SOIL NUTRIENT FUNDAMENTALS, COVER CROPS, and LEACHING

Golden Triangle Cropping Seminar
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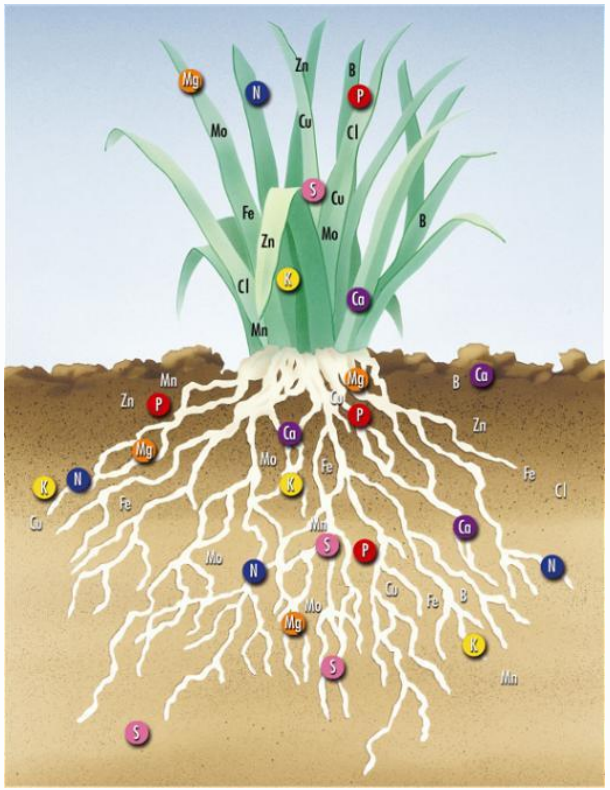
MSU Soil Fertility Extension

Objectives

- Present soil properties and how they interact with plant nutrients
- Illustrate the soil nutrient cycles of N, P, K, S and some micronutrients
- Discuss potential effect of cover crops on soil productivity
- Present management to minimize nitrate leaching

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 italic*** nutrients have been observed in Montana

Soil properties that influence nutrient availability

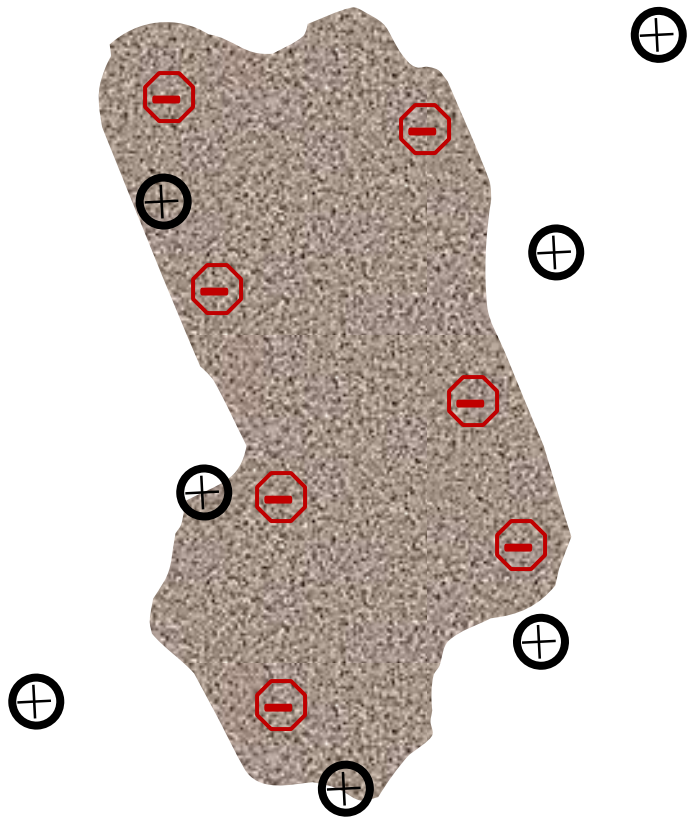
- Texture/surface area
- CEC (cation exchange capacity) and AEC (anion exchange capacity)
- SOM (soil organic matter)
- pH

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

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 SOM, have more CEC and surface area and therefore are generally more fertile.



CEC is generally >> AEC

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

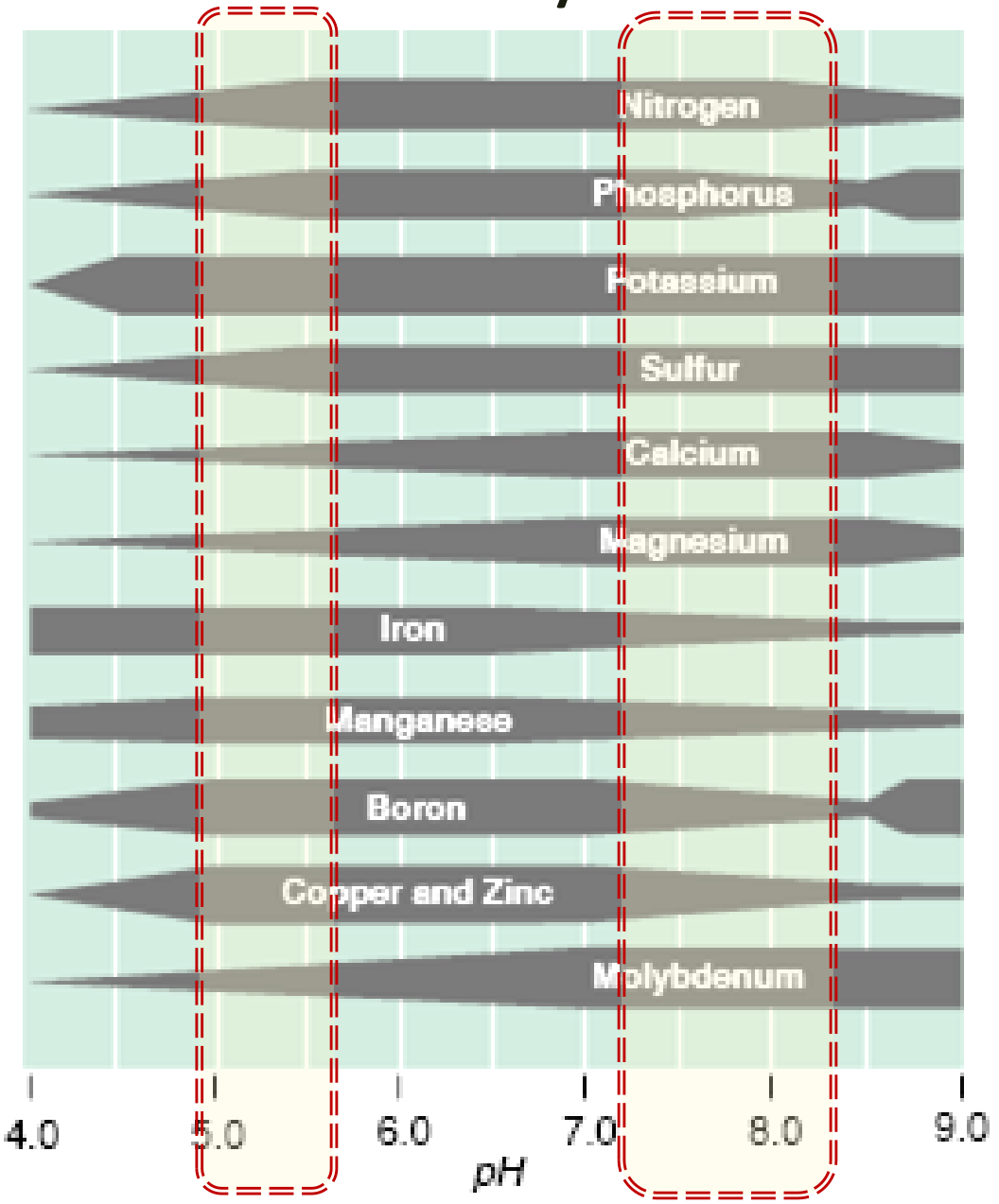
From Brady 1984

At CEC >15 soil has high capacity to hold cations such as K^+, NH_4^+

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, plants can't get them



pH summary

- Generally high in MT soils
- Can decrease with elemental sulfur, but likely not economical
- Fertilizing with ammonia-based fertilizer lowers pH over time
- If pH is low, consider liming or seed-placed lime (or tillage?). 3 pm talk will focus on low pH.
- Crops' tolerance varies with species and variety

Crop	Min pH
Alfalfa	5.7
Barley	5.3
Pea	5.5
Wheat	5.1-5.4

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)

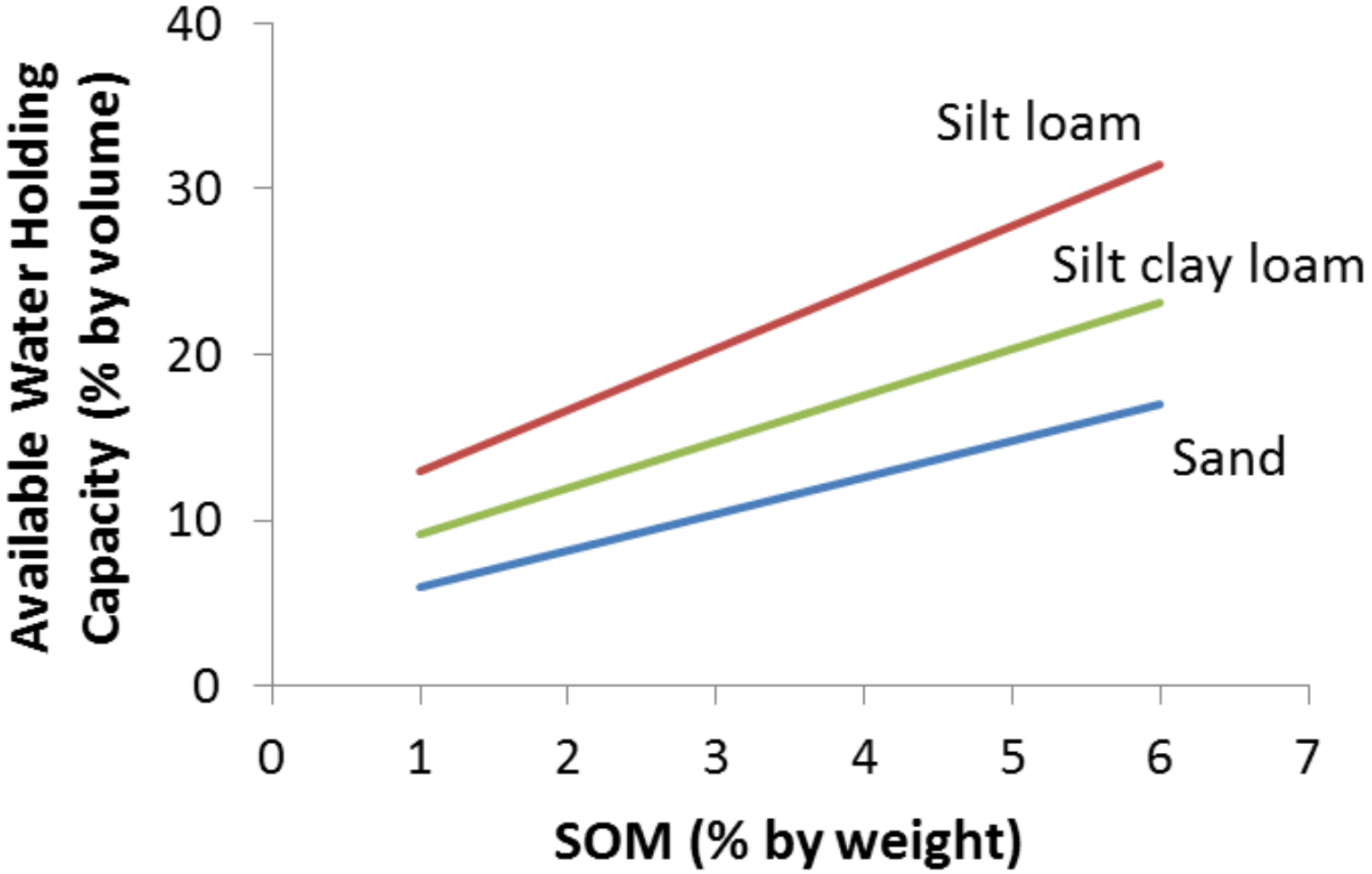
What does SOM do for soil?

- 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?

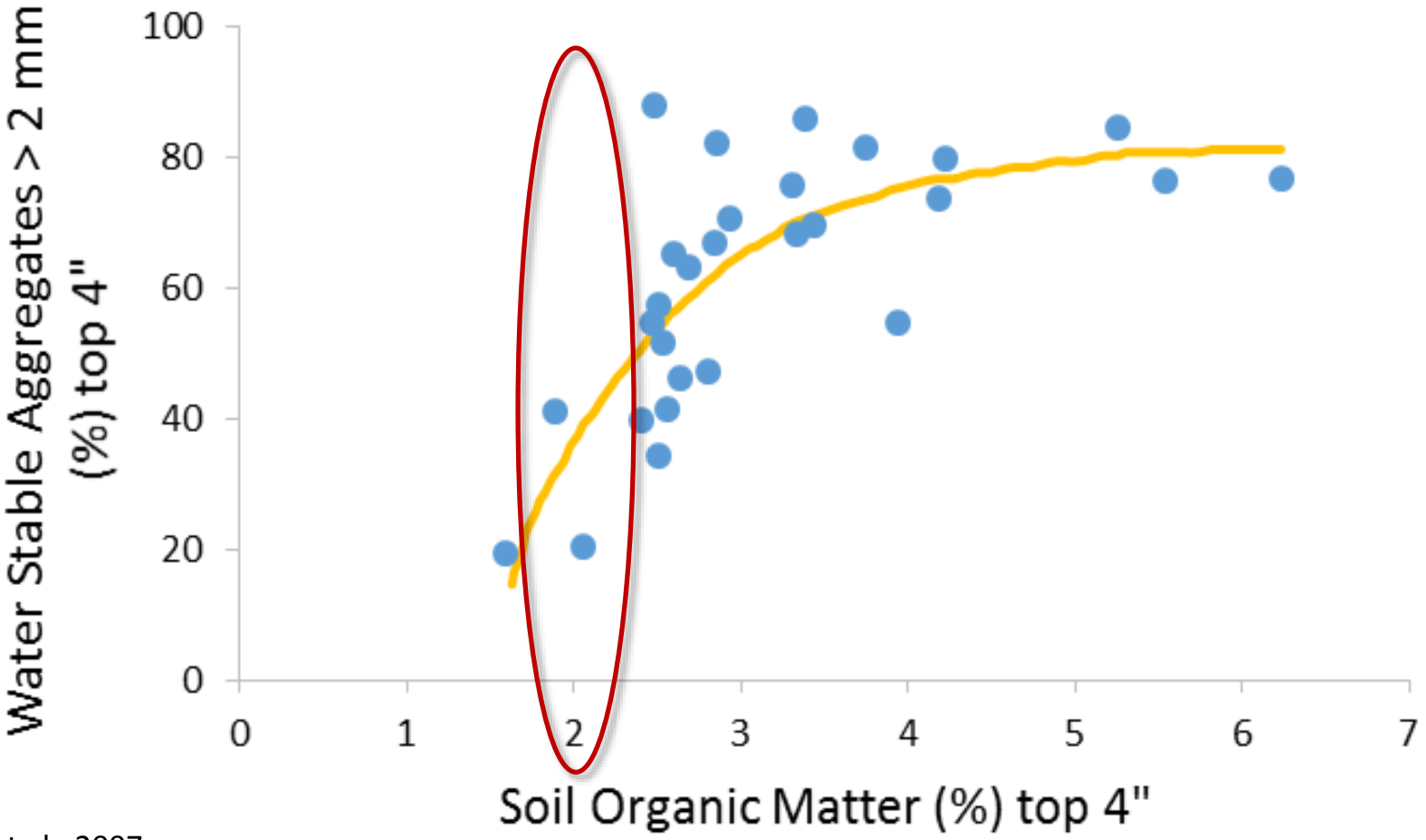
- As decomposes it releases nutrients bound in OM structure
- Holds water which helps nutrients move from soil to plant roots

SOM increases available water holding capacity



Hudson 1994

Small increases in SOM lead to potentially large improvement in soil structure.



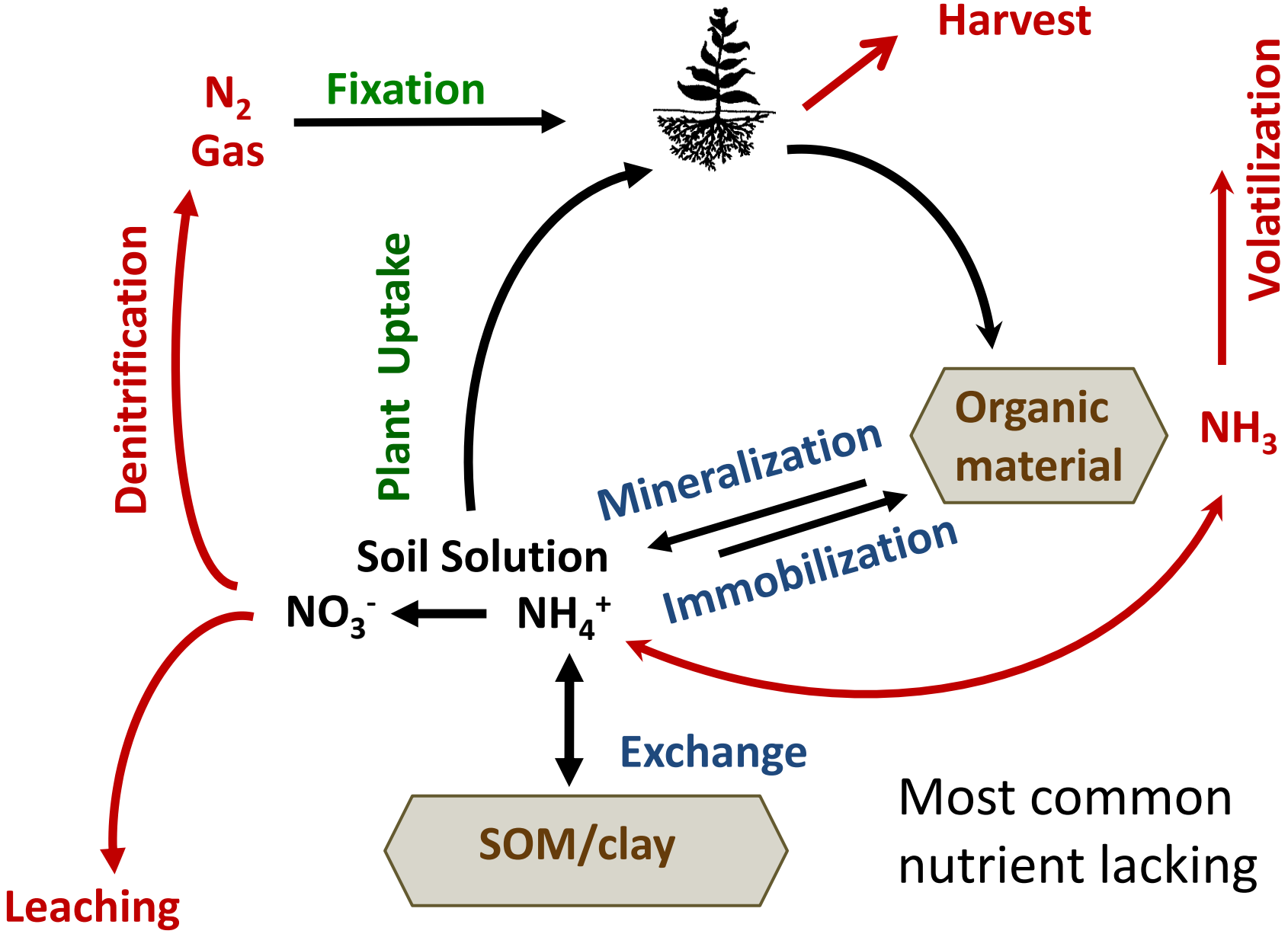
Fisher et al., 2007
Australia, irrigated, variety of soil types

Questions?

Now on to nutrient cycling

Some knowledge helps understanding of the whys of source, rate, timing and placement.

Nitrogen (N) gains and losses



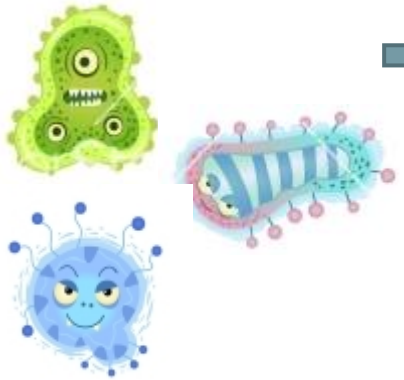
Most common nutrient lacking

Mineralization = decomposition of soil organic matter

N in soil organic matter

+

Microbes



Plant-available N

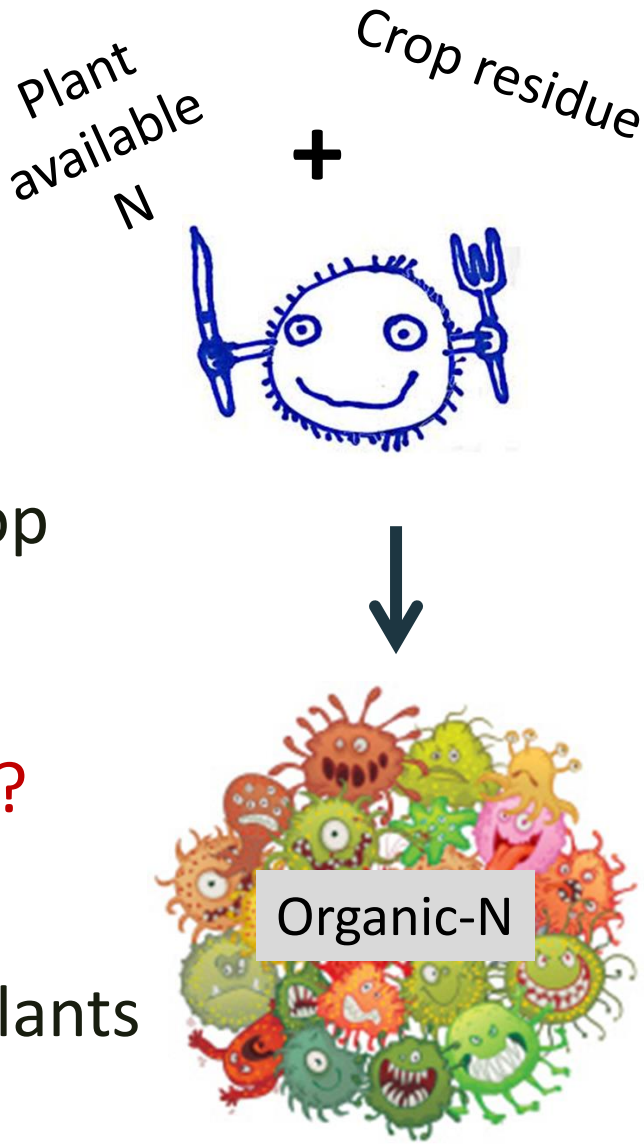
- High SOM allows reduction of fertilizer N

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



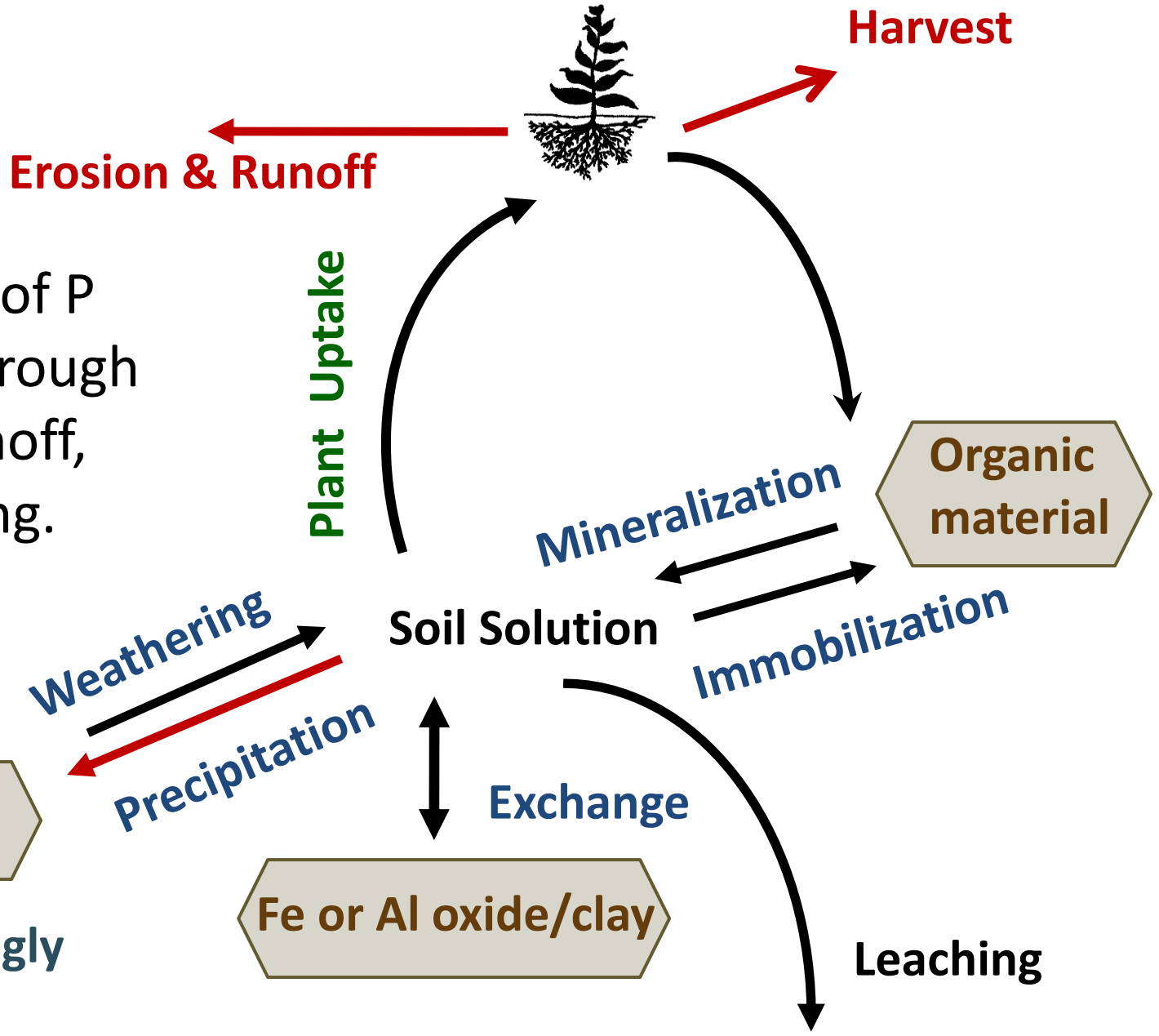
Is immobilized N lost from the system?
Yes/No?

No – just temporarily unavailable to plants

Questions on N cycle?

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

Phosphorus (P) gains and losses



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

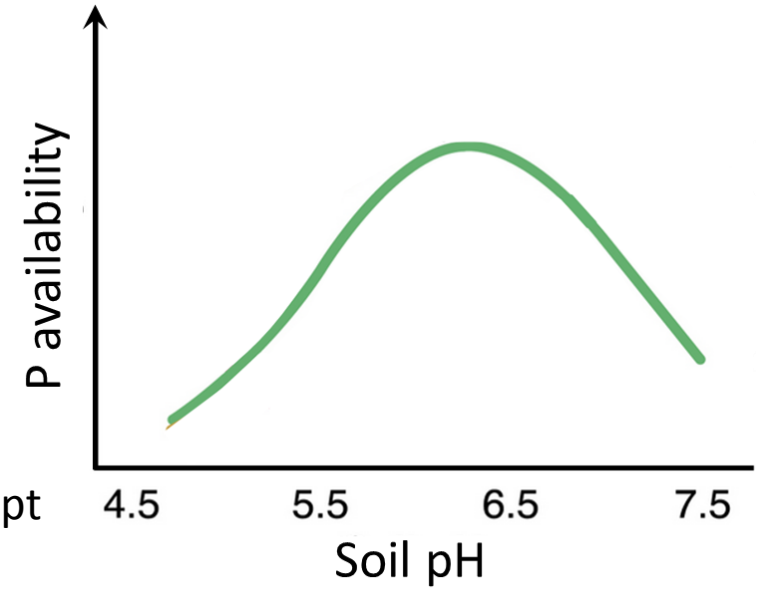
Why?

P binds strongly to soil

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

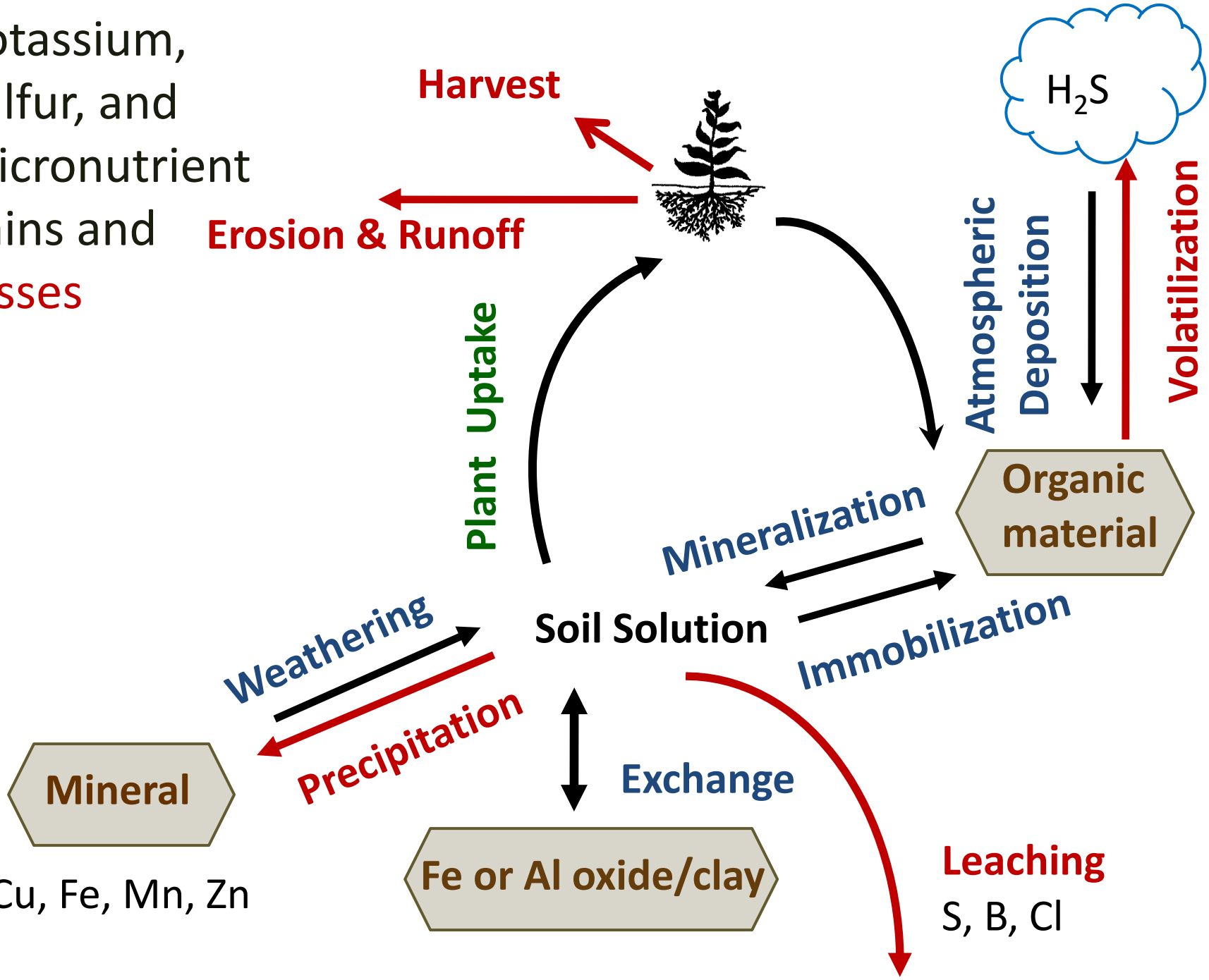
- Precipitation and low solubility of calcium phosphate minerals. This is very relevant in this region.
- Sorption (binding to minerals) and precipitation with iron and aluminum increases at low pH and is more of an issue in the Southeast U.S. (and Highwood Bench!)

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



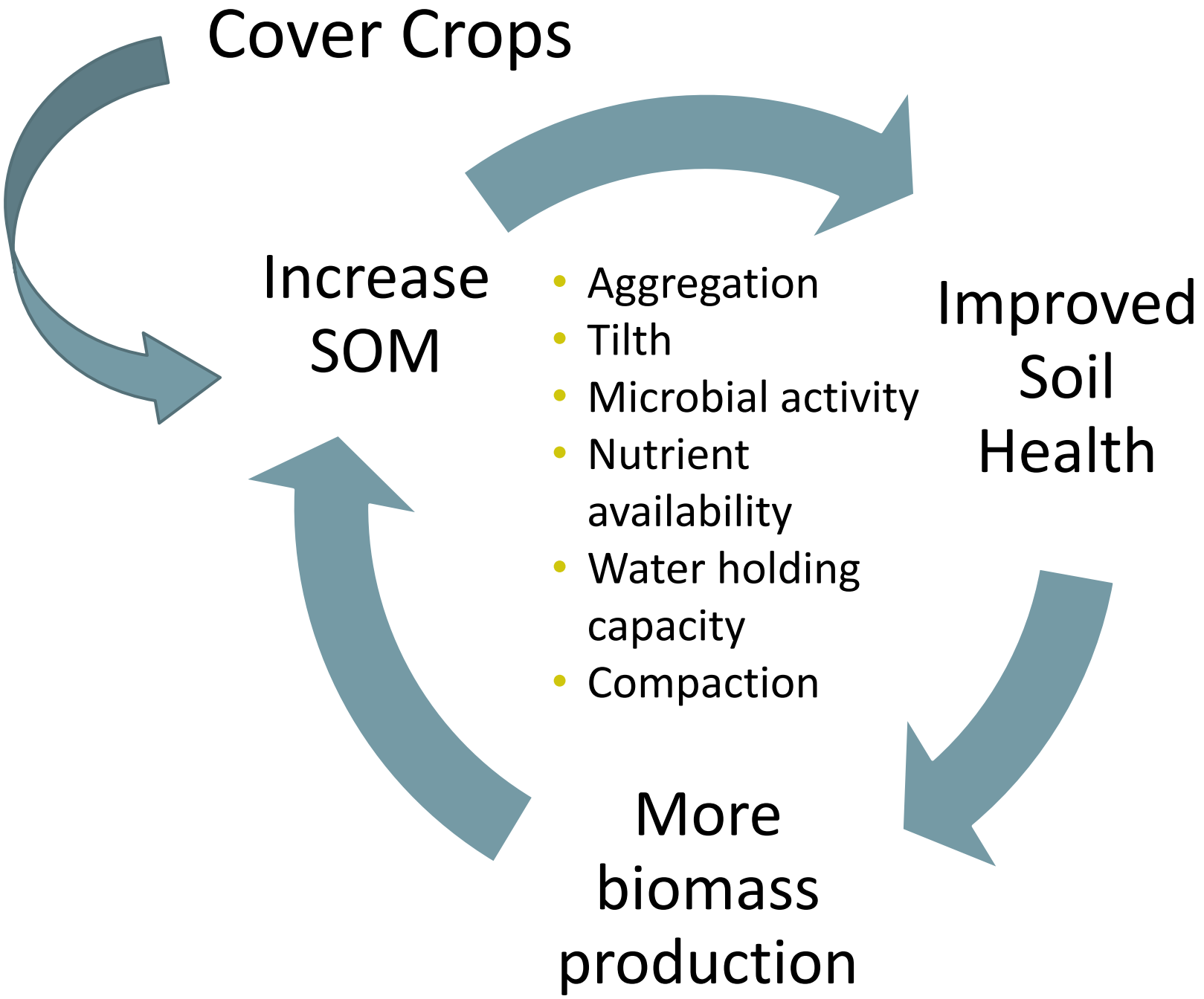
Gov. W. Australia, Dept of Ag. and Food

Potassium, sulfur, and micronutrient gains and losses



Questions?

And now for something completely different:
Cover Crops


Cover Crops
Increase SOM
Aggregation
Tilth
Microbial activity
Nutrient availability
Water holding capacity
Compaction
Improved Soil Health
More biomass production

MSU single species cover crop research since 1999 has found higher grain yields and/or protein after cover crops when:

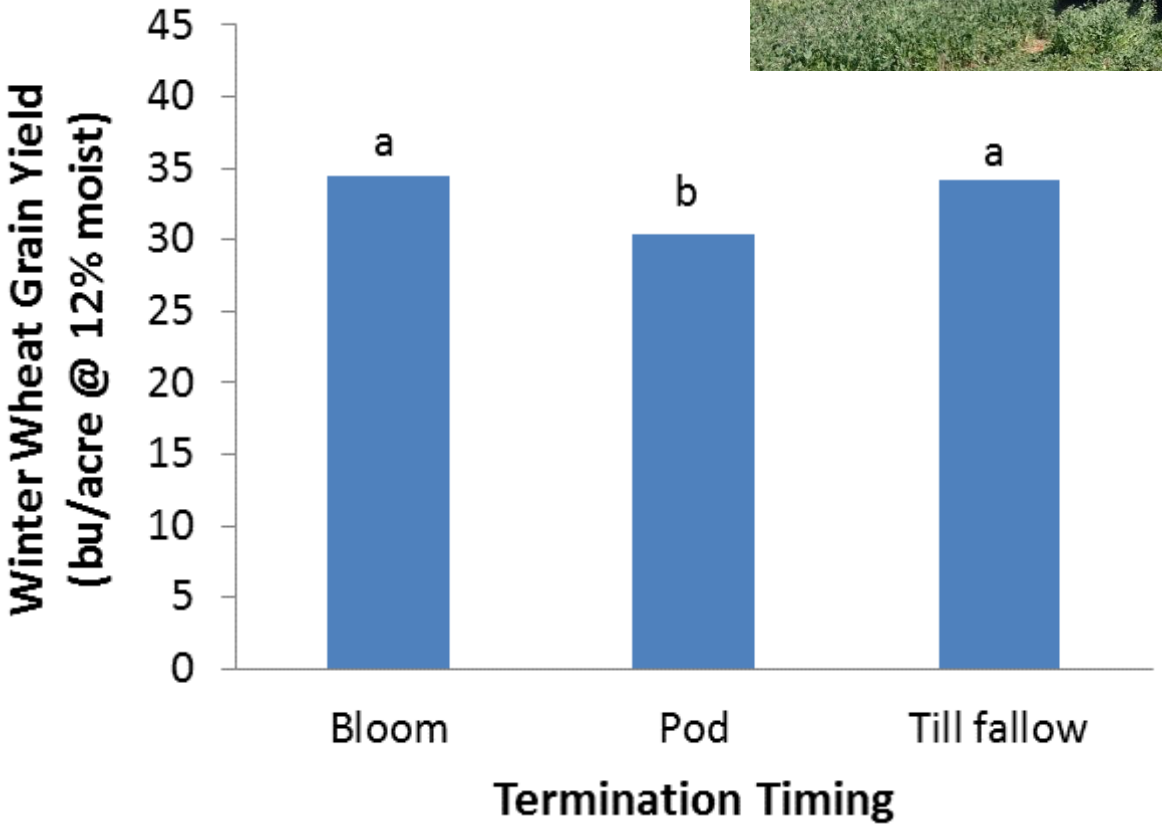
1. Seeding winter legumes (vs spring legumes)
2. Seeding spring cover crops early (vs late)
3. Terminating at first bloom (vs pod)
4. Tilling cover crop (vs spraying)

Why?

- More N fixed (1)
- More time for soil water to be recharged and N to become released from residue (1, 2, 3)
- Faster N release and fewer N losses (4)

Our MT studies confirmed early Saskatchewan studies that termination timing is key

WHY?



Terminating legume cover crop at early bloom produced higher organic wheat yields the following year than terminating at flat pod in 2006-2007

(Miller et al. 2011)

Similar results for advantage of bloom over pod in conventional systems

Cover Crop Cocktails Study

1. Compare crop and soil response to fallow, single species pea CC, and multi-species mixtures
   - Cover crop and wheat: Biomass, biomass quality, yield
   - Soil:
     - Microbial biomass
     - Soil enzyme activity
     - Soil temperature
     - Aggregate stability
     - Compaction
     - Soil water, nitrate, and Olsen P
     - Mycorrhizal colonization
     - Potentially mineralizable nitrogen
2. Determine the specific effects of 4 plant functional groups
3. 2 sites in Triangle, 2 in Gallatin Valley

Plant functional groups – planted individually and in groups

Nitrogen Fixers

Spring Pea
Common Vetch
Lentil

→ *Increase nitrogen*

→ *Add soil carbon*

Fibrous Root

Oats
Italian ryegrass
Proso millet

→ *Reduce compaction, move nutrients upward*

→ *Potential disease control*

Tap Root

Purple top turnip
Safflower

Brassica

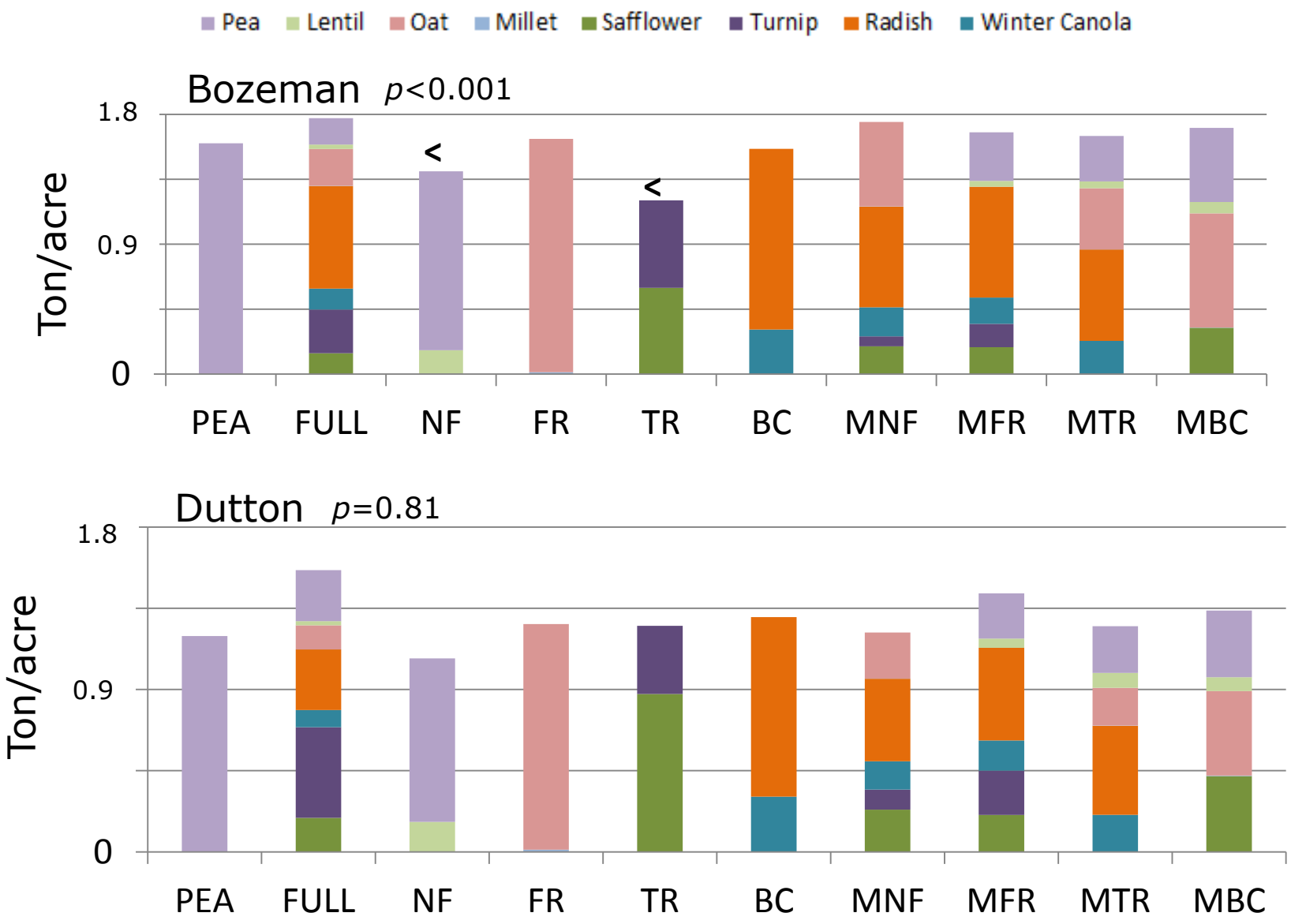
Daikon radish
Winter canola
Camelina

Lessons learned about plantings

Photo: Susan Tallman

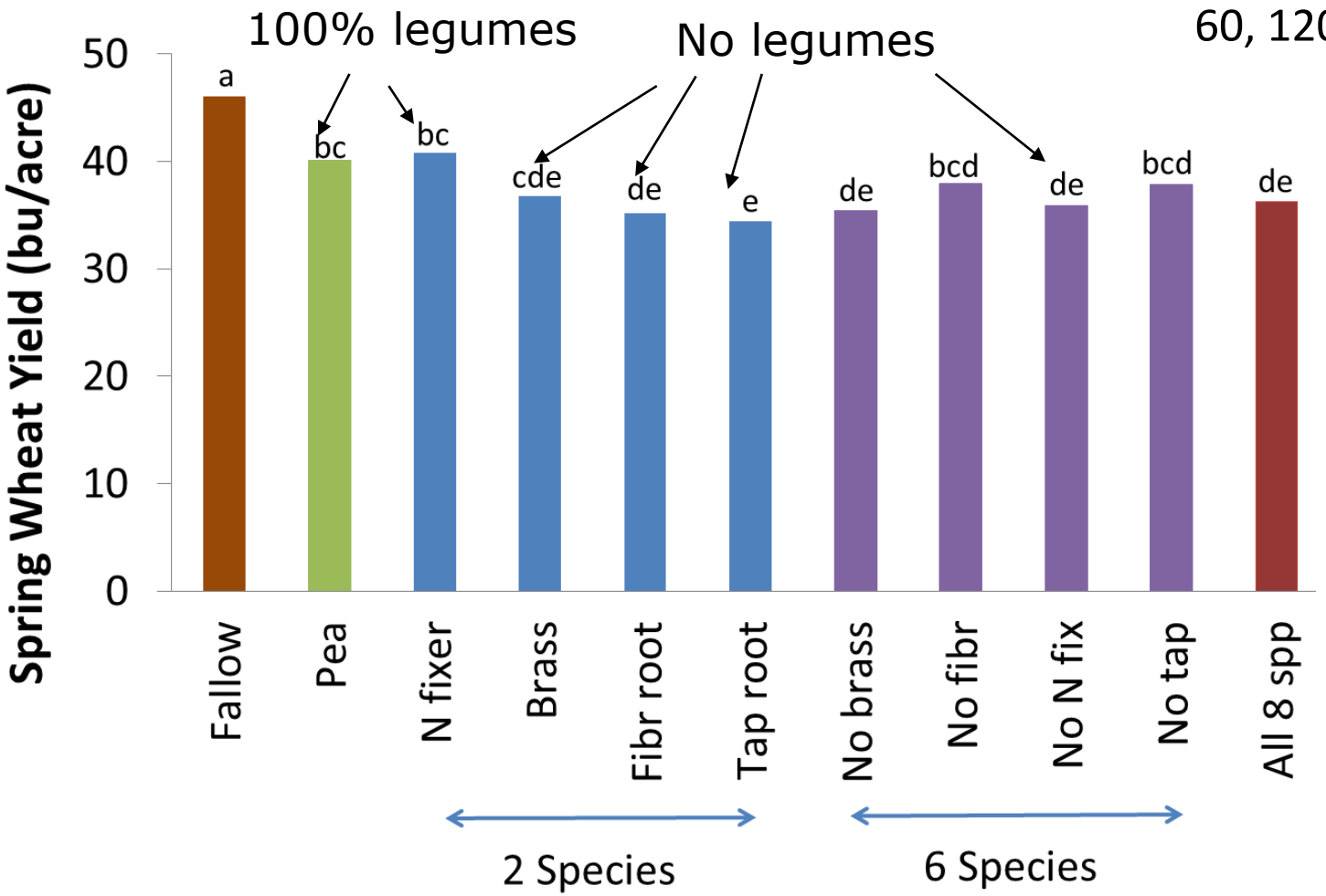
- Early weed control essential
- Common vetch difficult to terminate w/ glyphosate
- Camelina, Italian ryegrass, and lentil not competitive
- Radish bolts in late spring
- Millet not competitive in mid-spring mix
- Possible biological control benefits of wheat-stem sawfly with oat and radish

2013 Cover Crop Biomass – wet year



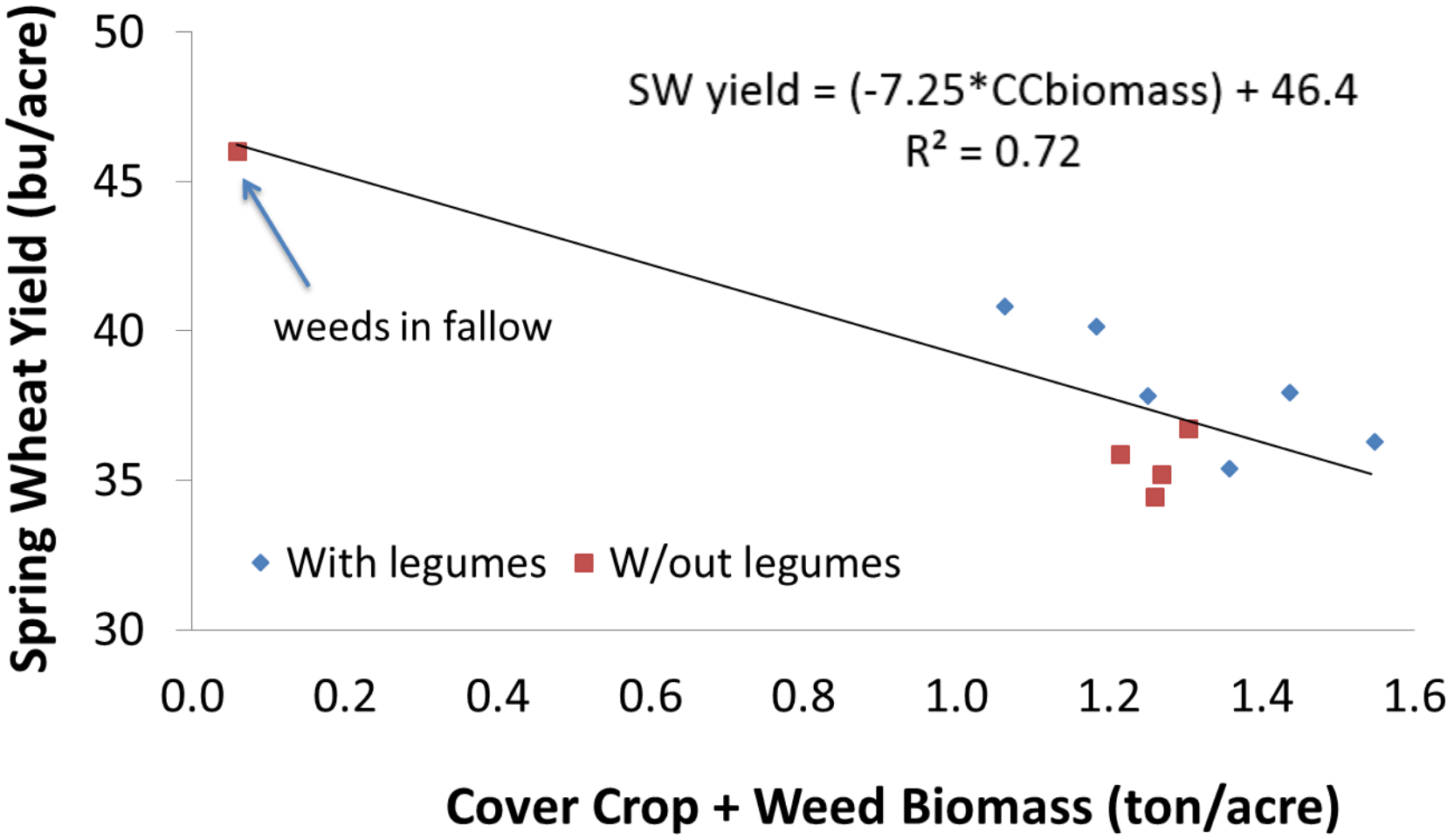
Effect of cover crop treatment on spring wheat grain yield at Dutton (2014)

Averaged over 0, 60, 120 lb N/acre



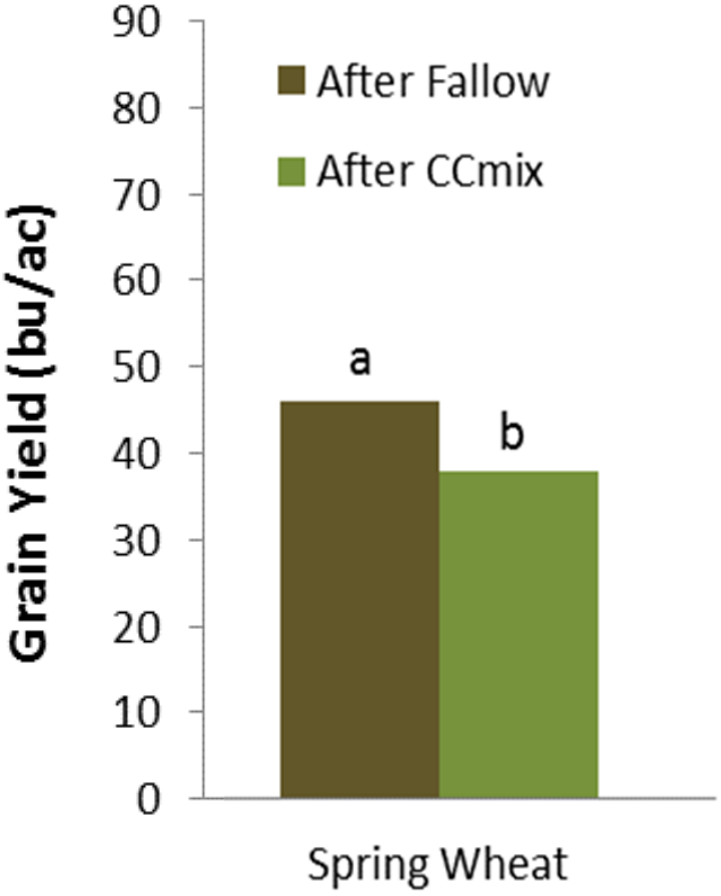
Housman et al., unpub. data, Dutton

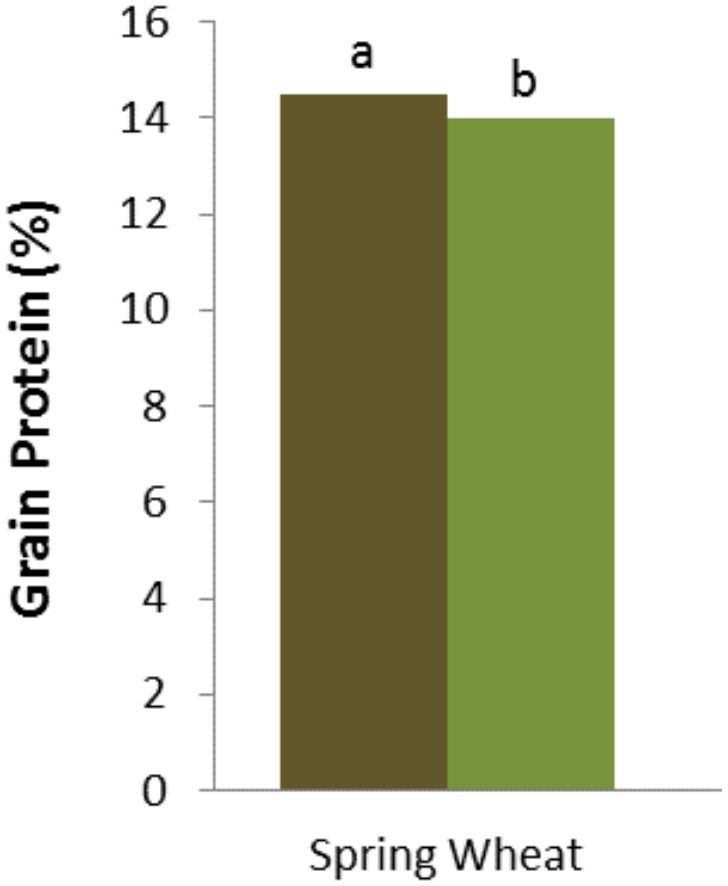
Spring wheat yield vs previous year total biomass (cc + weed)



Housman, Tallman, et al.,
unpub data, Dutton

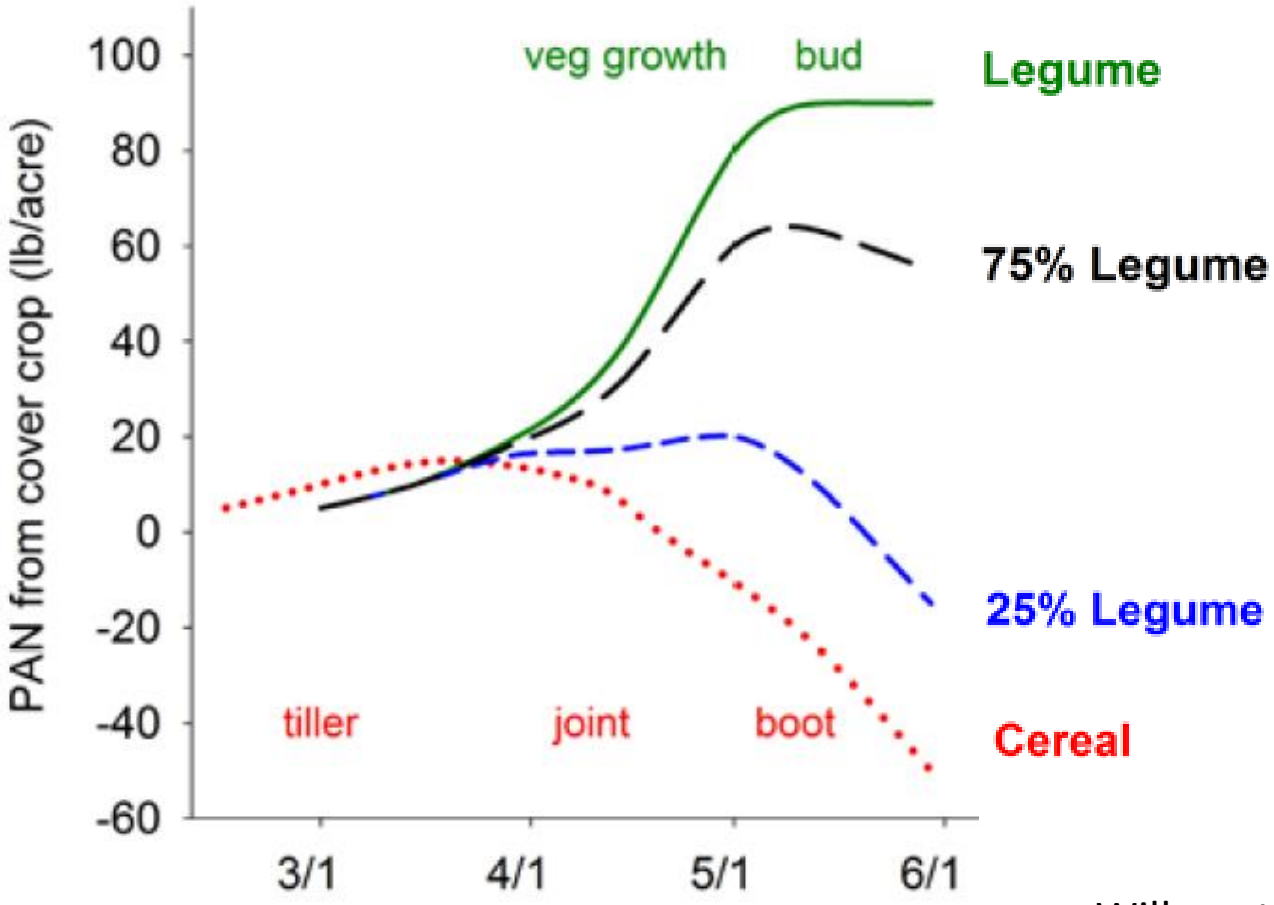
Cover Crop Cocktail Farm Study: Spring wheat grain yield and protein lower after mixed CC, Golden Triangle





Same pattern with barley.

Less than 50% legume can result in low available N, especially if terminated late

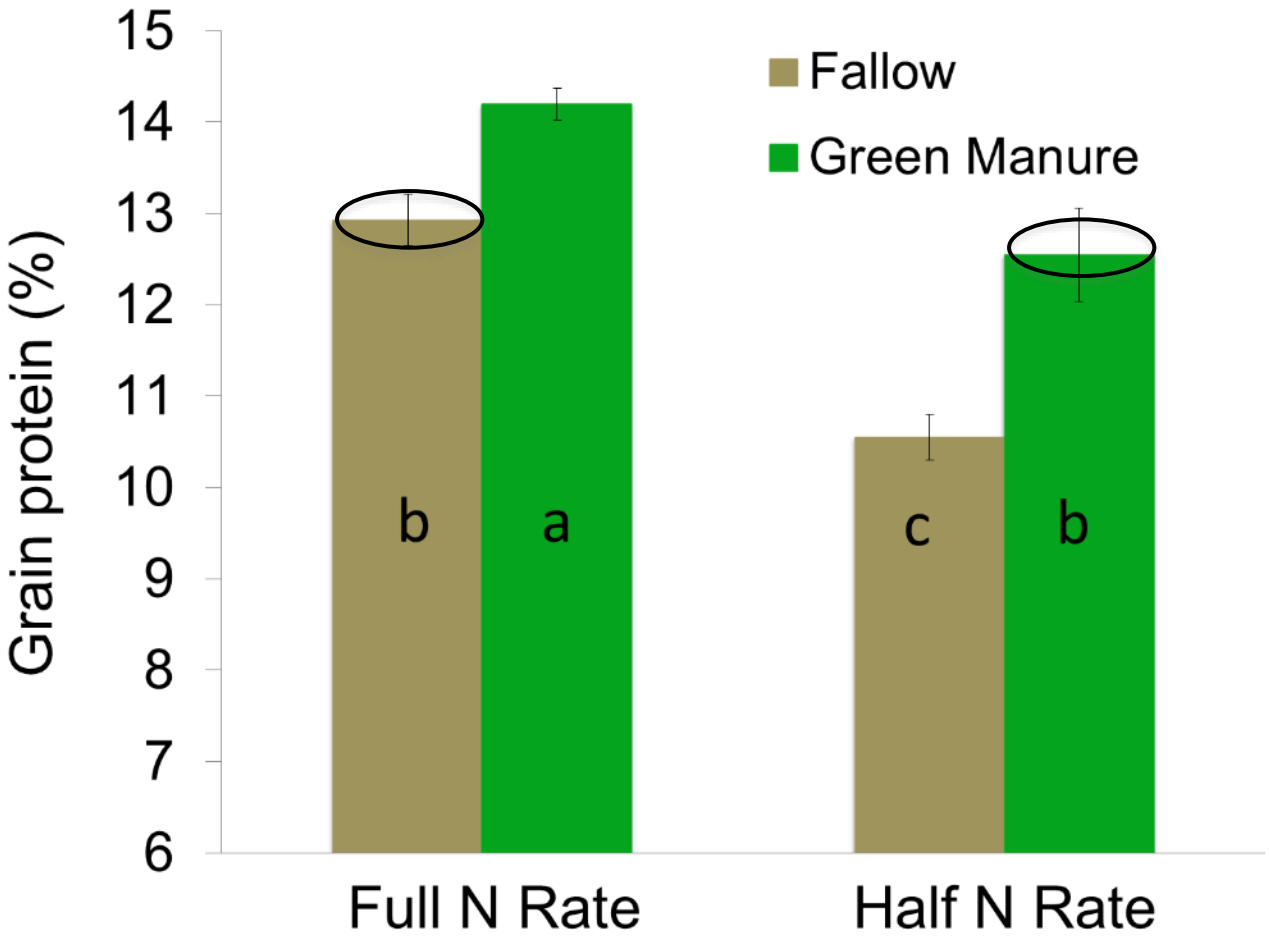


Willamette Valley, Oregon
Sullivan and Andrews, 2012

Cover Crop Cocktails Farm Study: Take home messages on yield and protein

- Spring wheat grain yield was lower after CC than fallow in four of six field-scale studies, protein results were varied.
- High water use from late termination was likely cause of yield differences.
- Low N availability from late termination & low legume % was likely cause of protein differences.

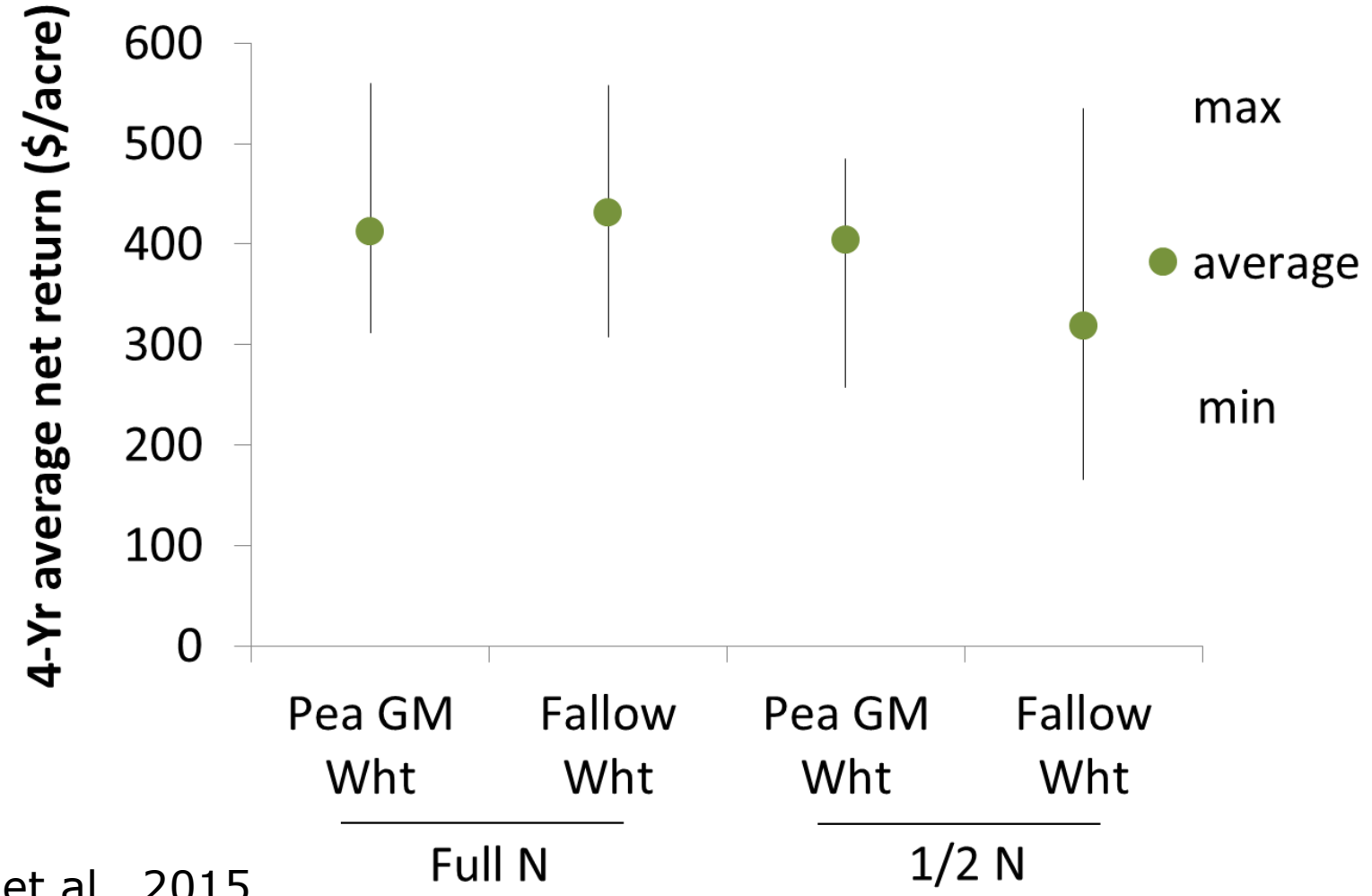
8 Year Plot Study:
Grain protein in 8th year



* N fertilizer rates	*Fallow-Wheat*	*LGM-Wheat*
Full N rate (lbs/ac)	124.00	83.00
Half N rate (lbs/ac)	39.00	0.00

Pea cover crop after 4 CC-wheat rotations saved **124 lb N/ac** compared to fallow.

After 4 rotations pea GM provides same net return as fallow, with less N



Miller et al., 2015

Questions?

Now on to *nitrate leaching*

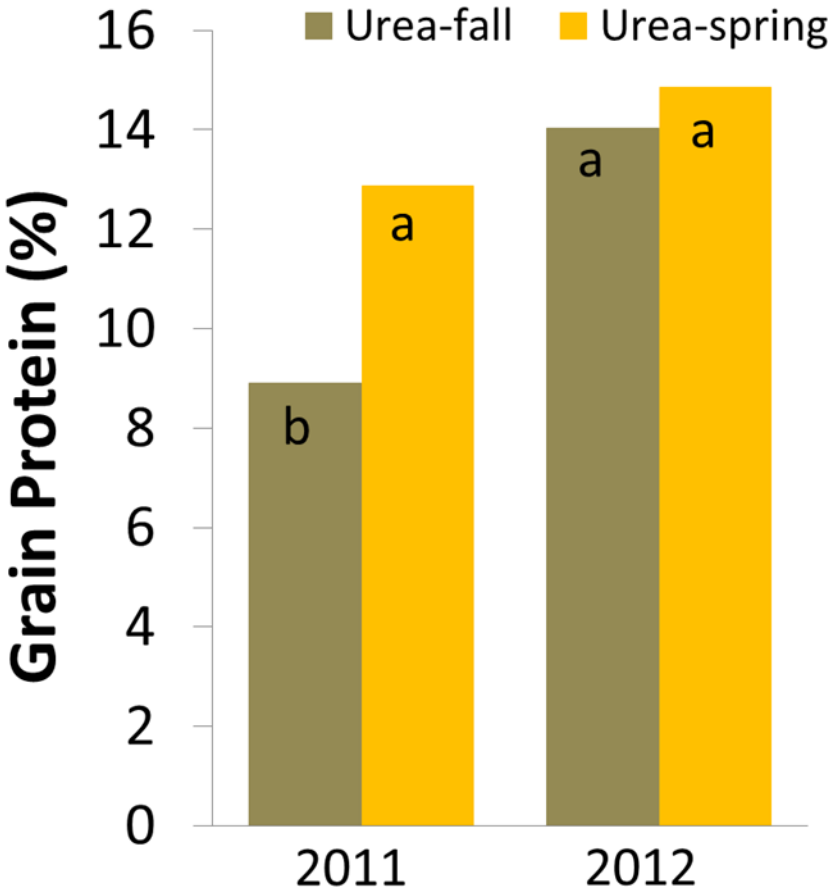
Crop management factors to decrease leaching of N (and pesticides)

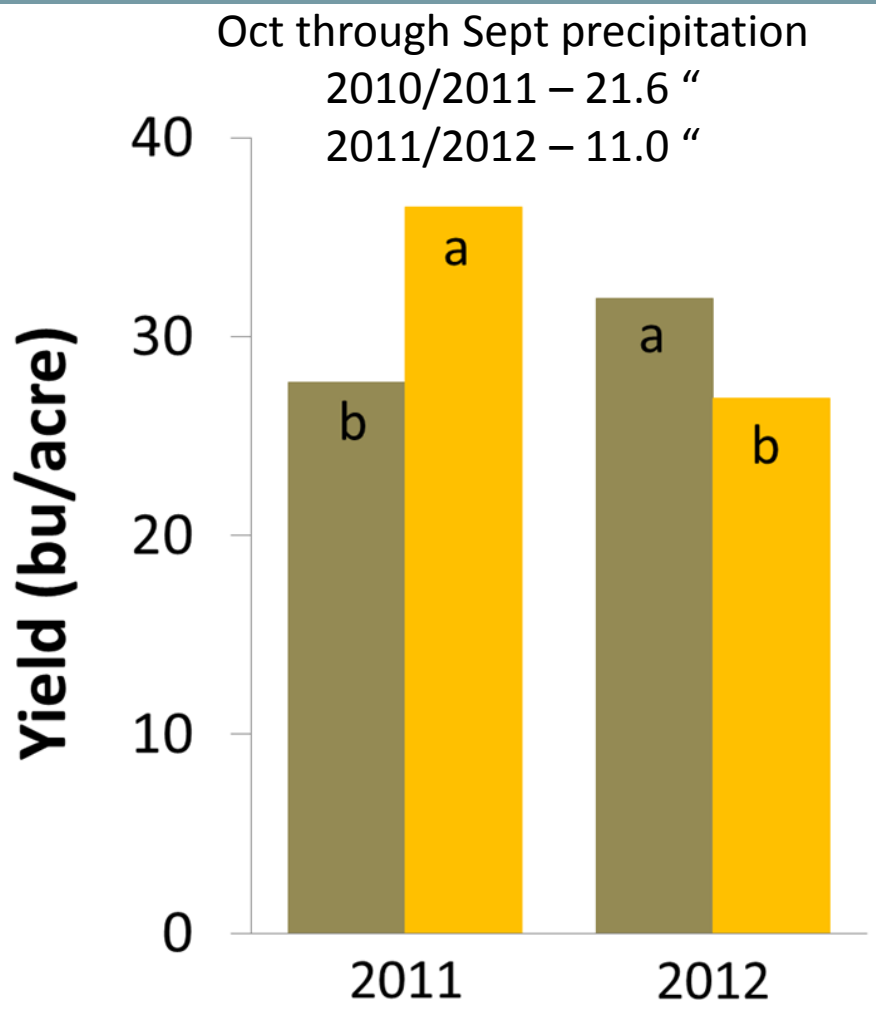
- Carefully manage irrigation, especially on coarse soils
- Consider sprinkler instead of flood irrigation
- Recrop rather than fallow
- Reduce tillage
- Include perennial and/or deep rooted crops
- Consider legumes since don’t need to fertilize w/ N

N management factors to decrease N leaching

- Apply N based on spring soil test ESPECIALLY if have > 50 lb N/acre in fall AND soils less than 2 ft deep
- Split N application to match plant needs
- Consider applying less N in areas that yield less or have shallow soils (variable rate application)
- Use an enhanced efficiency fertilizer?
- Apply N in spring rather than fall especially on shallow soils

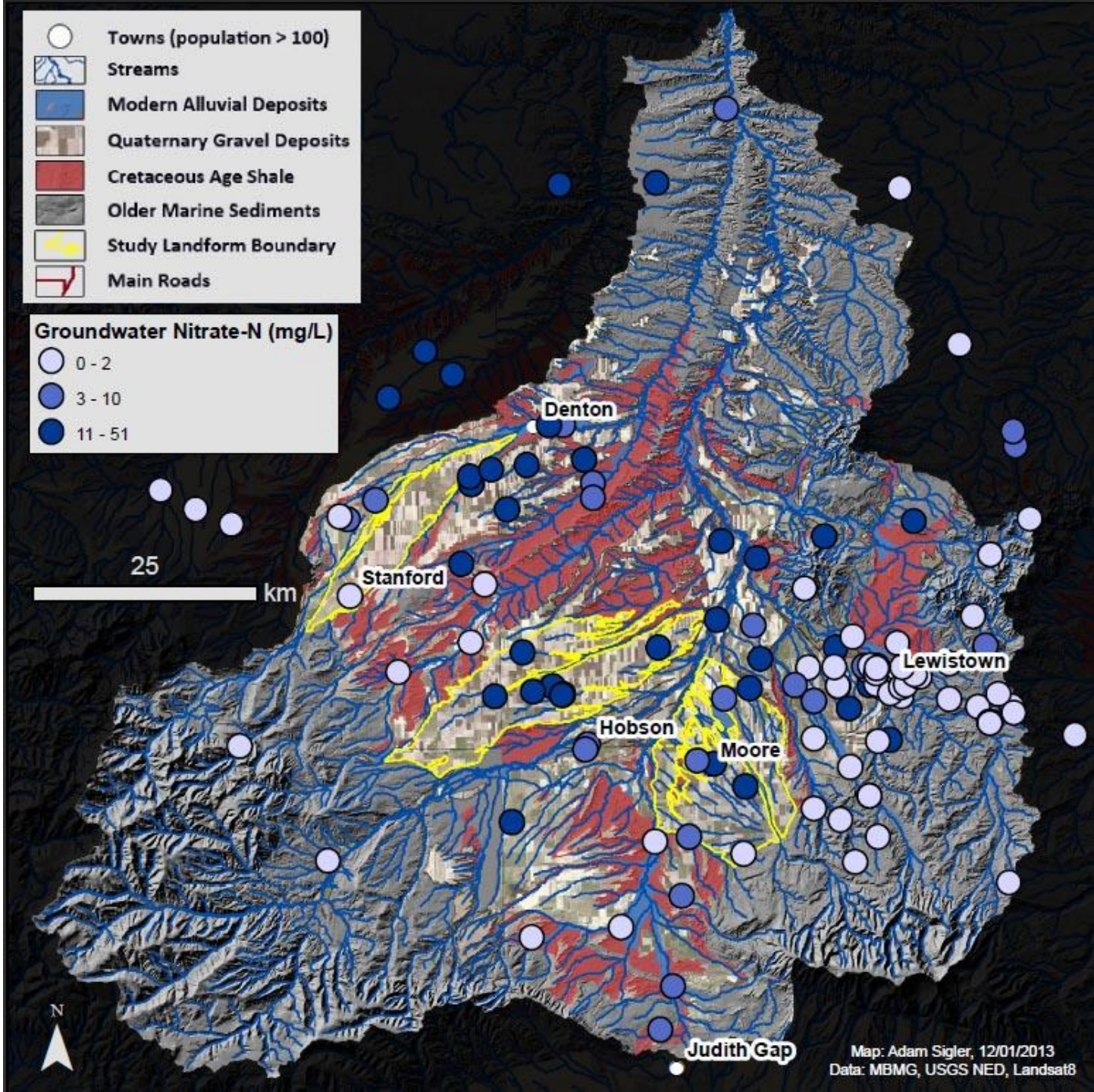
Effect of N application timing on winter wheat grain protein and yield





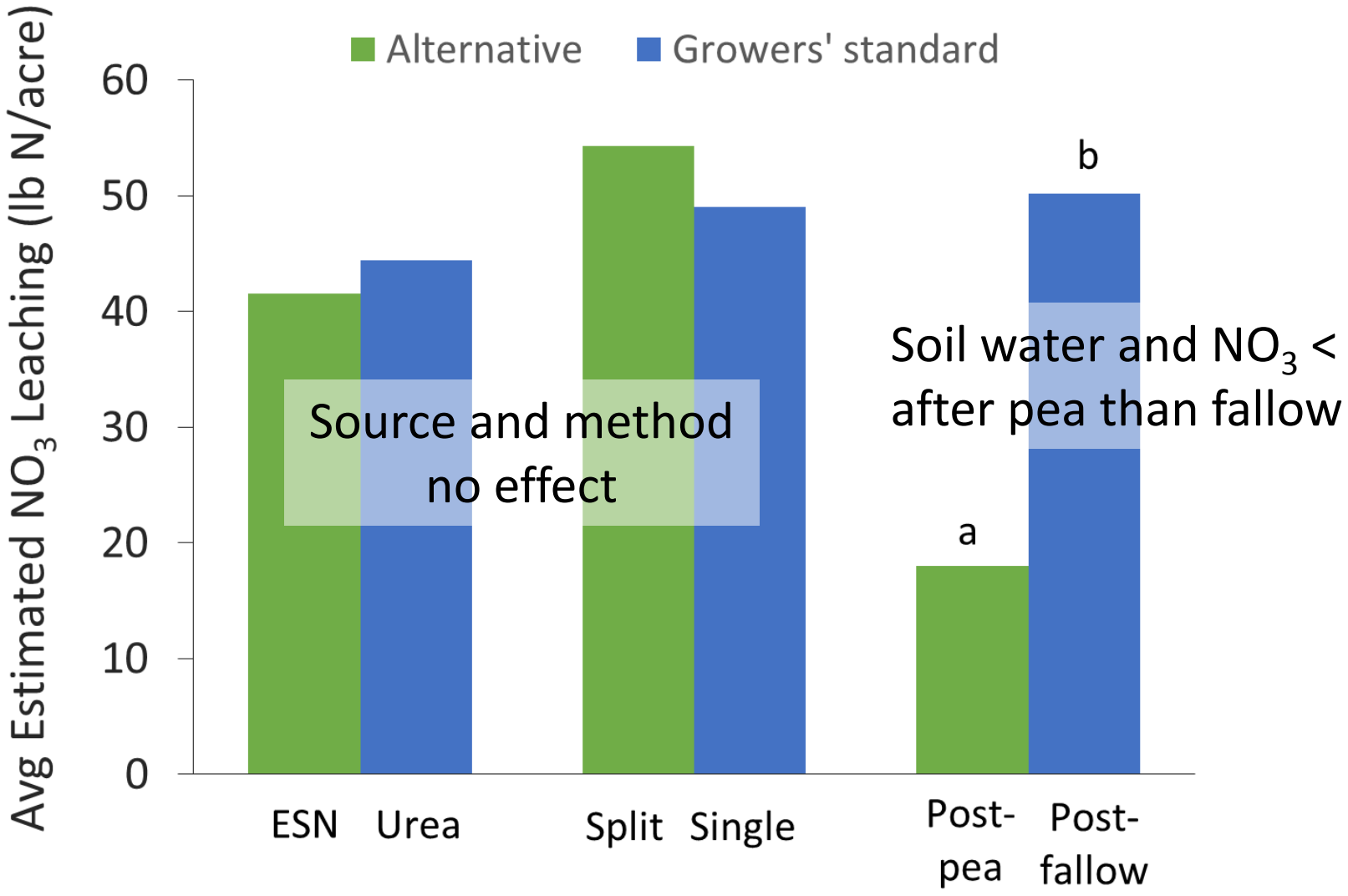
Fertilizer Fact 62, Moccasin, MT

Sources of Nitrate in Ground water?

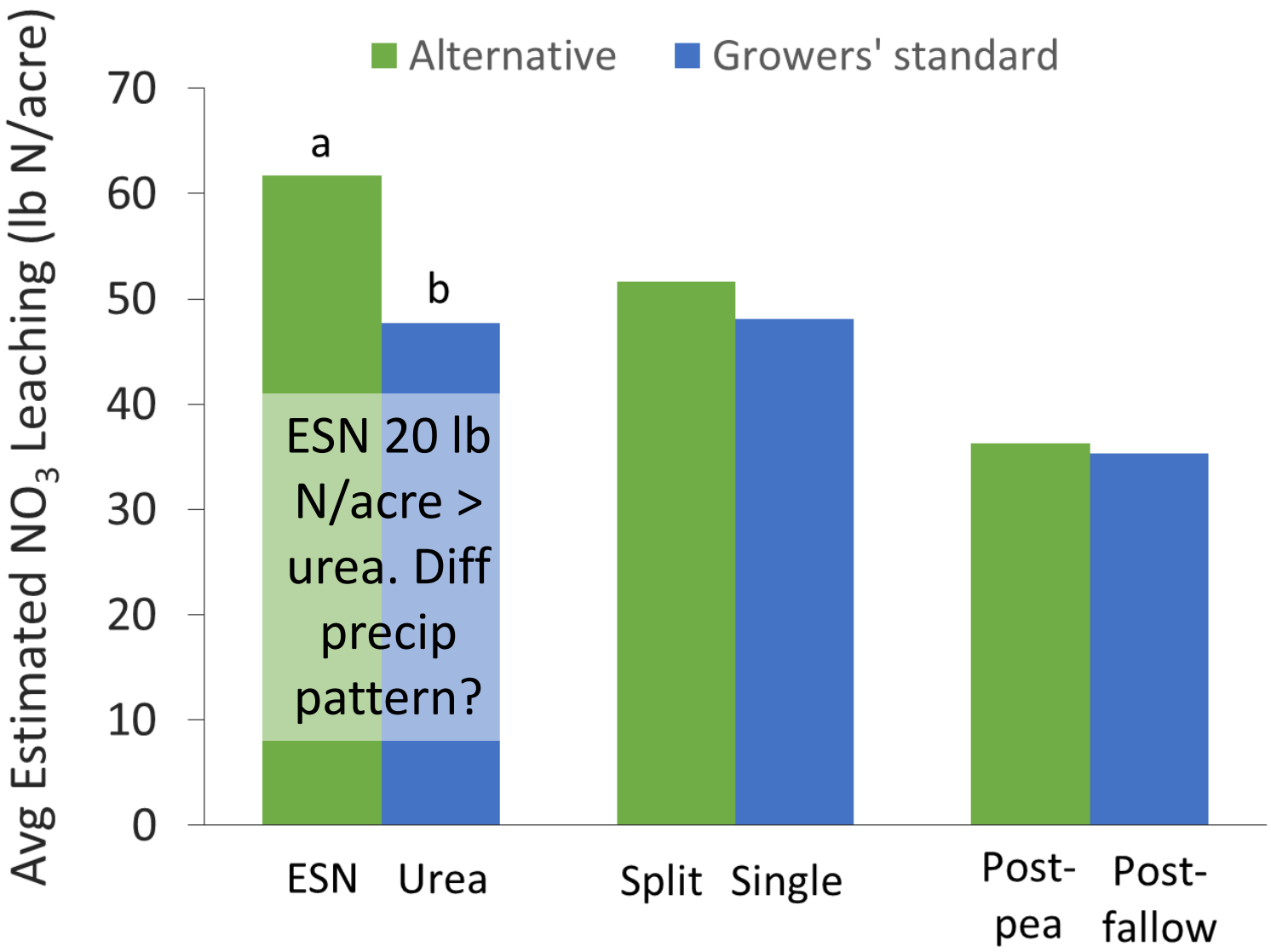


Adam Sigler presents a section on nitrate leaching – contact Adam at asigler@montana.edu for his slides

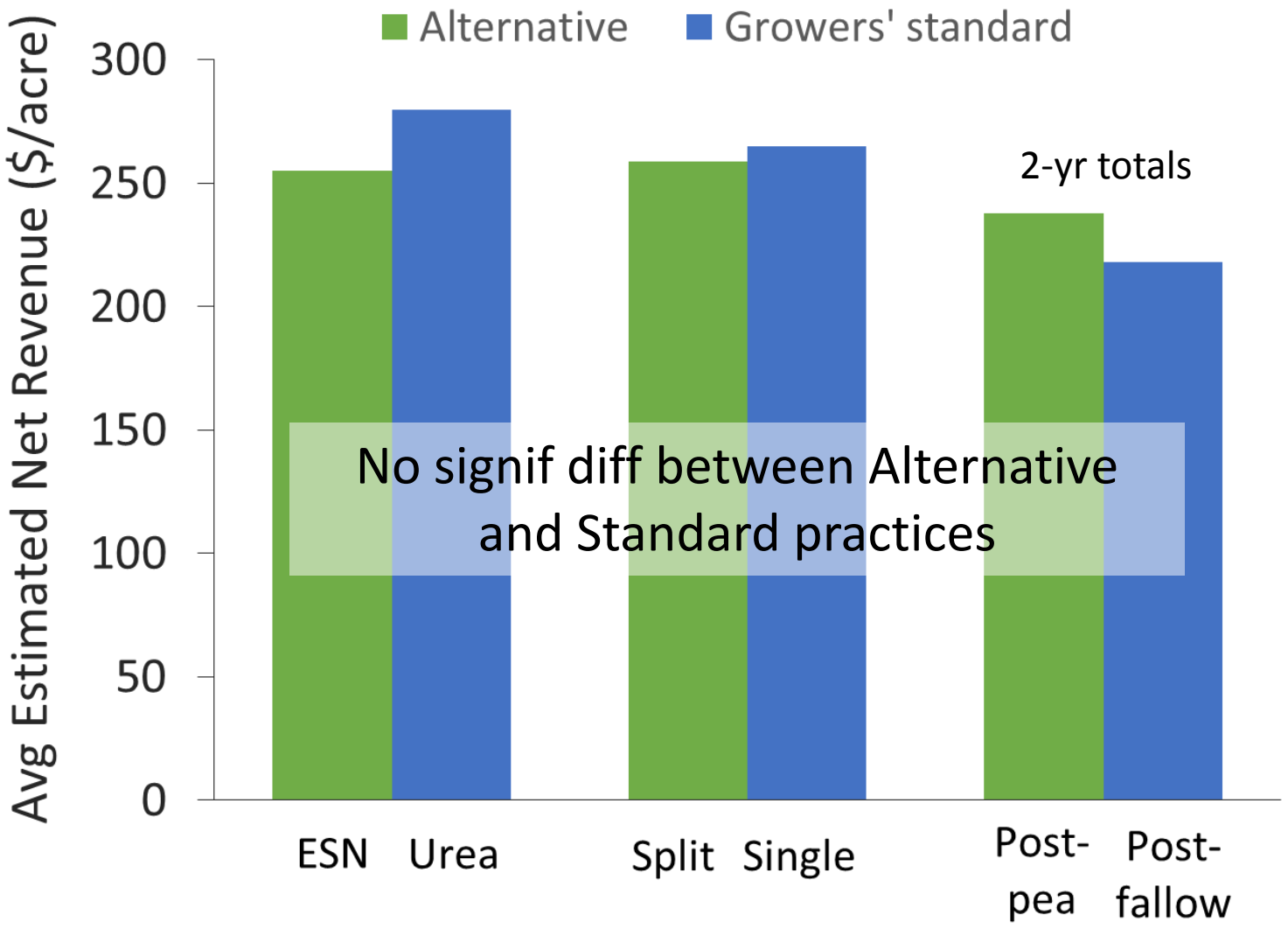
Estimated nitrate leaching Aug 2012 to Aug 2013 under winter wheat



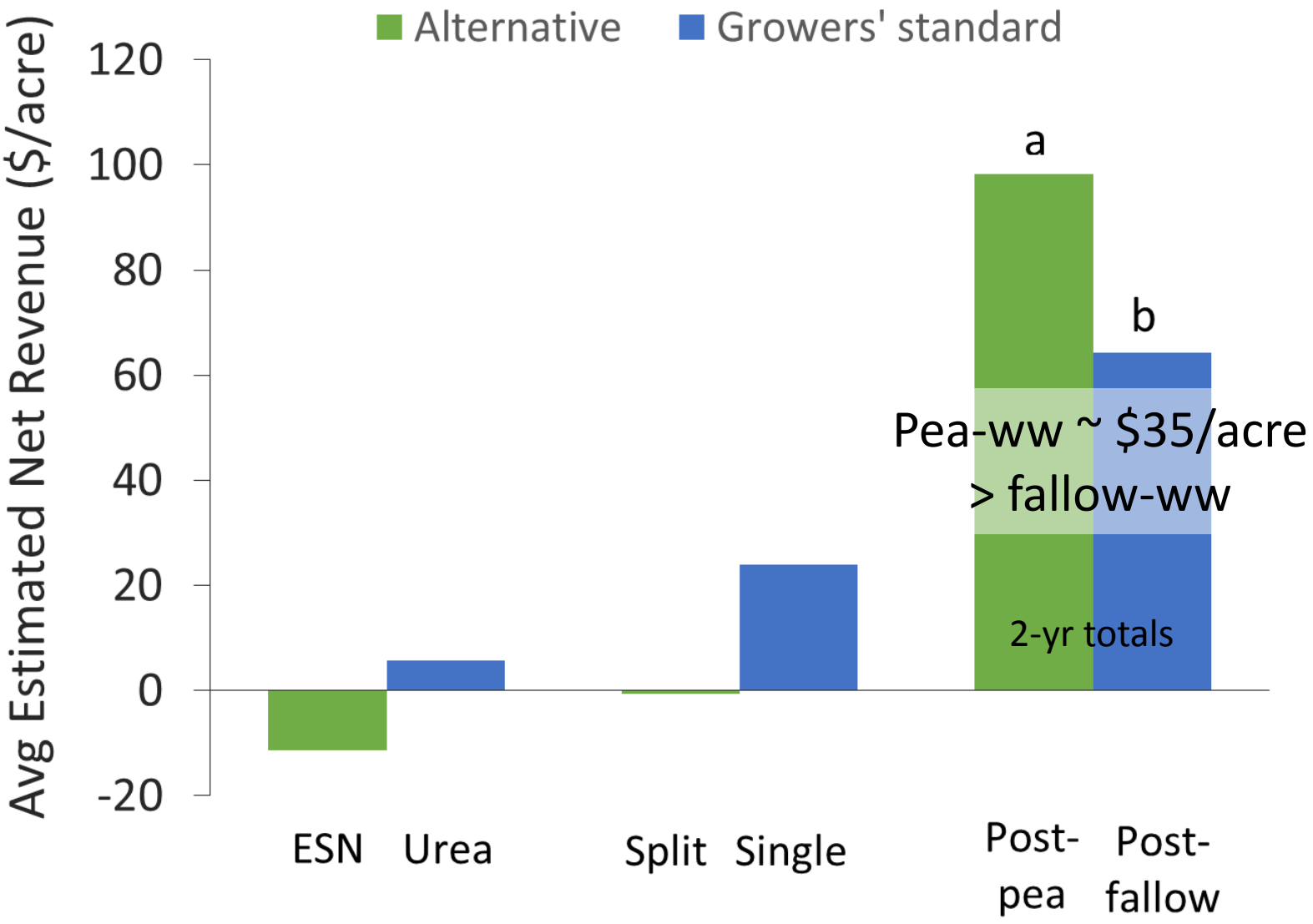
Estimated nitrate leaching in Aug 2013 -Aug 2014 crop year



2013 Net Revenue (w/out NRCS payments)



2014 Net Revenue (w/out NRCS payments)



Summary

- Nutrients need to be in the right form to be plant available
- Soil characteristics influence nutrient availability and most cannot readily be changed by management
- Soil organic matter is one that can be changed and has large impact on soil nutrient availability
- Crop rotation and fertilizer source and timing can help reduce leaching loss

Questions?

For more information see MSU Extension's

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

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

Crop & Fertilizer Management Practices to Minimize Nitrate Leaching
http://landresources.montana.edu/soilfertility/publications.html

Cover Crop Research
http://landresources.montana.edu/soilfertility/covercrops.html

Judith River Watershed Project
http://waterquality.montana.edu/judith/index.html