Soil Acidification

ID, prevent, and restore

CCA & Retailer Training, Huntley

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Objectives

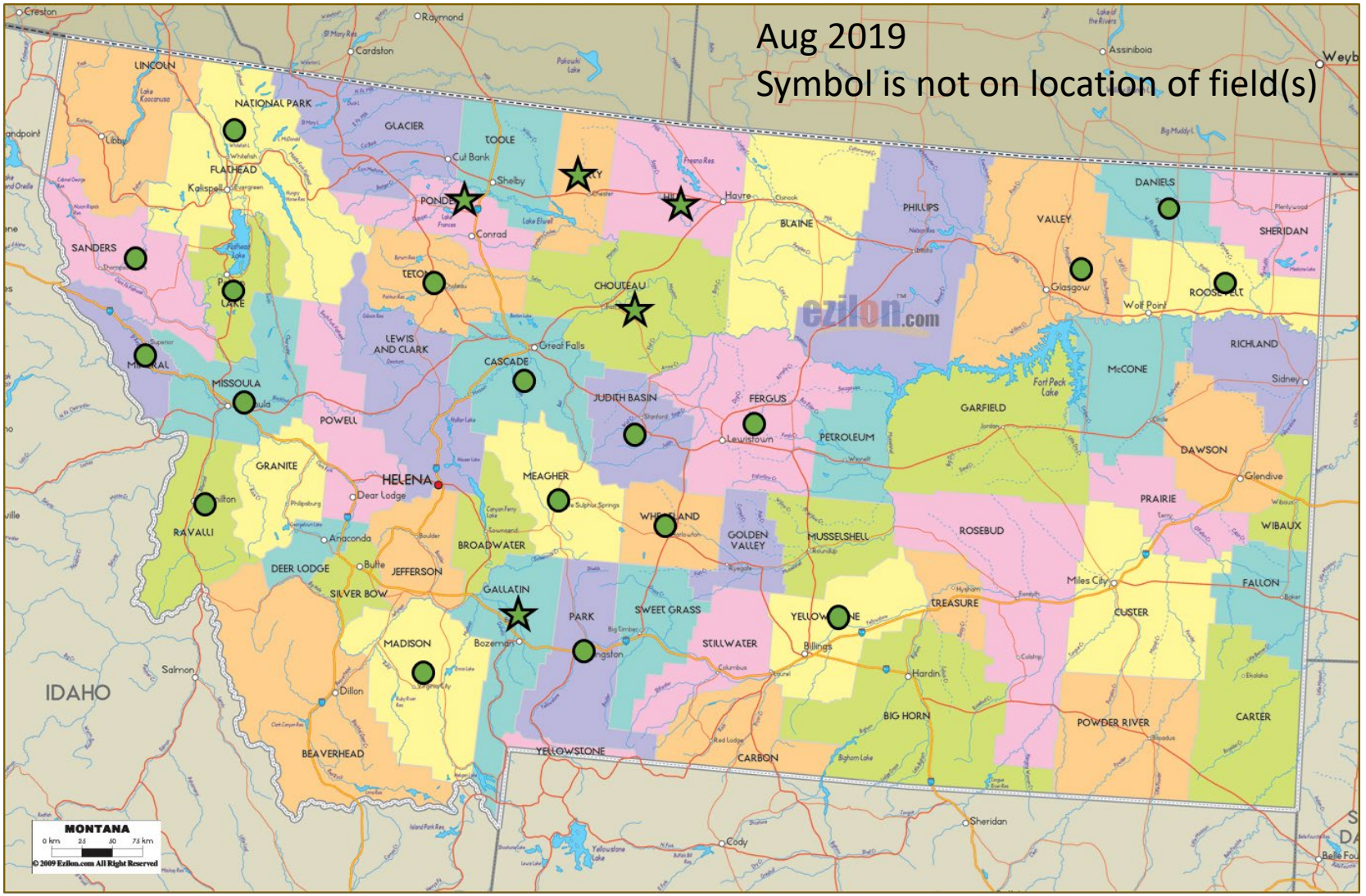
1. Show prevalence of acidification in Montana (similar issue in WA, OR, ID, ND, SD, CO, AB, and SK)


Safflower field near Big Sandy by Scott Powell

2. Review acidification's cause and contributing factors
3. Depict low-pH soil affected crops
4. Present ways to identify low soil pH
5. Discuss steps to prevent or reverse acidification
6. Suggest crop management options in low pH soil

The Montana Fertilizer Check-Off and the Western Sustainable Agriculture Research and Education Program help fund our studies.

Prevalence: MT counties with at least one field with pH < 5.5

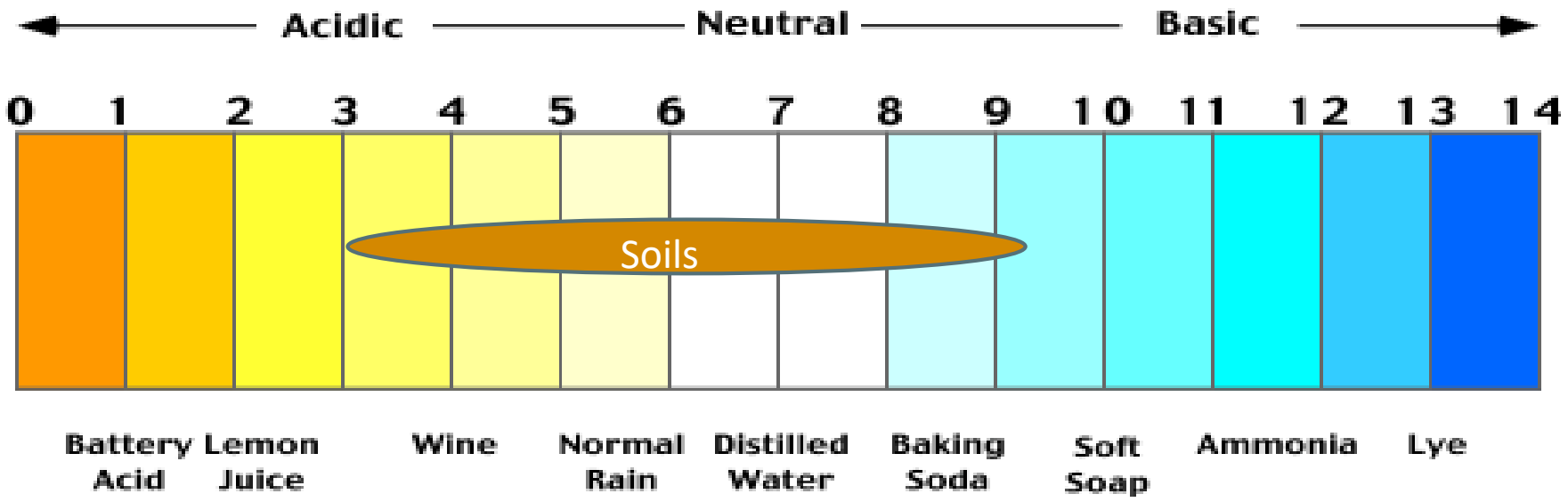


40% of 20 random locations in Chouteau County have pH < 5.5 in top 2”

A question for you

How many have found low pH in some portion of your clients' fields:

- <6.0?
- <5.5?
- <5.0?



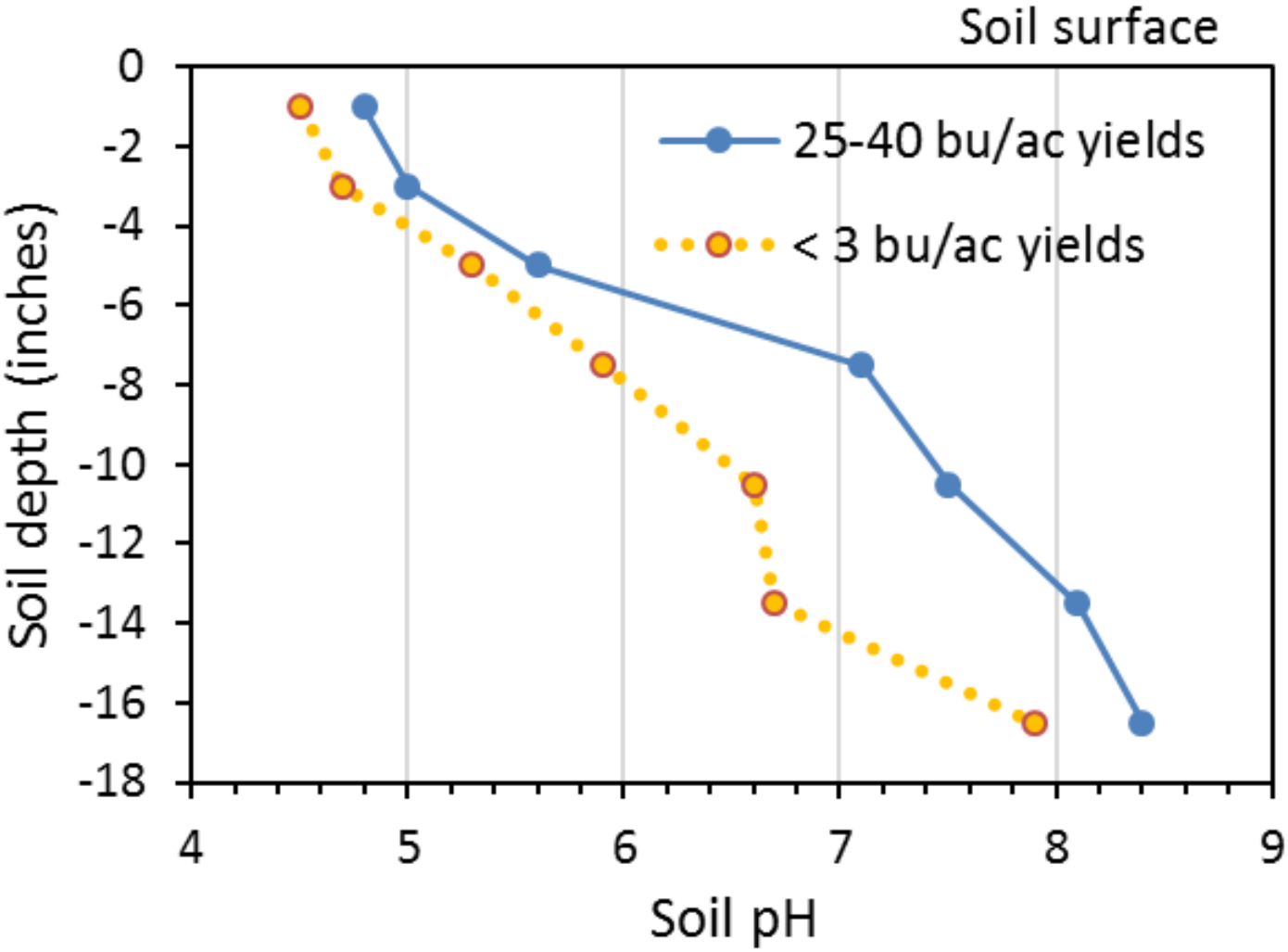
Agronomic reasons for low soil pH

- Ammonium-based N fertilizer above plant needs due to nitrification:

ammonium or urea fertilizer + air + H_2O→ nitrate (NO_3^-) + acid (H^+)

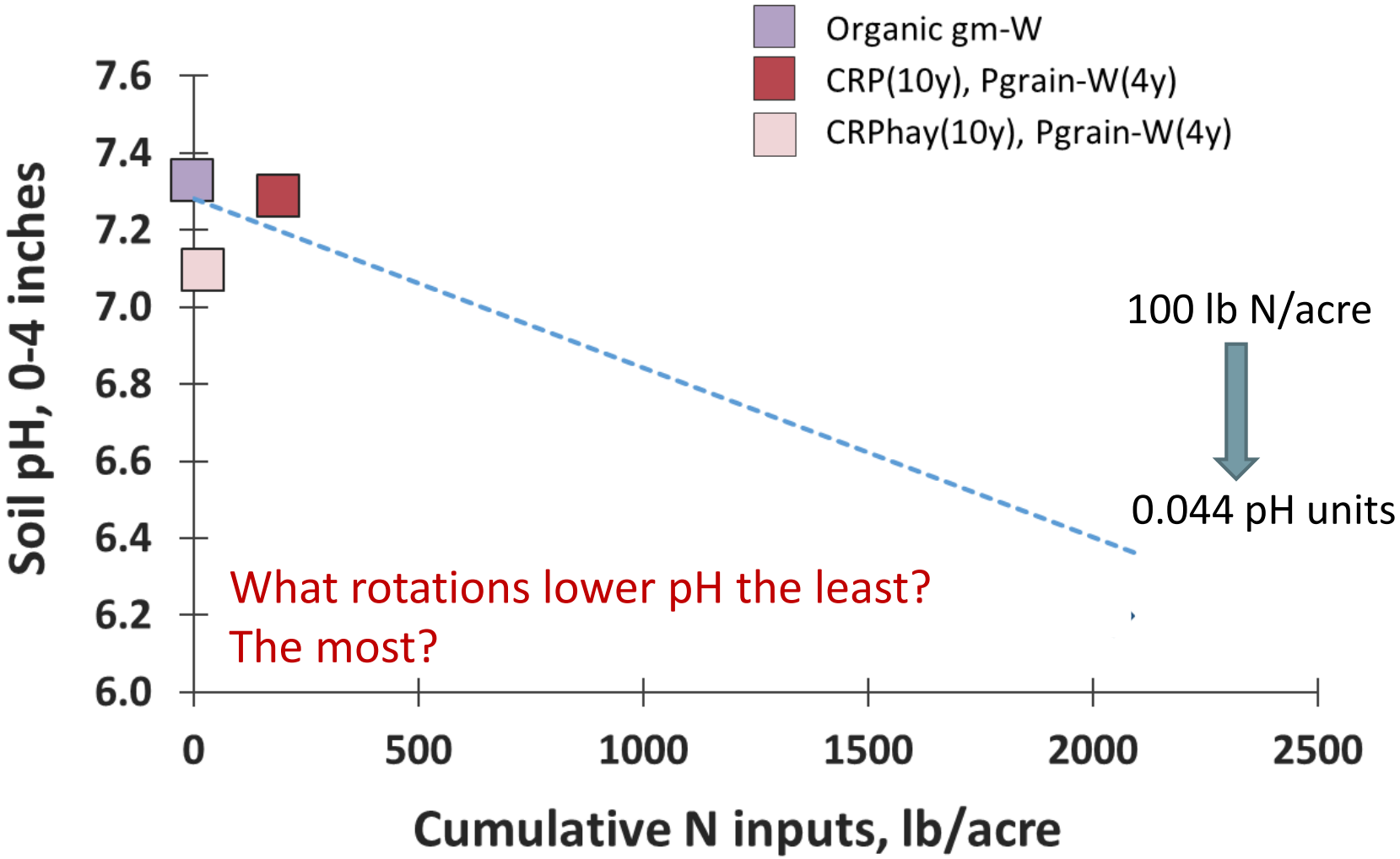
- Leaching loss of nitrate: less nitrate to take up = less root release of basic anions (OH^- and HCO_3^-)
- Crop residue removal: removes Ca, Mg, K ('base' cations).
- Lack of deep tillage concentrates acidity where N fertilizer applied
- Legumes acidify their rooting zone through N-fixation. Perennial legumes (e.g., alfalfa) more so than annuals (e.g., pea). Yet apparently much less than fertilization of wheat.

Low soil pH in MT's historically calcareous soils is generally only in upper 6 inches, 0.3 pH unit difference has huge impact on barley yields



Long farm, Highwood Bench, unpub Nov 2016 data

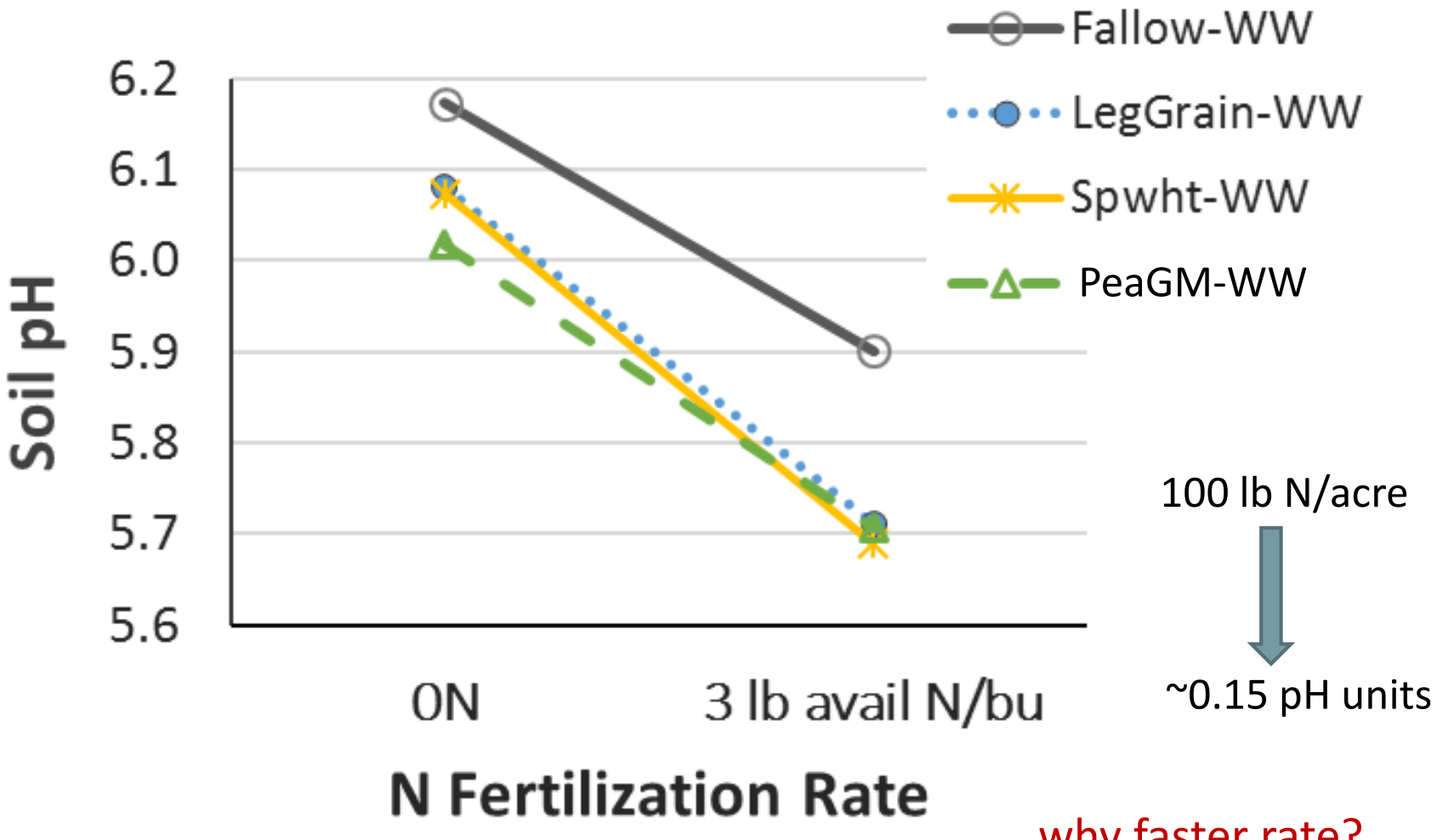
14-yr of N fertilization reduced top 4” pH on dryland cropping west of Bozeman up to 1 pH unit



Silt loam, 2% OM

Engel, Ewing, Miller, unpub data

6-yr N fertilization reduce soil pH (0-3”) west of Big Sandy



why faster rate?

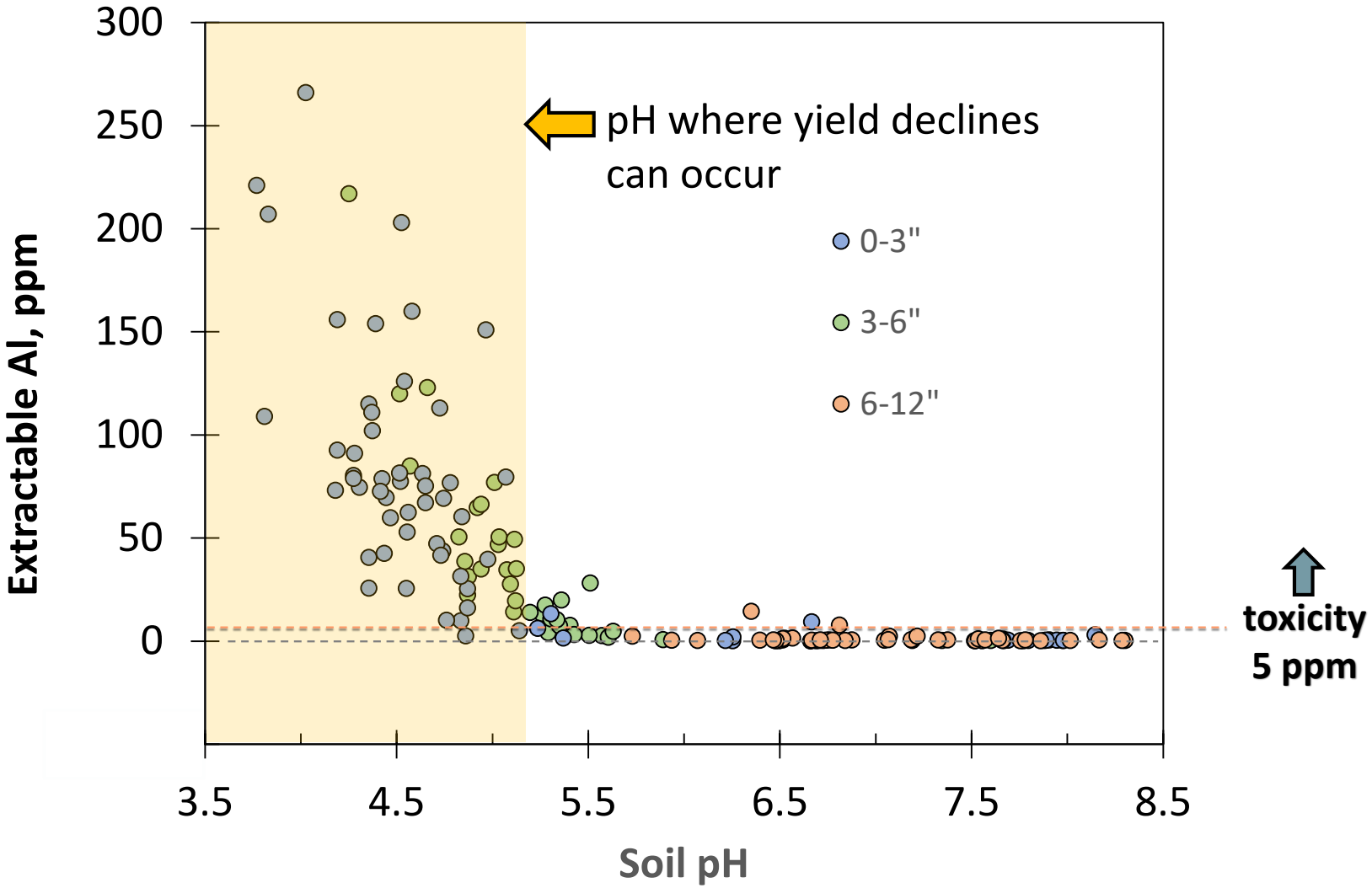
sandy clay loam, 1.1% OM

Alternate year was always winter wheat; Jones and Miller unpub data

Questions?

On to impact on crop

Low pH increases soil Al to toxic levels



Engel unpub. data, 2016, 5 farms near Highwood, MT

What to look for

- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)
  - small leaves, short thick internodes
  - yellow along margin near tip on older leaves
  - purple or brown lesions in chlorotic regions, indentations

A. Robson, https://agric.wa.gov.au/n/4487

Acid soils have additional negative impacts

Field pea: Gov. West. Australia

- Change in herbicide efficacy and persistence

http://pubs.cahnrs.wsu.edu/publications/pubs/fs189e/

- Poor N fixation by legumes
- Increase in some fungal diseases (e.g., Cephalosporium stripe) and root rot

"unexplained problems" may be first indicator of pH change

Image from *Wheat Disease ID*. MT Wht & Barley Co.

Questions?

On to diagnosis and prevention

Diagnose: scout, soil test

1. Scout or use aerial maps to locate healthy and unhealthy areas
2. Field pH test on soil/water slurry of top 3” or send to lab. Why not the standard 6”?
3. Test 3-6” if producer might till.
4. Avoid compositing samples from different slope areas.
5. pH varies seasonally and annually, test from same area and time of year by same lab using same method to see trend
6. Veris can also sample for pH
7. Can also use Google Earth, satellite, plane or drone imagery to look for poor growth spots to focus sampling

Management to prevent acidification:
Increase N fertilizer use efficiency

- Large overlap with management to reduce N leaching (see our N Leaching Extension bulletin and MTGuide)
- Soil test close to application time. Make sure enough PKS
- Use conservative pre-plant rate, top-dress if adequate moisture
- Apply N close to peak crop uptake
- Use variable, site specific rates: Less N in low production areas limited by factors other than N (e.g., low pH, shallow soils)
- Reduce N rates especially when protein discounts low

Management to prevent acidification:

- Change N source
- Legumes in rotation – no N fertilizer and residue increases soil surface pH more than non-legumes (Paul et al., 2003)
- Encourage producer to leave crop residue in field – retains base cations and SOM buffers pH changes and Al toxicity. 6x base cations removed by oat straw harvest than just oat grain harvest (Pierre and Banwart 1973)

Most acidifying

MAP = AS ≈ 2x urea

DAP (18-46-0)

Urea (46-0-0), UAN (28-0-0)

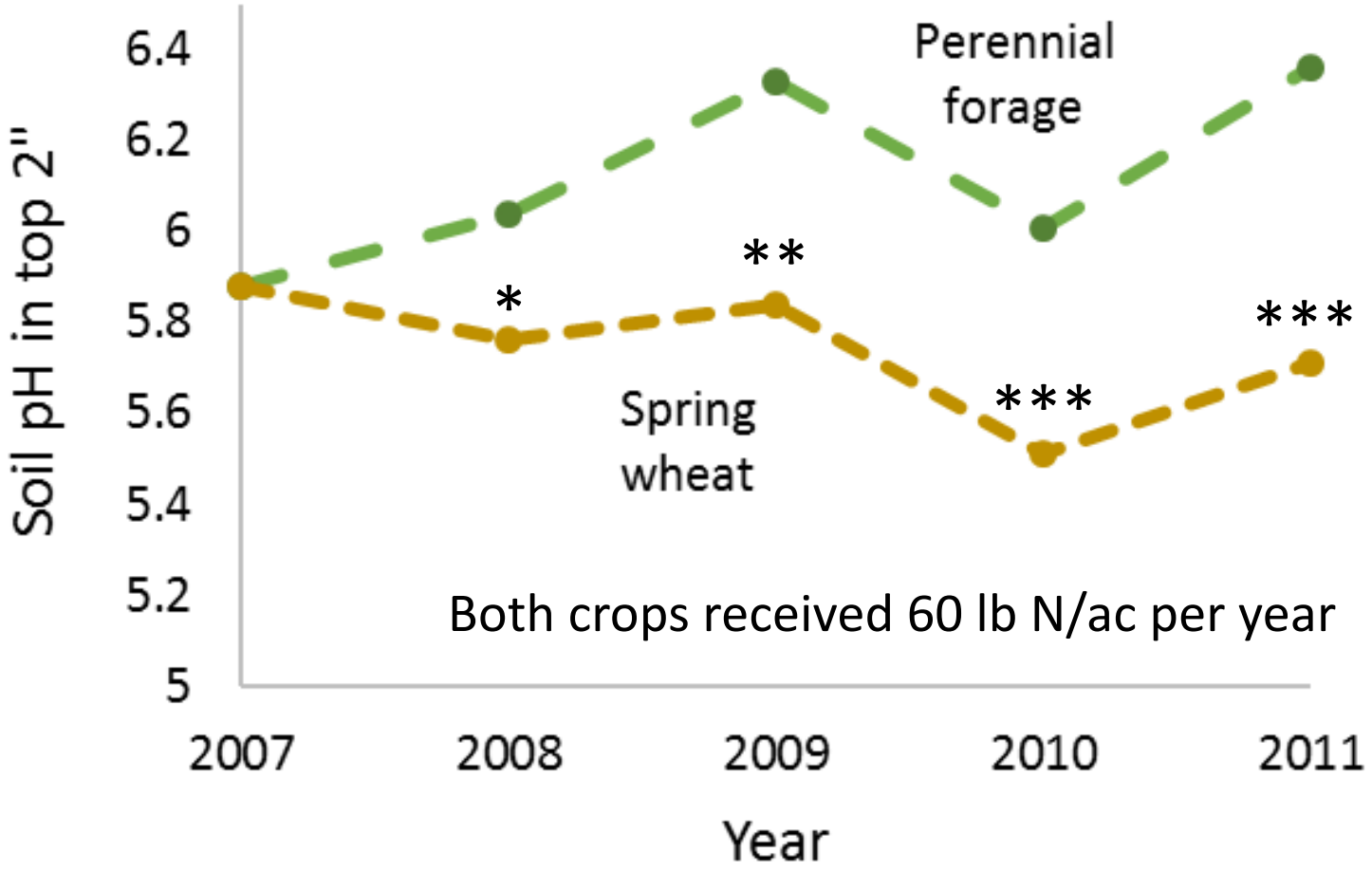
CAN ≈ 1/3x urea

Potassium nitrate (13-0-46)

Legumes and manure

Least acidifying

Perennial forage can maintain or increase soil pH



pH differs between crops with * > 90%, ** > 95%, *** > 99% confidence, Mandan, ND, Liebig et al., 2018

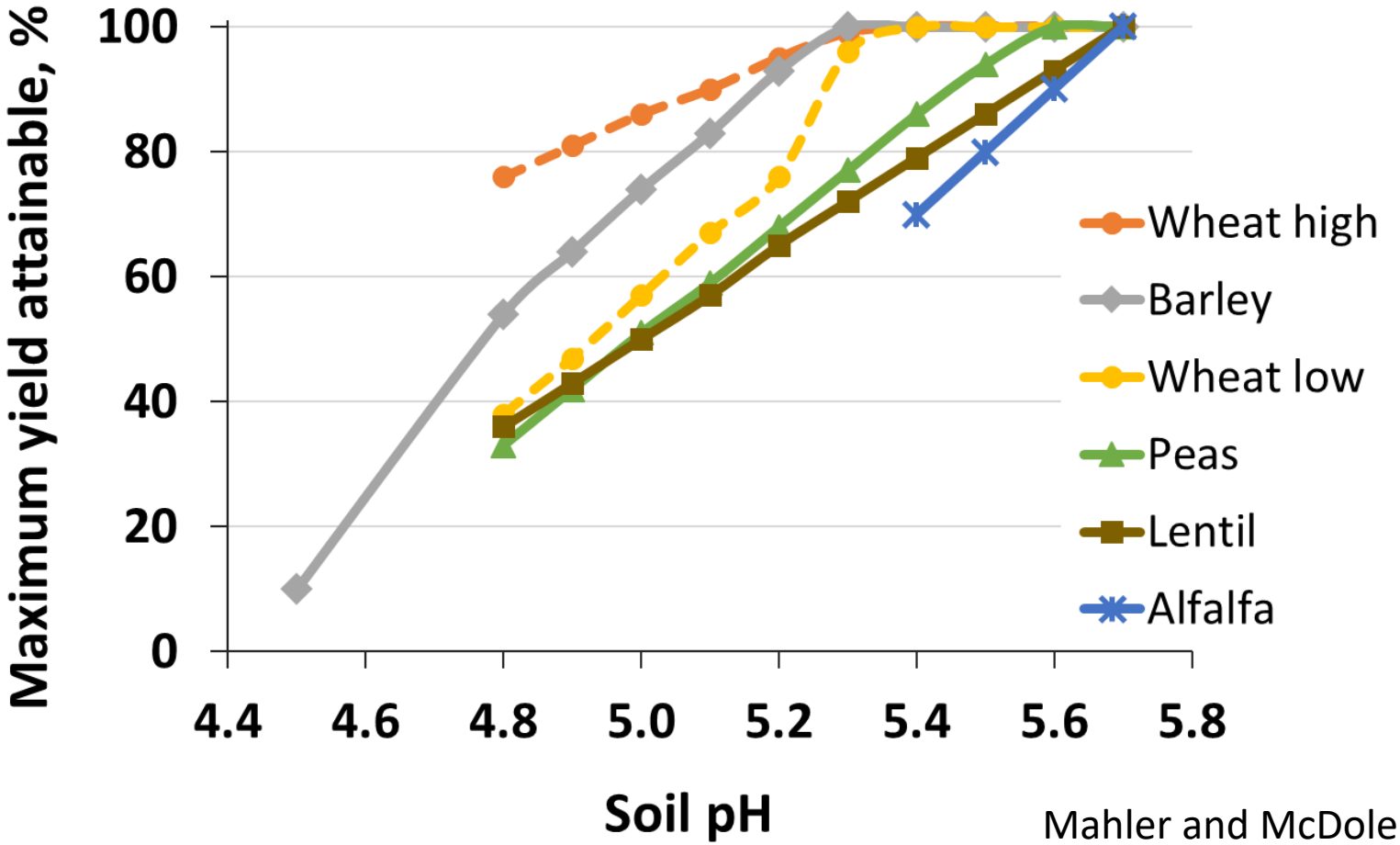
What else are you trying?

Questions?

On to adaptation and restoration options

Adaptation: Suggest tolerant crop species. Durum is low tolerant cereal, legumes (or their rhizobia) are least tolerant.

"Wheat high" are Al and acid tolerant varieties

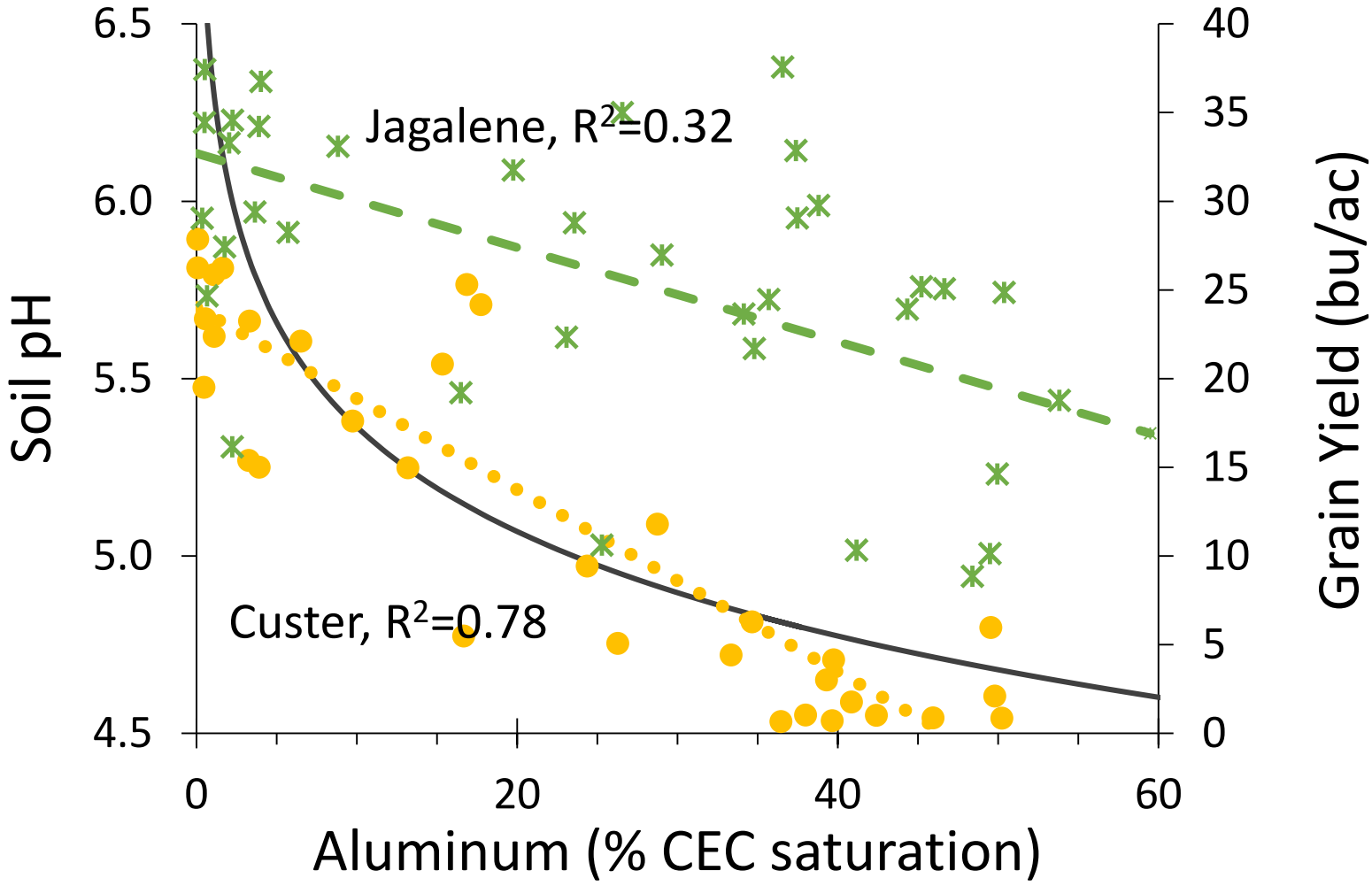


Mahler and McDole 1987
Long pers comm

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

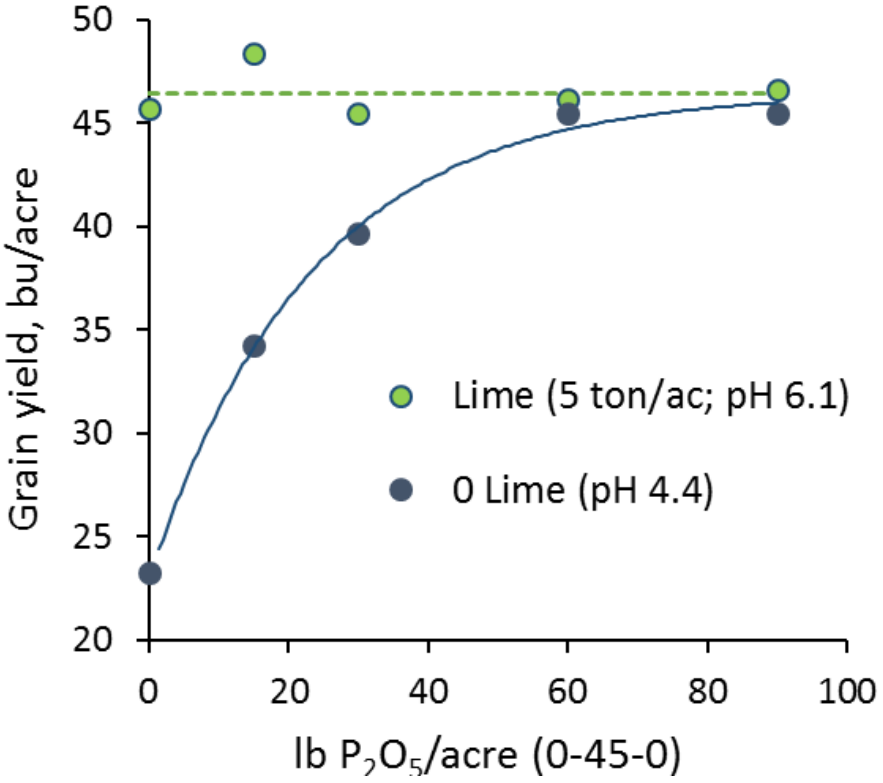
High variation among varieties

example winter wheat

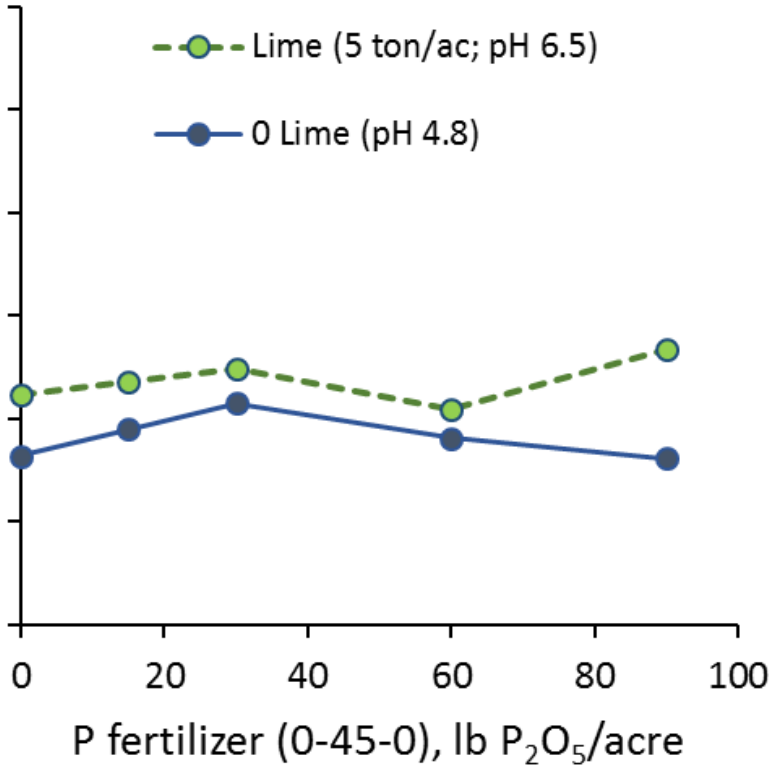


Kariuki et al., 2007, OK

Seed-placed P_2O_5: increased durum grain yield in one farm as much as lime, no response another farm



Olsen P = 48 ppm



Olsen P = 53 ppm

Economics?

Do field strip trials

Engel unpub data using Ag lime

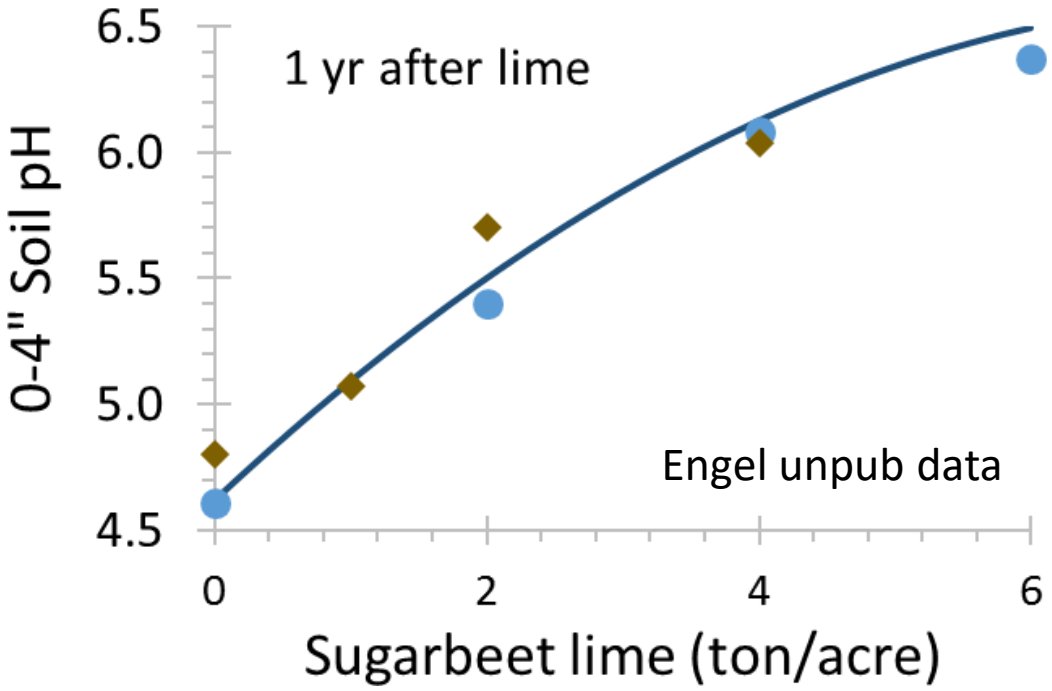
Restoration: Lime

Stoltzfus lime spreader, Stoltz Mfg.

- Sugarbeet lime
  - Good – it doesn't cost anything
  - Bad – shipping costs (not too high since at Western Sugar Co-op in Billings); challenging material to work with (moisture and clumping), need a wet lime spreader, contains chunks and some trash, and incorporation w/ tillage needed for best results
  - Rates of 3-6 tons/acre may be necessary to bring pH to acceptable level (pH > 6)
- Aglime – more expensive and further away
- Pelletized lime? Expensive and need about 400 lb/acre per year just to offset typical N rate.

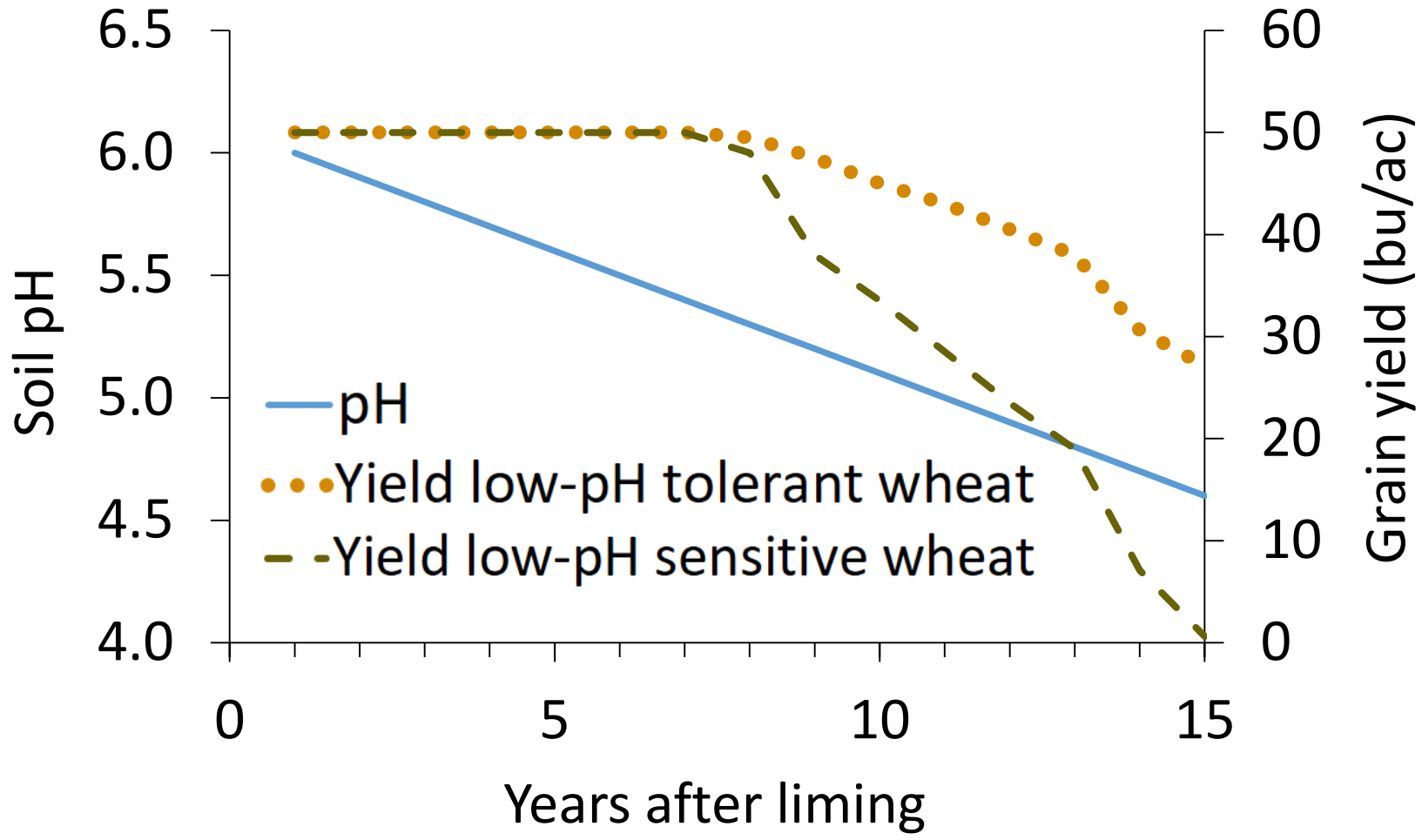
Restoration needs a lot of lime

- Rate:
  - Find from online tables (or your lab) with buffer pH and target pH
  - Or use MSU preliminary results
- Only lime field areas with low soil pH



Initial pH	Ton SBeet lime	
	To pH 6.0	To pH 6.5
4.0	4.7	7.2
4.5	3.8	6.3
5.0	2.8	5.2
5.5	1.6	4.0

Yield declines as lime ‘wears off’ and soil again becomes acidic (assumes linear pH decline)

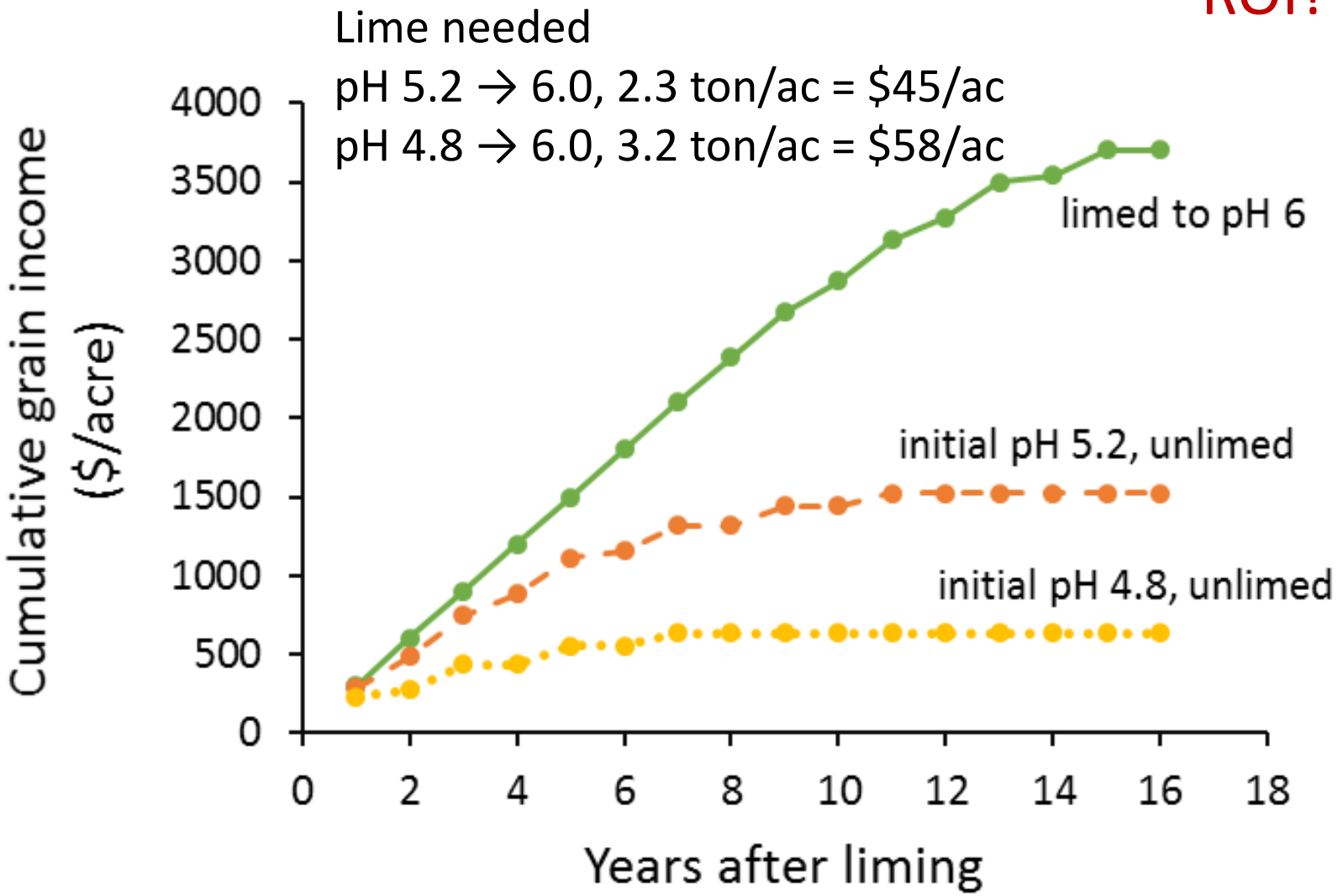


Modeled. Assumes 100 lb N/ac per year causes 0.1 pH drop/year

Mahler and McDole 1987, ID

Liming is a capital investment

ROI??

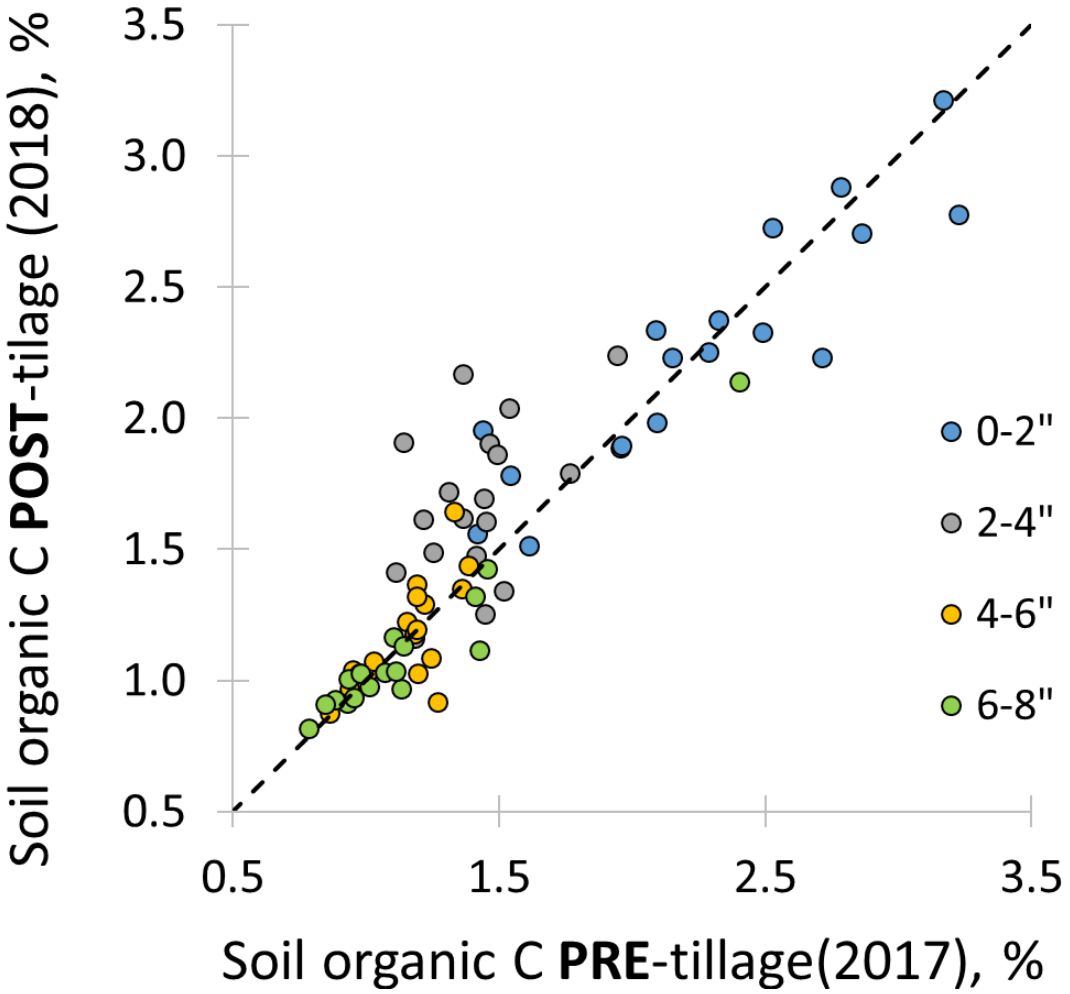


Mahler and McDole 1987 yield decline curves

50 bu/ac yield potential, $6/bu grain, $15/ton lime + $10/ac to spread

low-pH tolerant wheat/low-pH sensitive durum rotation; 100 lb N/ac/yr

Does one-time tillage reduce soil organic matter?



Inversion till to mix acid zone with higher pH zone below – one-time summer tillage doesn't negate long term benefits of no-till.

Problem: eventually make low pH zone deeper, when need to lime, requires more lime and deeper tillage. Will negate some no till benefits.

Engel unpub data 2018, single pass beavertail spike and harrow

Summary

- Cropland soils are becoming acidic, largely due to N fert.
- This reduces yields for several reasons
- Identify whether clients' fields have a problem **now** to slow or prevent acidification with sound management
- Recommending crop rotations with lower N needs is likely best way to prevent further acidification
- Crop and variety selection or seed placed P fertilizer can help adapt to acid soils
- Liming or planting perennials can reverse acidification
- HUGE opportunities for crop advisers (e.g. sampling, mapping, VR lime and N, etc.)

Thank you!

Questions?

Image from Oregon State University, Lane County, OR 1926.

For more information and links to additional resources on soil acidification see MSU's cropland soil acidification website http://landresources.montana.edu/soilfertility/acidif/index.html

If you have questions about soil and buffer pH tests go to https://www.youtube.com/watch?v=w9PWZSaFfb4