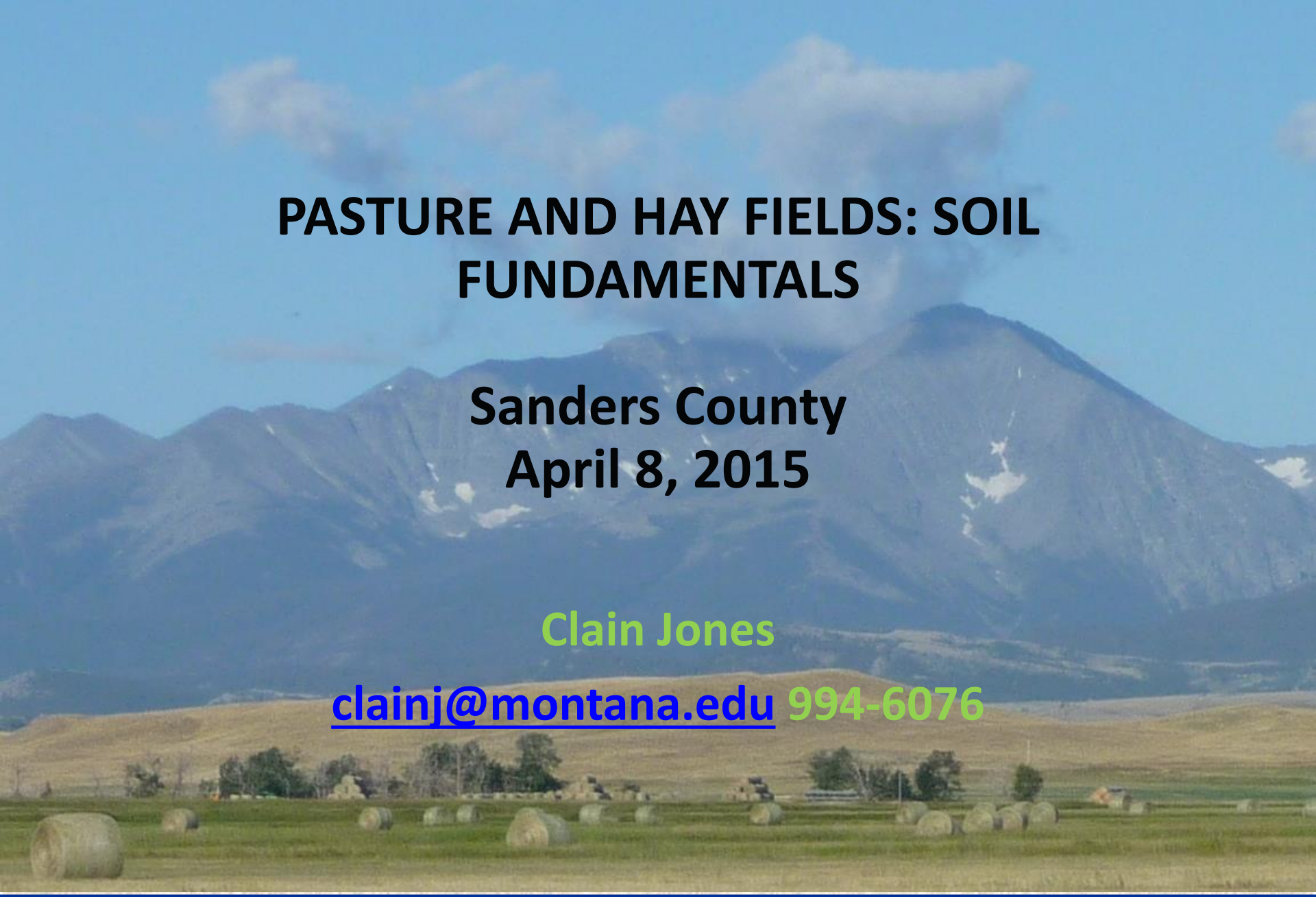

PASTURE AND HAY FIELDS: SOIL FUNDAMENTALS

Sanders County
April 8, 2015

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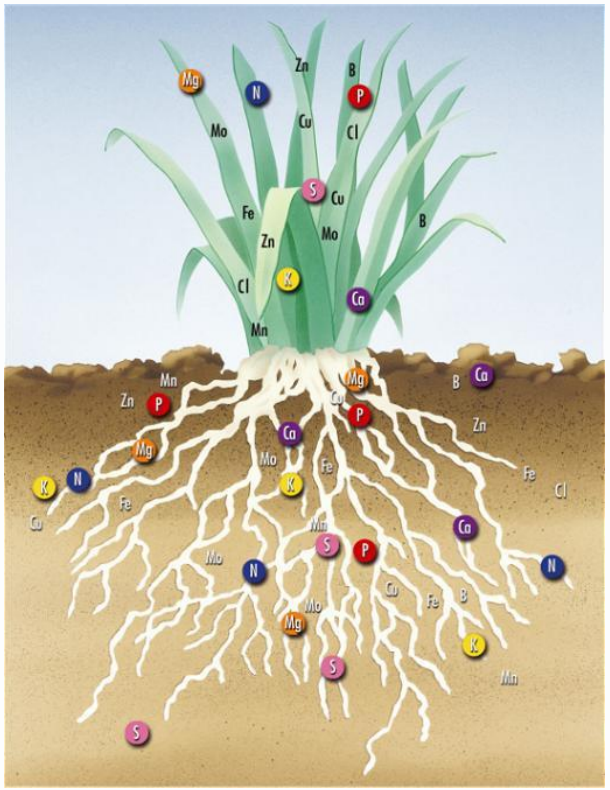
Objectives

- Present soil properties and how they interact with plant nutrients
- Illustrate the soil nutrient cycles of N, P, K, S and some micronutrients
- Understand plant available forms of nutrients and their relation to nutrient cycles
- Learn to plan and implement soil sampling
- Unravel the mysteries of soil test reports

An essential nutrient:

- Is required by plants to complete life cycle (seed to new seed)
- Cannot be replaced by another element
- Is directly involved in plant's growth and reproduction
- Is needed by MOST plants



There are 14 mineral nutrients that have been found to be essential for growth of most plants:

Macronutrients	Micronutrients
Nitrogen (N)	**Boron (B)**
Phosphorus (P)	**Chloride (Cl)**
Potassium (K)	**Copper (Cu)**
Sulfur (S)	**Iron (Fe)**
Calcium (Ca)	**Manganese (Mn)**
Magnesium (Mg)	Molybdenum (Mo)
	Nickel (Ni)
	Zinc (Zn)

The macronutrients are simply needed in larger amounts by the plant than the micronutrients.

Nutrient deficiencies of the bolded nutrients have been observed in Montana

Plant nutrient uptake

- For plants to take up nutrients they need to be:
  - in the right form (soluble or weakly bound)
  - in soil solution

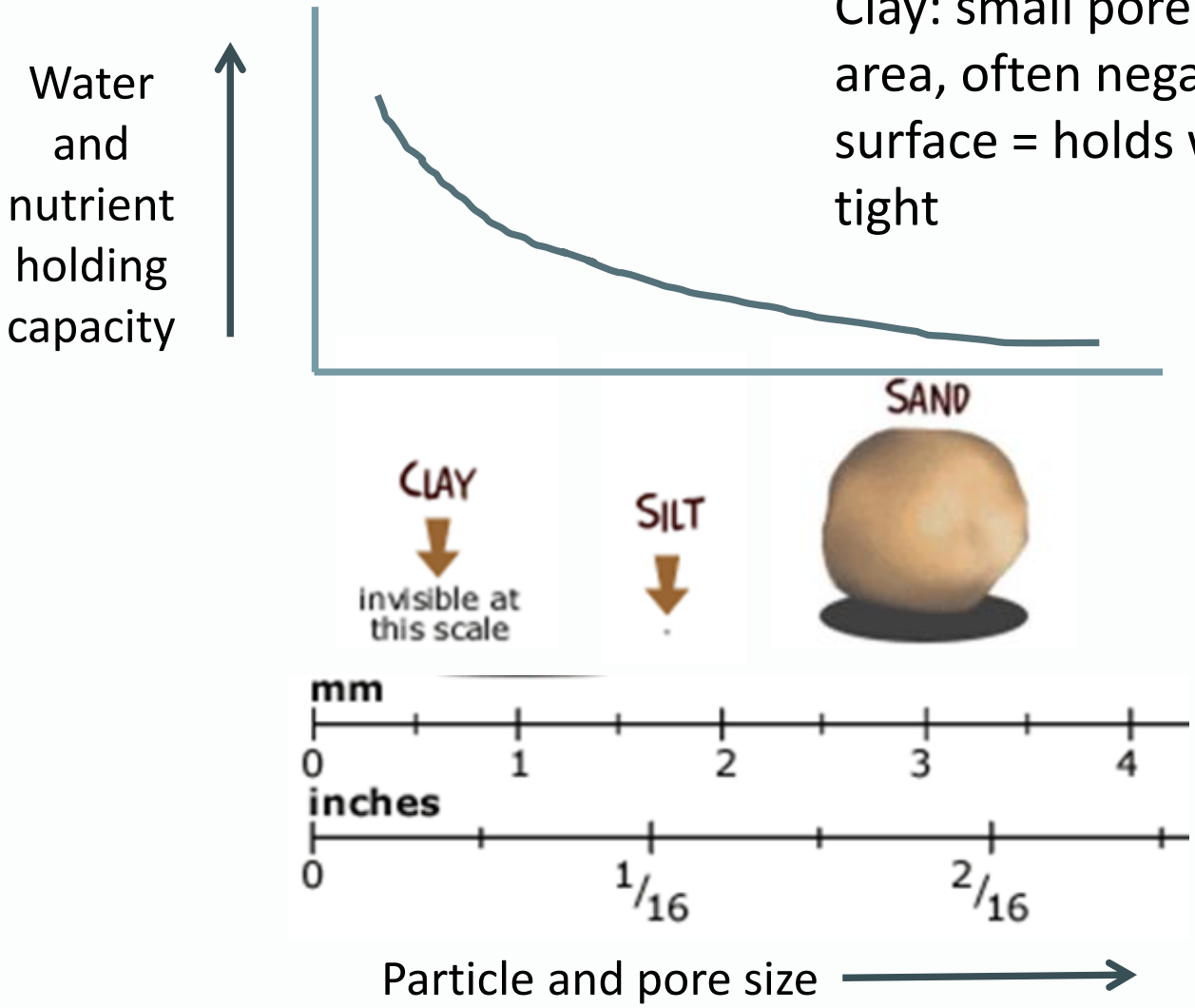
Some soil properties that influence nutrient availability

- Texture/surface area
- CEC (cation exchange capacity) and AEC (anion exchange capacity)
- pH
- SOM (soil organic matter)

Soil texture

Sand: large pore space, low surface area = low water or nutrient holding capacity

Clay: small pore space, large surface area, often negative charge on surface = holds water and nutrients tight



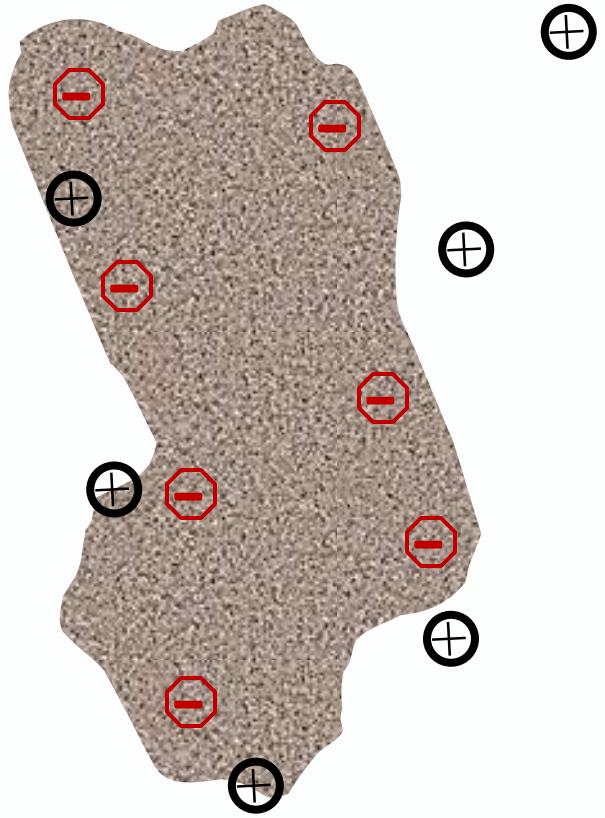
CEC and AEC

- Cation Exchange Capacity (CEC) - Total negative charge on a soil
- A measure of the soil's ability to hold onto and supply positive ions (e.g. NH_4^+) to a crop.
- Anion Exchange Capacity (AEC) – Total positive charge to hold onto nutrient anions such as SO_4^{-2}
- Generally weak bonds that release as concentration of nutrient in solution drops
- AEC is generally smaller than CEC.

Are soils better able to hold onto + or – charged nutrients?

Cation Exchange Capacity

- Many essential plant nutrients carry positive charges. Example: Potassium (K^{+}) and Zinc (Zn^{+2})
- A fertile soil has the capacity to attract and hold these nutrients.
- Soils with large surface areas, such as clay and O.M., have more CEC and surface area and therefore are generally more fertile.



CEC ranges for different soil types

Soil texture	CEC range (meq/100 g soil)
Sand	2-4
Sandy loam	2-17
Loam	8-16
Silt loam	9-26
Clay	5-58

From Brady 1984

A CEC >15 meq/100 g soil has high capacity to hold cations such as K^+, NH_4^+

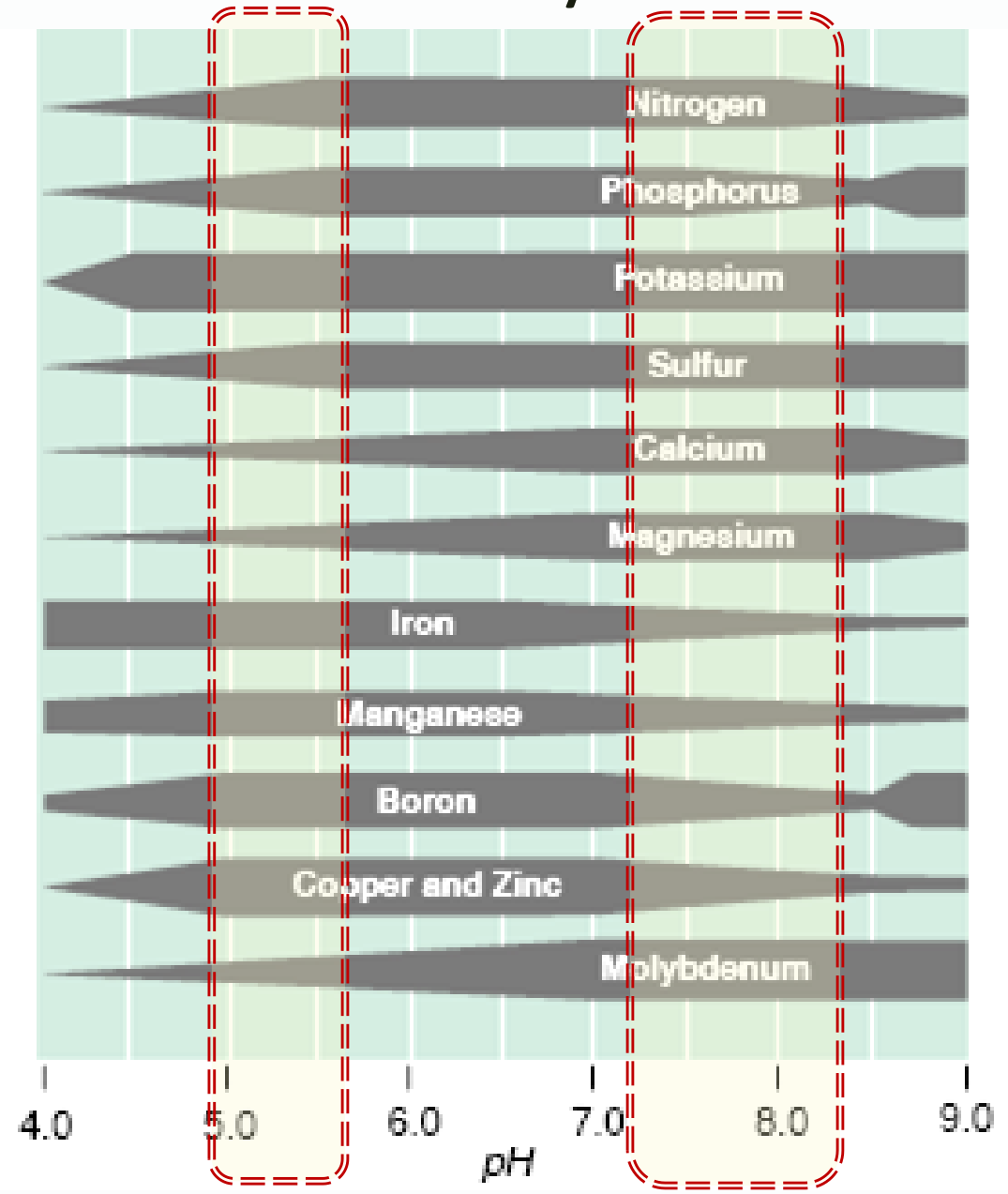
pH

- Generally low to neutral in western MT soils. If lower than 6 and growing alfalfa, then consider liming
- Can decrease pH with elemental sulfur, but likely not economical
- Fertilizing with ammonia-based fertilizer can lower pH over time
- Crops have different optimum pH ranges, e.g. alfalfa 6.2-7.5, barley 5.5-7.0, sugarbeet 6.5-8.0

pH affects soil nutrient availability

Low pH, acidic soils – may limit N, Ca, Mg, Mo because they don't stick tight and can leach away (Fe) or form minerals (P)

High pH, alkaline calcareous soils – may limit P, Fe, Mn, B, Cu, Zn because they stick tight to the soil, plant can't get them



SOM = Soil organic matter

- Is <6% of soil by weight but controls >90% of the function
- High surface area and CEC (215 meq/100 g vs. 58 for clay)

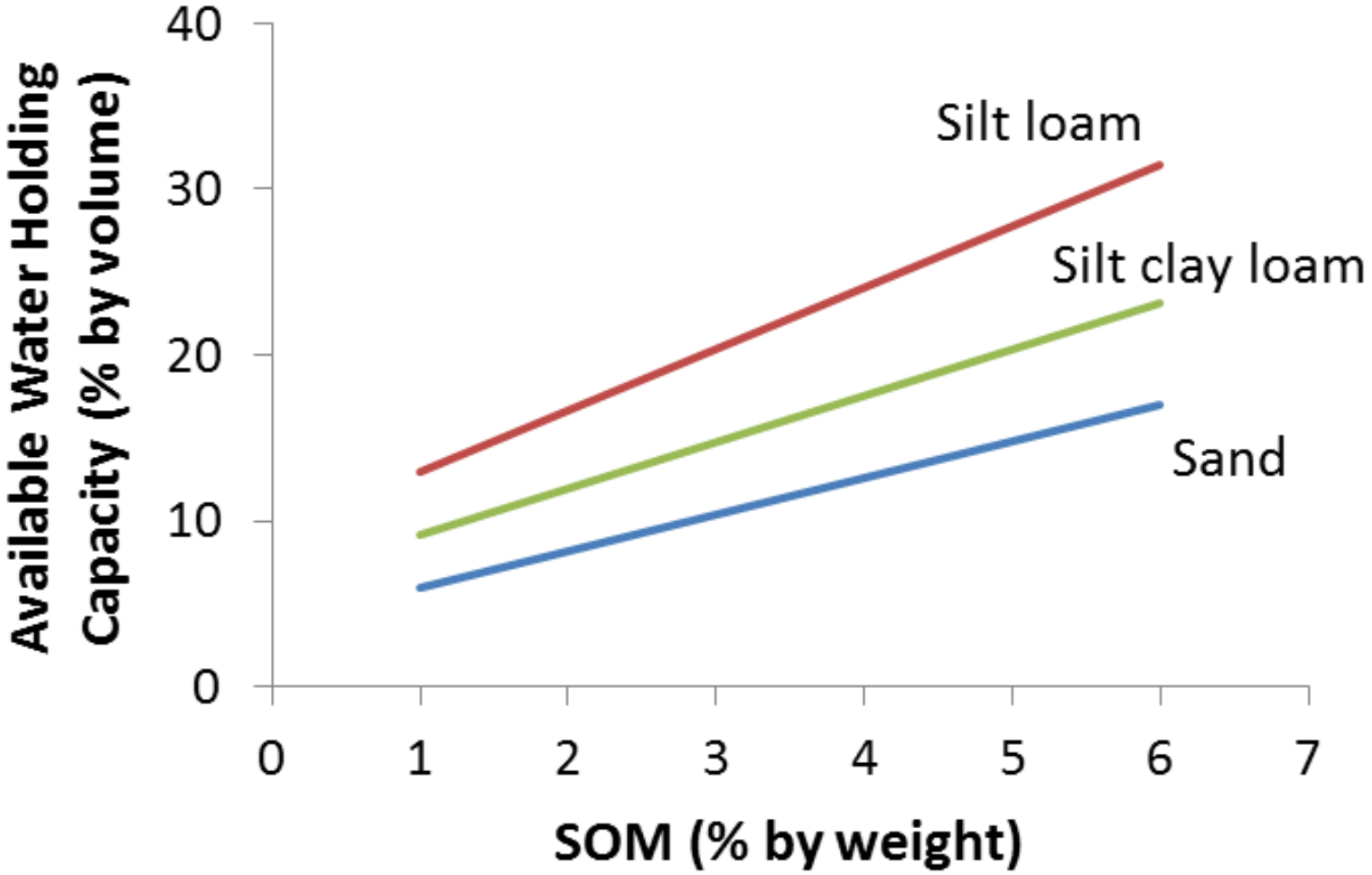
What does SOM do for soil?

- Increase CEC
- Can't change CEC of mineral soil or soil pH very well, but can increase SOM to influence soil CEC

What else does SOM do for soil?

- As decomposes it releases nutrients bound in OM structure
- Holds water which helps nutrients move from soil to plant roots

SOM increases available water holding capacity



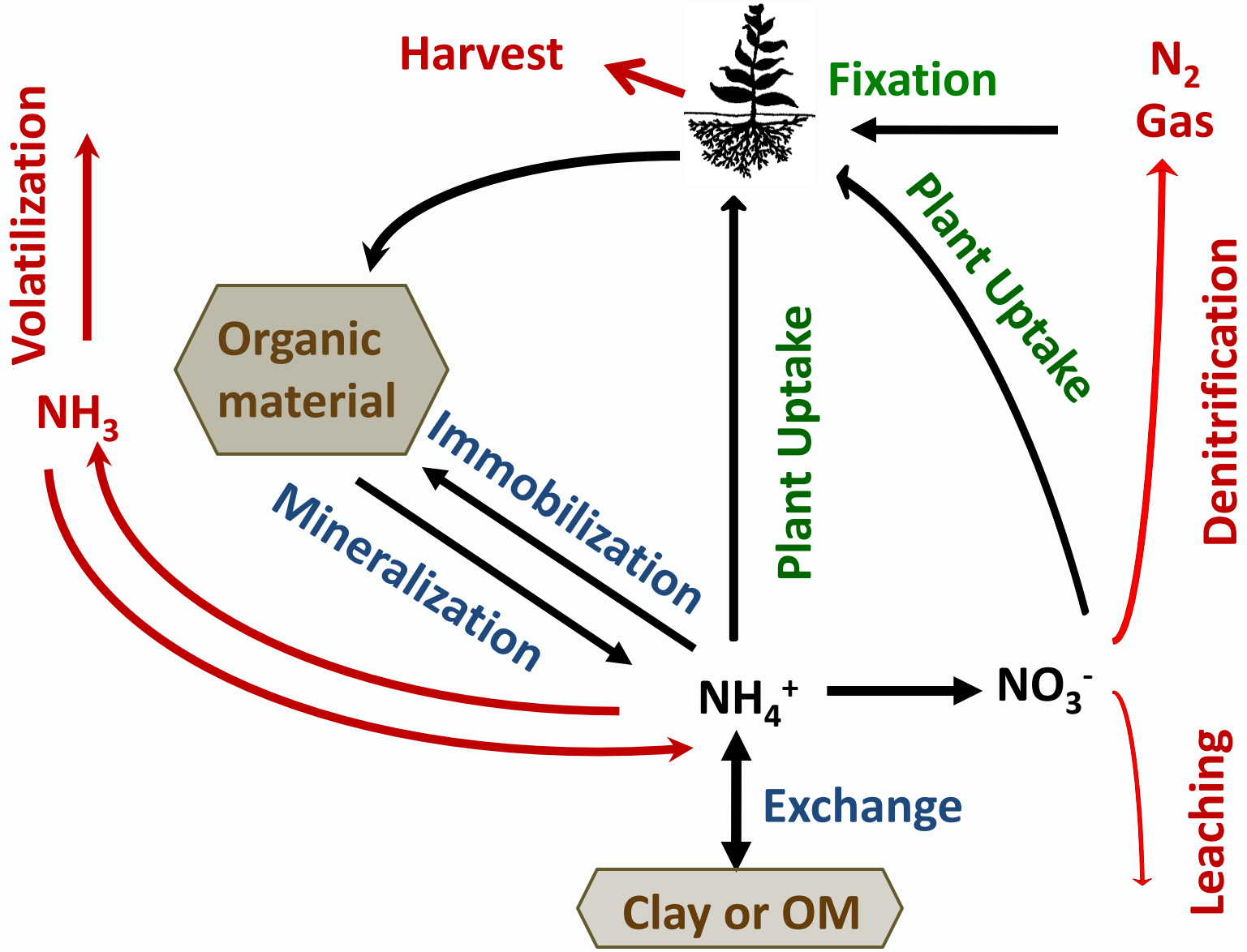
Hudson 1994

Questions?

Nutrient cycling

Some knowledge helps understand the whys of source, rate, timing and placement. Even my research associate still refers to nutrient cycling diagrams for clarity ☺

Most common lacking nutrient is nitrogen (N)

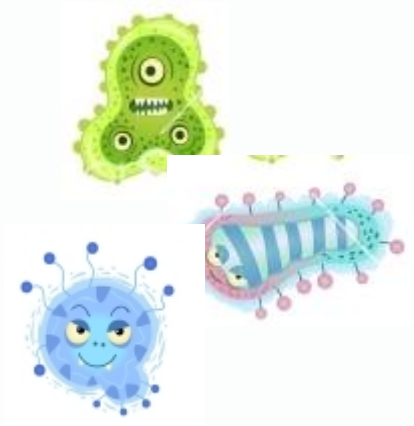


Mineralization

Decomposition of SOM by microbes, releasing available N

Organic-N

+



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Plant-Available N

How does high SOM affect recommended fertilizer N rate assuming yield goal is same?

1. Increases N rate
2. Depends on whether the field has legumes or not
3. Decreases N rate

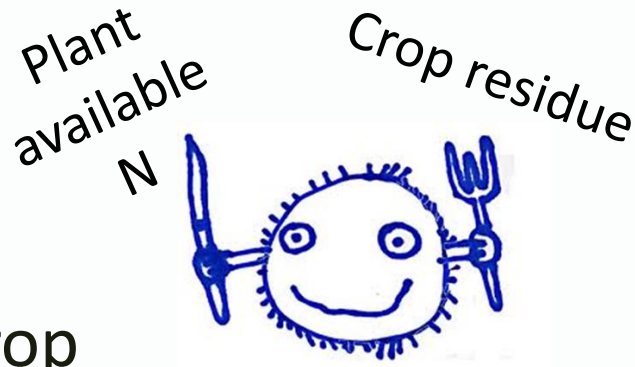
SOM supplies N

Immobilization

Uptake of available N by microbes

Why need to know about it?

- Crop residue is microbes' energy
  Microbes use plant available N
- We need to provide more N for crop



Is immobilized N lost from the system?
Yes/No?

No – just temporarily unavailable to plants

Questions on N cycle?

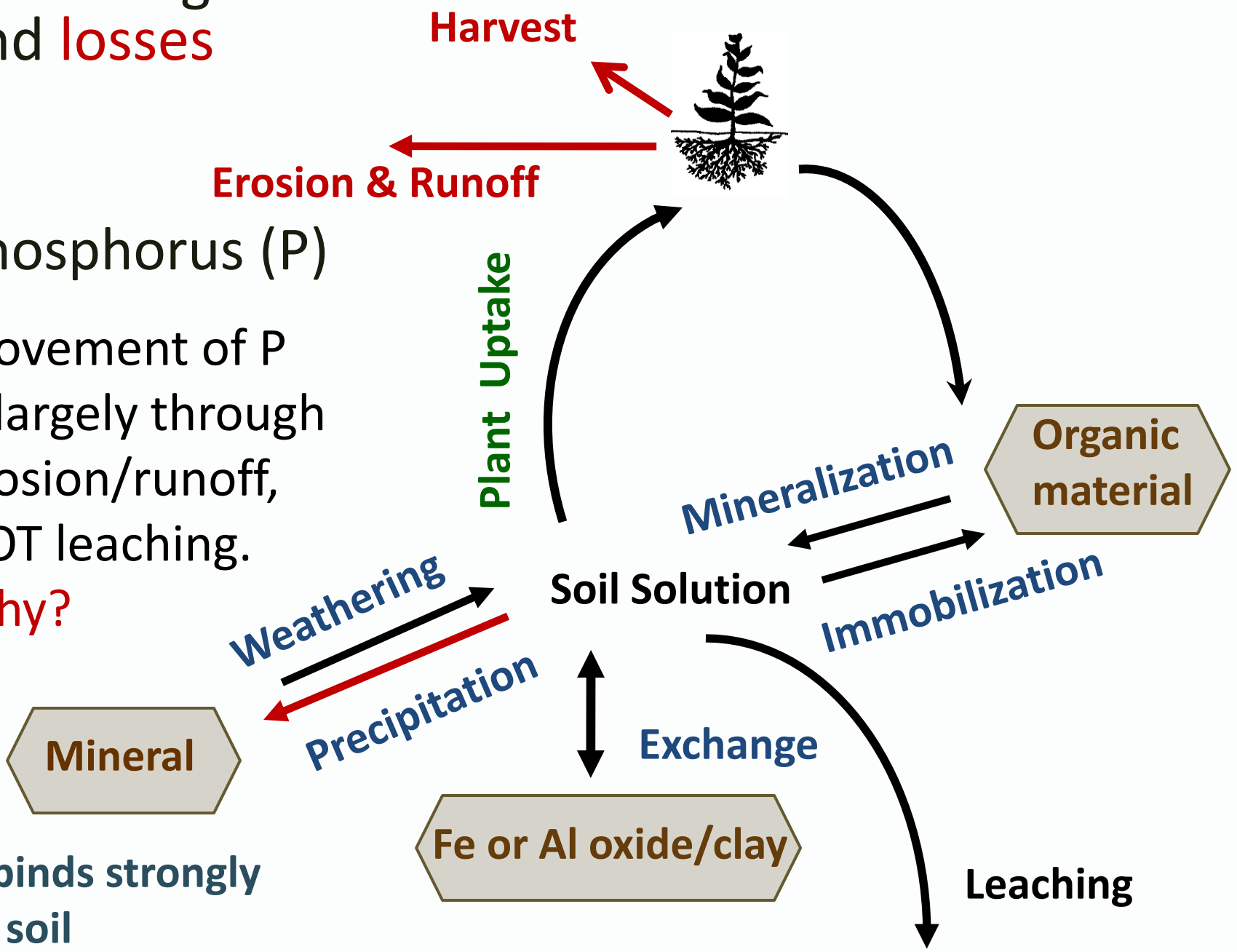
References for more information are provided at end of this ppt.

Nutrient gains and losses

Phosphorus (P)

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

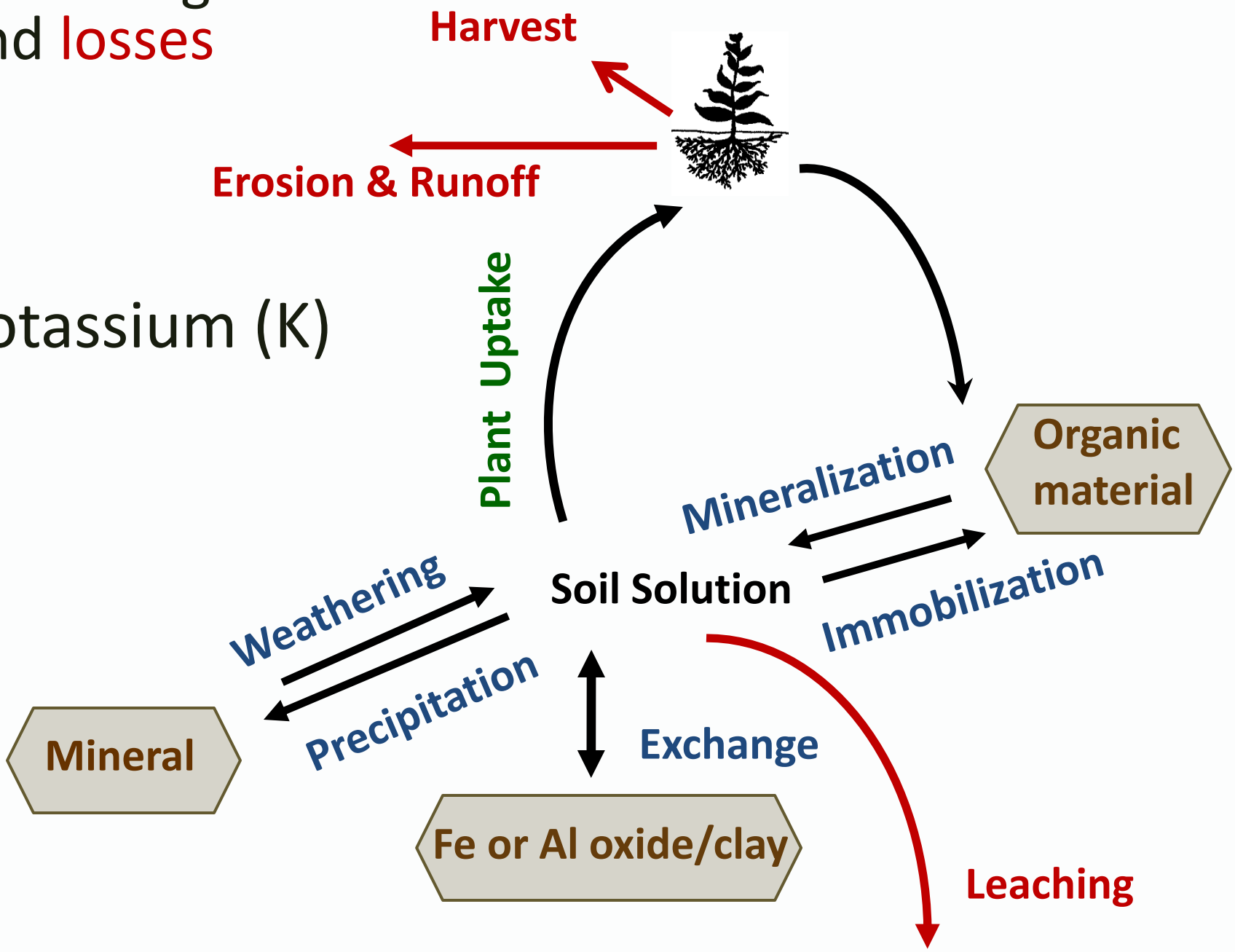
Why?



P binds strongly to soil

Nutrient gains and losses

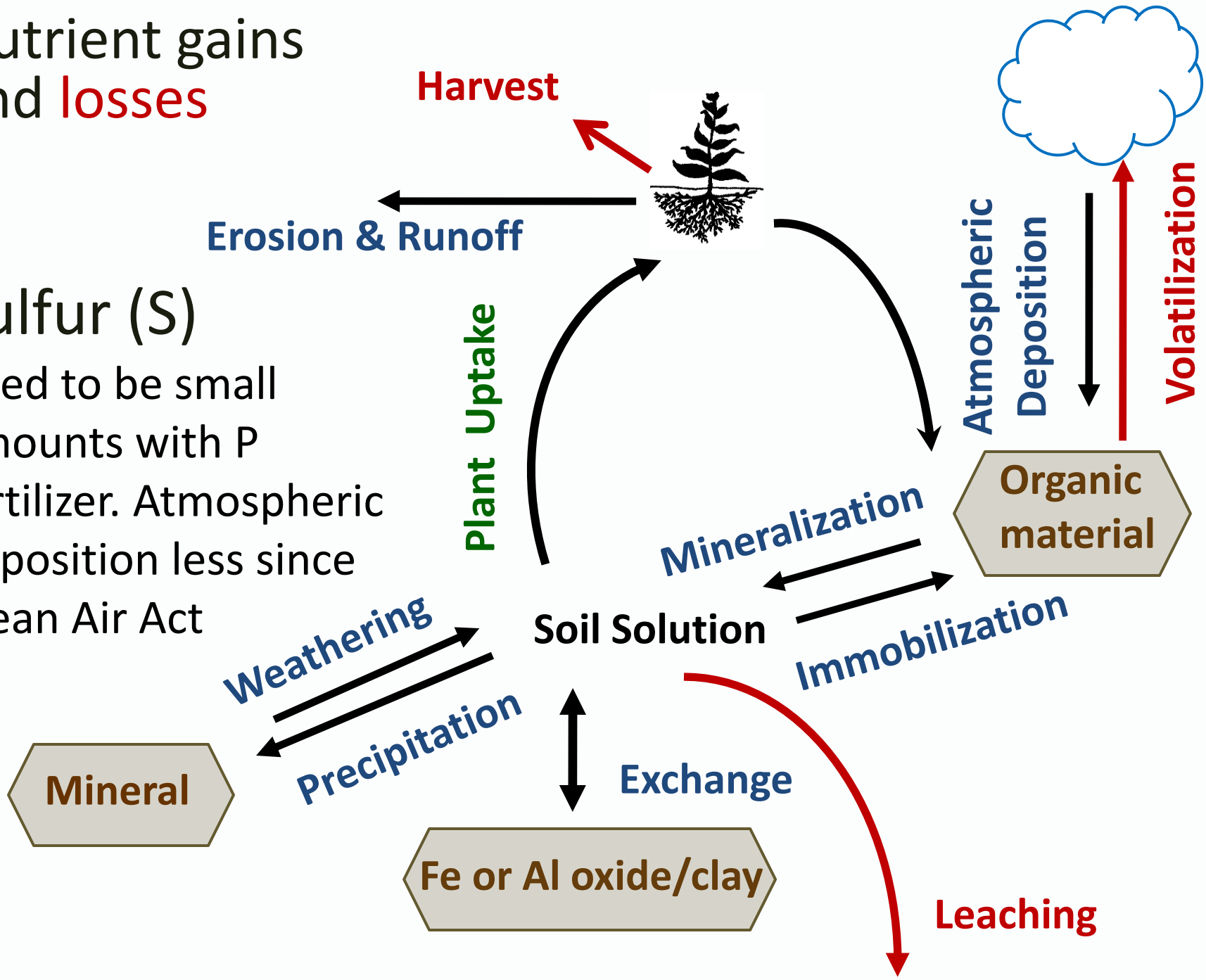
Potassium (K)



Nutrient gains and losses

Sulfur (S)

Used to be small amounts with P fertilizer. Atmospheric deposition less since Clean Air Act



Micronutrient gains and losses

Harvest

Erosion & Runoff

Plant Uptake

Metal micronutrients
(Cu, Fe, Mn, Zn)
Required in tiny amounts
Much in soil but little available

Mineralization

Organic material

Weathering

Soil Solution

Immobilization

Precipitation

Mineral

Exchange

Fe or Al oxide/clay

B and Cl are more available but can be lost to

Leaching

Summary

- Nutrients need to be in the right form to be plant available
- Nutrients cycle among different forms in the soil
- Soil characteristics influence nutrient availability
- Many soil properties cannot readily be changed by management
- Soil organic matter is one that can be changed and has large impact on soil nutrient availability

Questions?

Advantages of soil testing (even if only occasionally)

- To identify nutrient deficiency or imbalance
- To help calculate optimal fertilizer rates
- Especially important in case where soil nutrient availability has been depleted or is in excess
- Can increase yield and/or save on fertilizer costs, and decrease environmental risks

Why are more samples better when it comes to soil sampling?

Variability can be large!

Range and average of test values from 40 individual soil cores from a 80-acre field[1].

Analysis	Range (lb/acre)	Average (lb/acre)
Nitrate-N	12-225	53
Phosphorus	5-250	39
Potassium	156-1164	557

[1] From Swenson et al. (1984)

Use 10 cores to composite into each sample submitted

Why is N tested to 2 feet and P and K to only 6 inches?

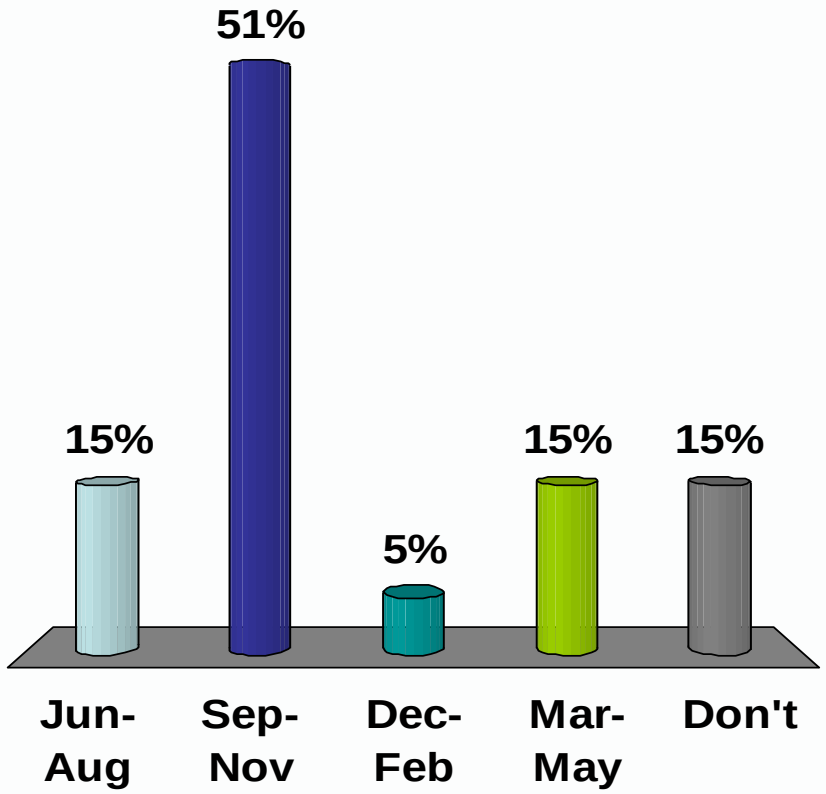
- N can easily move to 2 feet (and beyond) and the lower depths often have substantial amounts of N.
- P and K fertilizer generally stay in upper ½ foot and amounts are often very low below there.

Timing of soil sampling

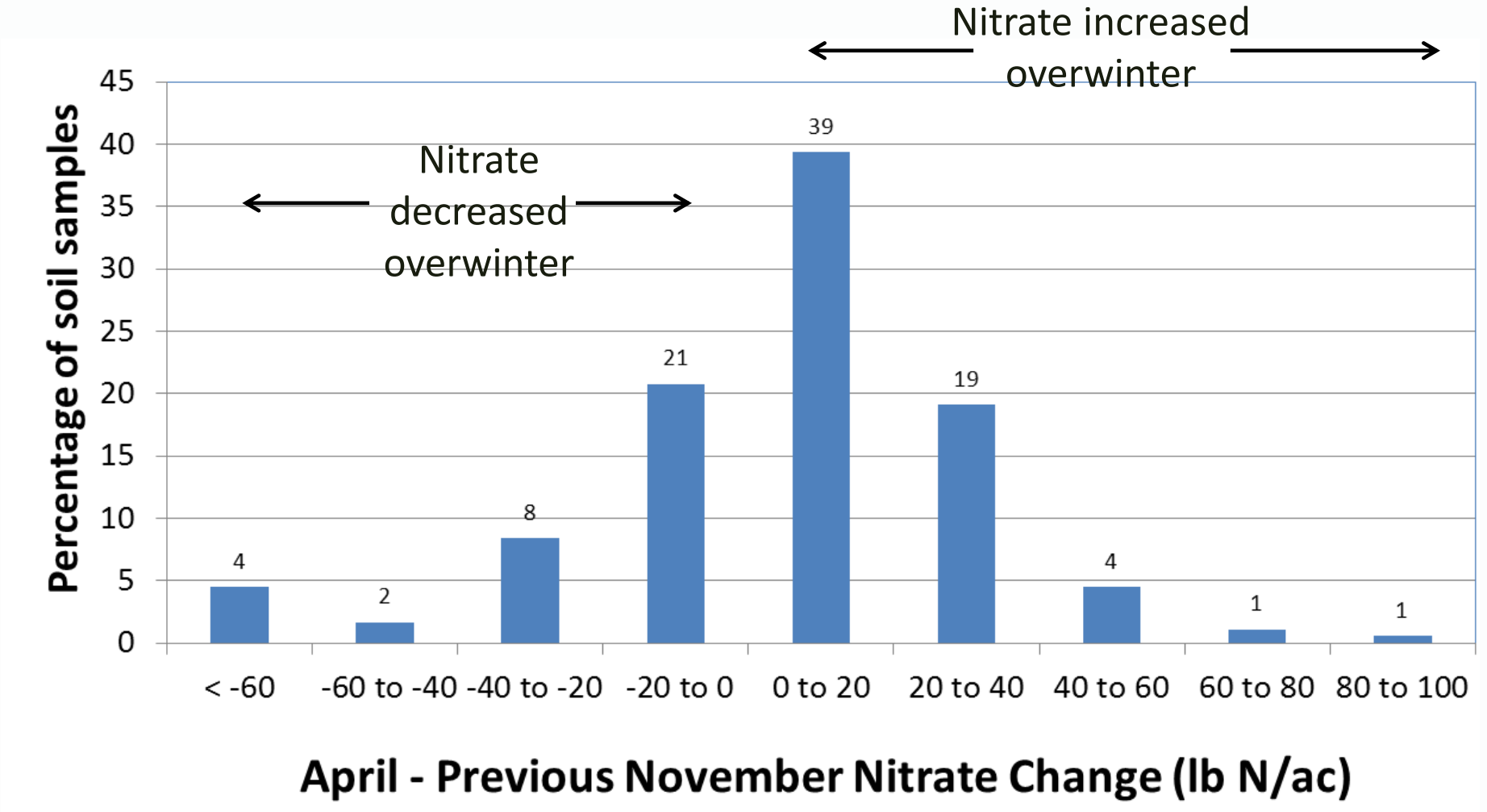
- Nitrogen fertilizer guidelines are based on spring soil samples for nitrate in Montana
- BUT, most sampling in MT occurs from late summer to late fall

Based on 35 ‘clicker’ responses at MABA 2010 Convention, when asked when crop advisers do most of their soil sampling:

Why is this a potential problem?



November to April nitrate changes, Montana data based on 180 samples (Jones et al. 2011)



Soil sampling timing summary

- Changes in nitrate levels from late summer/fall to spring can be large and highly variable
- High nitrate levels on shallow coarse soils can be lost overwinter, resulting in under-fertilization
- Nitrate levels can increase overwinter (from ‘mineralization’), resulting in over-fertilization
- Sampling later will better represent growing season nitrate levels

Soil health tests

- Measure and monitor over time or between fields
- Useful to assess effect of management or evaluate problem areas
- Standardized methods may not yet be in place
- Currently no calibration between test values and fertilizer recommendations for northern Great Plains
- See NRCS for info on soil health

http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/

Soil testing summary

- Soil tests can increase yield and/or save on fertilizer costs, and decrease environmental risks
- Soil tests for N are best done in the spring, can be done in fall for P and K, and not worthwhile for S
- Soil *health* tests are useful to assess management or problem areas, but currently no calibration between tests and fertilizer recommendations

Soil test interpretation

What are the first things to look for on a soil test report?

Factors affecting crop production

Factor	Value	Impact/consider
Soil organic matter	≤ 1 (%)	Minimize fallow, add a perennial, increase N
	> 3 (%)	N credit (~15 lb N/ac)
Soil pH	< 6	Poor legume nodulation
	> 8.3	Sodic soil, nutrients tied up
Soluble salts (EC)	> 4 (mmhos/cm)	Too saline, water stress, nutrient imbalance

Example soil test report from Trout Creek, MT

REPORT OF ANALYSIS	
YOUR SAMPLE NUMBER	HAY FIELD
Soil pH	6.0
Buffer Index	6.6
Excess Carbonate	VL
Soluble Salts mmhos/cm	0.2
Sodium ppm	23.0
% Organic Matter	3.7
ANALYSIS OF NUTRIENT ELEMENTS IS IN PARTS PER MILLION (ppm)	
Nitrate N	1.0
Phosphorus Bray 1 Olsen	10 –
Potassium	88
Magnesium	220
Calcium	1035
Sulfate Sulfur	8
Zinc	3.0
Manganese	–
Copper	–
Iron	–
Boron	–
Bulk Density	1.1

FERTILIZER GUIDLINES IN: Lbs/Acre

1st Option Intended Crop	Grass_Hay		2nd Option Intended Crop			3rd Option Intended Crop		
Yield Goal			Yield Goal			Yield Goal		
Preceding Crop			Preceding Crop			Preceding Crop		
PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES	PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES	PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES
N	135.0	175	N			N		
P_2O_5	75.0	66	P_2O_5			P_2O_5		
K_2O	230.0	140	K_2O			K_2O		
MgO	5.0		MgO			MgO		
S	6.5		S			S		
Zn	0.0		Zn			Zn		
Mn			Mn			Mn		
Cu			Cu			Cu		
Fe			Fe			Fe		
B			B			B		
Lime	4380		Lime			Lime		

Lime Guidelines are for 100% Effective Calcium Carbonate (ECC) with a 6" Incorporation Depth.

ACTUAL AND SUGGESTED PERCENT OF TOTAL CEC (BASE SATURATION)								ESTIMATED		
Actual % Hydrogen	Suggested Hydrogen	Actual % Potassium	Suggested Potassium	Actual % Magnesium	Suggested Magnesium	Actual % Calcium	Suggested Calcium	Actual % Sodium	Suggested Sodium	CEC for Your Soil
40.5	0 - 5	1.8	4.1 - 7	14.9	15 - 20	42.0	65 - 75	0.8	0 - 5	12.3

Example soil test report from Trout Creek, MT

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Copper	–
Iron	–
Boron	–
Bulk Density	1.1

FERTILIZER GUIDLINES IN: Lbs/Acre

1st Option Intended Crop			2nd Option Intended Crop			3rd Option Intended Crop		
Grass_Hay								
Yield Goal			Yield Goal			Yield Goal		
Preceding Crop			Preceding Crop			Preceding Crop		
PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES	PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES	PLANT FOOD GUIDELINE RANGES		CROP REMOVAL RATES
N	135.0	175	N			N		
P_2O_5	75.0	66	P_2O_5			P_2O_5		
K_2O	230.0	140	K_2O			K_2O		
MgO	5.0		MgO			MgO		
S	6.5		S					
Zn	0.0		Zn					
Mn			Mn					
Cu			Cu					
Fe			Fe			Fe		
B			B			B		
Lime	4380		Lime			Lime		

Lime Guidelines are for 100% Effective Calcium Carbonate (ECC) with a 6" Incorporation Depth.

Nutrients are discussed in next presentation

ACTUAL AND SUGGESTED PERCENT OF TOTAL CEC (BASE SATURATION)								ESTIMATED		
Actual % Hydrogen	Suggested Hydrogen	Actual % Potassium	Suggested Potassium	Actual % Magnesium	Suggested Magnesium	Actual % Calcium	Suggested Calcium	Actual % Sodium	Suggested Sodium	CEC for Your Soil
40.5	0 - 5	1.8	4.1 - 7	14.9	15 - 20	42.0	65 - 75	0.8	0 - 5	12.3

Questions?

For more information: see Extension publications at http://landresources.montana.edu/soilfertility/

Soil Sampling Strategies (MT200803AG)
Interpretation of Soil Test Reports for Agriculture (MT200702AG)

Nutrient Management Modules: **http://landresources.montana.edu/nm/**

- NM2 Plant nutrition & soil fertility
- NM3 Nitrogen
- NM4 Phosphorus
- NM5 Potassium
- NM6 Sulfur (and Ca, Mg)
- NM7 Micronutrients
- NM8 Soil pH and SOM

Soil & Water Management Modules: **http://landresources.montana.edu/SWM/**

- SWM1 Basic soil properties