pH so is less of an issue here.

At what pH levels would you likely need to fertilize with more P?

The effect of soil pH on P retention and availability. From Havlin et al. (1999).



Banding Phosphorus

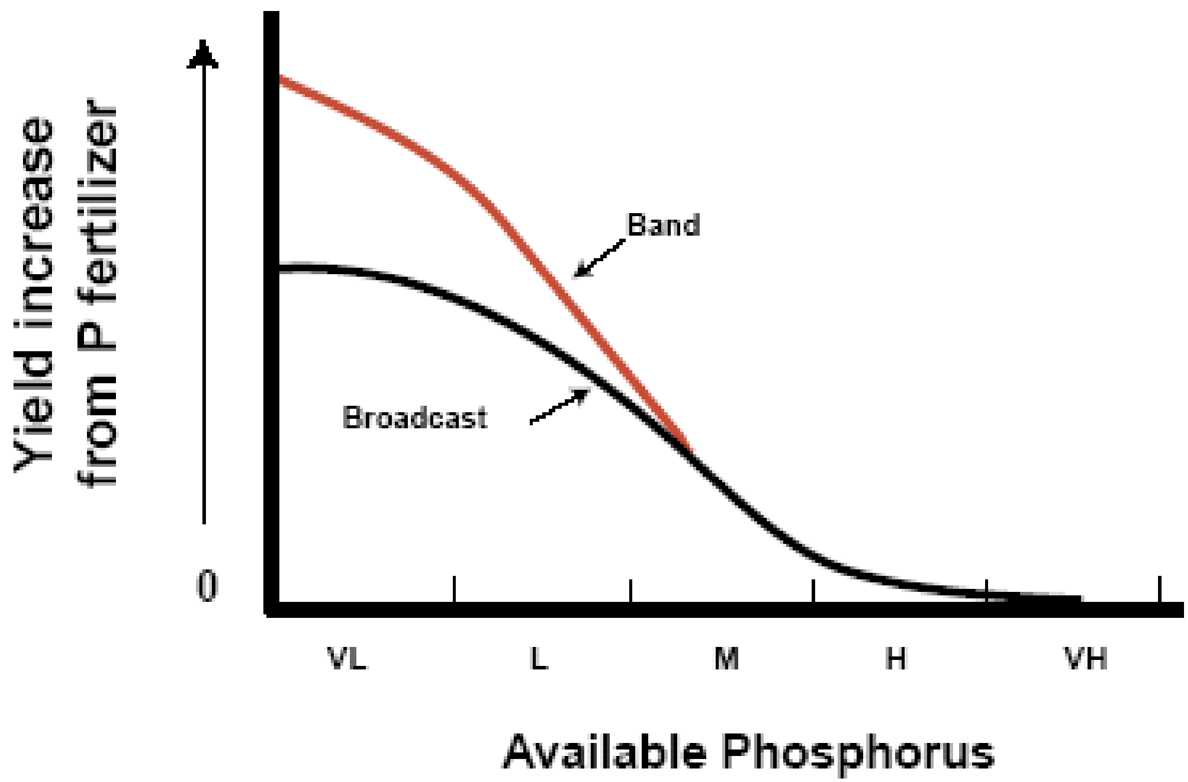


Figure 7. The advantages of P banding are greatest when STP levels are very low (VL) to low (L). From Randall and Hoeft (1988).

Banding P is much more effective than banding N, because P is much more immobile in the soil.

Relevance to manure application?

If you want more information on P cycling, go to Nutrient Management Module 4 at:

http://landresources.montana.edu/nm

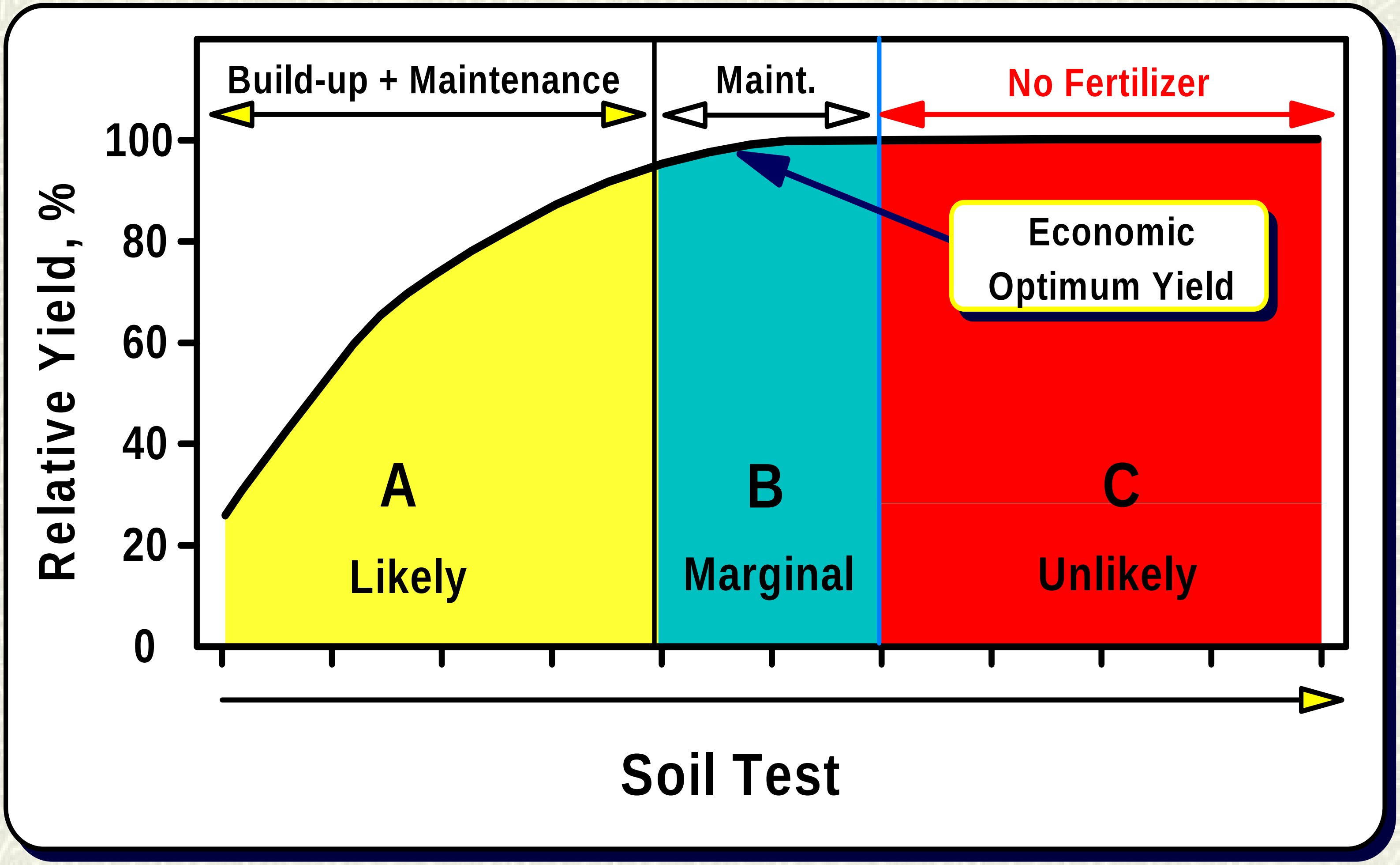
Questions so far?

Exercise 9: P recommendations

Why is the necessary sampling depth for N higher than for P in the MSU Fertilizer Guidelines?

- N fertilizer can easily move to 2 feet (and beyond) and the lower depths often have the majority of N.
- P fertilizer generally stays in upper ½ foot and P levels are often very low below there.

Generalized Crop Yield Response Curve



'Sufficiency' approach (MSU): Minimum needed, on average, to maximize yield in that year.

Why does yield potential affect N fertilizer guidelines, but not P guidelines?

- N is very soluble, so the amount of soil nitrate-N + available N added will have a direct effect on yield.
- P is very insoluble- It's been found if the P soil test is greater than the 'critical level' (16 ppm), yield is not greatly increased by fertilizing more, regardless of yield potential.

If Olsen P = 16 ppm, and your client wants to really push yield goals, would you recommend more P than guidelines? Could you recommend more manure P based on DEQ requirements?

What table should I use?

SUFFICIENCY APPROACH (MSU)

- If Olsen P ≤ 16 ppm, use Table 18.
- If Olsen P > 16 ppm, use Table 21-crop removal amounts.

BUILD/MAINTENANCE APPROACH

- Add Table 18 values to Table 21 removals.
- Question: Is this approach allowed by DEQ for manure?

Phosphorus

Table 18. Phosphorus fertilizer guidelines based on soil analysis.

Crop	Olsen P Soil Test Level (ppm)				
	0	4	8	12	16*
	P Fertilizer Rate (lbs P_2O_5/a)				
Alfalfa	140	110	75	40	0
Alfalfa-Grass	55	50	40	25	10
Barley-Feed/Malt	50	40	30	20	10
Bean	30	25	20	15	5
Buckwheat	45	35	30	20	10
Canola	45	40	35	30	25
Corn-Grain	100	80	60	40	20
Corn-Silage	80	65	50	35	25
Flax	35	30	20	15	10
Grass	45	35	30	20	5
Lentil, Chickpea and Pea	35	30	25	20	15
Millet	40	35	25	20	5
Oat	45	35	30	25	20
Potato	170	145	115	75	20
Safflower	50	40	30	20	10
Soybean	60	50	40	25	5
Sugarbeet	85	70	55	40	10
Sunflower	35	30	25	20	15
Wheat-Spring	50	45	35	30	20
Wheat-Winter	55	50	45	40	35

Phosphorus

Crop	Olsen P Soil Test Level (ppm)				
	0	4	8	12	16*
	P Fertilizer Rate (lbs P_2O_5/a)				
Wheat-Spring	50	45	35	30	20
Wheat-Winter	55	50	45	40	35

Example

Winter wheat

Olsen P = 10 ppm

P_2O_5 needed = **42.5 lb/ac**

Your turn

- Soil test P = 65 ppm
- P index indicates P applied should not exceed crop removal
- Crop: Alfalfa/Grass (50/50), 4 t/ac yield
- Available P_2O_5 to add=?

Use Table 21:
P removed =

If you would rather use a web based calculator, Montana fertilizer guidelines are at:

http://www.sarc.montana.edu/calculators

Conclusions

- Nitrogen is much more soluble and mobile than phosphorus.
- Nitrogen levels are largely dependent on breakdown of organic matter.
- Phosphorus levels are low in Montana due to insoluble calcium-P minerals.
- Nutrient needs can be determined if know soil test levels of N and P, yield potential, and previous crop.
- Nutrient management with manure is not as straightforward as with commercial fertilizers.

Want more information on soil fertility?

Go to:

http://landresources.montana.edu/soilfertility