Soil Testing for Plant and Soil Health

February 10, 2017, Western MT Grazing & Ag. Conference, NRCS/MACD

by Clain Jones, 406 994 6076; clainj@montana.edu

MSU

Dept Land Resources and Environmental Sciences

Goals today

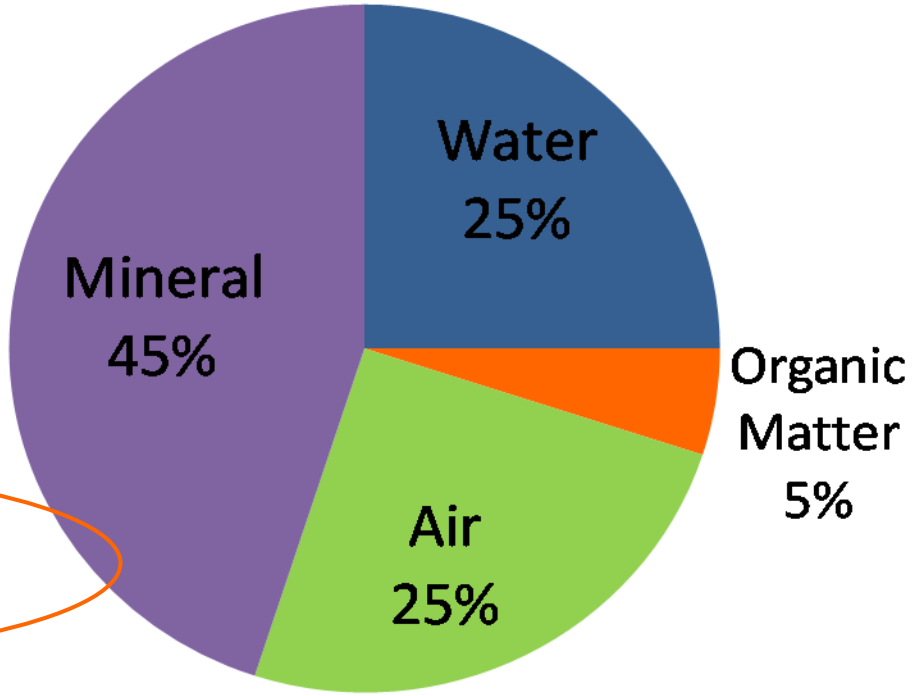
- Discuss key soil properties including texture, organic matter, nutrients, pH, and salts.
- Show an example soil test and what it tells us about the soil
- Illustrate fertilizer guidelines for forages and for market gardens
- Discuss soil health and methods to improve

Questions for you

- Raise hand if mostly interested in forage production
- Raise hand if mostly interested in market gardening
- Others?
- Handouts

An Ideal Soil – yes, “soil”, not “dirt” ☺

- 50% Pore Space
  - 25% Air
  - 25% Water
- 50% Solid Material
  - 5% Organic Matter
  - 45% Mineral



How much organic matter?

- 5-8% O.M. is optimal – O.M. is not the cure-all for all soil ailments.

  Ex 1: saline soil might need better drainage or less water
  Ex 2: a soil that cracks will likely still crack with more O.M.

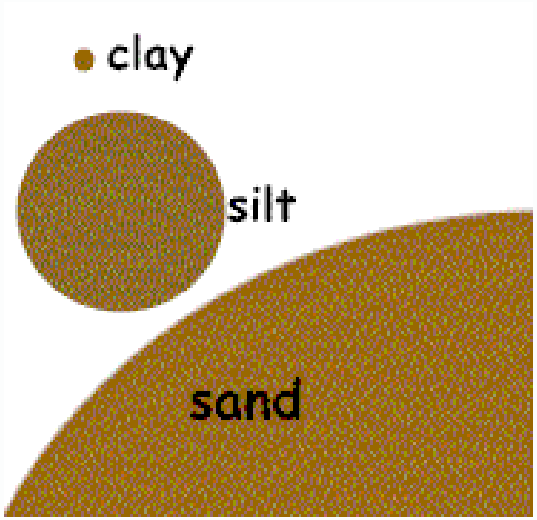
- 1” manure compost will add about 1.5% O.M.
- 1” yard/kitchen compost will add ~3% O.M.

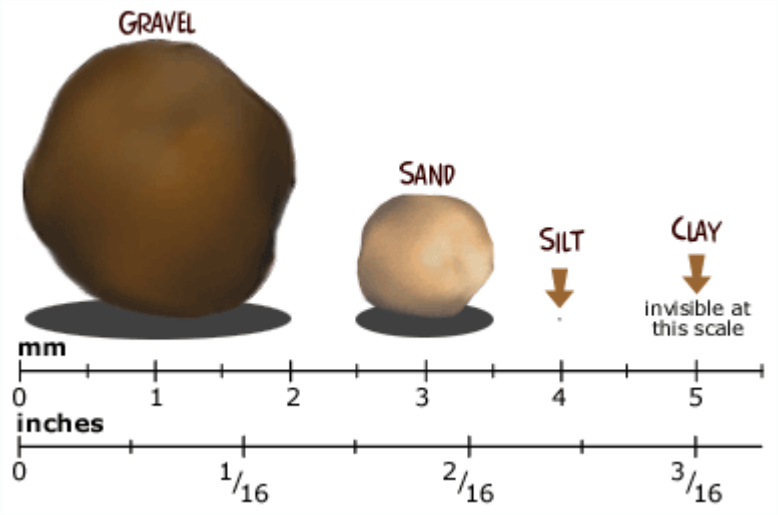
Why the difference?

Manure compost ≈ 20% O.M. (often contains soil)
Yard/kitchen compost ≈ 40% O.M.

45% mineral = sand, silt, and clay

- Clay is hard when dry, sticky when wet, forms ribbon when rolled between fingers
- Silt feels smooth, floury – very fertile
- Sand feels gritty between your fingers when moist





Texture effects on soil properties

	Drainage	Water holding capacity	Aeration	Cation Exchange Capacity (CEC)
Sand	excellent	poor	excellent	low
Silt	good	good	good	med
Clay	poor	excellent	poor	high

Ideal is loam = approx. equal parts of each

14 mineral nutrients have been found 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)

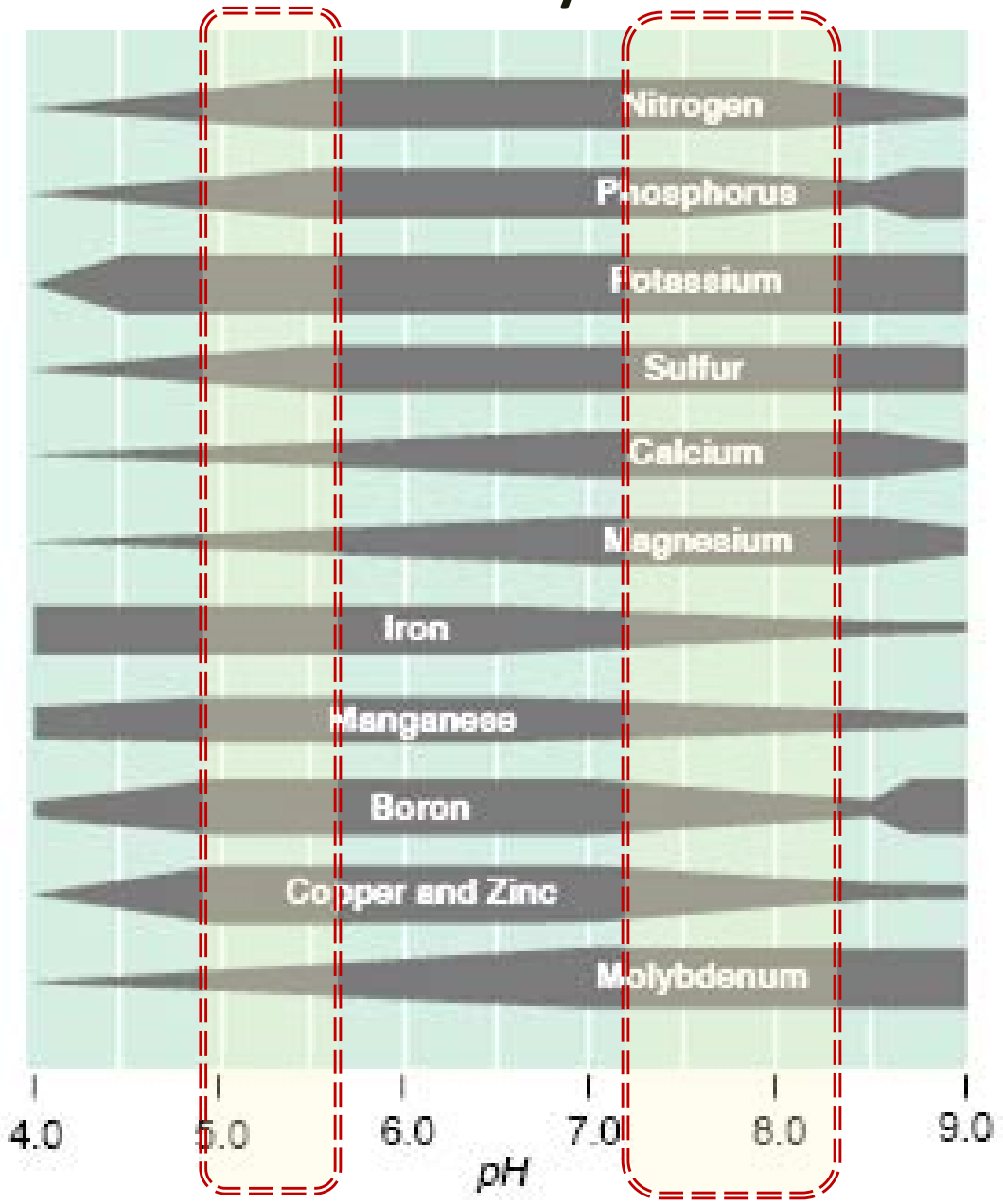
The macronutrients are simply needed in larger amounts by the plant than the micronutrients.

Nutrient deficiencies of the **bolded** nutrients have been observed in Montana

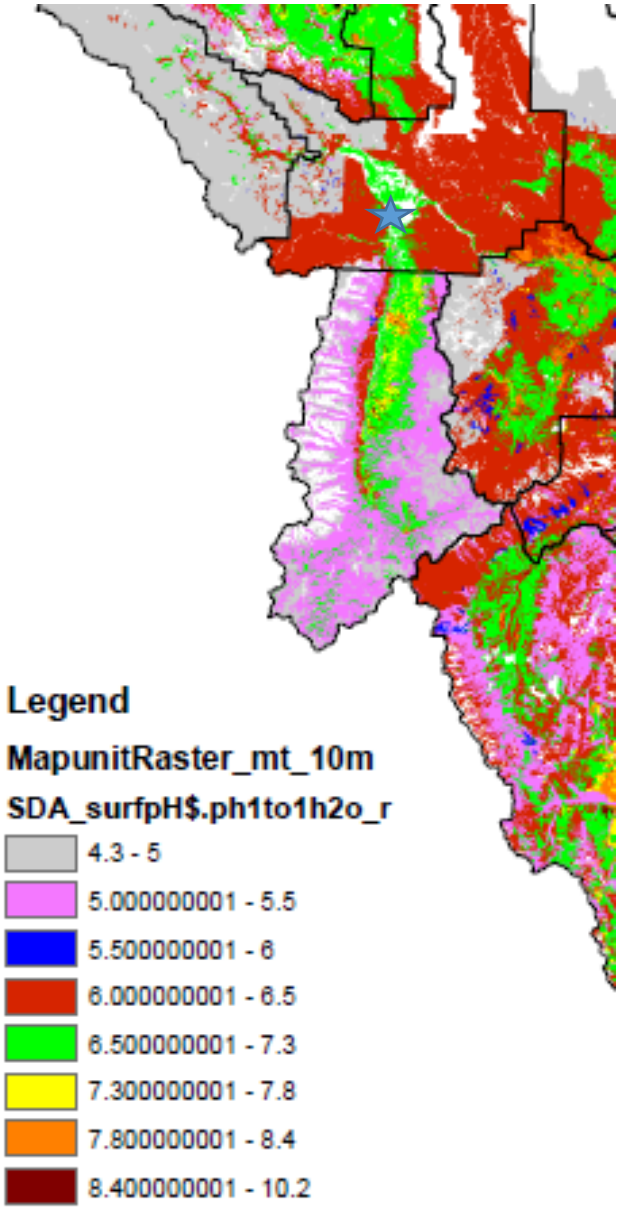
pH affects soil nutrient availability

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



What are surface horizon pH values in this region?

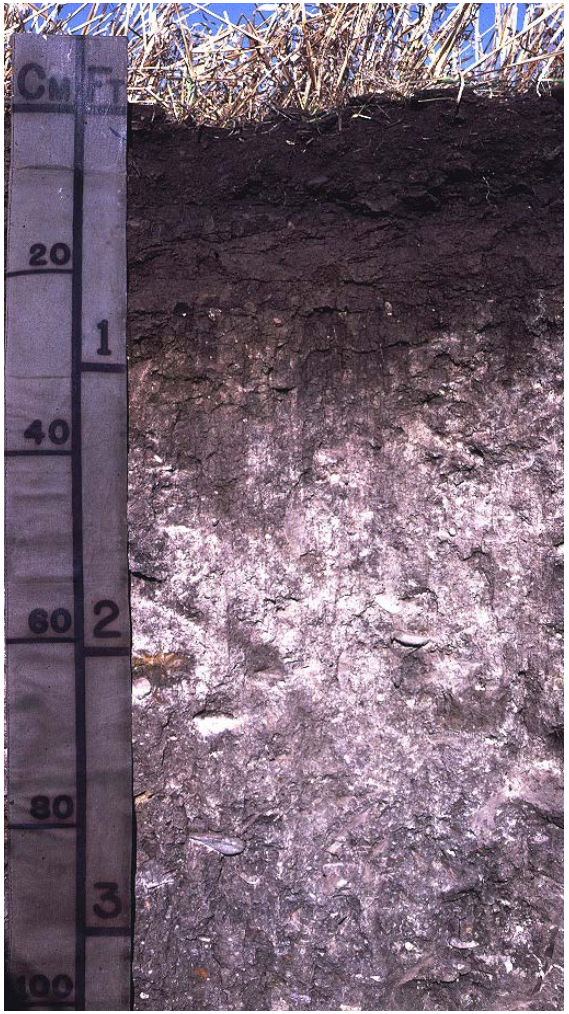


There are known areas in western Montana with top 6” pH < 5.5
Ex: Near Hamilton and Plains
Other areas have pH levels near 8.0.

Map courtesy of NRCS

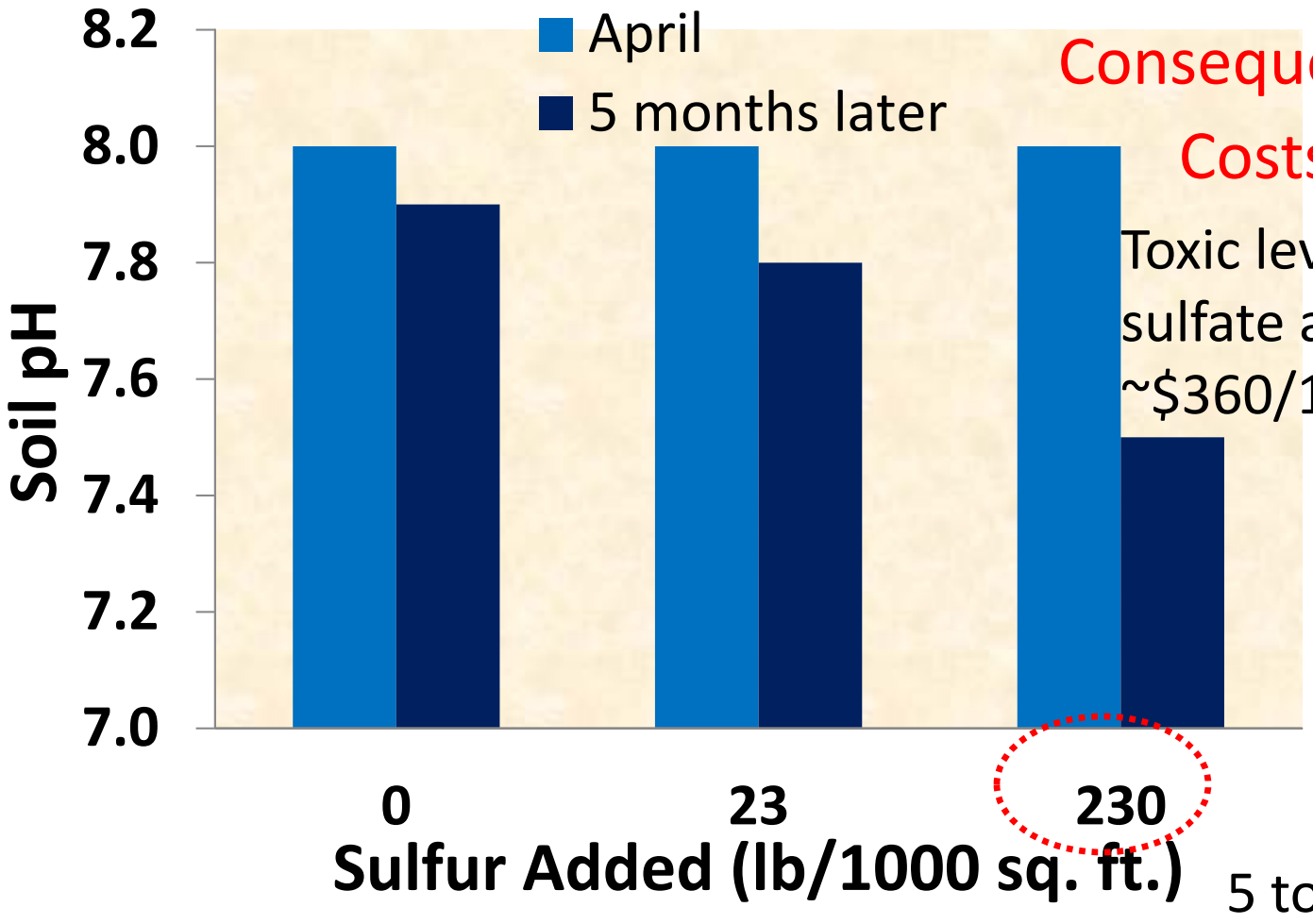
Why are MT soils generally high pH?

- Most MT soils are highly calcareous = alkaline
- Even if surface soil isn't alkaline, the subsoil usually is
- Most common method to attempt to lower pH: elemental sulfur (S)



Mollisol – common in Montana and or semi-arid regions

Adding elemental sulfur to lower pH



Consequences?

Costs?

Toxic levels of sulfate and ~$360/1000 sq ft

5 ton/acre!

AgVise Laboratories

Adding gypsum (calcium sulfate) to lower pH

Gypsum only lowers pH on high sodium (sodic) soils which generally have pH > 8.5 and are uncommon in w. Montana

What about issues with *acid* soils?

Acid soils have many negative impacts

- Herbicide persistence (Raeder et al., 2015)
- Damaging to rhizobia (N-fixing by legumes)
- Increase in fungal diseases
- Increase Al and Mn to toxic levels

Images from Creative Commons

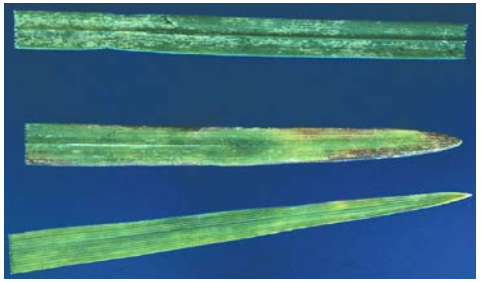
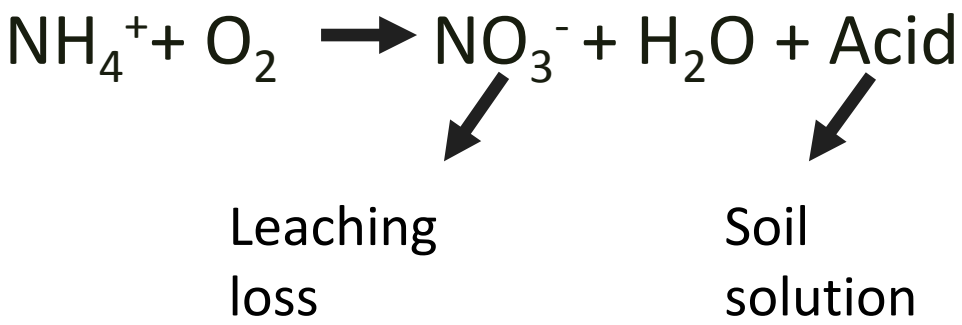


Image from CIMMYT, Int.

Conditions for low soil pH

- Soils with low buffering capacity, granitic > calcareous
- Sandy soils > clay
- Historical forest/long term cropland > historical grassland (still have buffering capacity)
- Crop residue removal – removes Ca, Mg, K, all “+” ions
- No-till (concentrates acidity in 3-5” zone)
- Leaching loss of nitrate (NO_3^-)
- High rates of ammonium (NH_4^+) fertilizers



Additional info on acid soils and pH

For more information and example liming calculations see the 2 Soil Scoops:

- *Soil Acidification: Problems, Causes, & Testing*
- *Soil Acidification: Management*

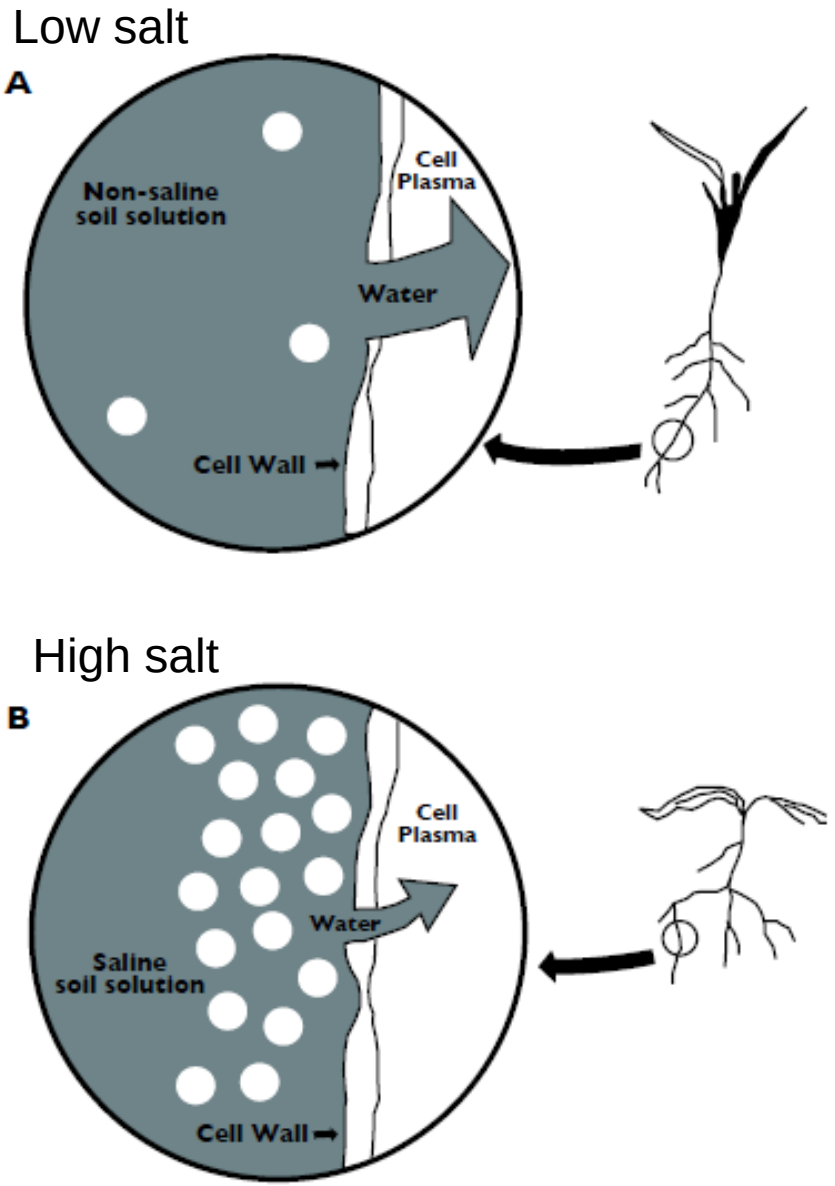
http://landresources.montana.edu/soilfertility/soilscoop.html

- *Soil pH: Nutrient Management Module 8*

http://landresources.montana.edu/nm

Salinity

- High salts (EC > 4.0)
  - reduce water availability
  - plant energy expenditure to exclude salts and take up water
- Sources
  - excess fertilizer
  - road salt
  - marine shales



Salinity

Image by J. LaForrest, Univ Georgia

Management:

- check irrigation water for salts
- water to flush salt below root zone – 8-12” to leach salts from top foot of soil, but will also leach nutrients
- fertilize plants only when necessary
- limit fertilization when moisture stressed (e.g., summer)

Questions so far?

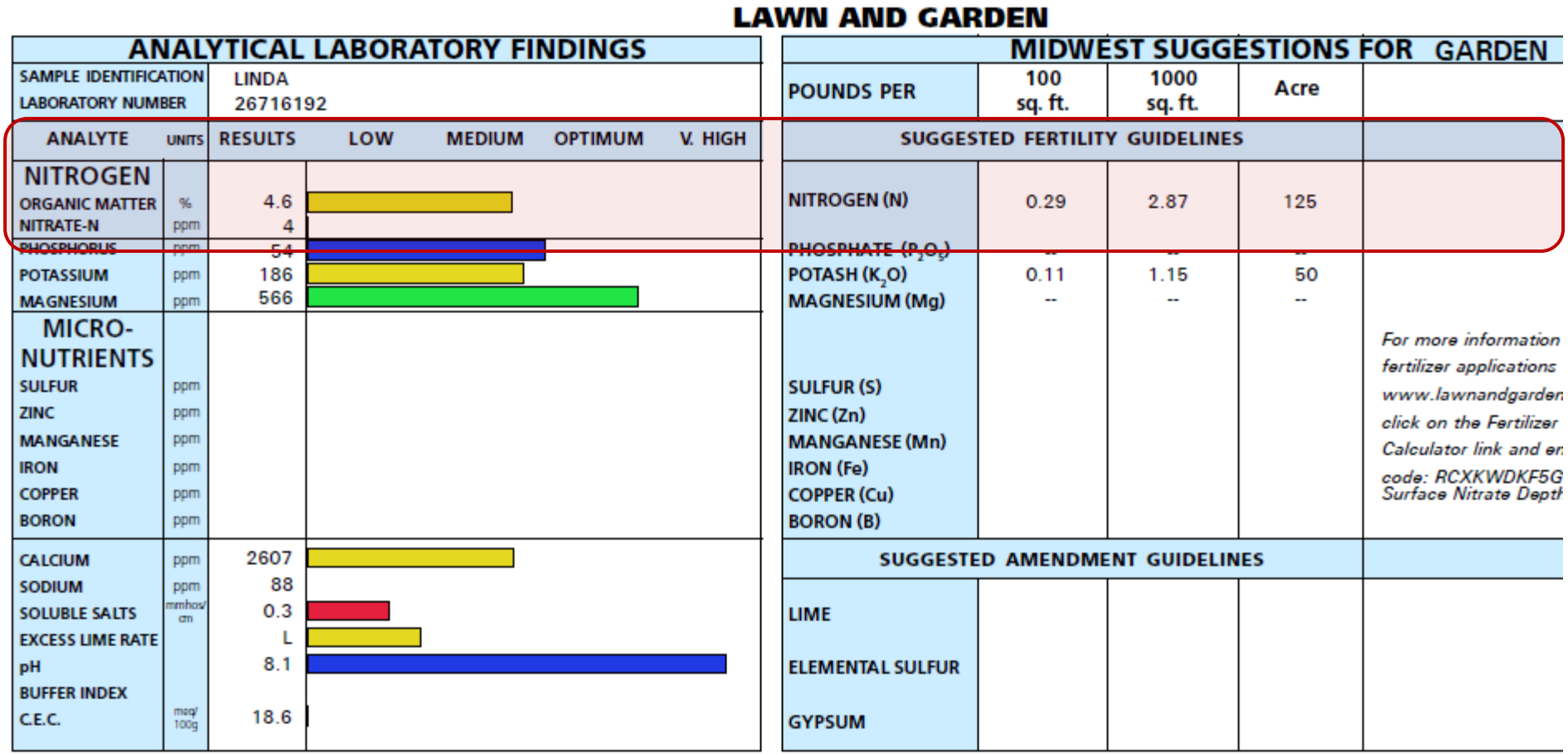
Benefits of soil testing

- ID current nutrient deficiency or imbalance
- Help calculate fertilizer rates
- Save on fertilizer cost
- Decrease environmental risks

Soil testing

- Remove grass/mulch mat from top, sample 6 inches deep
- Combine 10 subsamples per 1000 sq. ft. of garden or per field
- Separate samples for, e.g., gardens, turf, shrub areas
- Use probe, auger or tulip bulb planter
- Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall

Example soil test



LAWN AND GARDEN

ANALYTICAL LABORATORY FINDINGS

SAMPLE IDENTIFICATION	LINDA
LABORATORY NUMBER	26716192

ANALYTE	UNITS	RESULTS	LOW	MEDIUM	OPTIMUM	V. HIGH
NITROGEN						
ORGANIC MATTER	%	4.6				
NITRATE-N	ppm	4				
PHOSPHORUS	ppm	54				
POTASSIUM	ppm	186				
MAGNESIUM	ppm	566				
MICRO-NUTRIENTS						
SULFUR	ppm					
ZINC	ppm					
MANGANESE	ppm					
IRON	ppm					
COPPER	ppm					
BORON	ppm					
CALCIUM	ppm	2607				
SODIUM	ppm	88				
SOLUBLE SALTS	mmhos/cm	0.3				
EXCESS LIME RATE		L				
pH		8.1				
BUFFER INDEX						
C.E.C.	meq/100g	18.6				

MIDWEST SUGGESTIONS FOR GARDEN

POUNDS PER	100 sq. ft.	1000 sq. ft.	Acre
SUGGESTED FERTILITY GUIDELINES			
NITROGEN (N)	0.29	2.87	125
PHOSPHATE (P_2O_5)	--	--	--
POTASH (K_2O)	0.11	1.15	50
MAGNESIUM (Mg)	--	--	--
SULFUR (S)			
ZINC (Zn)			
MANGANESE (Mn)			
IRON (Fe)			
COPPER (Cu)			
BORON (B)			
SUGGESTED AMENDMENT GUIDELINES			
LIME			
ELEMENTAL SULFUR			
GYPSUM			

For more information
fertilizer applications
www.lawnandgarden
click on the Fertilizer
Calculator link and en
code: RCXKWDKF5G
Surface Nitrate Depth

Is this soil saline? Would you be concerned with its pH? How about OM?

What if lab doesn't provide a recommendation (or is from another state)? For gardens use Table 3 from MontGuide (MT200705AG) or Table 1 from Feeding the Vegetable Garden for N

Soil Test	Organic Matter (%)		
Nitrate - N	< 1.5	1.5 – 3.0	> 3.0
lbs /acre	lbs/1000 sq.ft.		
<20	4	3	3
20-40	2	2	2
40-80	1	1	0.5
>80	0	0	0

Forage N rate depends on legume to grass ratio

N fertilizer guidelines for alfalfa and grass in MT

(Table 1 in EB0161 and Forages: Nitrogen Management soil scoop)

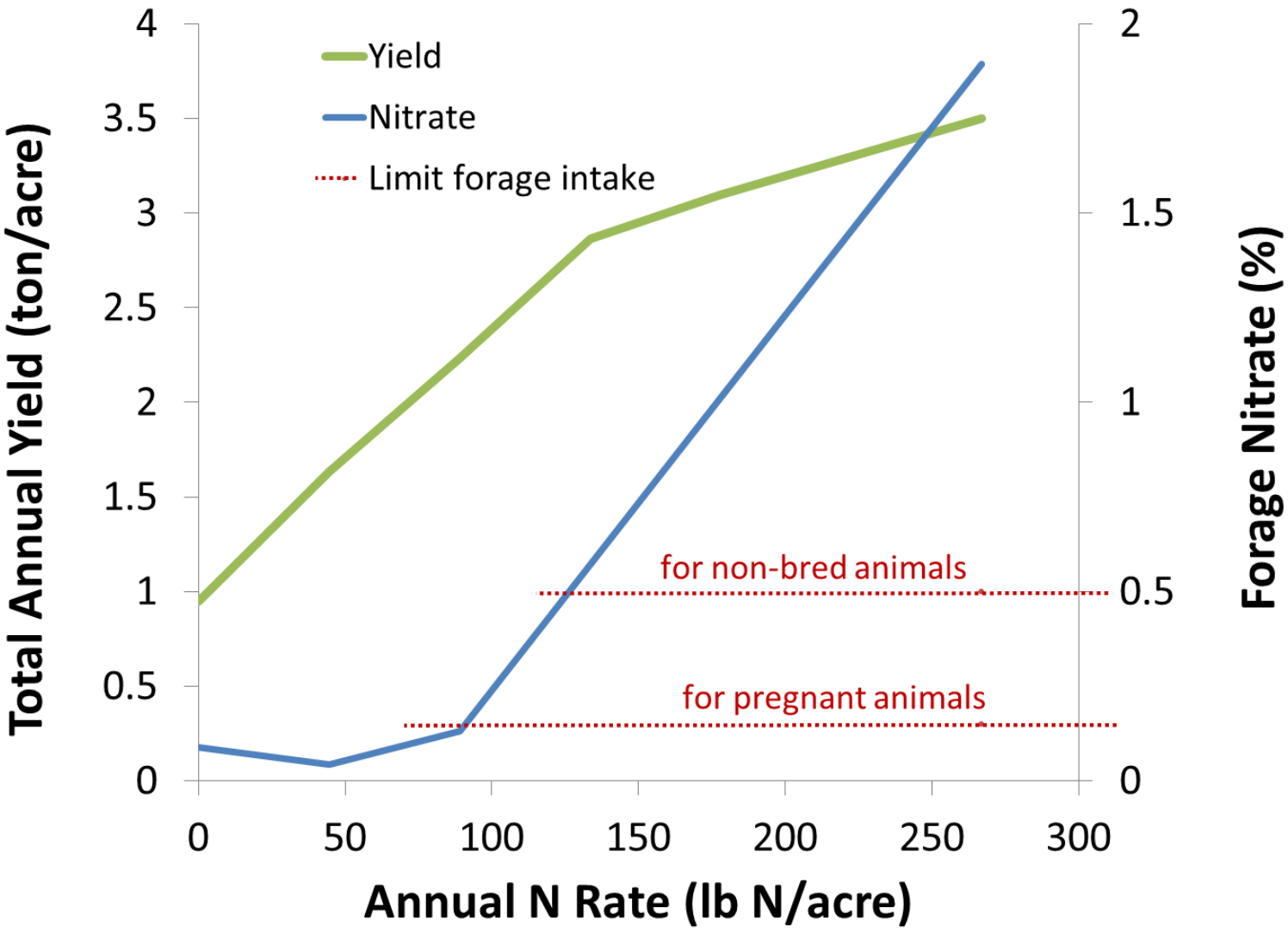
Yield Potential (ton/acre)	Alfalfa/Grass				
	80/20	60/40	40/60	20/80	0/100
	Available N Need (lb/acre)**				
1	5	10	15	20	25
2	10	20	30	40	50
3	15	30	45	60	75
4	20	40	60	80	100*
5	25	50	75	100*	125*
6	30	60	90	120*	150*

*Do not exceed 100 lb/ac in a single application on cool season grasses (Brummer et al. 2011).

** Fertilizer N = Available N Need – Soil nitrate-N in top 2’ ←

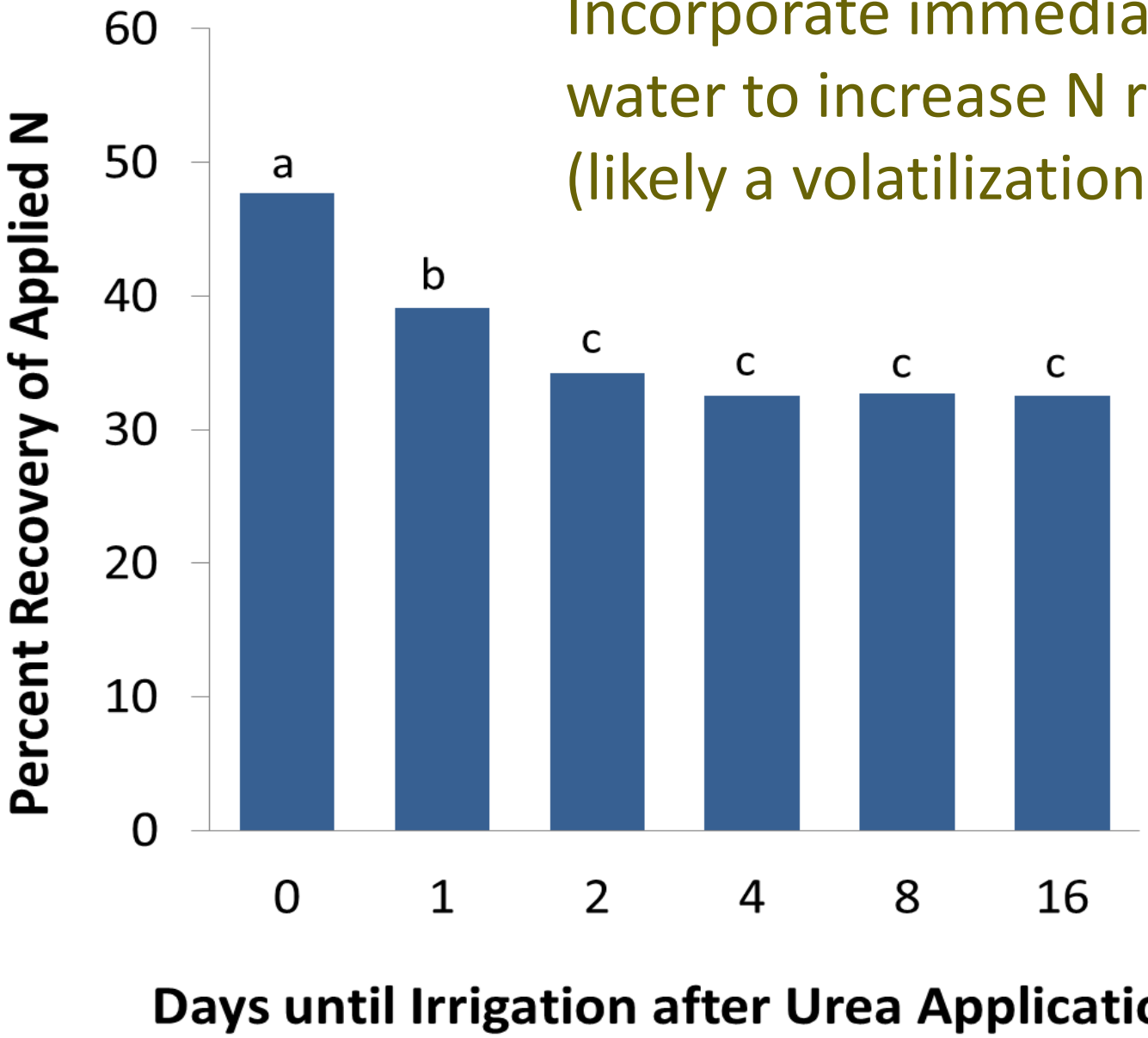
Need to divide by fraction of N in fertilizer to find total fertilizer need

Trade-off between yield and forage nitrate



Bromegrass, Vimy, Alberta
Penny et al. 1990 and MT200505AG

Incorporate immediately with water to increase N recovery (likely a volatilization effect)



0.8” irrigation

Eckville, Alberta

Bromegrass, Malhi et al. 1995

For Gardens use Tables 4-5 from MontGuide (MT200705AG) or Table 2, Feeding the Vegetable Garden soil scoop

	Olsen P (ppm)				
	< 4	**4 – 8**	**8 – 12**	**12 – 16**	**> 16**
lb P_2O_5/1000 sq. ft.	5	4	3	2	1
	K (ppm)				
	< 75	**75 – 150**	**150 – 250**	**>250**	
lb K_2O/1000 sq. ft.	3	2	1	0	

Approximately how much total N, P, and K does manure compost supply compared to removal at harvest?

	N	P_2O_5	N:P	K_2O
	lbs/1000 sq. ft.			
Removed by average vegetable harvest	3.4	0.3	11:1	3.2
1” manure	40	16	4:1	40
1000 lb manure	10	4	4:1	10

One local composted manure tested had a total N:P of 6:1

Morris, Ping, and Durgy. University of Connecticut.
http://www.newenglandvfc.org/pdf_proceedings/SoilOrganicAmend.pdf

MSU P rates for forage

P guidelines for alfalfa and grass based on soil analysis
(Table 18 in EB0161 w/ alfalfa/grass revised, and Table 1, soil scoop)

Crop	Olsen P Soil Test Level (ppm)				
	0	4	8	12	16
	P Fertilizer Rate (lb P_2O_5/acre)				
Alfalfa	140	110	75	40	20
Alfalfa/grass (50/50)	93	73	53	30	13
Grass	45	35	30	20	5

If soil test is above 16 ppm then consider using removal rate (10 to 11 lb P_2O_5/ton)

MSU K rates for forage

K guidelines for alfalfa and grass based on soil analysis (Table 19 in EB0161, alfalfa/grass rates revised, and Table 2, soil scoop).

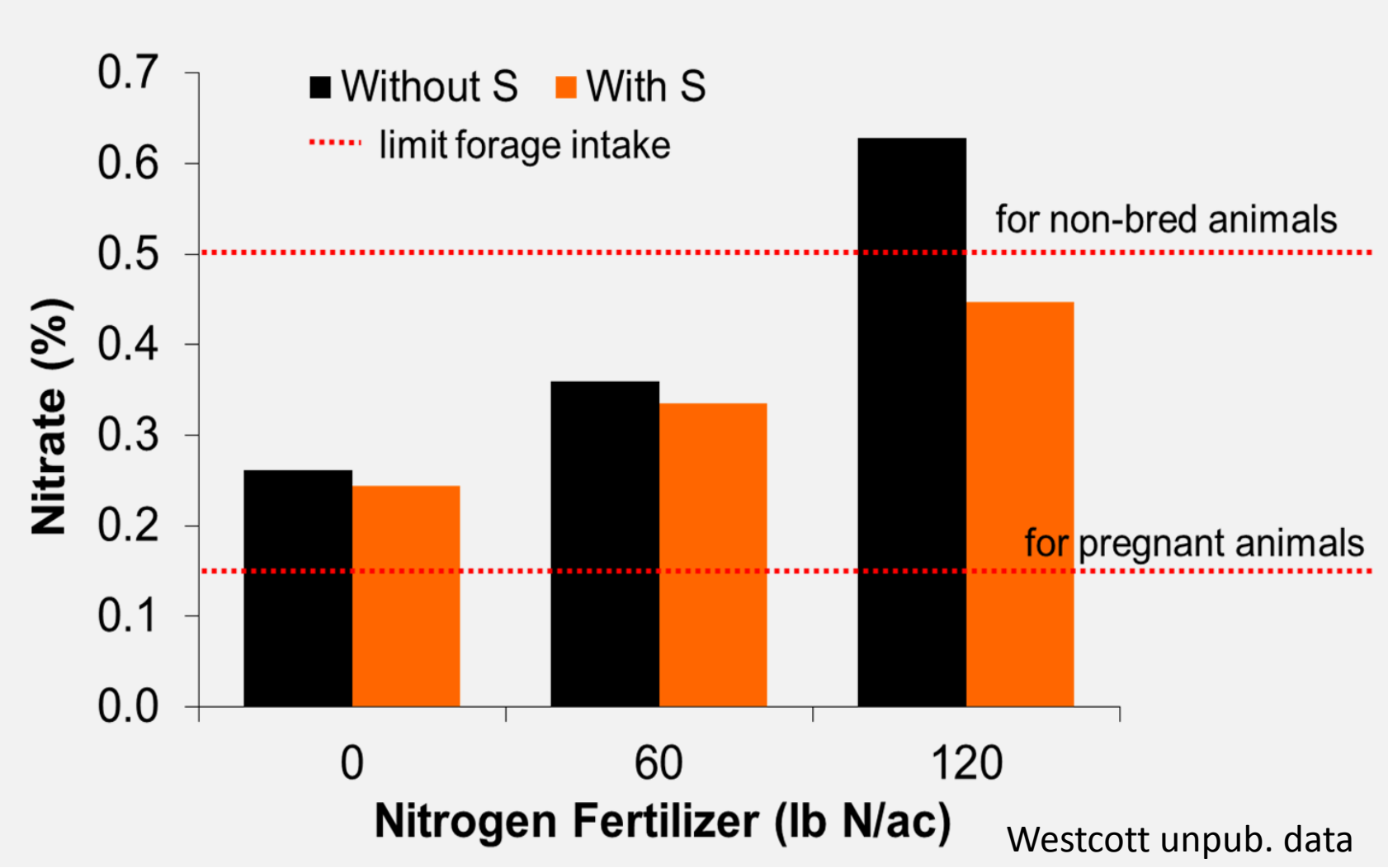
Crop	K Soil Test Level (ppm)					
	0	50	100	150	200	250
	K Fertilizer Rate (lb K_2O/acre)					
Alfalfa	240	205	170	140	95	30
Alfalfa/grass (50/50)	192	165	137	112	76	26
Grass	80	70	60	45	30	15

If soil test is above 250 ppm then consider using removal rate 38 lb K_2O/ton grass, 53 lb/ton alfalfa

Sulfur tissue tests and visual symptoms are better than soil tests

- Standard sulfate soil test too unreliable
- Tissue tests or visual symptoms (yellow or light green upper leaves) likely better
- If < 0.20% S in forage grass (upper most leaves right before heading), or < 0.22% in alfalfa (top 6” bud stage), S is likely deficient.
- S > 0.30% can cause livestock health problem

S influence on annual forage quality
(western Montana)



Westcott unpub. data

Your turn

	OM %	Nitrate –N lb/ac	P ppm	K ppm	pH
Test	1.8	15	13	200	7.5

Market gardeners: Using this data and Tables 1 and 2 from Feeding the Vegetable Garden soil scoop, how much N, P, and K are required for this garden?

Forage producers: Using this data and tables from the 2 forage soil scoops, how much N, P, and K are required to grow 3 ton/acre of grass?

N, P, and K rates?

	OM %	Nitrate –N lb/ac	P ppm	K ppm	pH
Test	1.8	15	13	200	7.5

Nutrient	Garden (lb/1000 sq ft)	Forage (lb/acre)
N	3	60*
P_2O_5	2	~20
K_2O	1	30

*Need to subtract out soil nitrate-N from available N need

Questions?

On to soil quality

Soil Quality vs Soil Health

Soil Quality = properties that change little, if at all, with land use management practices

- Texture
- pH
- Cation Exchange Capacity

Soil Health = dynamic properties which may be subjective to measure

- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

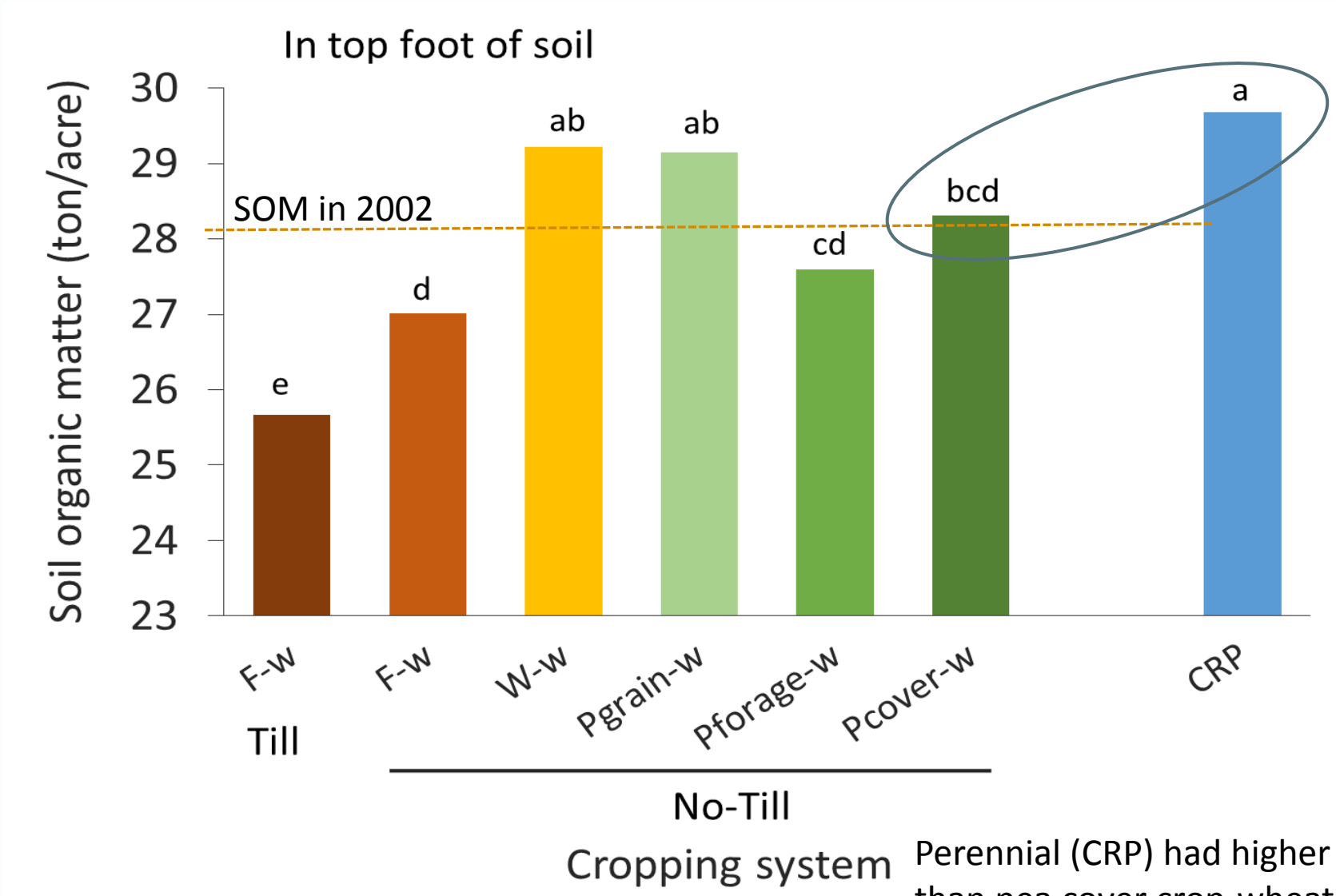
Which is more likely to be influenced by cover crops?

SOM often is included in both lists

Cover crops can be used by both small and large acreage producers to increase soil health and pollinators

- Will need patience. Most of our measured soil health parameters did not increase after two cycles of cover crops when used to replace fallow at 4 sites.
- Cover crops take out a possible revenue stream unless grazed.
- For small acreage market gardens, can increase soil organic matter, and hence soil health, much faster with compost.
- For large acreage farms, perennials have been found to increase soil organic matter more than most annual cropping systems, including those with CCs.

SOM after 10 years of cropping systems (2012)



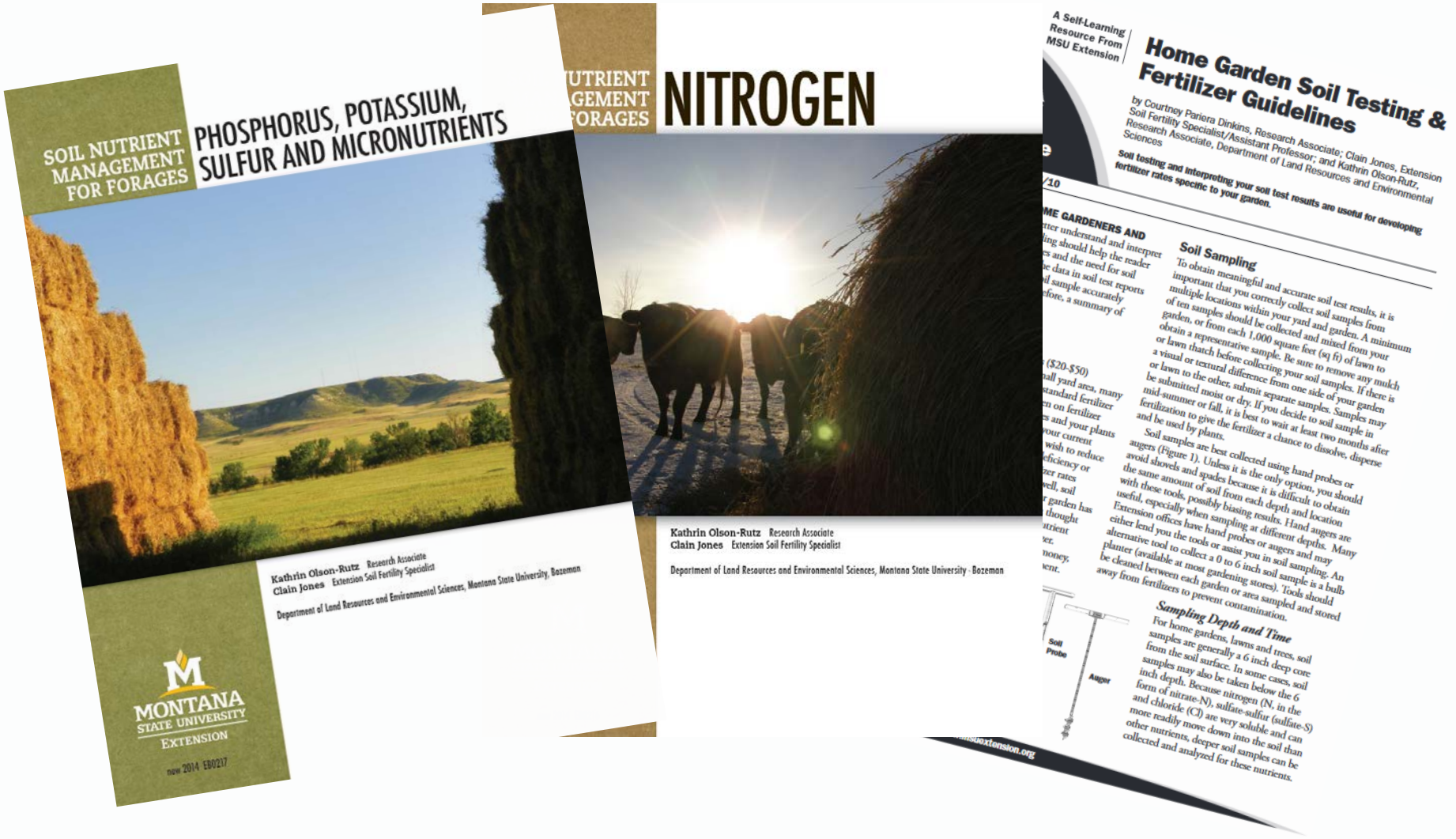
Perennial (CRP) had higher SOM than pea cover crop-wheat

Engel, in press, MSU Post Farm, 4 miles west of Bozeman

Summary

- Soil testing is critical for identifying possible issues with salt, pH, or low organic matter
- Soil testing is essential for determining fertilizer needs. “If don’t know what’s there, can’t know how much to add”
- Building soil health and organic matter takes time or a lot of manure

Pick up a copy or download these Extension Bulletins



Questions?

Photo by Kelly Gorham

Additional info at:

http://landresources.montana.edu/soilfertility/