MONTANA STATE UNIVERSITY | EXTENSION

The Roots of Soil Health

Benefits of Perennials and Recrop

Montana Organic Assoc. Dec 10, 2025

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Extension soil fertility specialist

Today's objectives

- Discuss effects of integrating perennials into an annual system (mostly good)
- Illustrate importance of crop residue on soil health
- Show effects of recrop and perennials on soil health and wheat yield/protein

Keep in mind that you know your soil, your management, your goals, and what I share might not apply to your farm or environment– let me know if that's the case and why!

A little about You

Raise your hand if you grow

- Only annuals
- Only perennials
- Both
- Own livestock

Pros and cons of perennials and deep roots

Image from Landinstitute.org

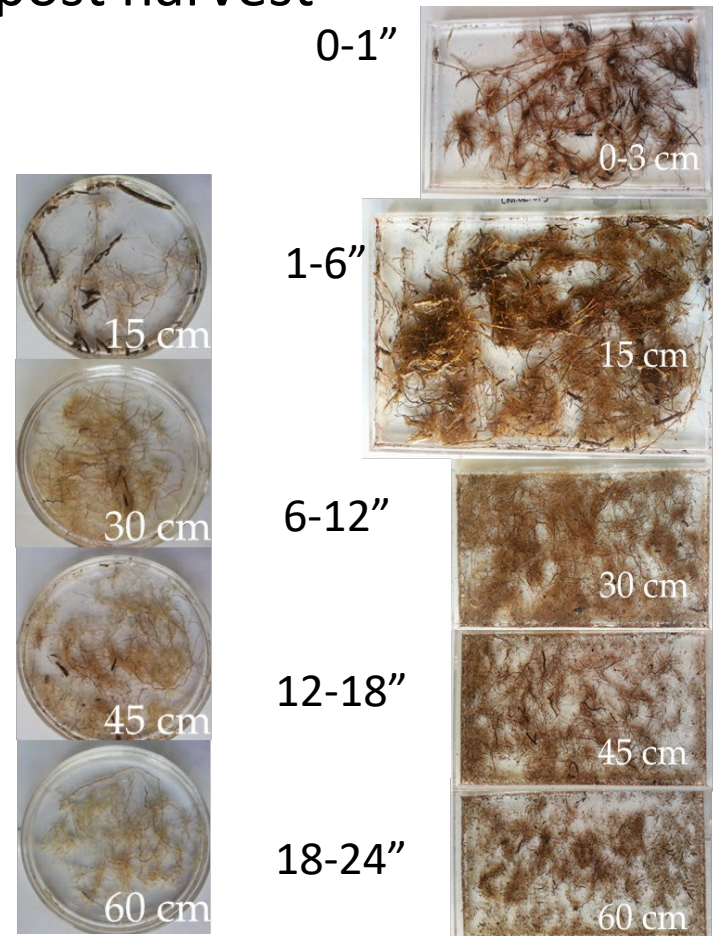
+ Far more roots
+ Root residue improves soil health
+ Root-derived SOM stays in soil 2.4-fold longer than shoot-derived SOM (Rasse et al. 2005)
+ Perennials prevent nitrate leaching

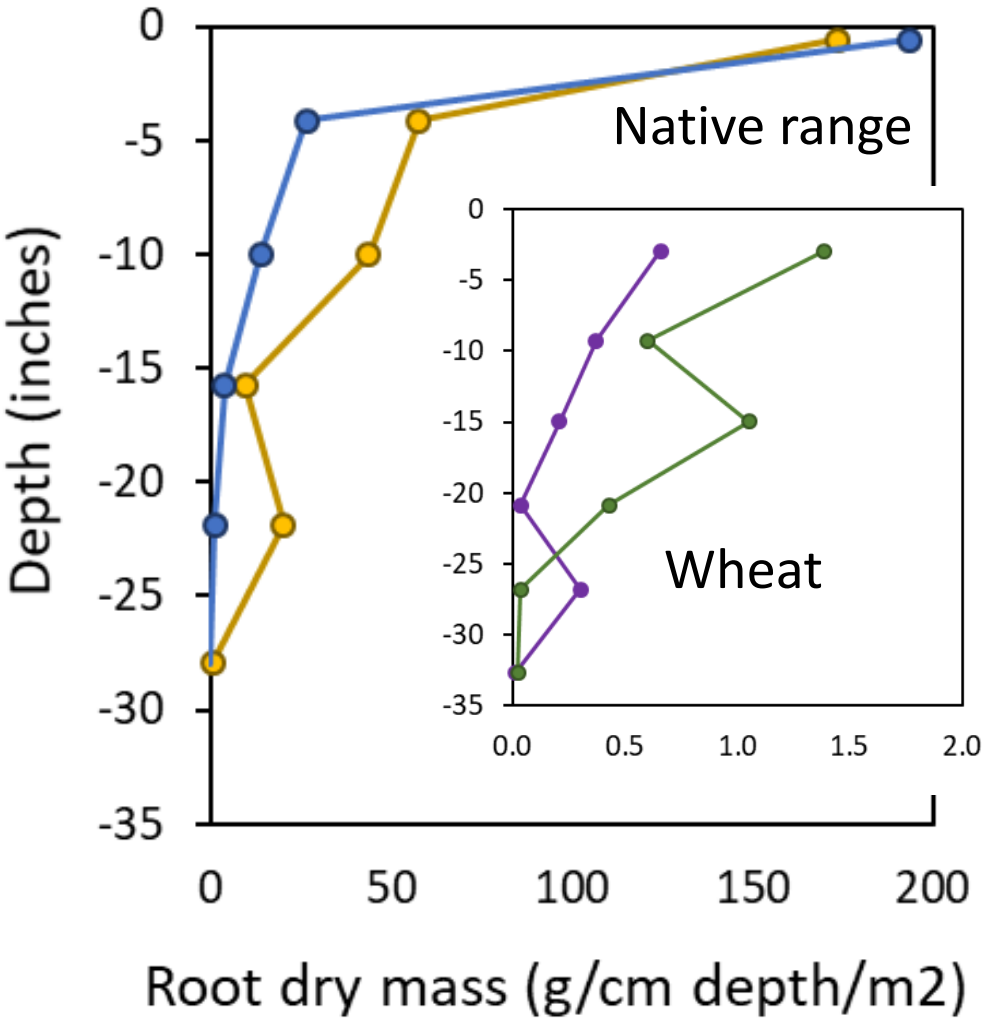
- Perennials use more water, impacting yield (Miller et al. 2019)
- Alfalfa harvest removes 11 lb P_2O_5/ton – implications?
- Likely need a swather or livestock

Root density far greater in perennial systems (central Montana)!

Wheat immediately post harvest

Adjacent native range



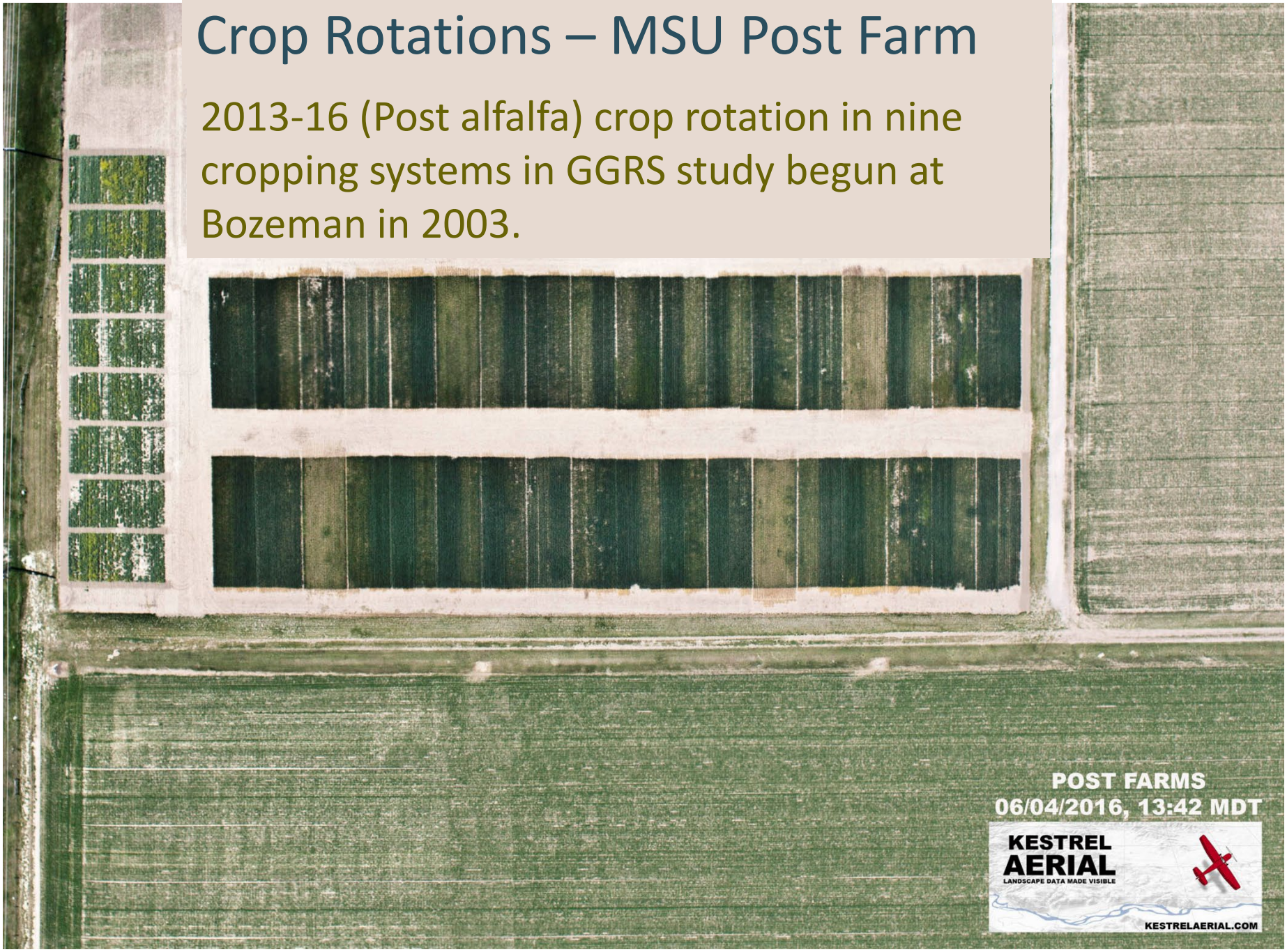


Images by L. Gill

Root analysis by Ewing, Zabinski, Gill

Crop Rotations – MSU Post Farm

2013-16 (Post alfalfa) crop rotation in nine cropping systems in GGRS study begun at Bozeman in 2003.

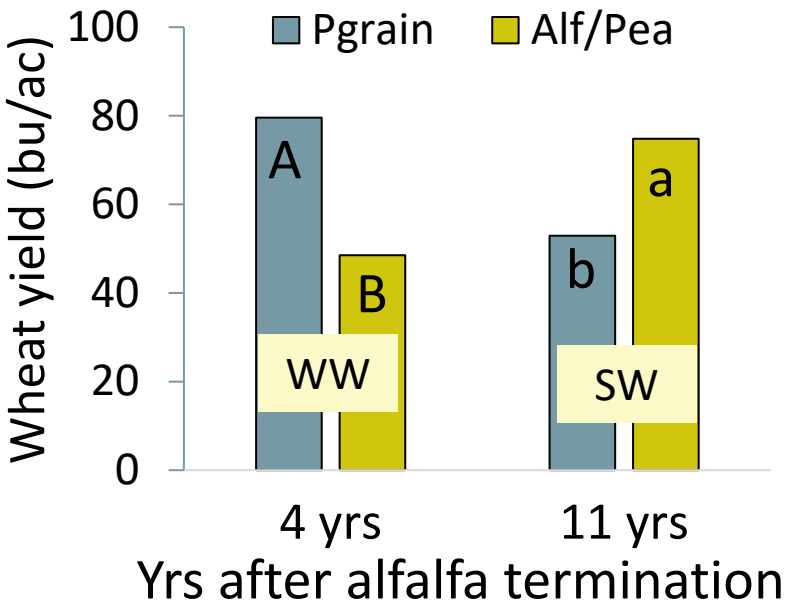


Crop Rotations – MSU Post Farm

2013-16 (Post alfalfa) crop rotation in nine cropping systems in GGRS study begun at Bozeman in 2003.

Rotation with wheat
1) Fallow (Till)
2) Fallow (NT)
3) Wheat
4) Oilseed
5) Pea(seed)
6) Pea(hay)
7) Pea(brown manure)
8) Pea(green manure) (ORGANIC)
9) ex-alfalfa: Pea(seed)

Legacy of 10 yrs alfalfa on wheat yield

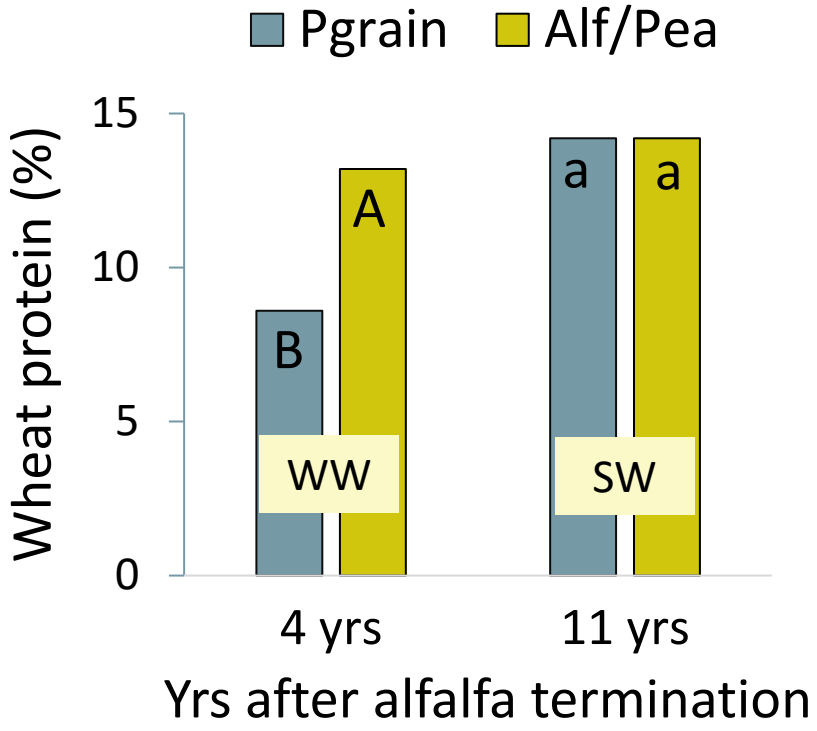


In a DRYLand system:

- Alfalfa-caused water hangover for about 4 years, resulting in wheat yield loss.
- If irrigated, yield loss should go away
- <u>Alfalfa grown 10-20 years earlier benefited yield 11 years after termination.</u> *Not sure why.*

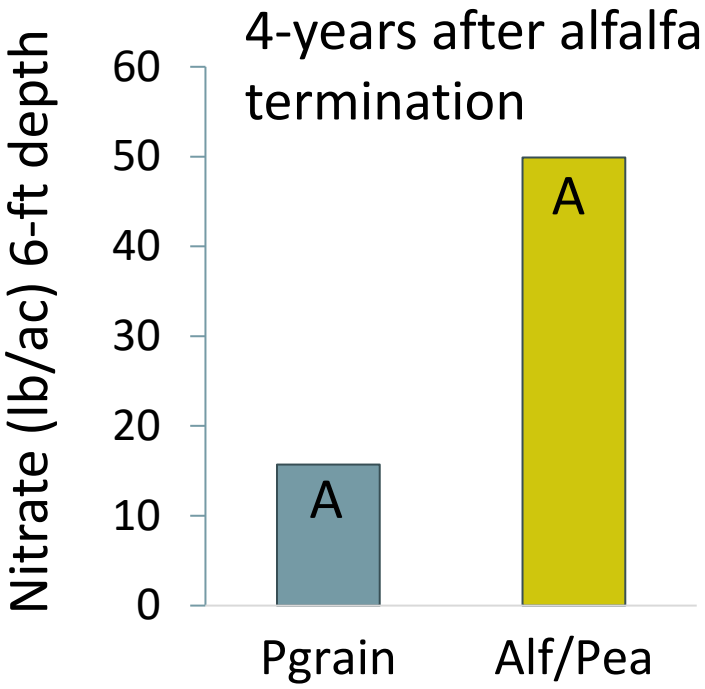
At low N; Miller et al. unpub. data

Legacy of 10 yrs alfalfa on wheat protein and deep soil nitrate



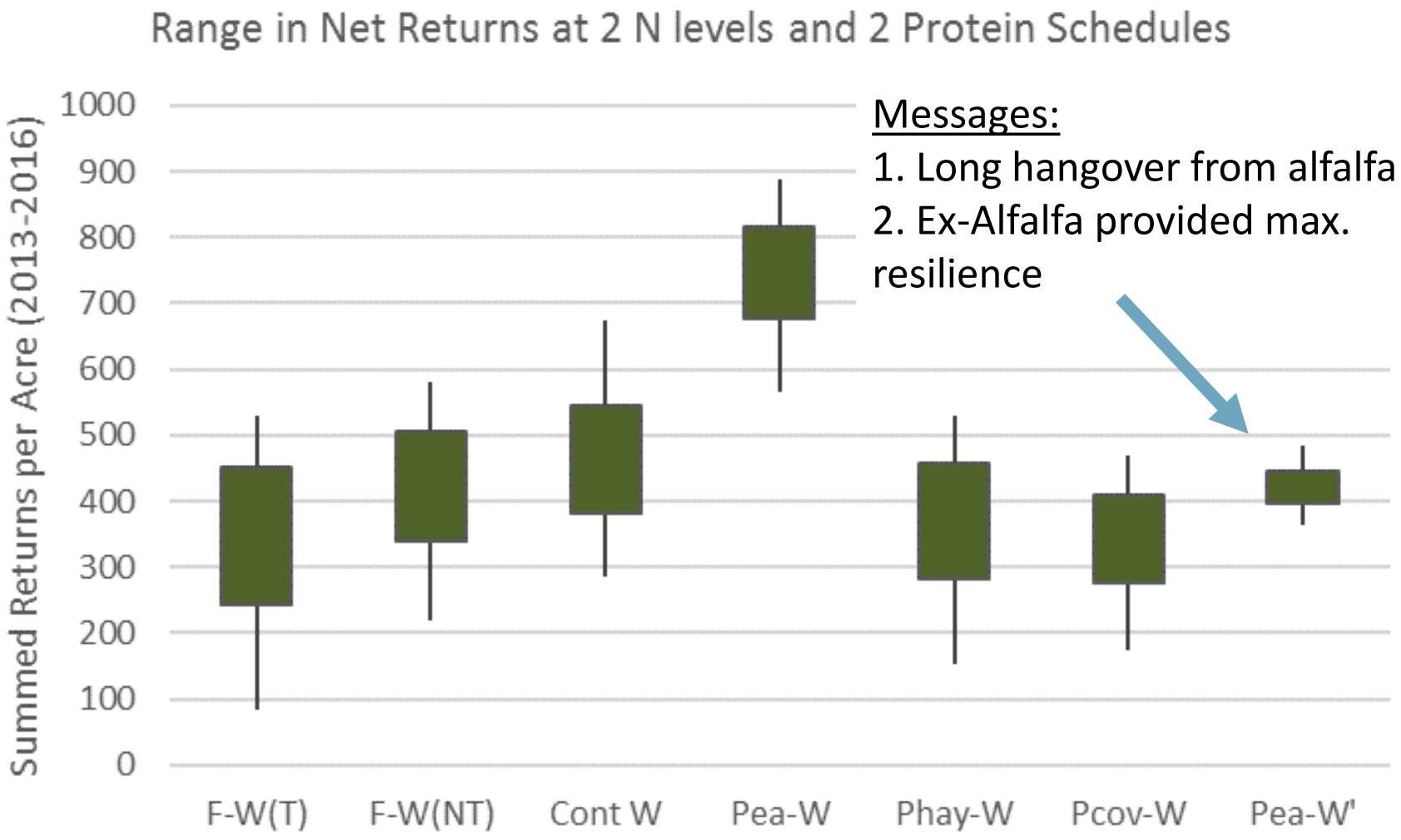
In a DRYLand system:

- Alfalfa benefit to wheat protein by 4 yrs post termination
- By 11 yrs pgrain rotation caught up; alfalfa still benefited wheat yield



At low N; Miller et al. unpub. data

4-year Net Returns to Land and Management (excl. insurance)

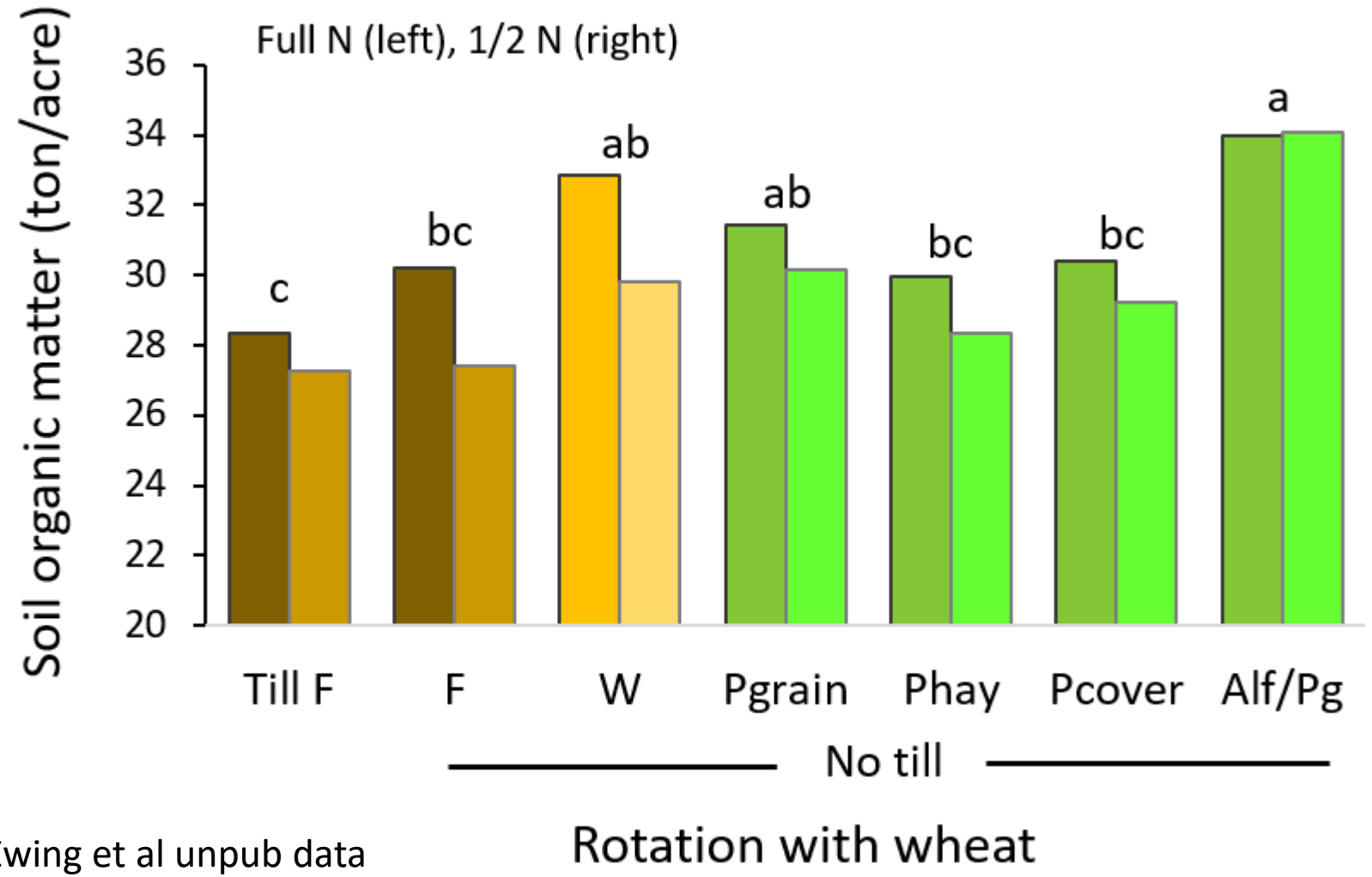


Questions?

On to

Soil health properties

SOM in top foot after 14 years of cropping systems at 2 N rates near Bozeman, MT (2016)

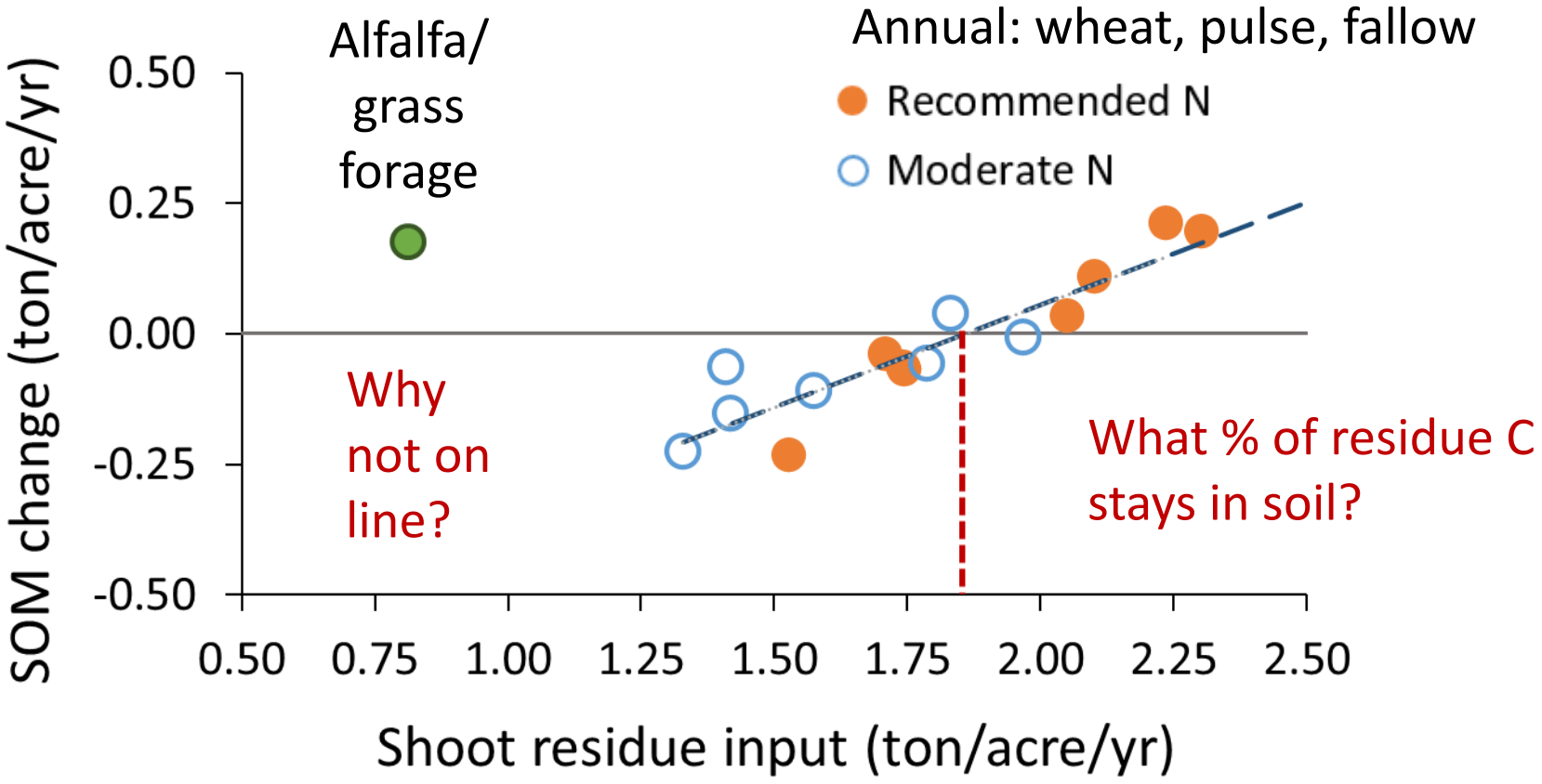


Ewing et al unpub data

Alf = >85% Alfalfa

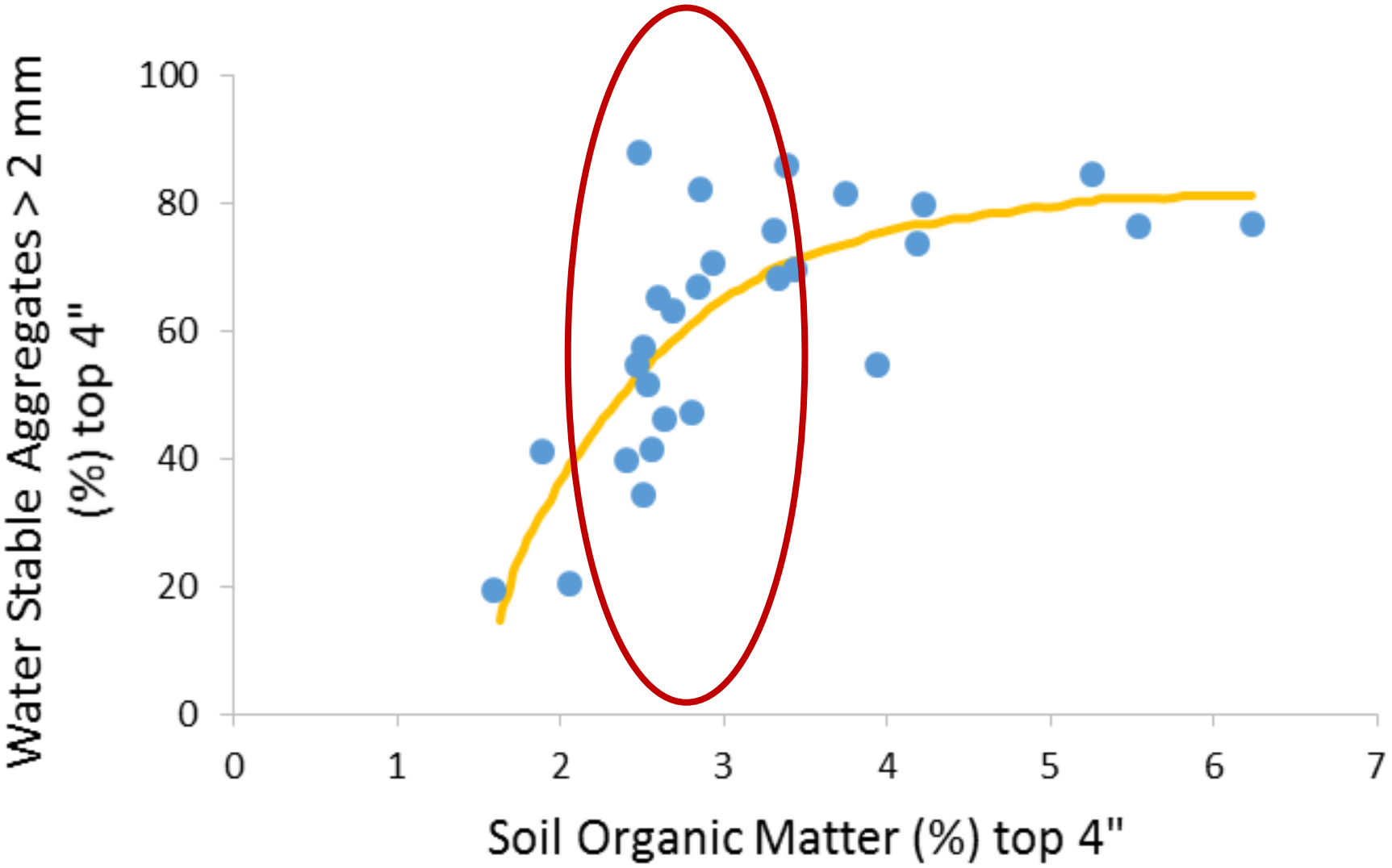
Maintain or increase soil organic matter

Need ~1.8 ton shoot residue/ac/yr to maintain SOM in more productive NGP regions



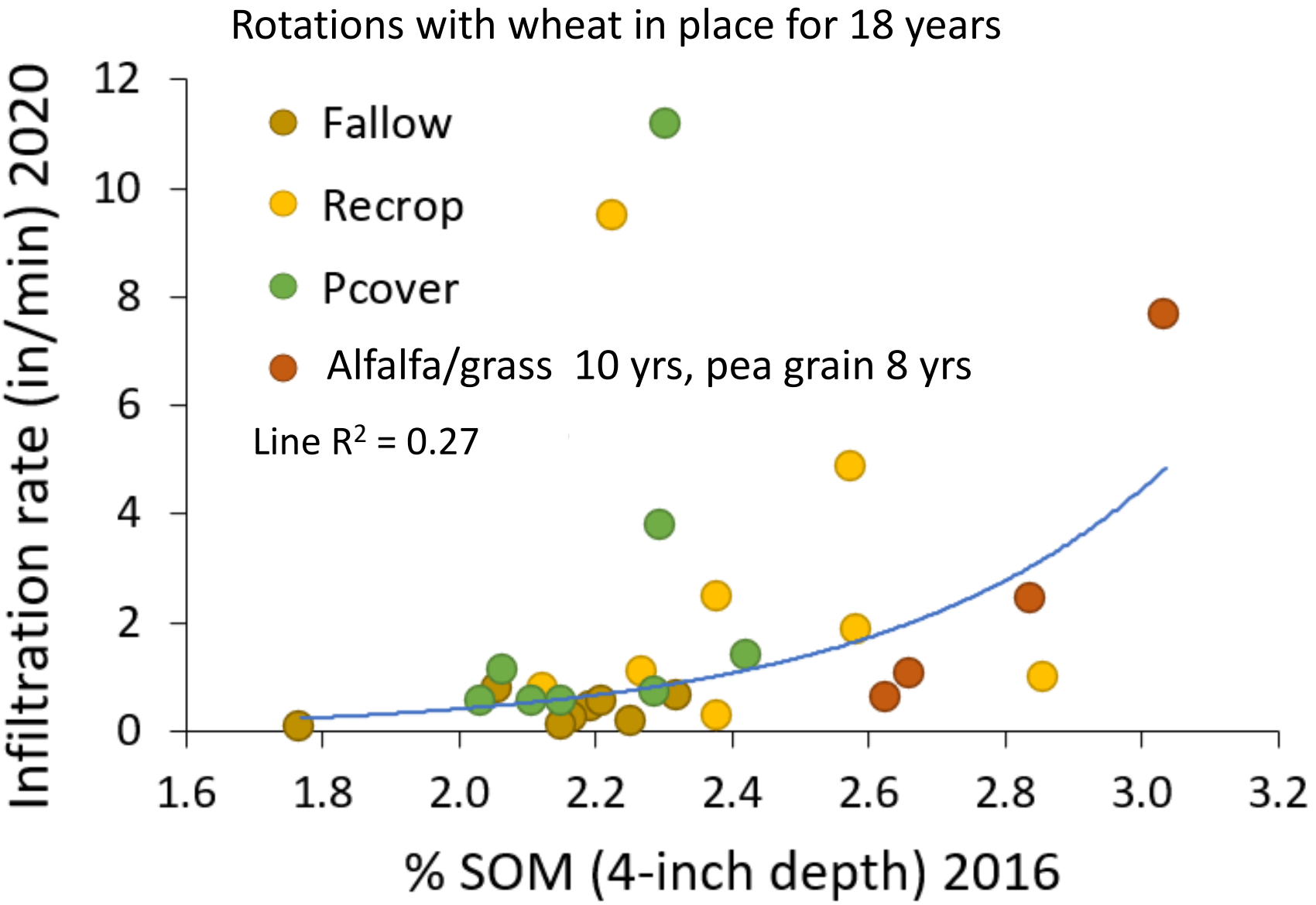
Engel et al. 2017, Gallatin Valley, MT, 16” precip zone; Shrestha et al. 2013, SK

Small increase in SOM → large increase in soil structure



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

Infiltration rates correspond with SOM in top 4”

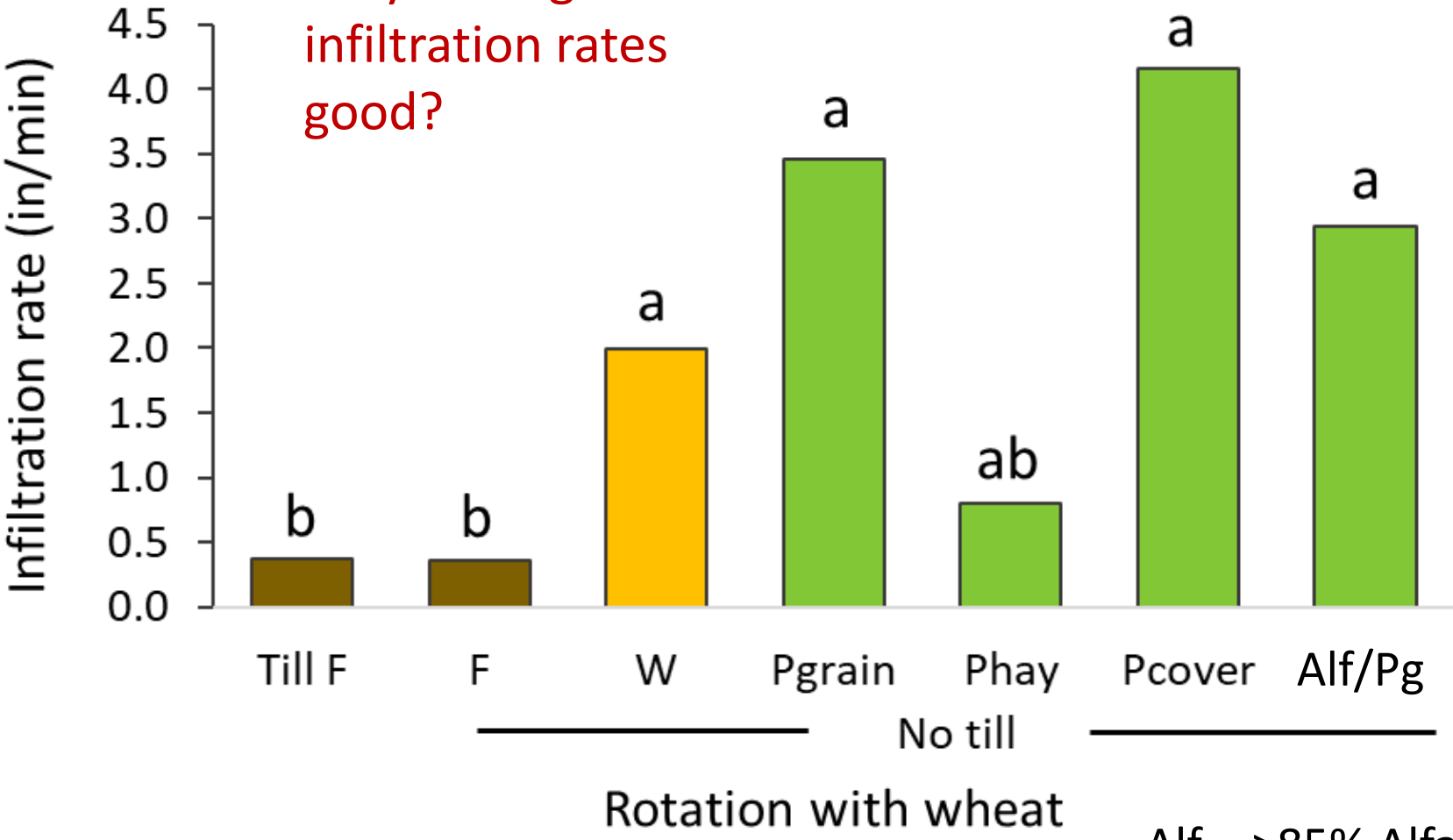


Ewing and Jones unpub data

Infiltration rates were 7-FOLD higher after 18 years of recrop than after fallow at Bozeman (2020)

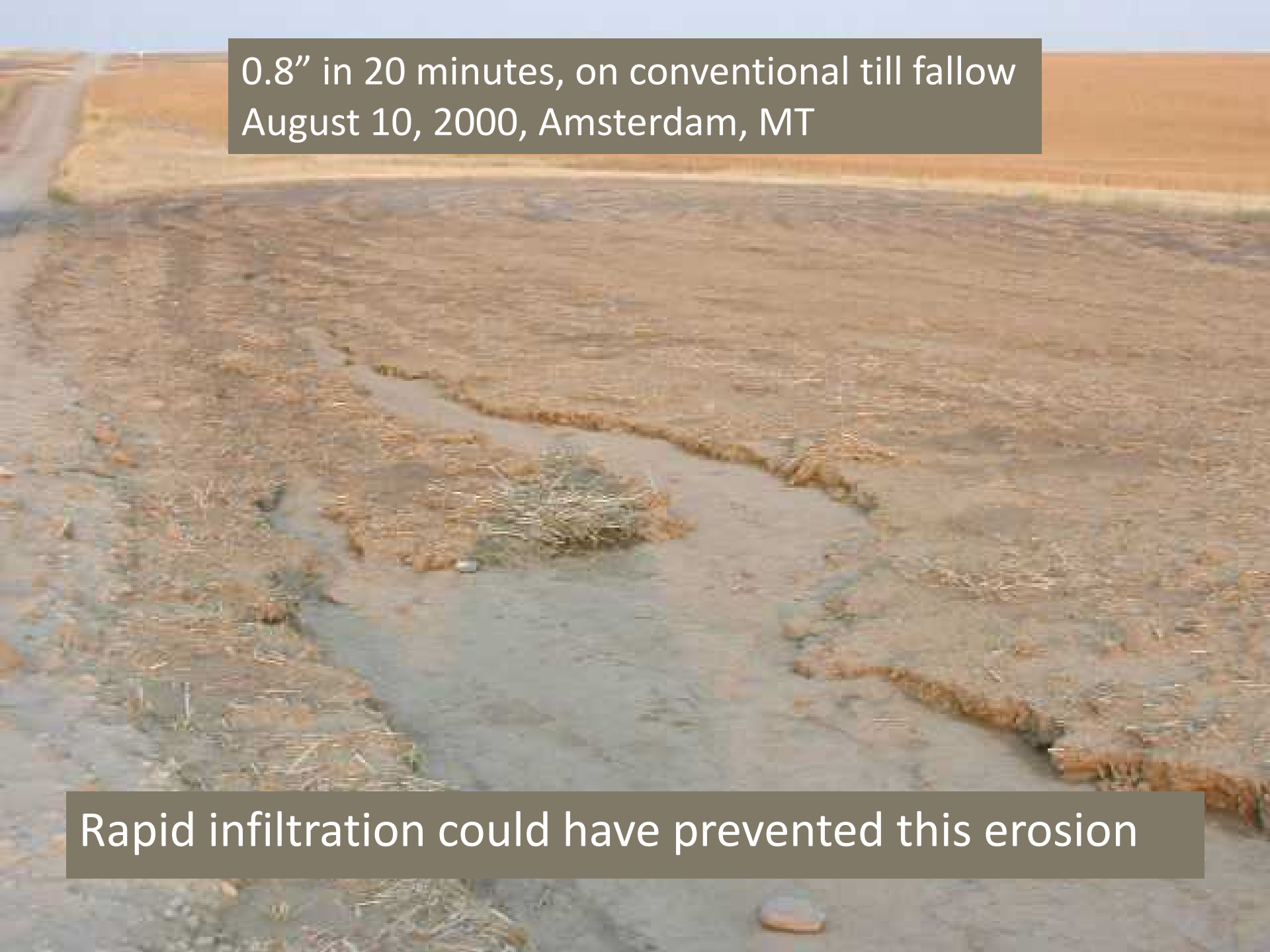
I doubt this is only from SOM. What else might cause?

Why are high infiltration rates good?

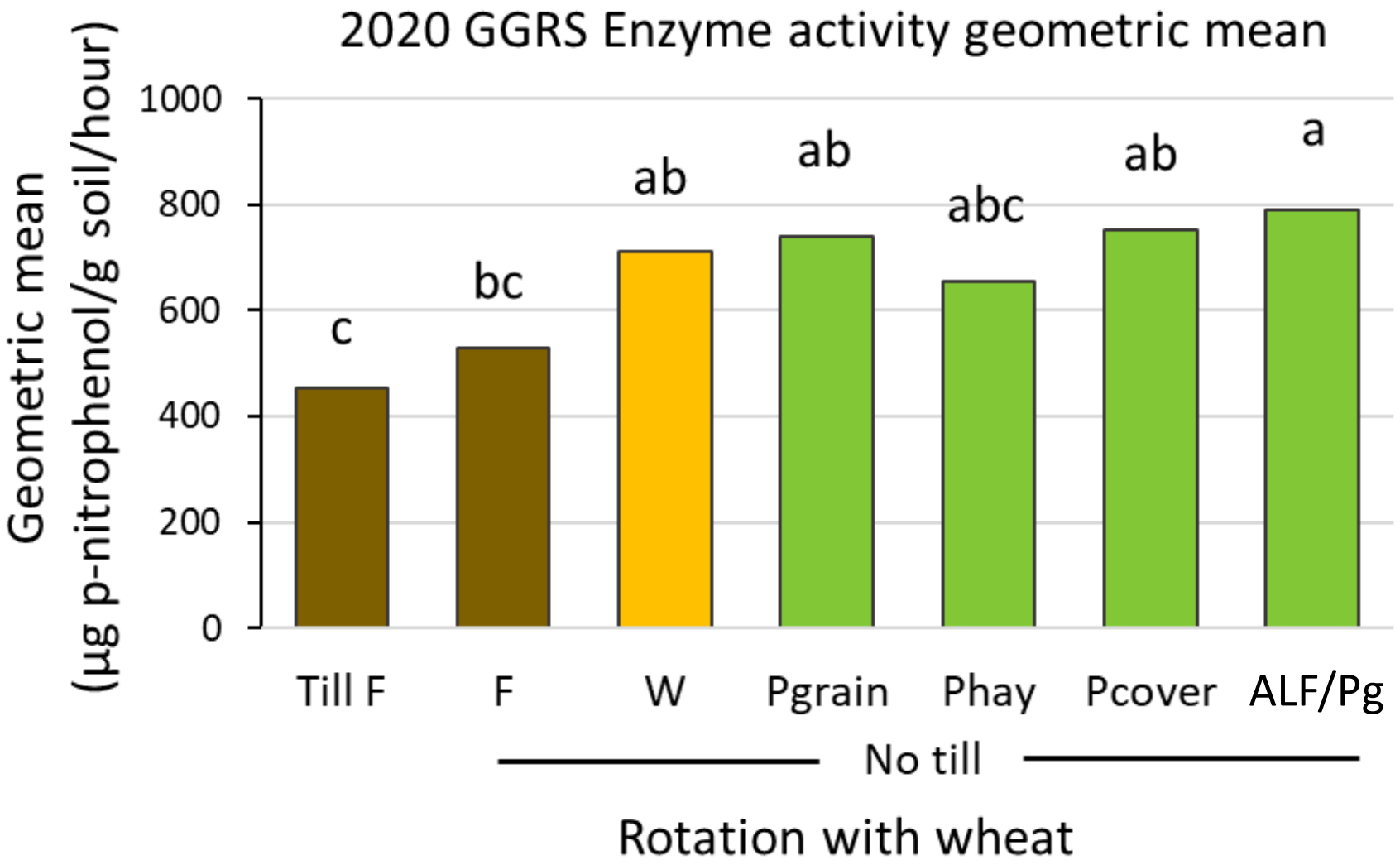


Jones unpub data

Alf = >85% Alfalfa


0.8” in 20 minutes, on conventional till fallow
August 10, 2000, Amsterdam, MT
Rapid infiltration could have prevented this erosion

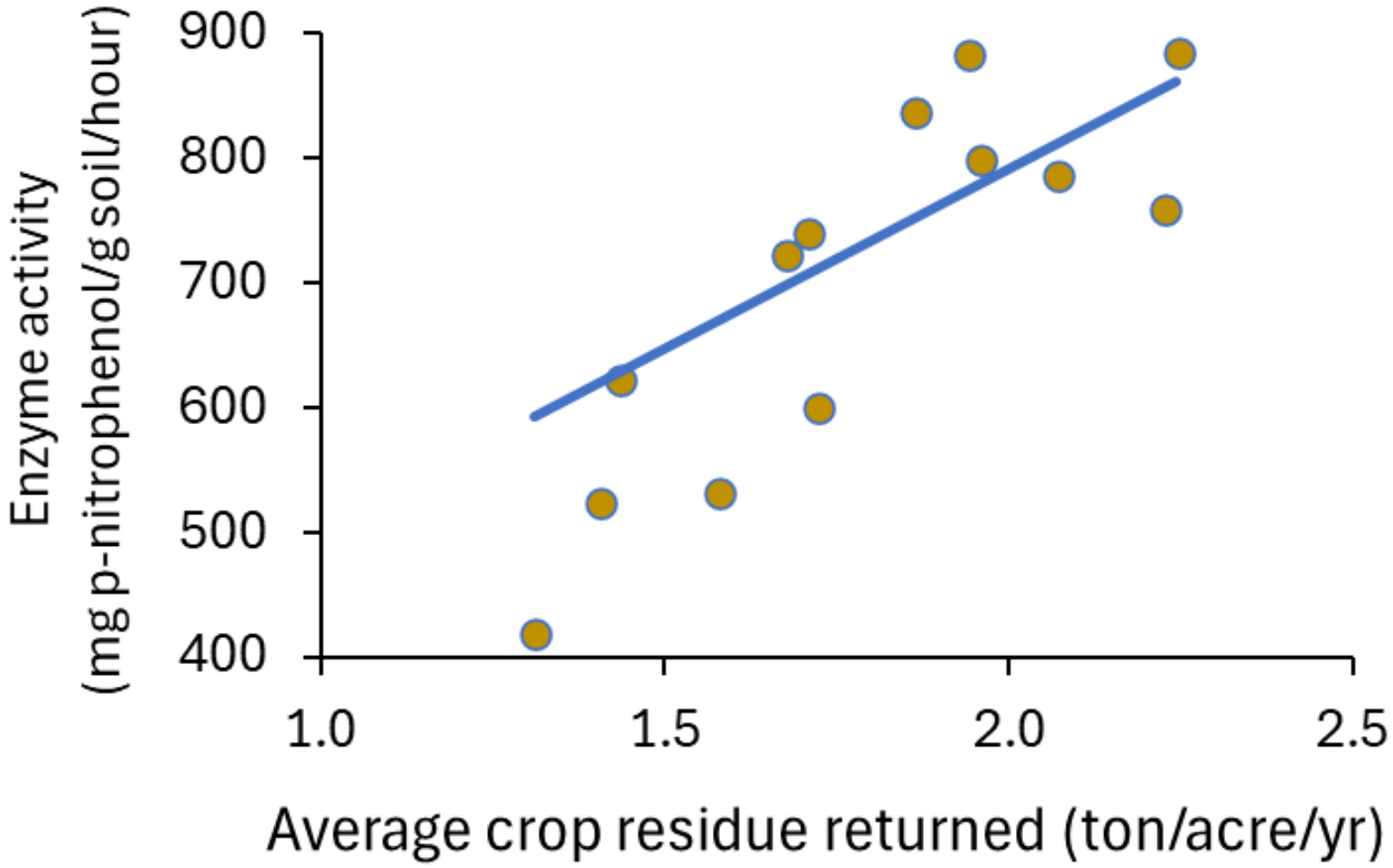
Enzyme activities approximately mirrored SOM



Jones et al. 2022

ALF = >85% Alfalfa

Geometric mean enzyme activity vs average crop residue returned annually over 18-yrs



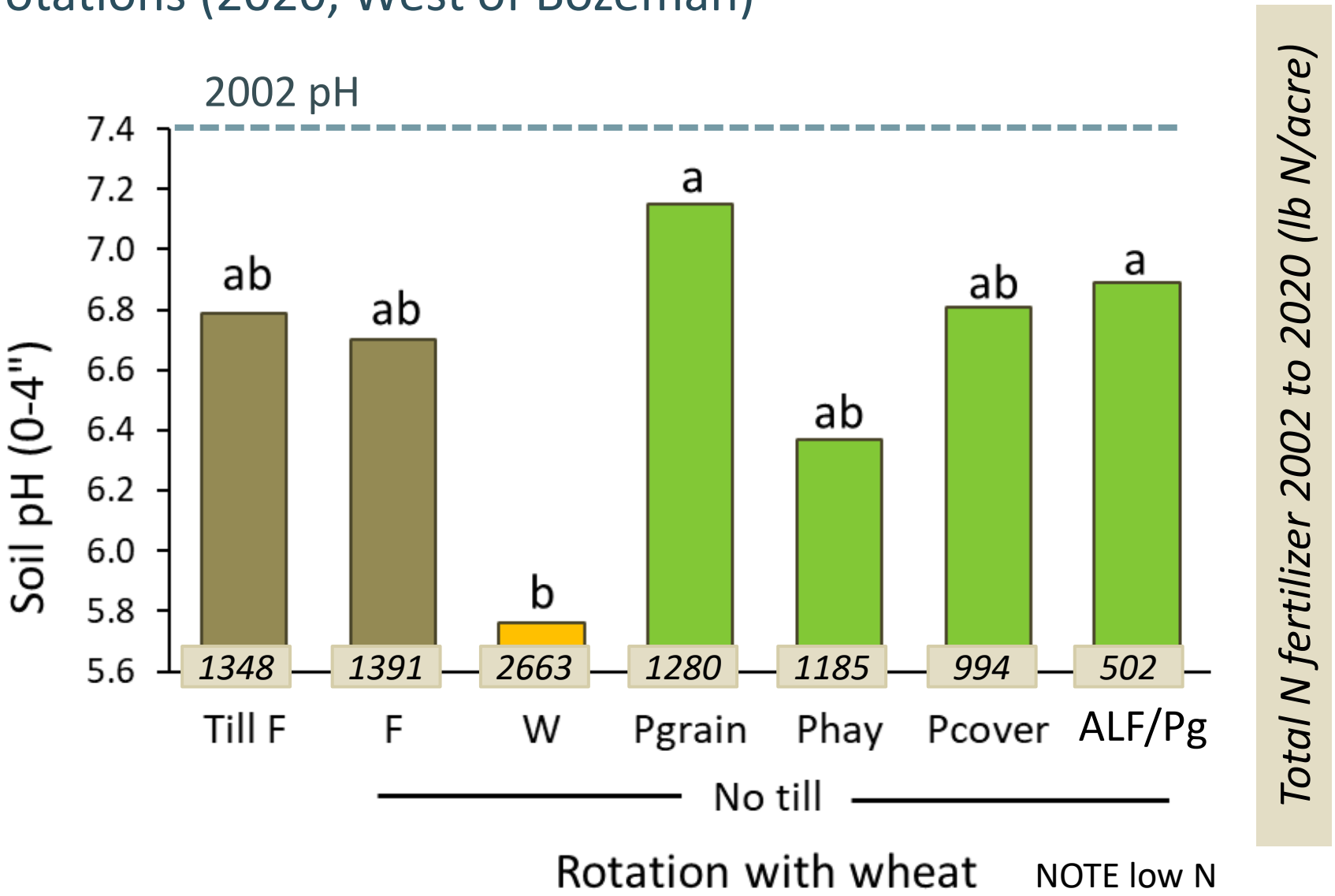
Zabinski unpub data

Questions?

On to

Soil pH and nitrogen

Soil pH after 18 years of ‘normal’ urea addition to various crop rotations (2020, West of Bozeman)



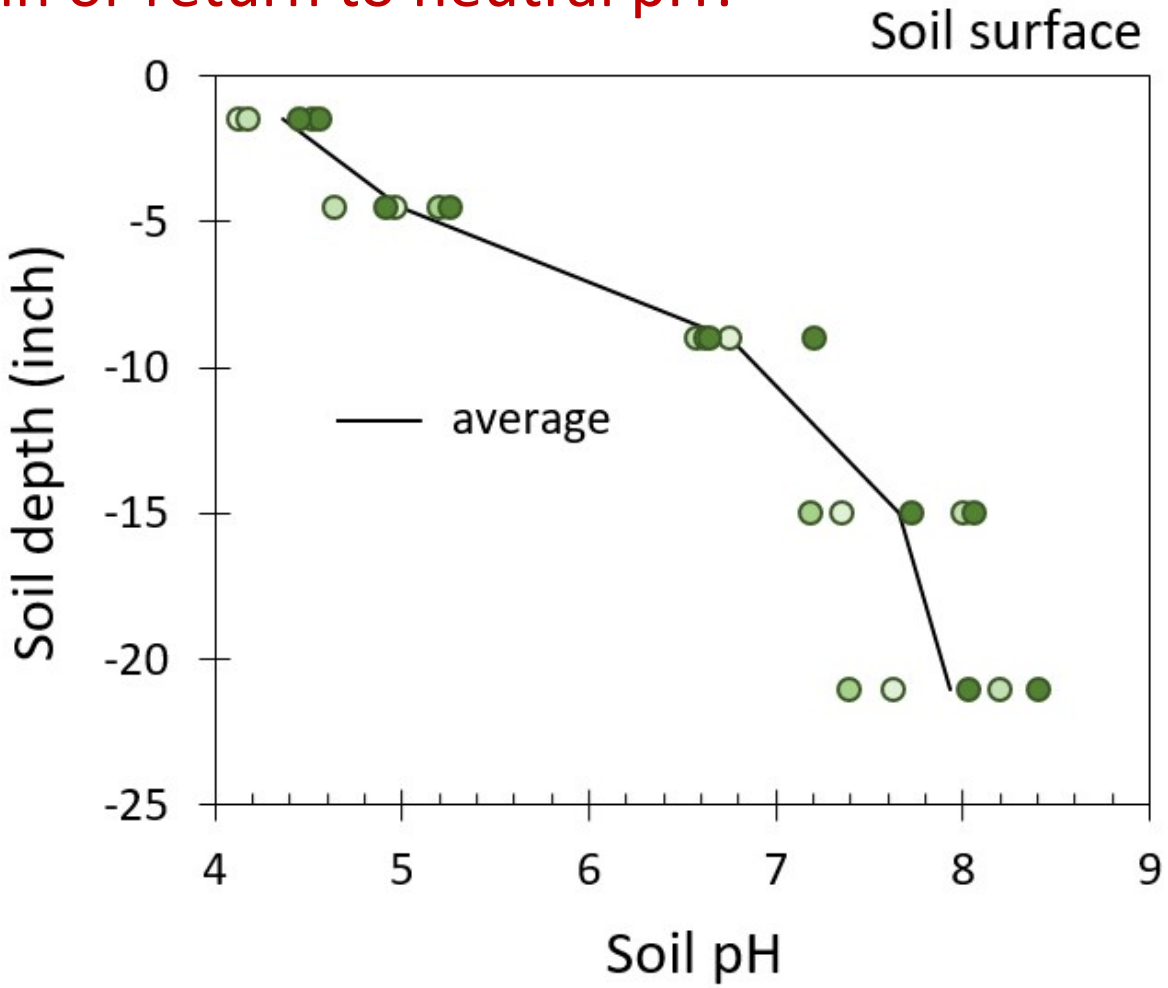
ALF = >85% Alfalfa

NOTE low N applied in ALF/Pg

Most MT soils are high in $CaCO_3$ with pH> 7 at 12” and lower

How can we maintain or return to neutral pH?

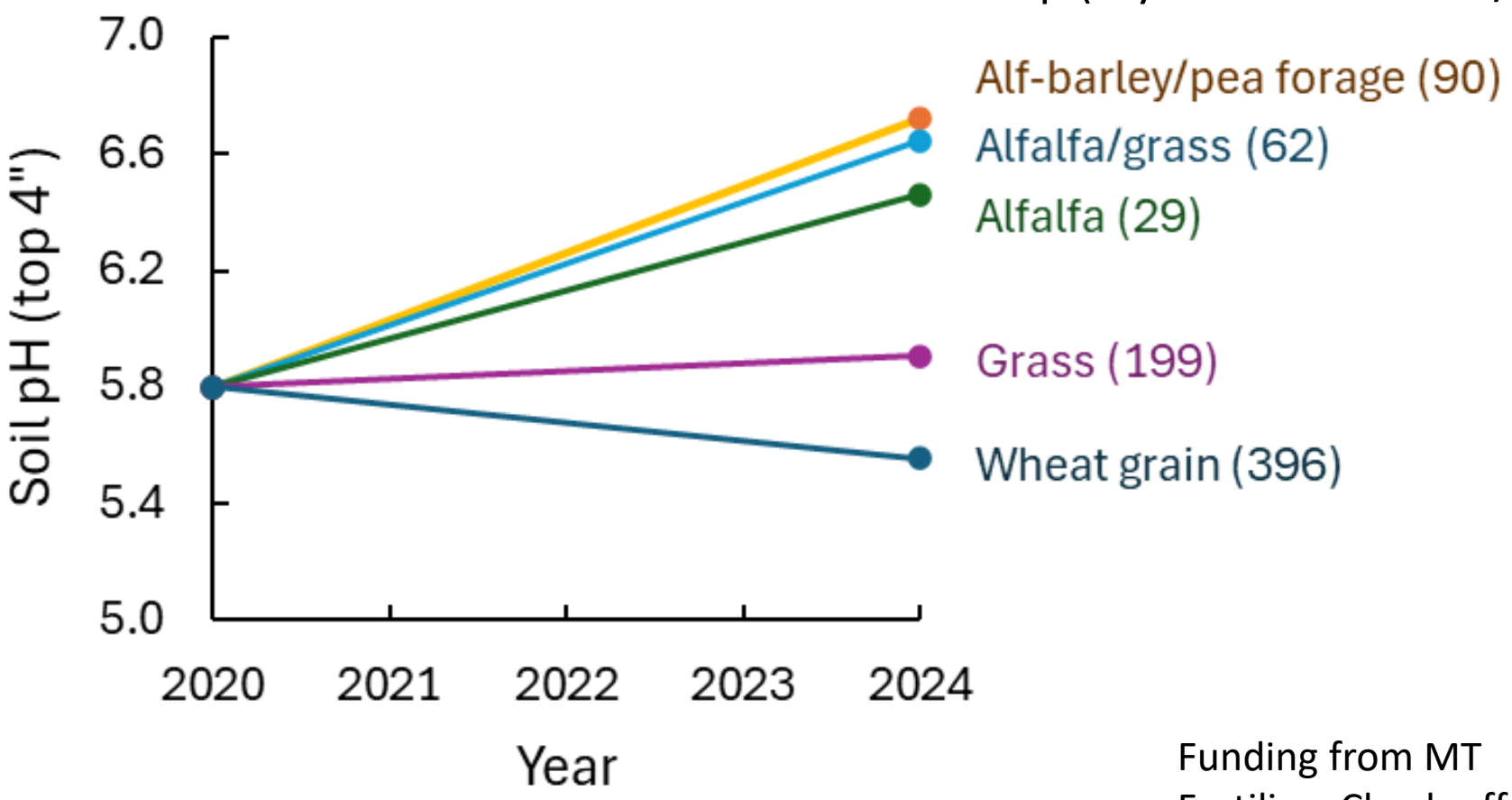
- Bring $CaCO_3$ to the surface
- Grow legumes
- Plant crops that capture residual the NO_3^- and release HCO_3^- or OH^- anion to maintain charge balance



pH stratification on 5 MT farms, Fertilizer Fact No. 78

Alfalfa and alfalfa-grass increased pH after 4 years (Bozeman)

Soil pH in alfalfa and alfalfa-grass increased ~0.7 pH units in 4 years!
In an organic system, w/o N fertilizer, that increase should remain, preventing need for lime.



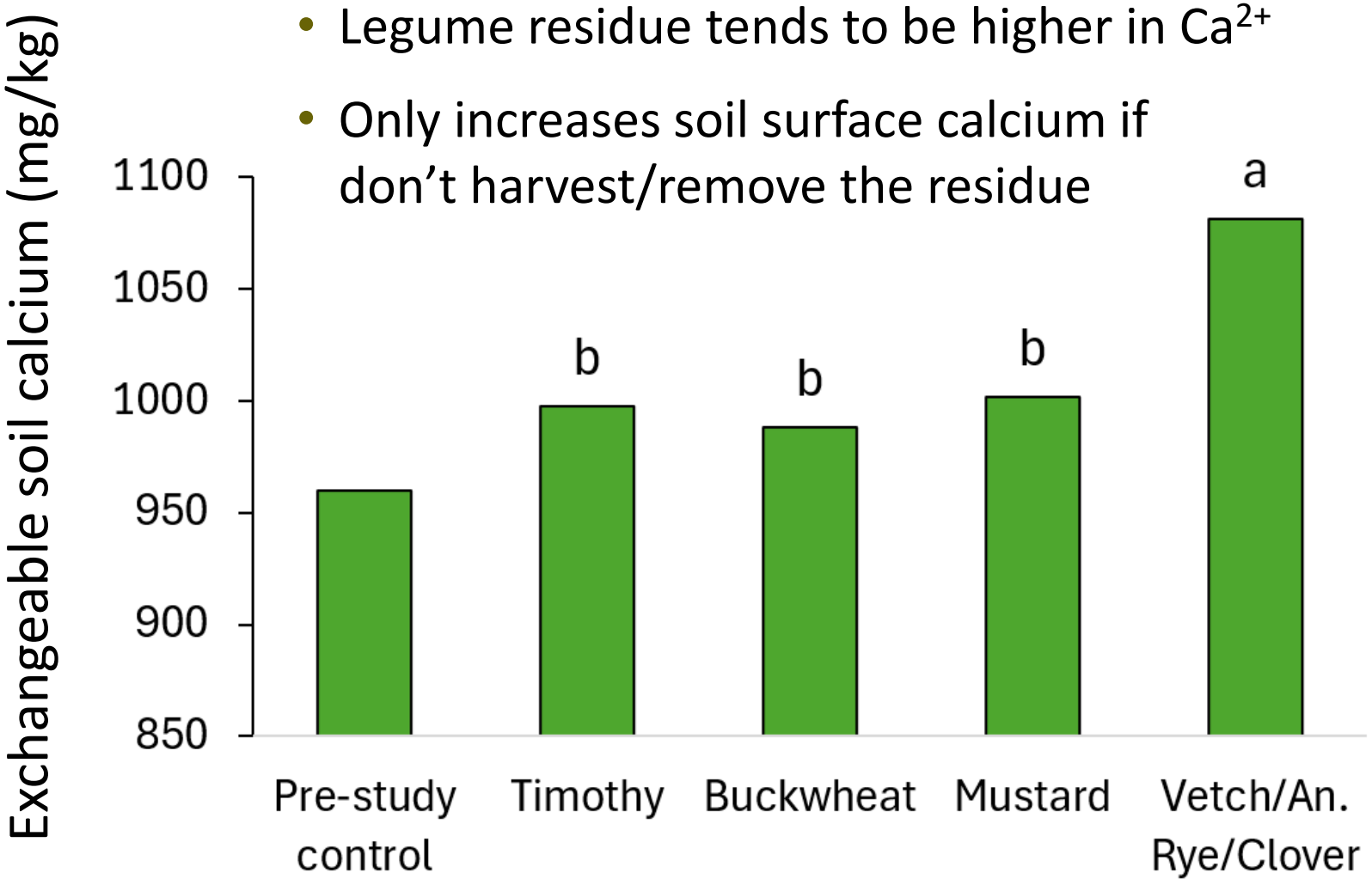
Alfalfa/grass and alfalfa pH > wheat (> 95% probability)

Funding from MT Fertilizer Check-off

Jones unpub. data

Some plant residues increase surface soil Ca^{2+}

- Legume residue tends to be higher in Ca^{2+}
- Only increases soil surface calcium if don't harvest/remove the residue

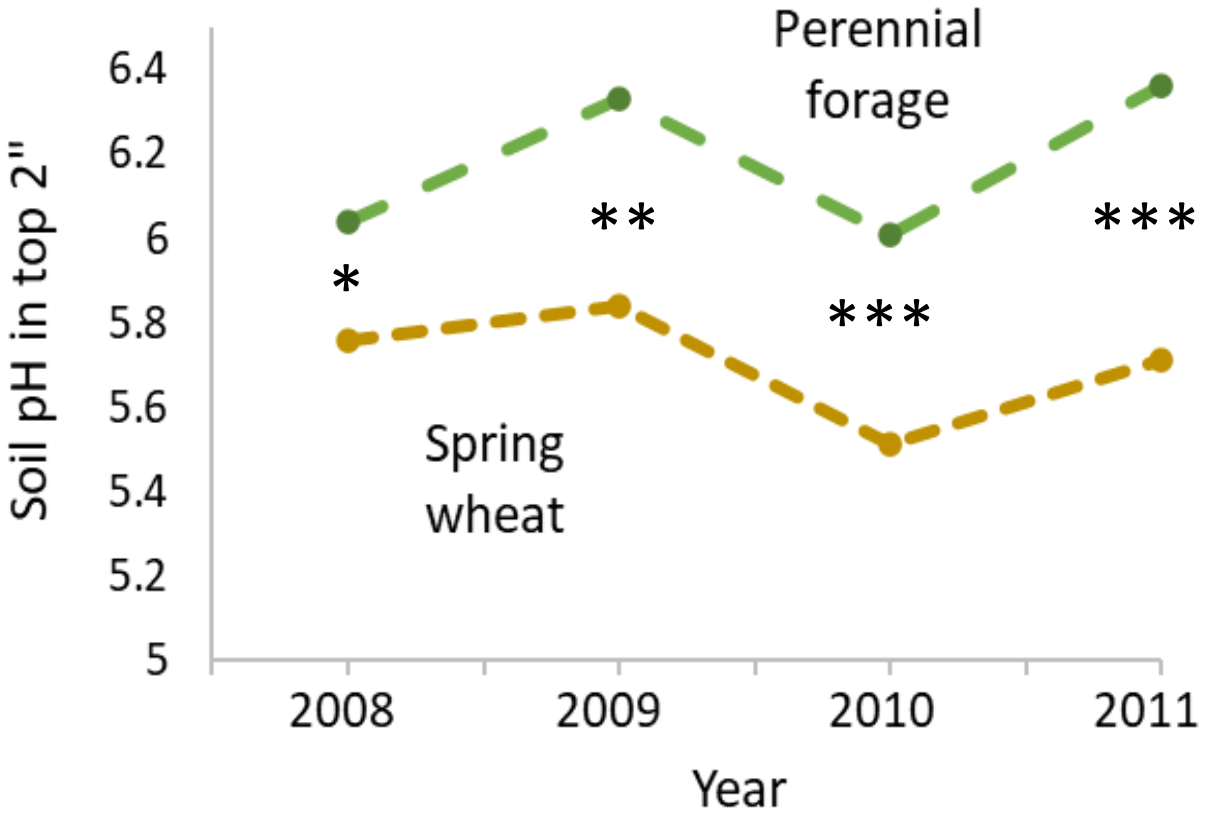


Cover terminated at peak flowering and incorporated.
Soil sampled 0-6", fine sandy loam

Khan et al. 2021, Prince Edward Island

Perennial forages had similar pH effects in ND after 5 years

3 perennial grasses, alfalfa/grass, alfalfa seeded in 2006



Yrs to when perennial higher than wheat

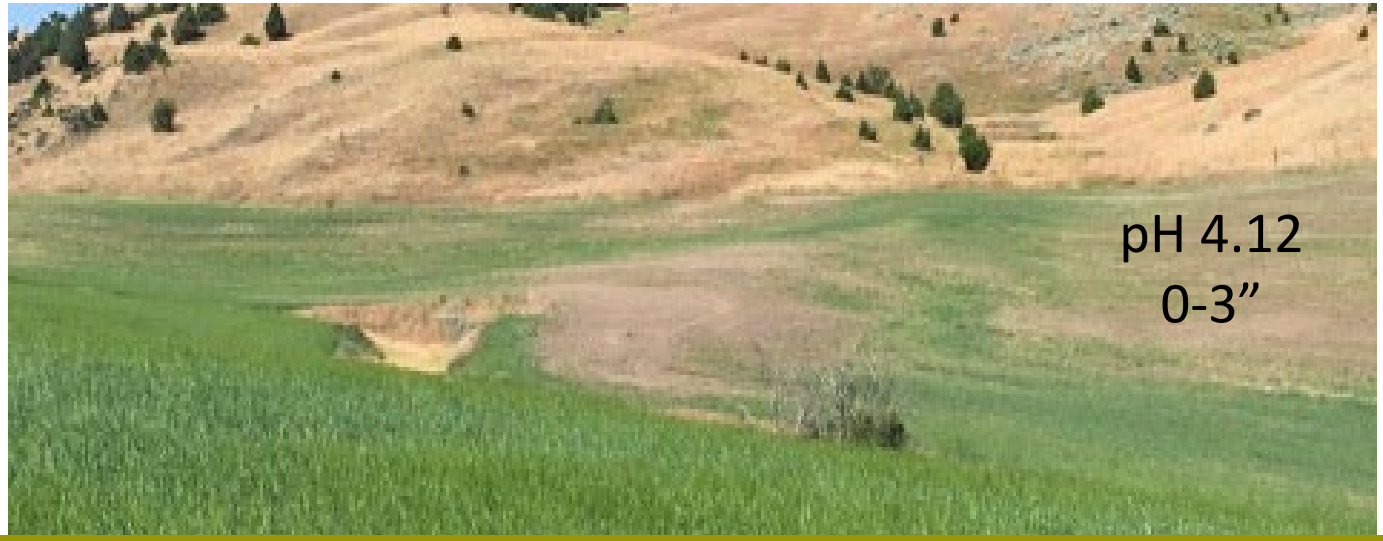
- pH (2)
- Water stable ag (2)
- Blk-density (4)
- Total SOC (4)
- Particulate OM (4)

pH differs between crops with * > 90%, ** > 95%, *** > 99% confidence

All treatments received 60 lb N/ac

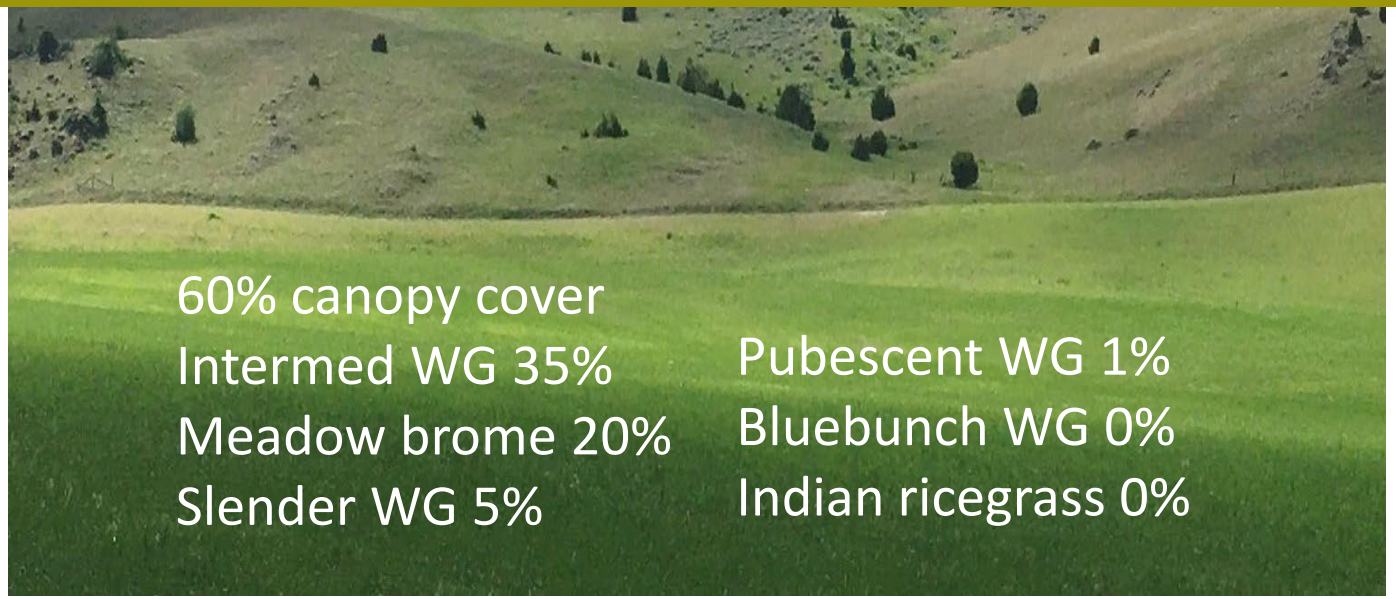
Liebig et al. 2018, Mandan, ND

Barley 2017



What species do well in low pH?

6-sp. grass mix
- seeded 2018
- photo 2020

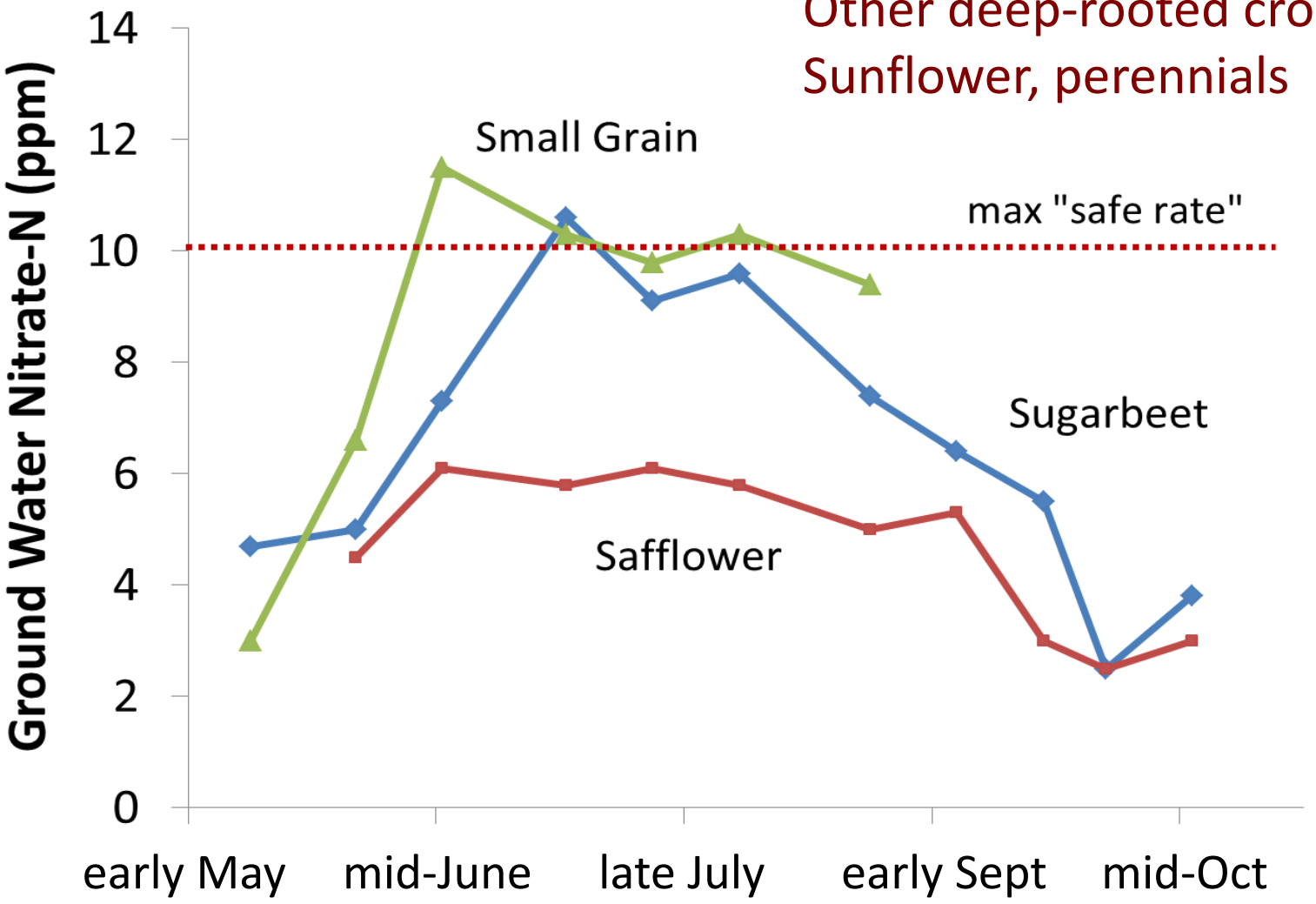


MT variety trial results
http://landresources.montana.edu/soilfertility/acidif/index.html

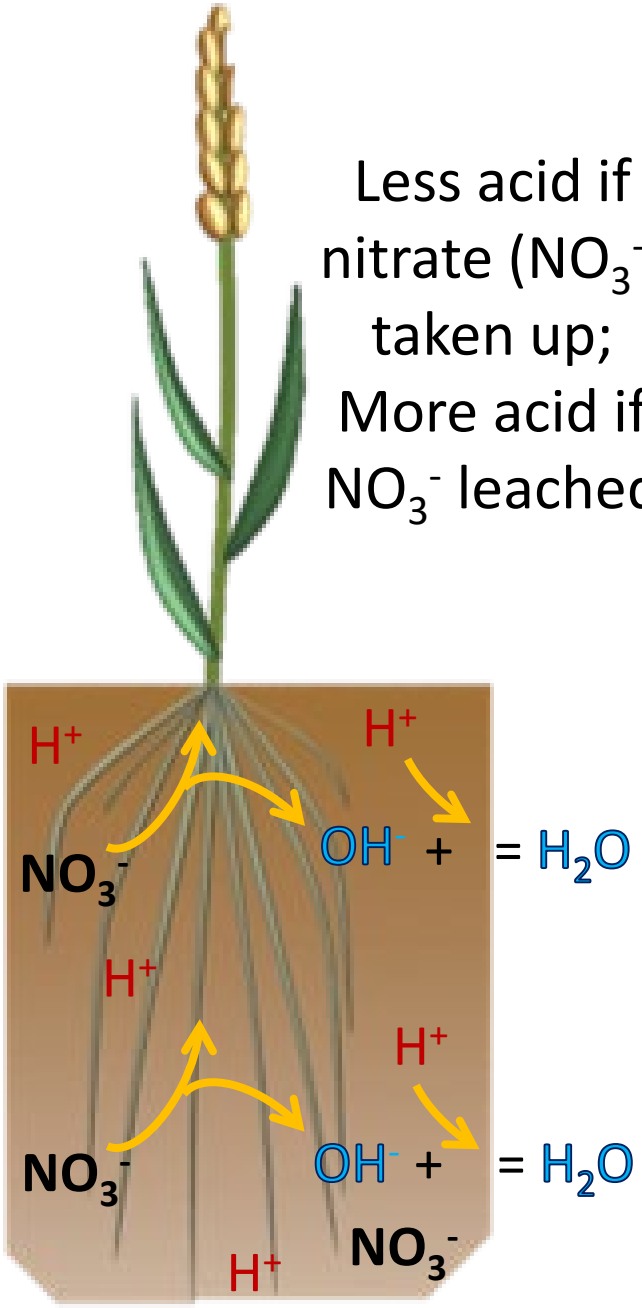
Jones unpub. data and images

Deep rooted crops recover deep N and help keep nitrate out of groundwater

Other deep-rooted crops?
Sunflower, perennials



6-yr average, Sidney, MT, MSU Fertilizer Fact 9



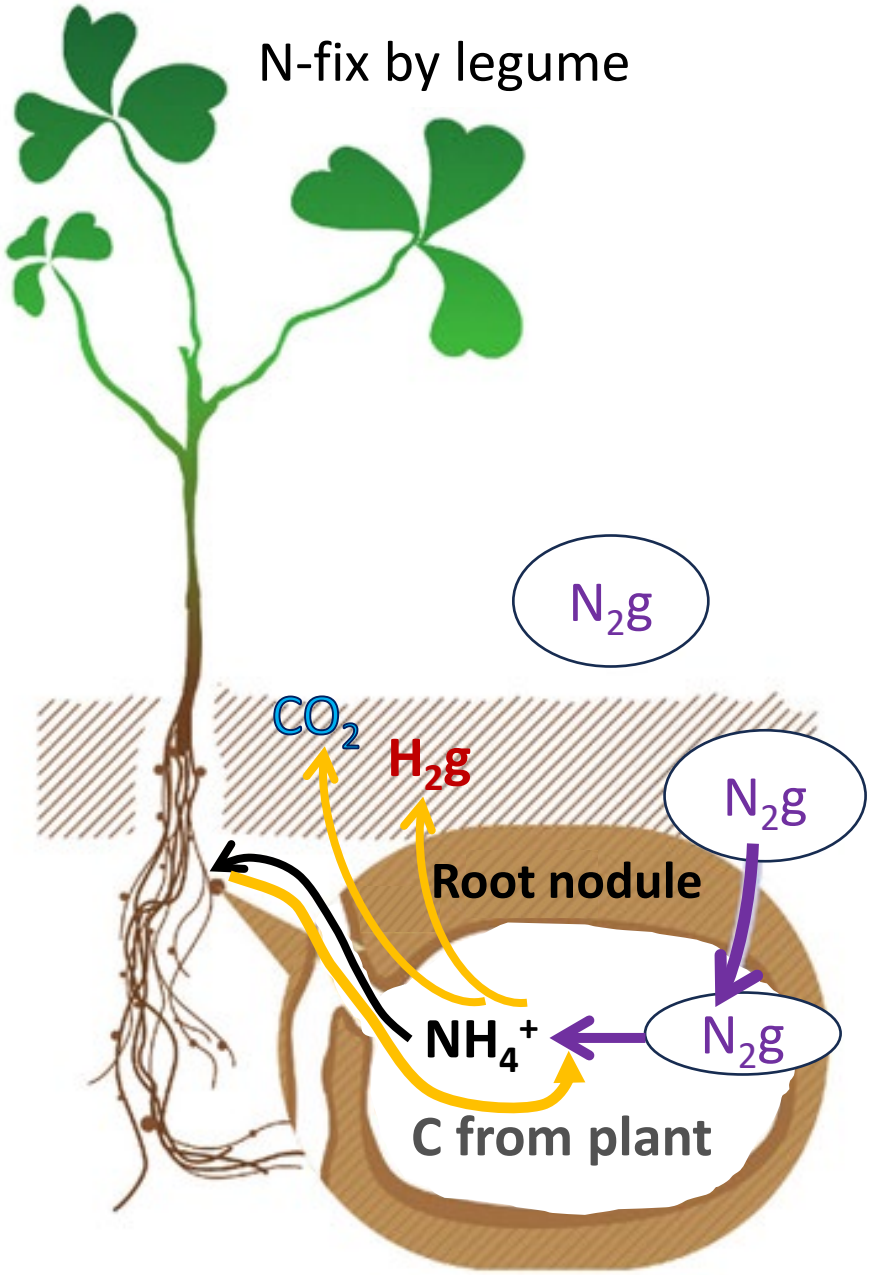
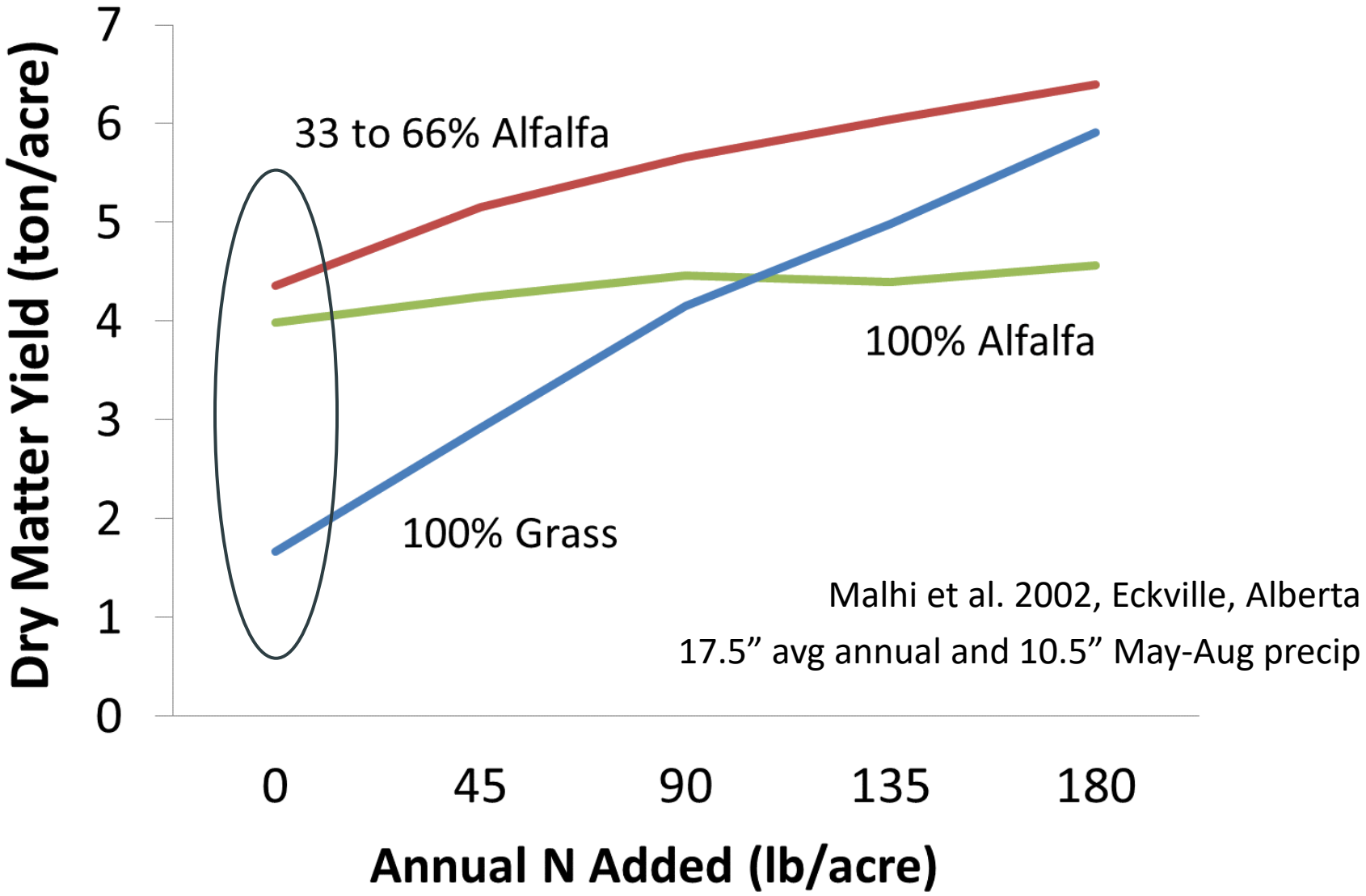


Image by T. Uchiumi, Kagoshima Univ. Modified by K. Olson-Rutz

Adding N – having alfalfa in mix may be best source of N



Malhi et al. 2002, Eckville, Alberta

17.5” avg annual and 10.5” May-Aug precip

Conclusions

- Perennials can increase organic matter, microbial activity, infiltration rates, and soil pH.
- Perennials can hurt subsequent annual crop yield in short term (< 4 yrs), help protein in short term, and benefit yield in long term, even well after termination
- Alfalfa and alfalfa-grass need little N
- If don't have a swather or livestock, recrop might be a better option than perennials.
- Recrop benefits soil health compared to fallow

Extension Plans w.r.t Perennials

- Write an Extension Bulletin by Aug 2026 on effects of perennials on Soil Health (Jones and Olson-Rutz)
- Write an Extension Bulletin by Aug 2026 on Alfalfa management, including management in **organic systems** (Goosey, Jones and others)

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Thank you!

Questions?


Image from Landinstitute.org

For additional information

Soil Fertility Website:

http://landresources.montana.edu/soilfertility

Contains links to previous presentations, Extension bulletins on cover crops, pulses, forages, organic small grains production, and more.

Or pick up handouts!