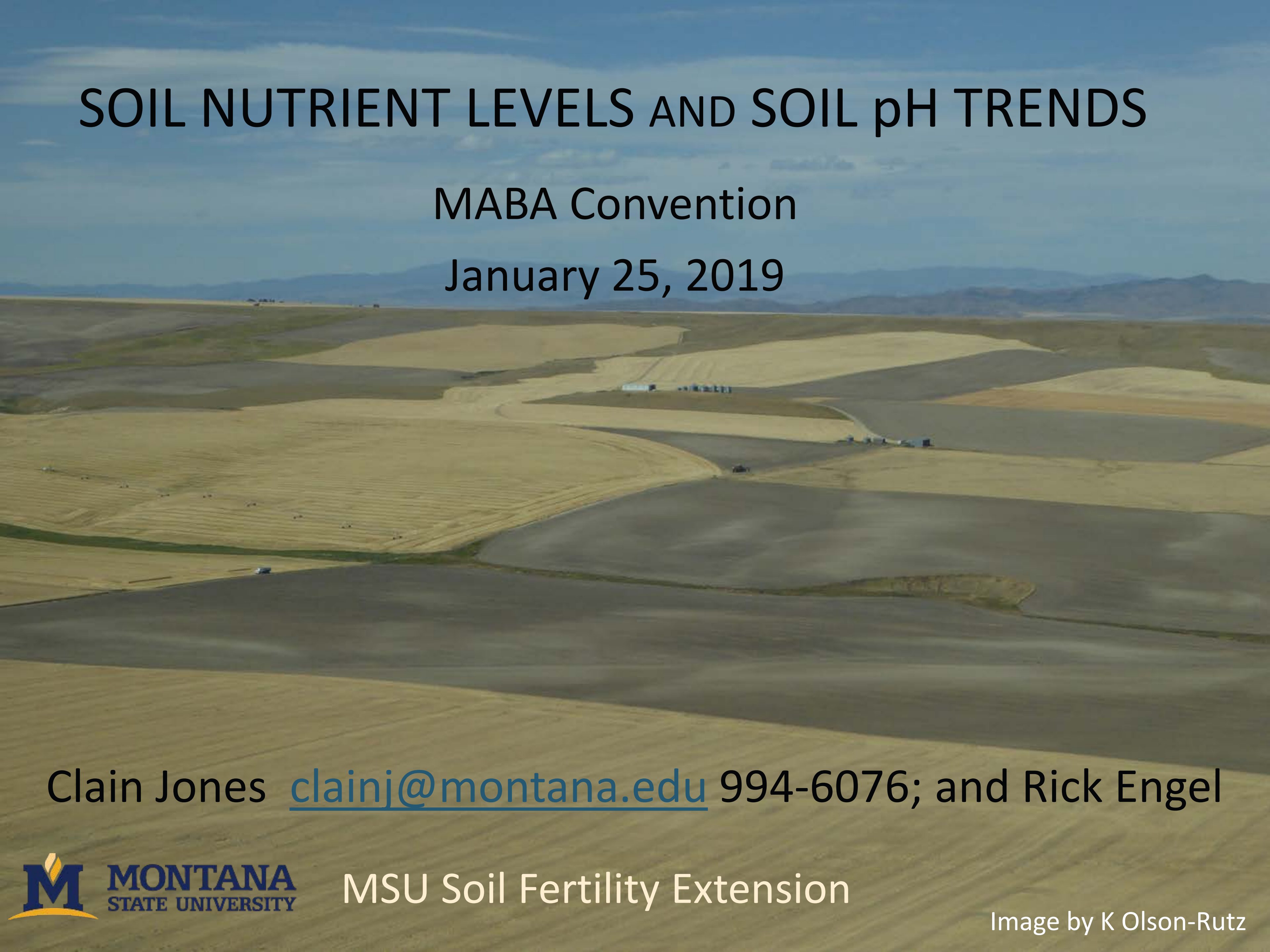
SOIL NUTRIENT LEVELS AND SOIL pH TRENDS

MABA Convention

January 25, 2019



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MONTANA STATE UNIVERSITY

MSU Soil Fertility Extension

Image by K Olson-Rutz

Today's topics

- Trends in soil nutrient levels
- Limitations of soil tests
- Effect of soil pH on soil nutrients
- Changing soil pH on MT croplands
- Management options with acidifying soils

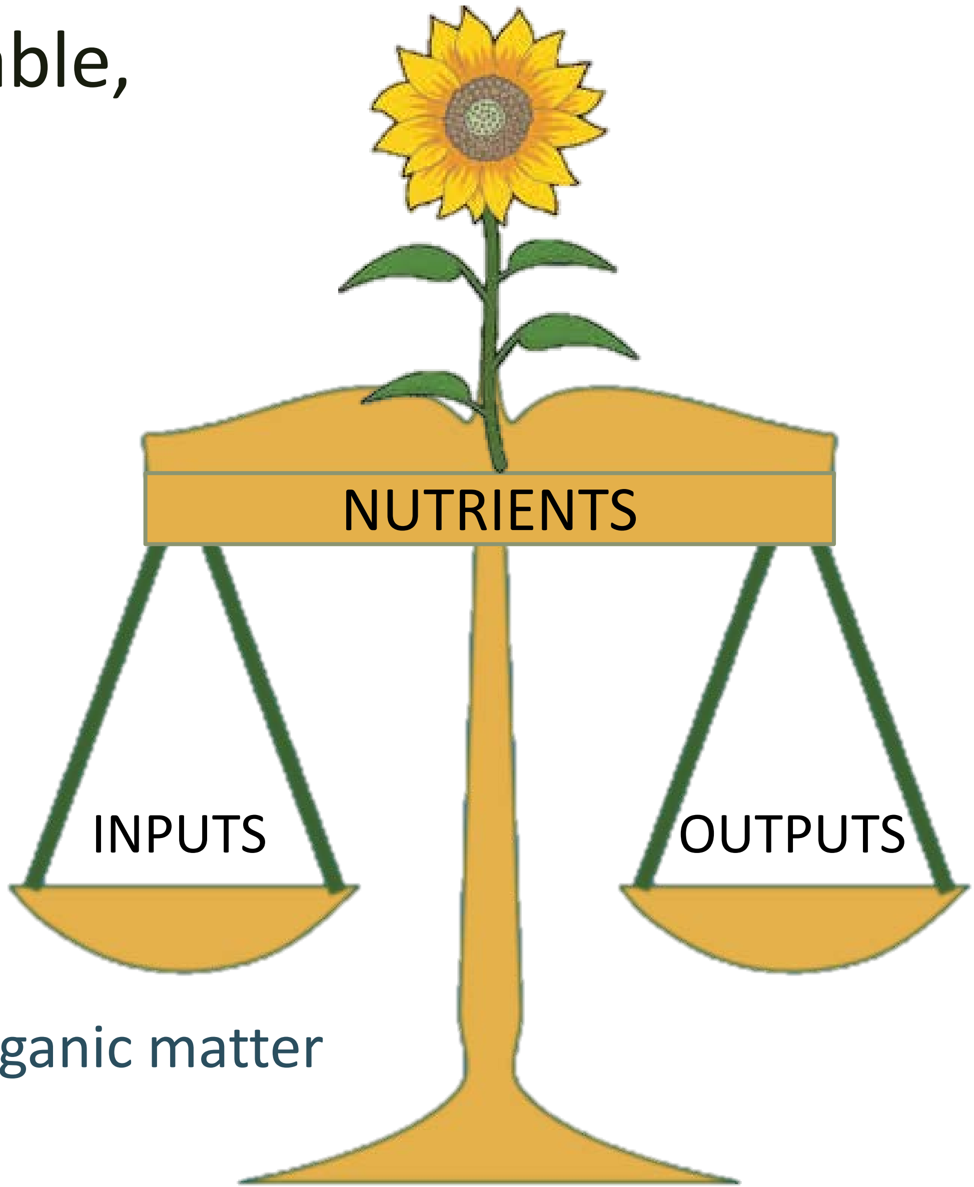
The Montana Fertilizer Advisory Council and the Western Sustainable Agriculture Research and Education Program are major funding sources for MSU studies.

For sustainable, healthy production

Fertilizer
Manure

N-fixation by legumes

Mineral soil/organic matter



Harvest

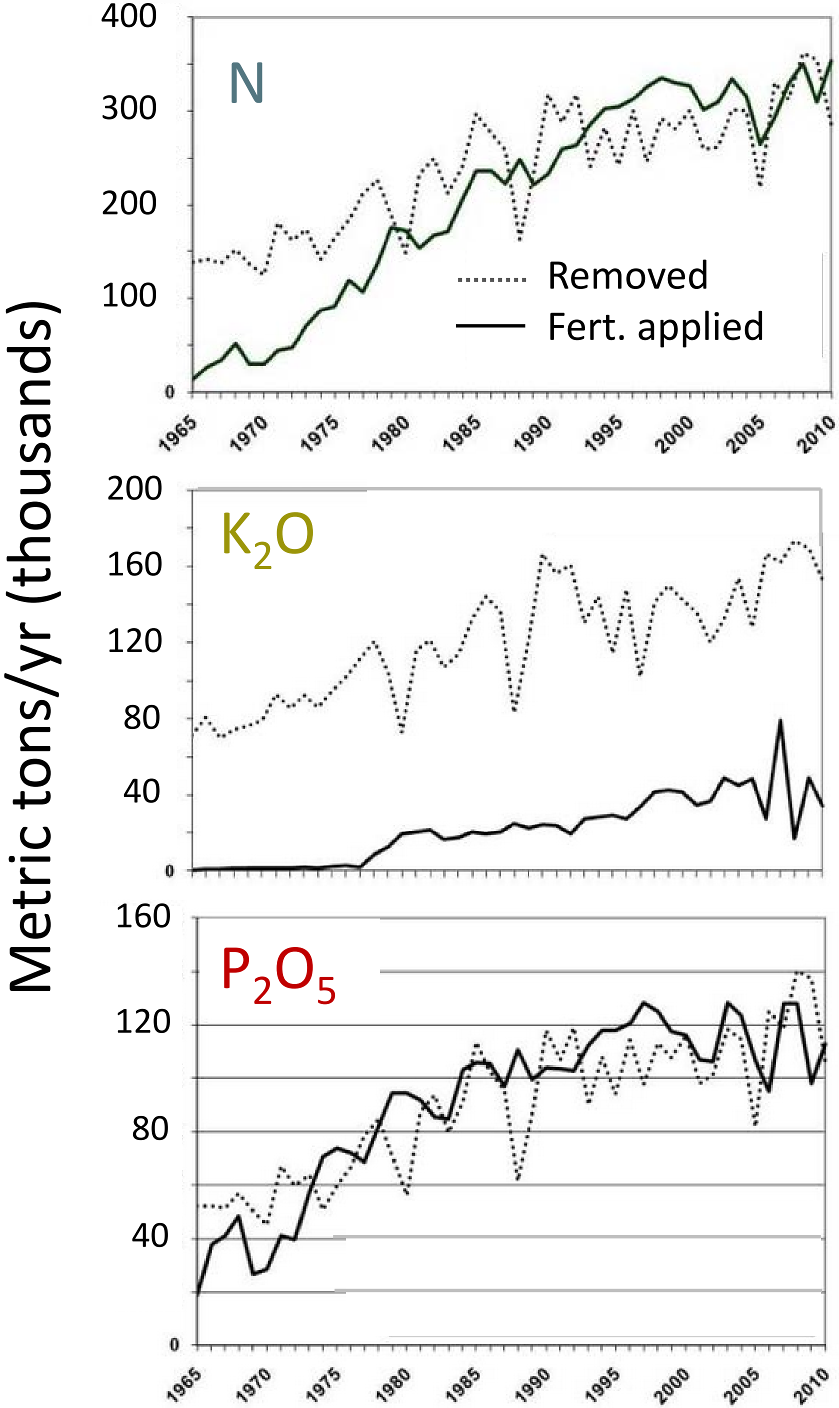
Erosion

Runoff

Leaching

In many ag systems, outputs > inputs = mining the soil for nutrients

Nutrient harvest vs fertilizer applied in Manitoba, 1965-2010



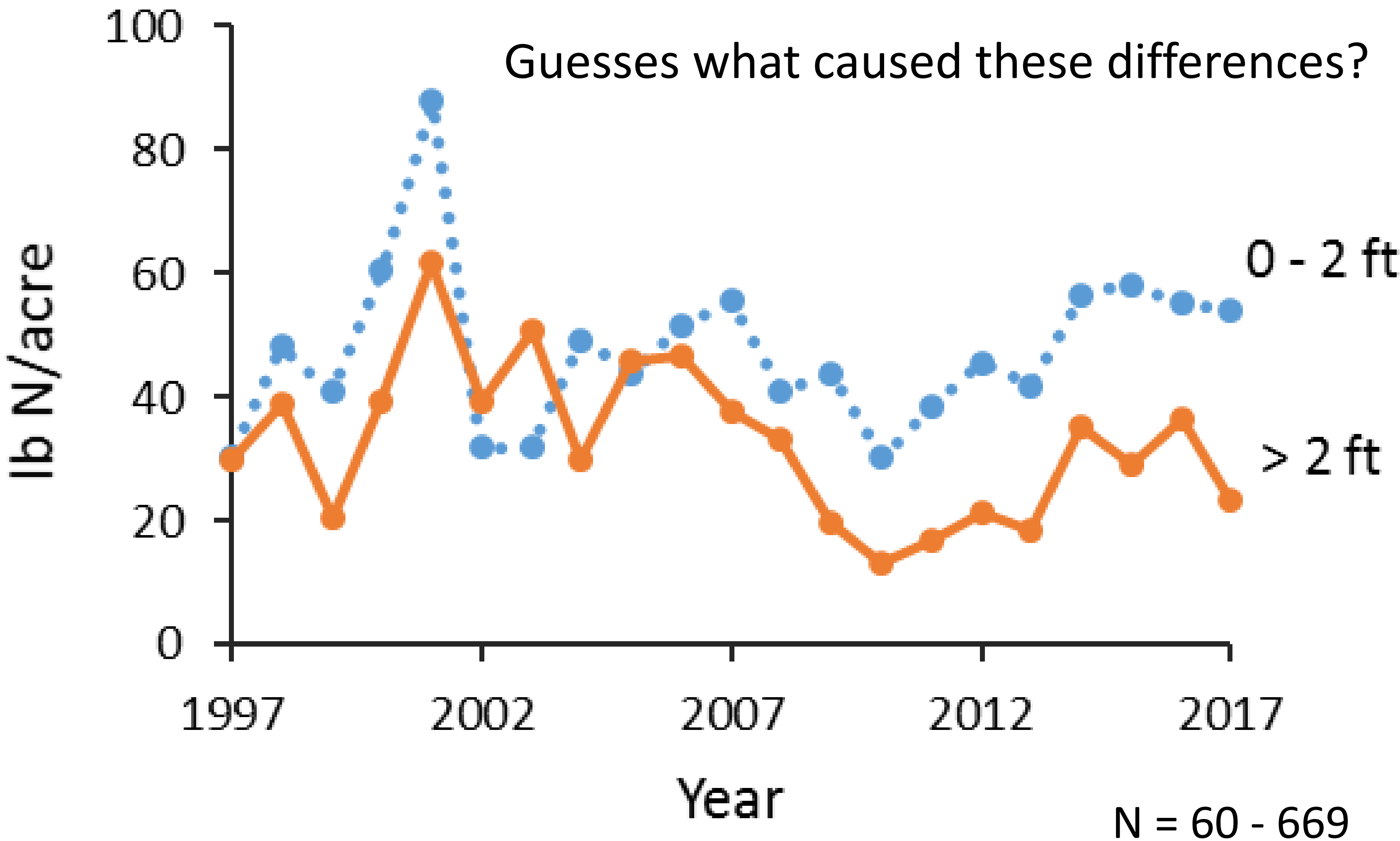
Nitrogen: soil reserves depleted long time ago

K_2O: soil sustains needs for now, issues may arise on coarse soils with high K demand crops

P_2O_5: recent trend is greater removal than application

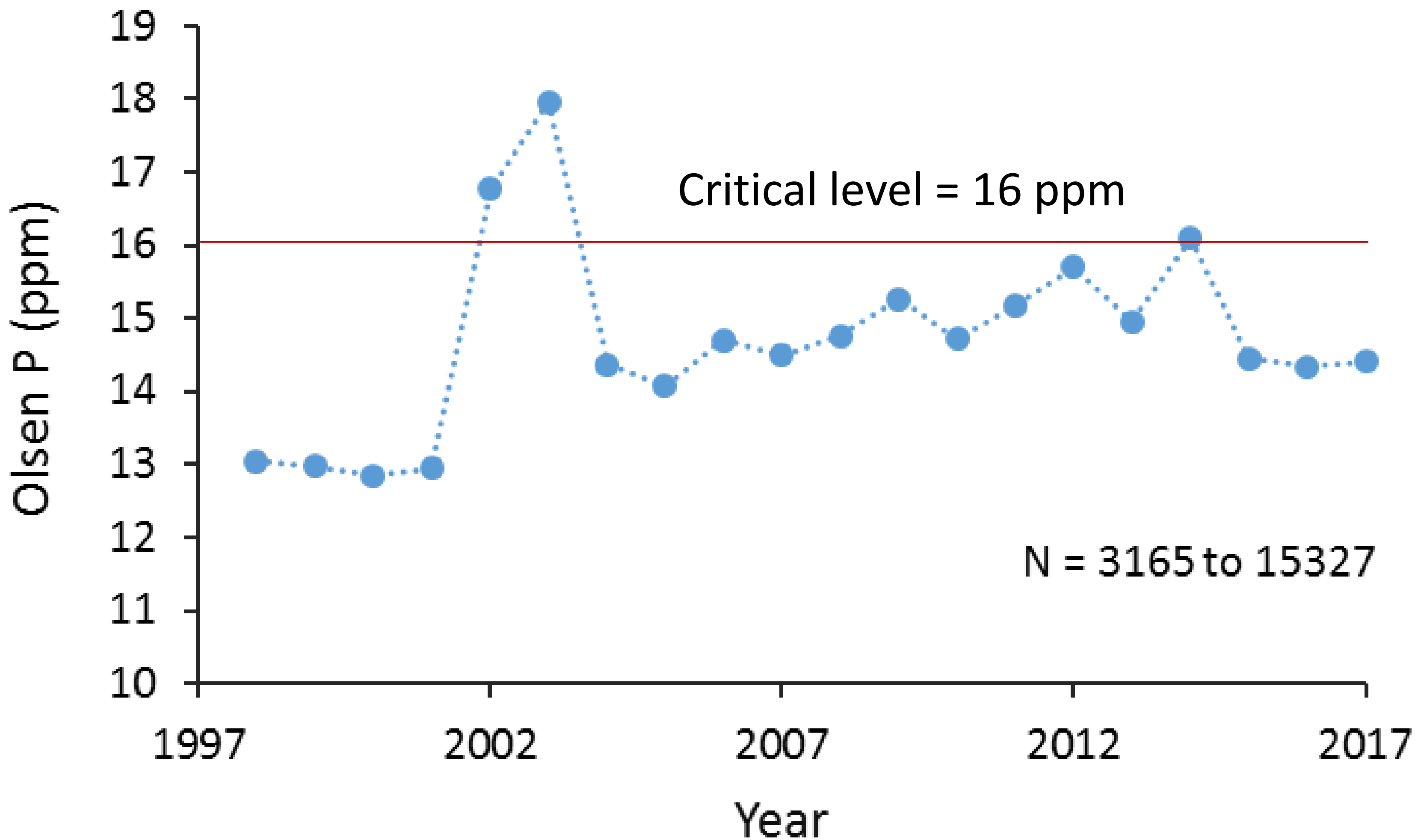
Heard, 2011
https://www.gov.mb.ca/agriculture/crops/soil-fertility/nutrient-balances-in-manitoba.html

Average available N at 0-2 and > 2 ft depth in Golden Triangle over past 20 years



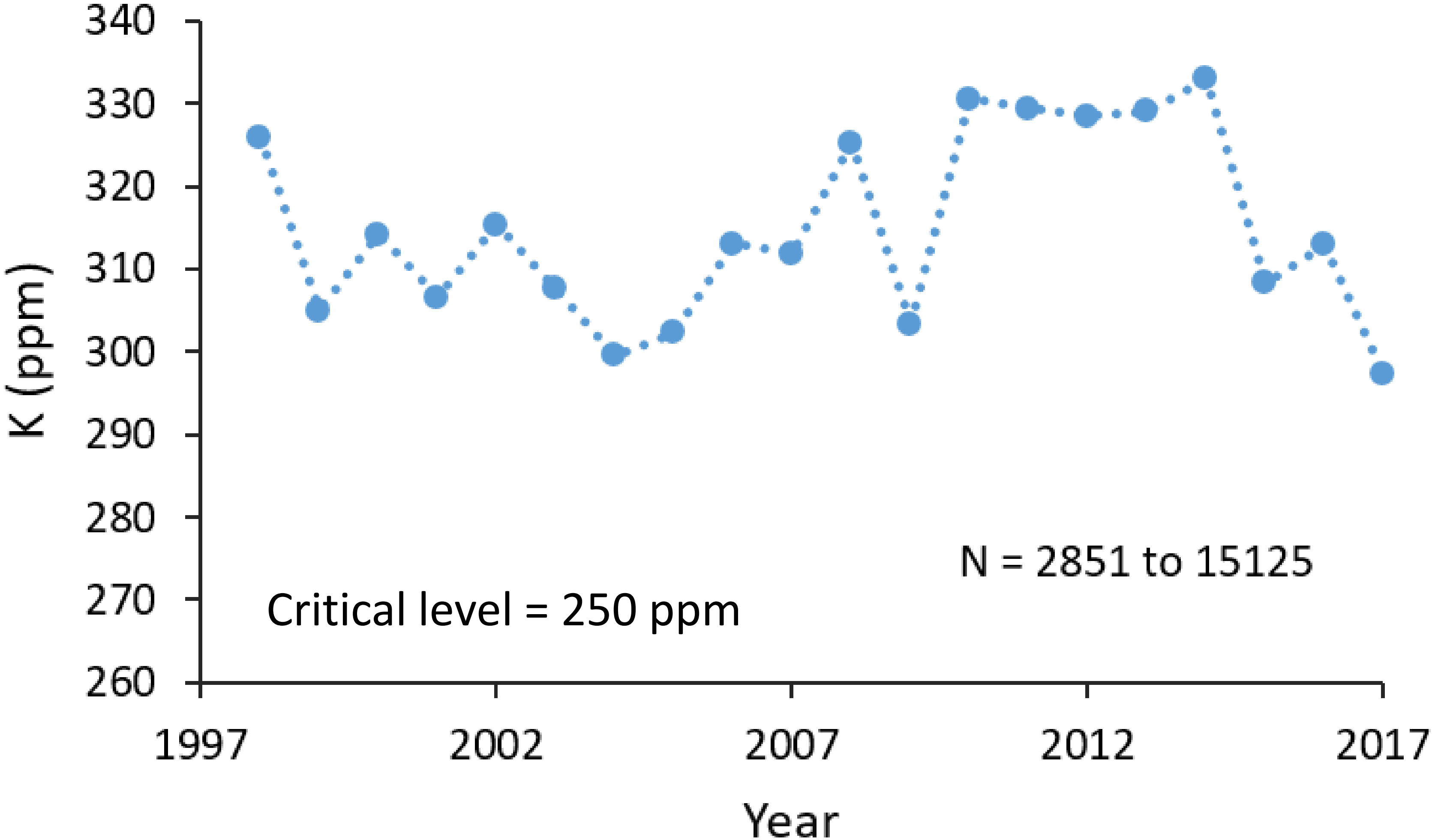
Data provided by AgVise

Average 0-6" Olsen P in MT: no strong trend over 20 years



Data provided by AgVise

Average 0-6” K in MT over past 20 years



Data provided by AgVise

Selected total and available micronutrients in MT surface soils in past 38 years

	1979* (n=301)		2017** (n=4000-10,500)
	Total	Available	Available
Nutrient	(ppm in top 0-6”)		
Copper	30	2.0	1.0 (0.5 crit lev)
Iron	38,000	15.8	21.0 (5 crit lev)
Manganese	600	12.4	4.1 (1 crit lev)
Zinc	50	1.2	1.0 (0.5 crit lev)

The majority of metals are bound in minerals or soil organic matter, not immediately available to plants. *Haby and Sims 1979, **Agvise

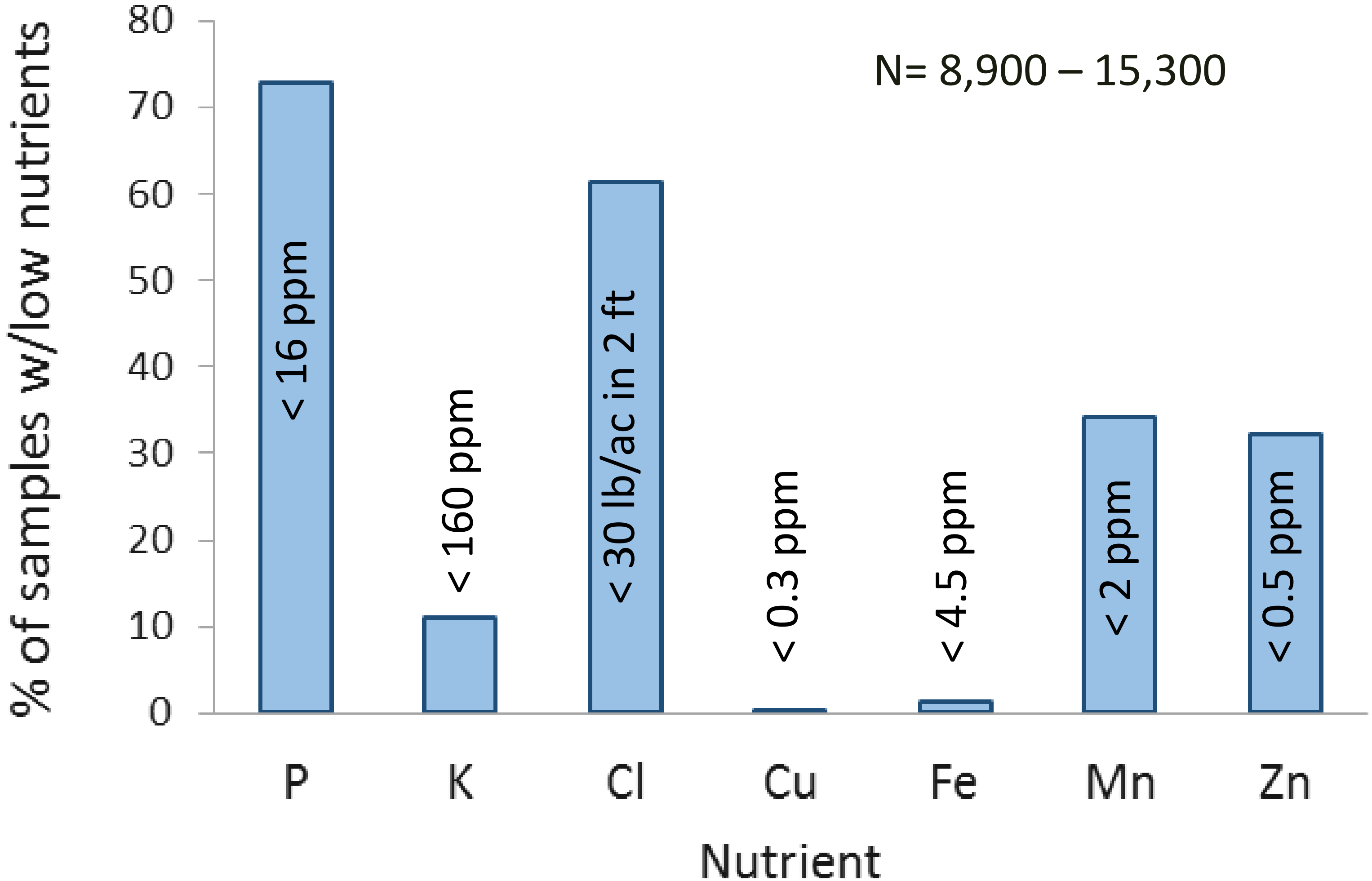
Why might we be seeing, or eventually see, more micronutrient deficiencies?

There is a finite amount of micronutrients in the soil. Micronutrient deficiencies will likely increase as:

- Yields and amount removed from field increases
- Few micronutrients are added (individually, in manure)

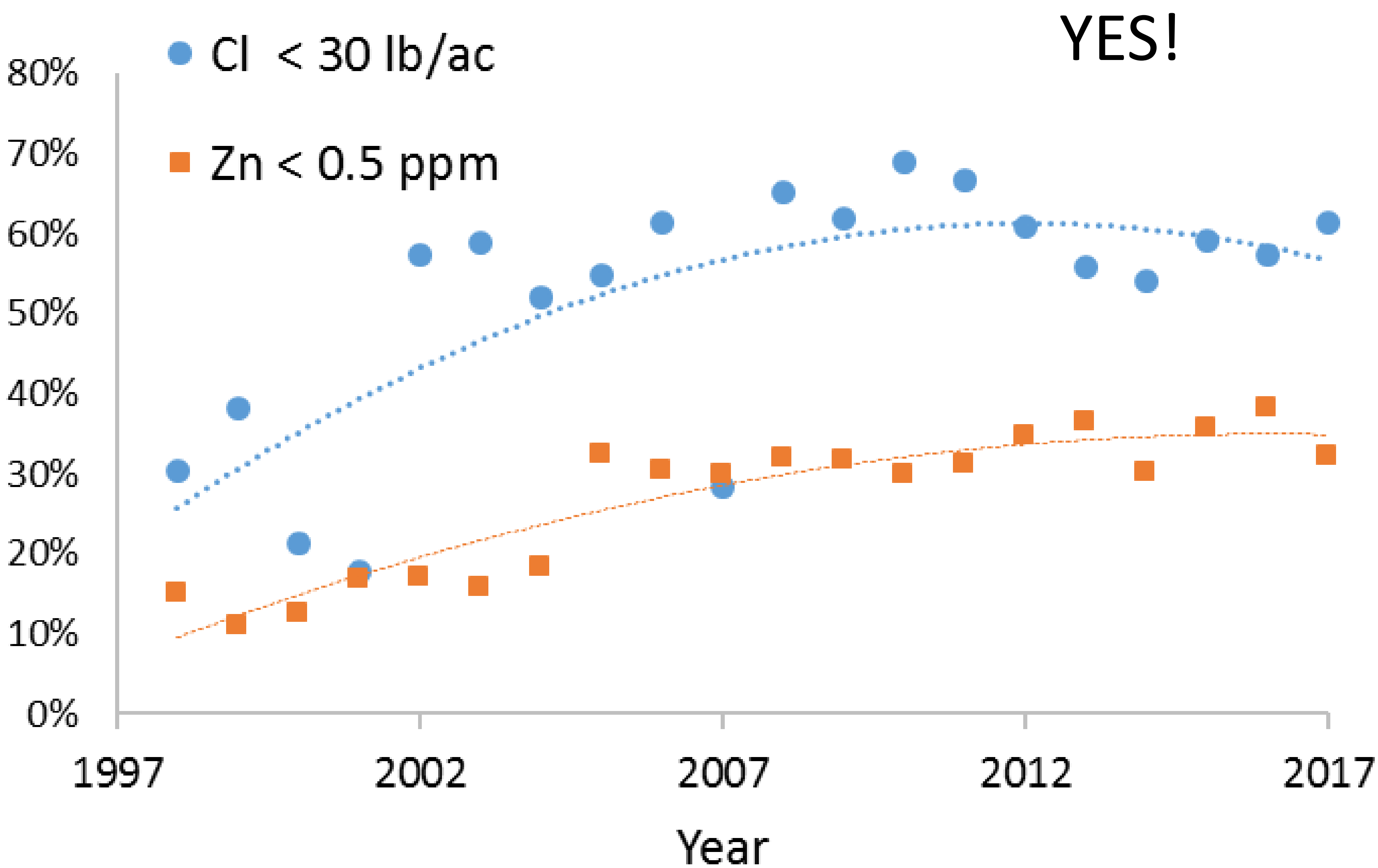
Deficiencies observed in MT: B, Cl, Cu, Fe, Mn, Zn

MT soils with “low” macro and micro nutrient concentrations in top 6” (source: Agvise, 2017)



There may be bias because more samples may be submitted when deficiency symptoms are suspected than when not

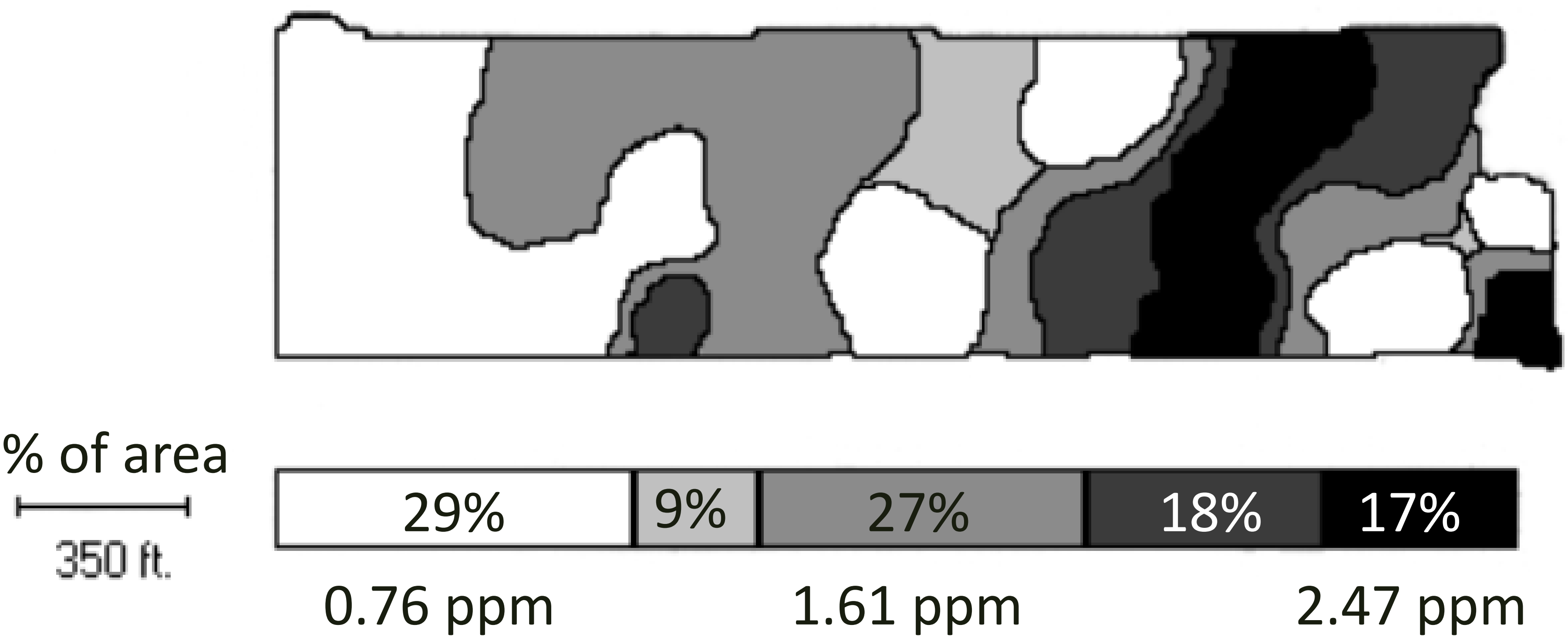
Have % of soil chloride or zinc levels below MSU's 'critical level' increased in last 15 years in Montana?



Source: Agvise, unpub. data

Spatial variation of soil test results

Cu levels on a 2-acre sampling grid of a 40-acre field near Rosetown, SK



What would a field composite Cu level be?

In Flaten et al. 2000, map by Bulani Agro, Rosetown, SK

Soil test considerations

- If comfortable with choice, use same lab repeatedly
- Base decision to fertilize micronutrients on multiple sources.
  - Field scout for visual deficiency See *Plant Nutrient Functions and Deficiency and Toxicity Symptoms (NMM 9):* http://landresources.montana.edu/nm
  - Test plant tissue: few guidelines for tissue test and fert recommendation, and test results vary with plant part and maturity, time of day, handling.
  - Do on-farm strip test trials.

Soil nutrients summary

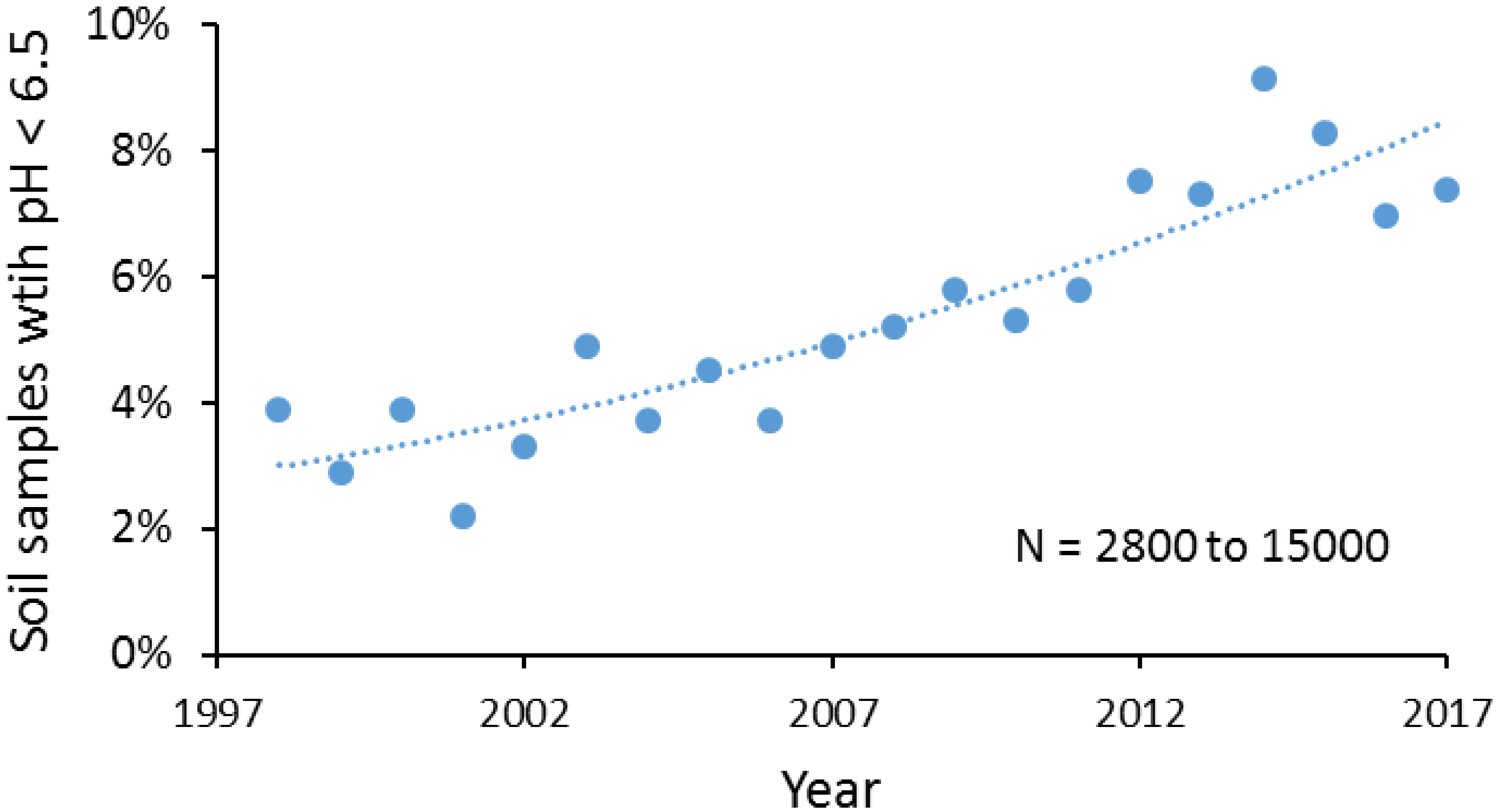
- Mining soils for nutrients is not sustainable, yet is occurring in Montana.
- Track soil nutrient levels with soil tests, tissue testing, deficiency symptoms
- Have any of you plotted nutrient levels for fields you sample? If so, PLEASE send me your data. Client can remain anonymous.

Questions?

On to soil pH

Apologies for repetition for those who attended CPMS

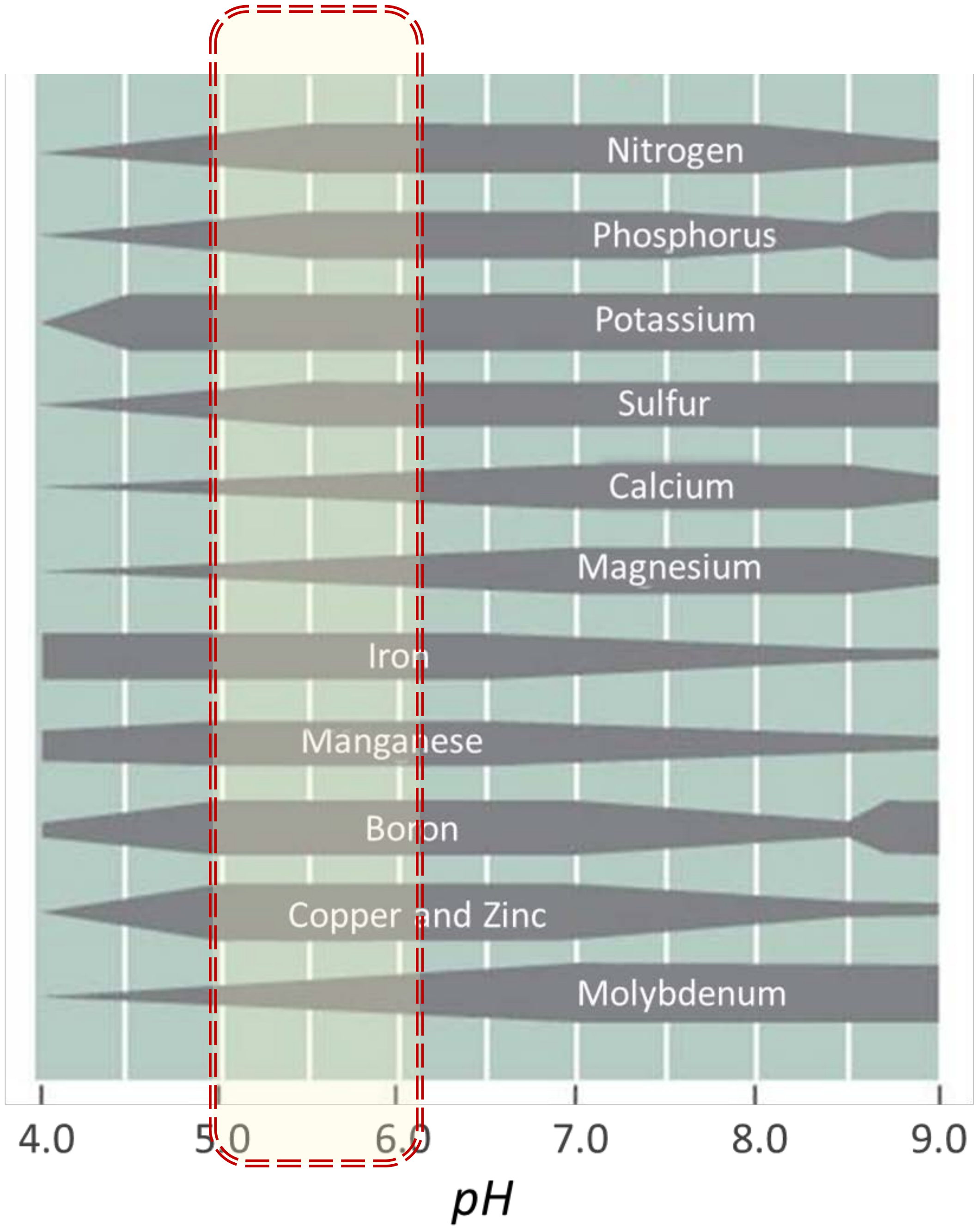
MT soil samples with pH < 6.5



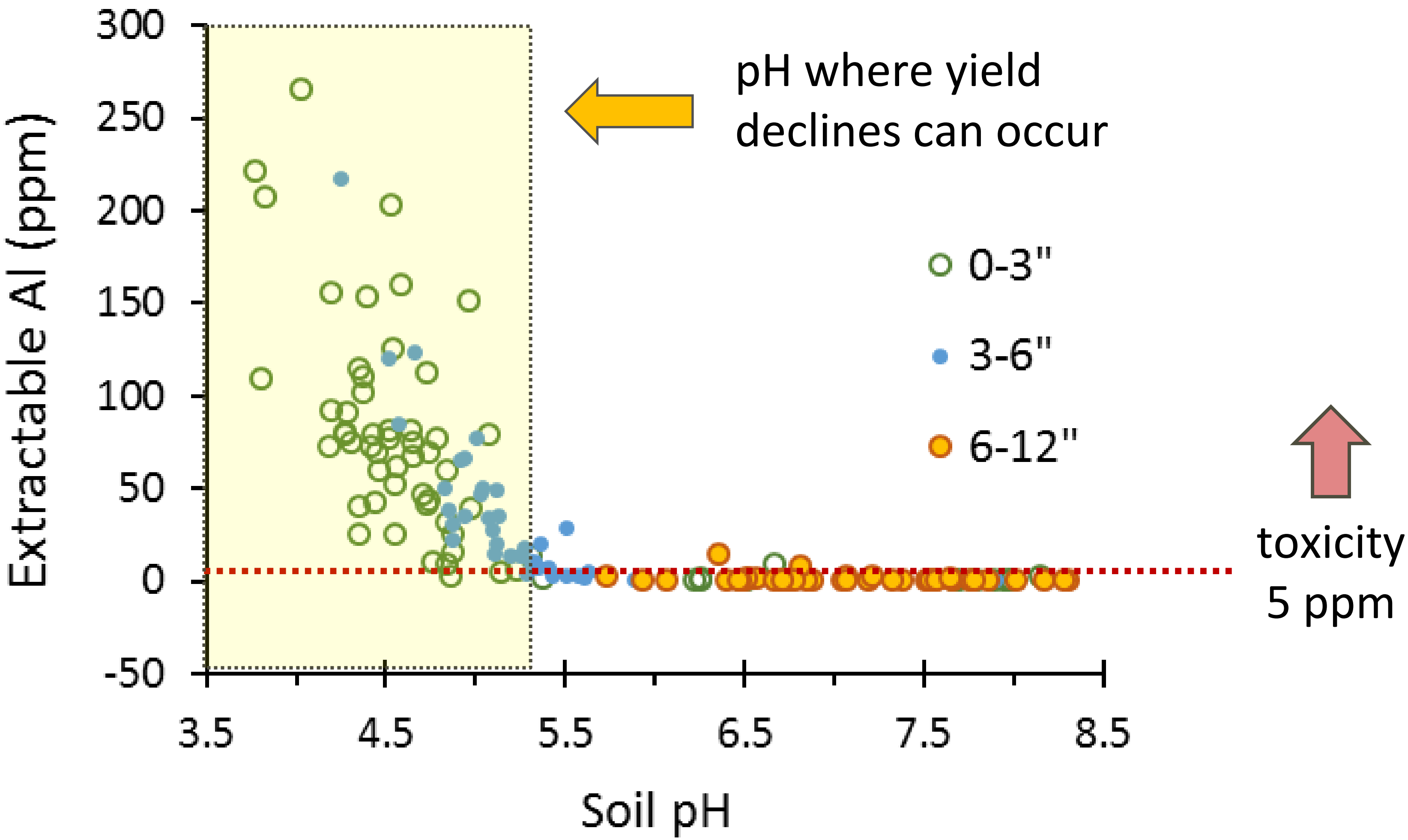
AgVise, 2017

Dropping pH changes nutrient availability

- Start watching for unexplained N, P, S, and Mg deficiencies
- Al becomes ‘available’ reaching toxic levels



Dropping pH increases aluminum availability



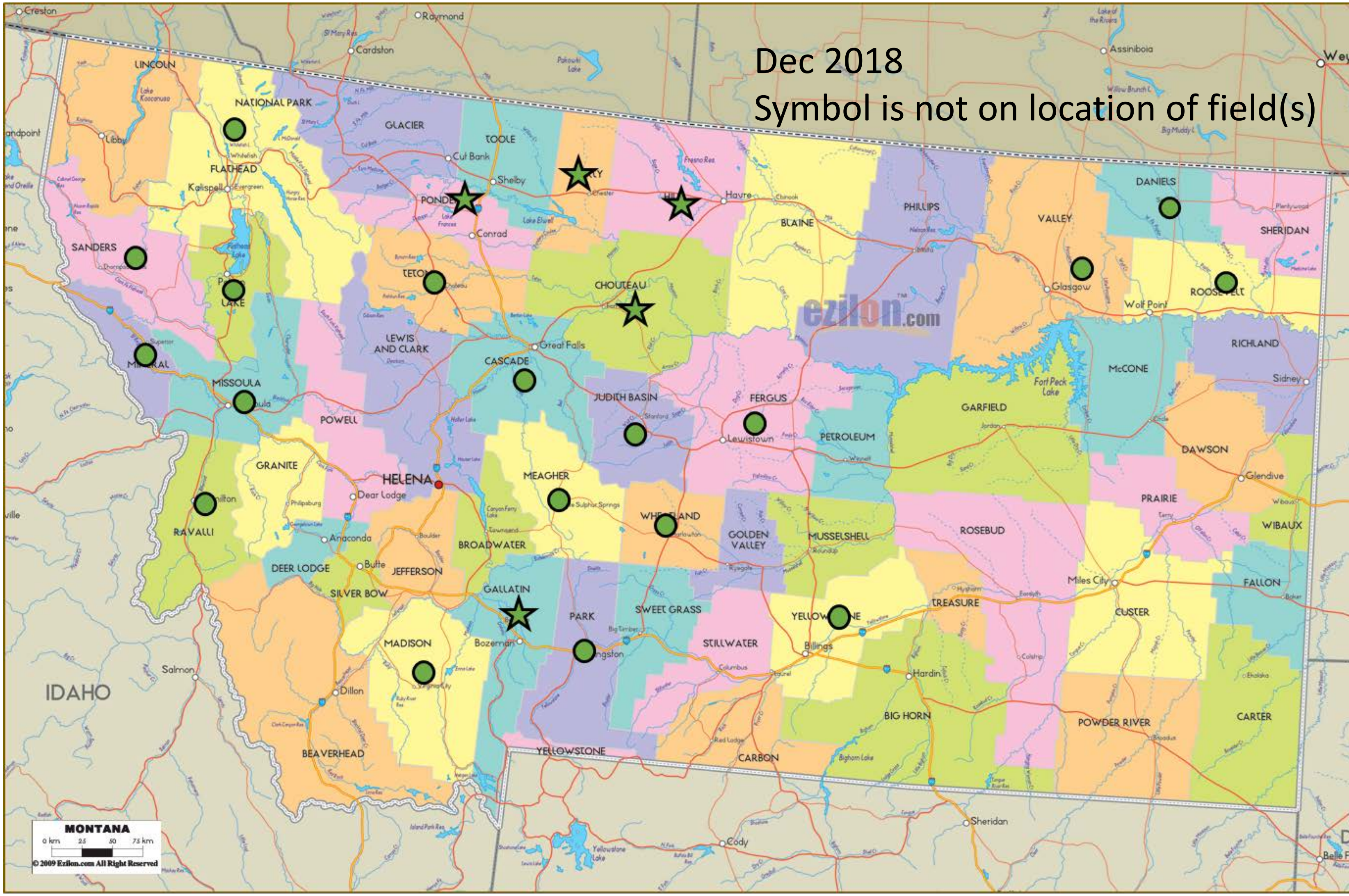
R. Engel unpub data, 5 locations in north-central MT

Is this a real issue or Rick and me looking for more work?

Safflower field near Big Sandy, 2018
pH 4.3 – 4.5 in bare areas

Image courtesy Scott Powell

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



☆ Measured by MSU ● Reported by CCA, Ext. Agent, or producer

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

Natural reasons for low soil pH

- Soils with low buffering capacity (low soil organic matter, coarse texture, granitic rather than calcareous)
- Historical forest vegetation soils have lower pH than historical grassland
- Regions with high precipitation, leading to leaching of nitrate (and higher yields, therefore generally receiving more N fertilizer)

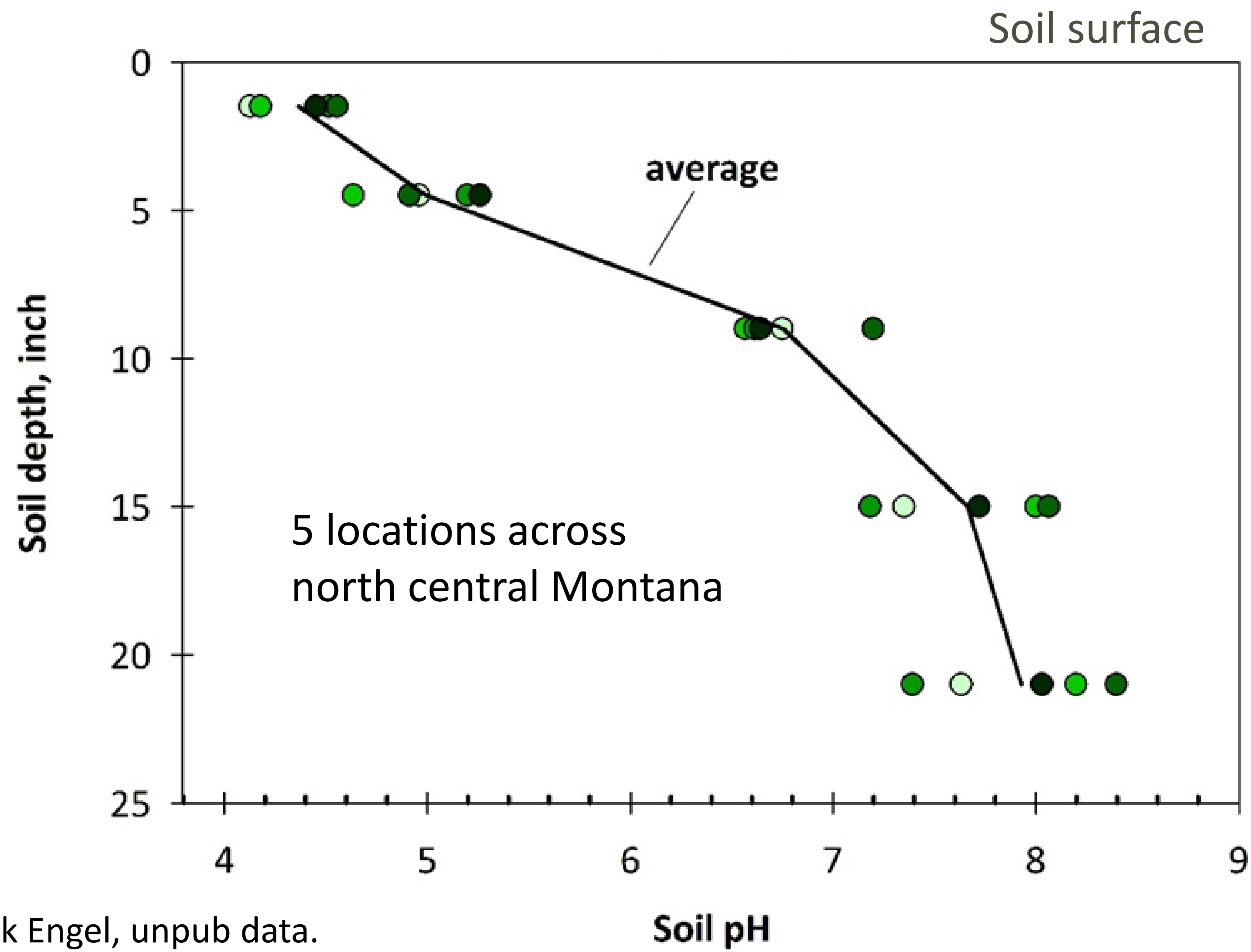
Agronomic reasons for low soil pH

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

ammonium or urea fertilizer + air + $H_2O \rightarrow$ nitrate (NO_3^-) + acid (H^+)

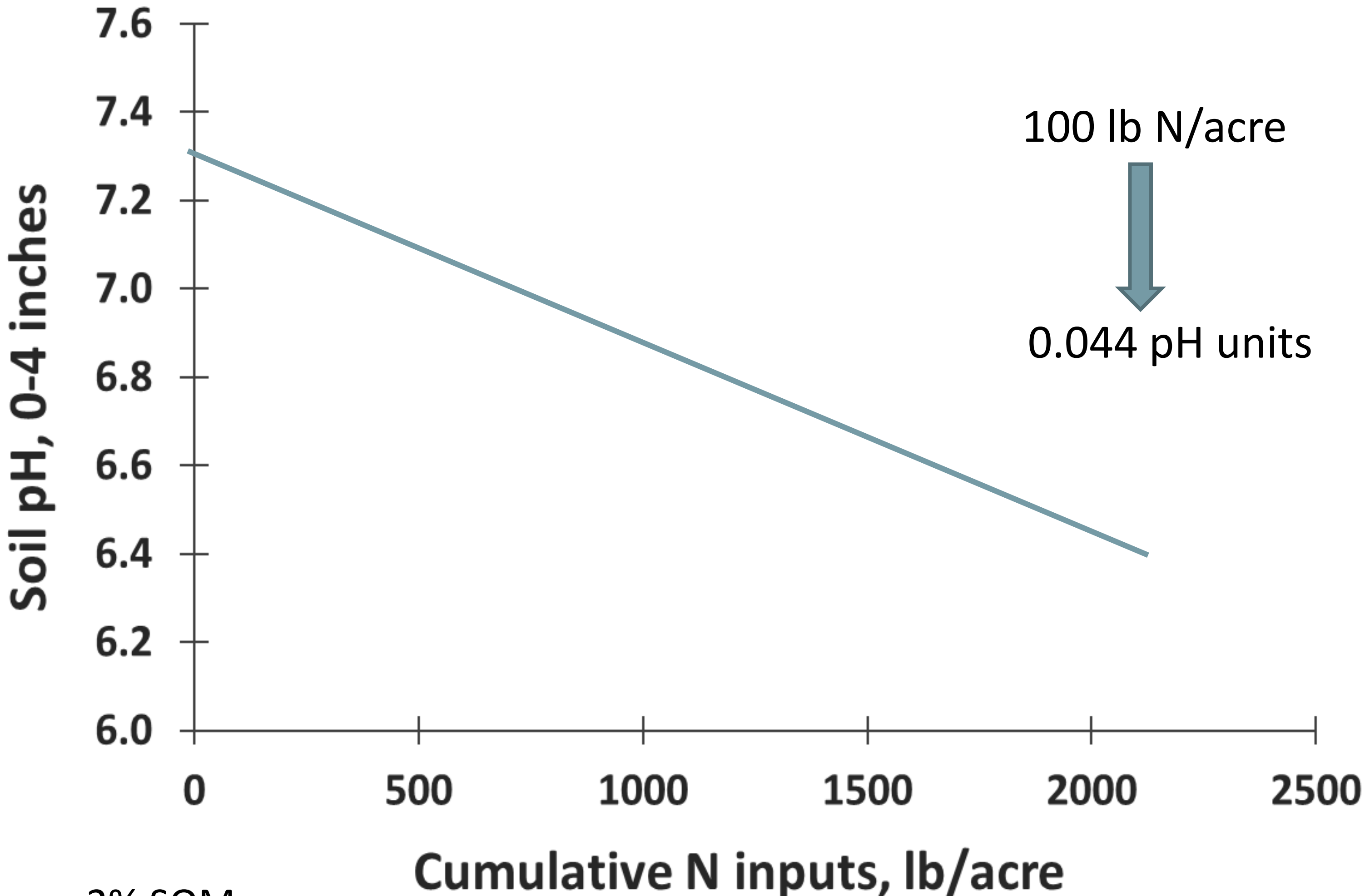
- Leaching loss of nitrate – less nitrate uptake and less root release of basic anions (OH^- and HCO_3^-)
- Crop residue removal – removes Ca, Mg, K ('base' cations). 6x the lime to replace base cations removed by oat straw harvest than just oat grain harvest (NE Ext G1503)
- Lack of deep tillage concentrates 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 Montana's historically calcareous soils is generally only in upper 6 inches



Rick Engel, unpub data.

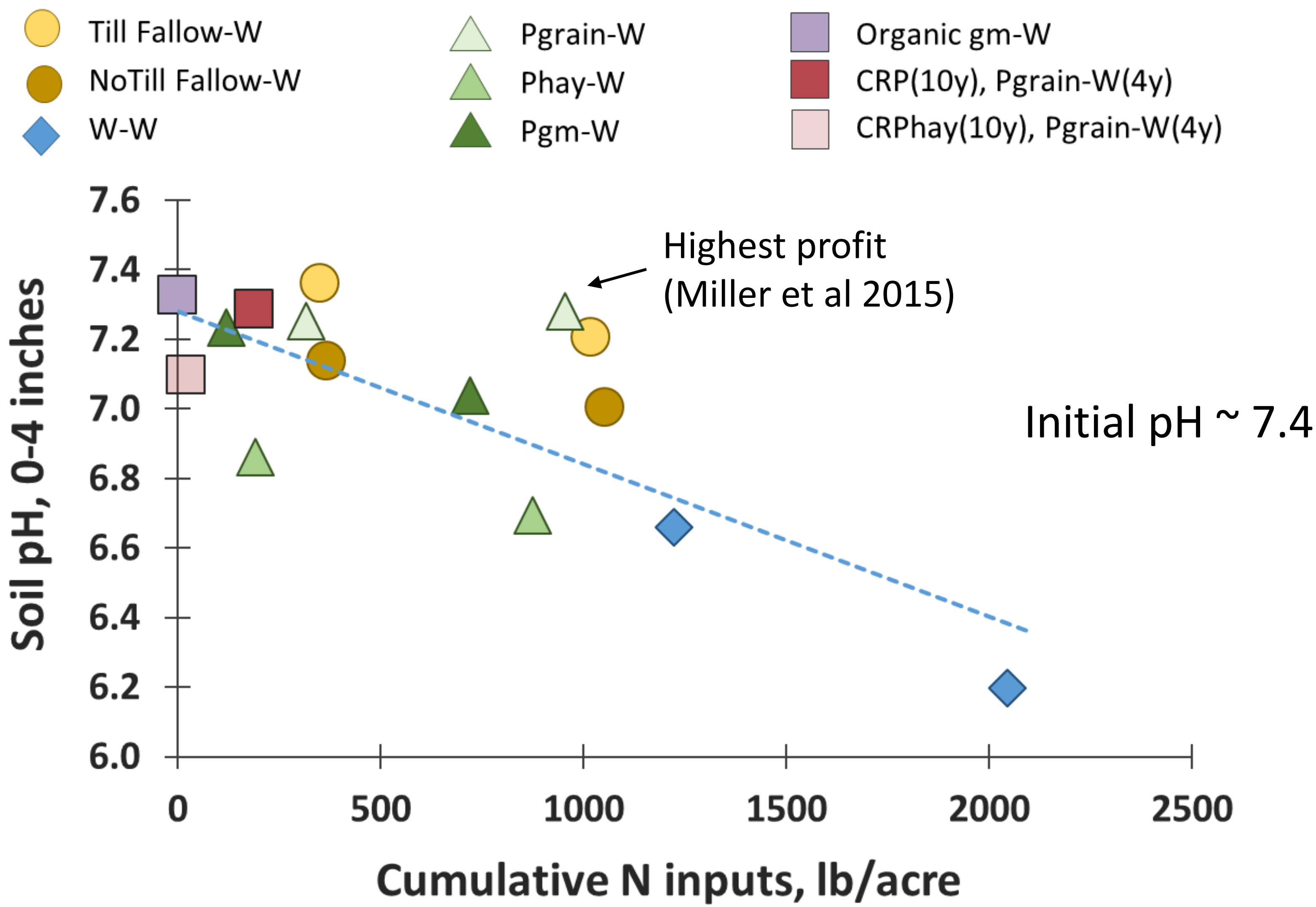
14-yr of N fertilization reduced top 4” pH on dryland cropping west of Bozeman. Initial soil pH ~ 7.4



Silt loam, 2% SOM

Engel, Ewing, Miller, Jones unpub data

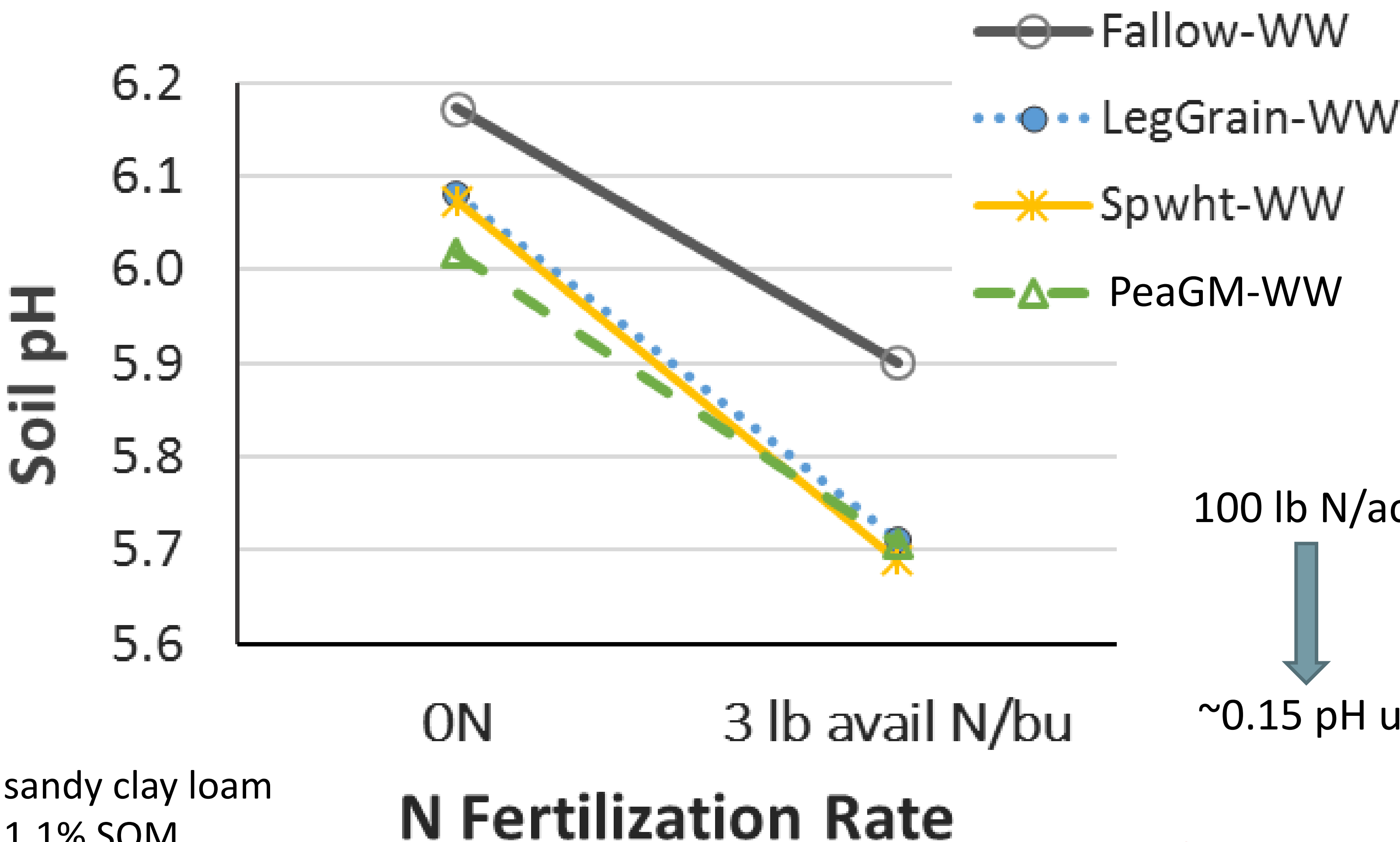
Some dryland crop rotations reduced top 4" soil pH more than others



Why did pea hay reduce pH?

Silt loam; Engel, Ewing, Miller, unpub data

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



100 lb N/acre

~0.15 pH units

sandy clay loam
1.1% SOM

why faster rate?

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

Acid soils have many additional negative impacts

- Changes persistence and efficacy of herbicides (Raeder et al., 2015)
- Damage to rhizobia (N-fixing by legumes)
- Increase in some fungal diseases (e.g., Cephalosporium stripe)

Image from Creative Commons

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

Questions?

On to "What to do?"

What to do?

- Look for evidence of decreased soil pH, or “unexplained” chemical damage
- Soil test
- Prevent, adapt, restore

Photo by R. Engel

What to look for

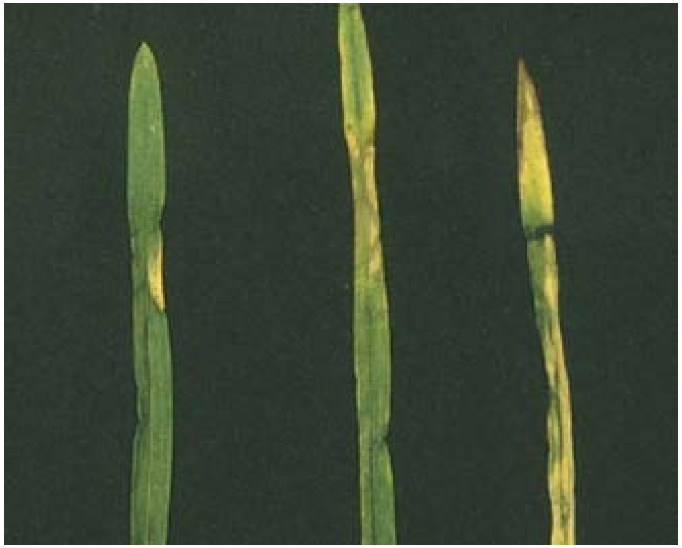
- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)

photo sources: Engel

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

Above ground symptoms of Al toxicity

- small leaves, short thick internodes
- yellow along margin near tip on older leaves
- purple or brown lesions in chlorotic regions, indentations
- leaf withering and collapse in center



Courtesy CIMMYT.org

courtesy Engel

Managing low pH: Prevent

- Optimize N use efficiency – minimize left-over N, leaching loss
- Consider different N and S sources; legumes, calcium ammonium nitrate (27-0-0), manure, gypsum for S source (instead of 21-0-0-24)
- Retain crop residue

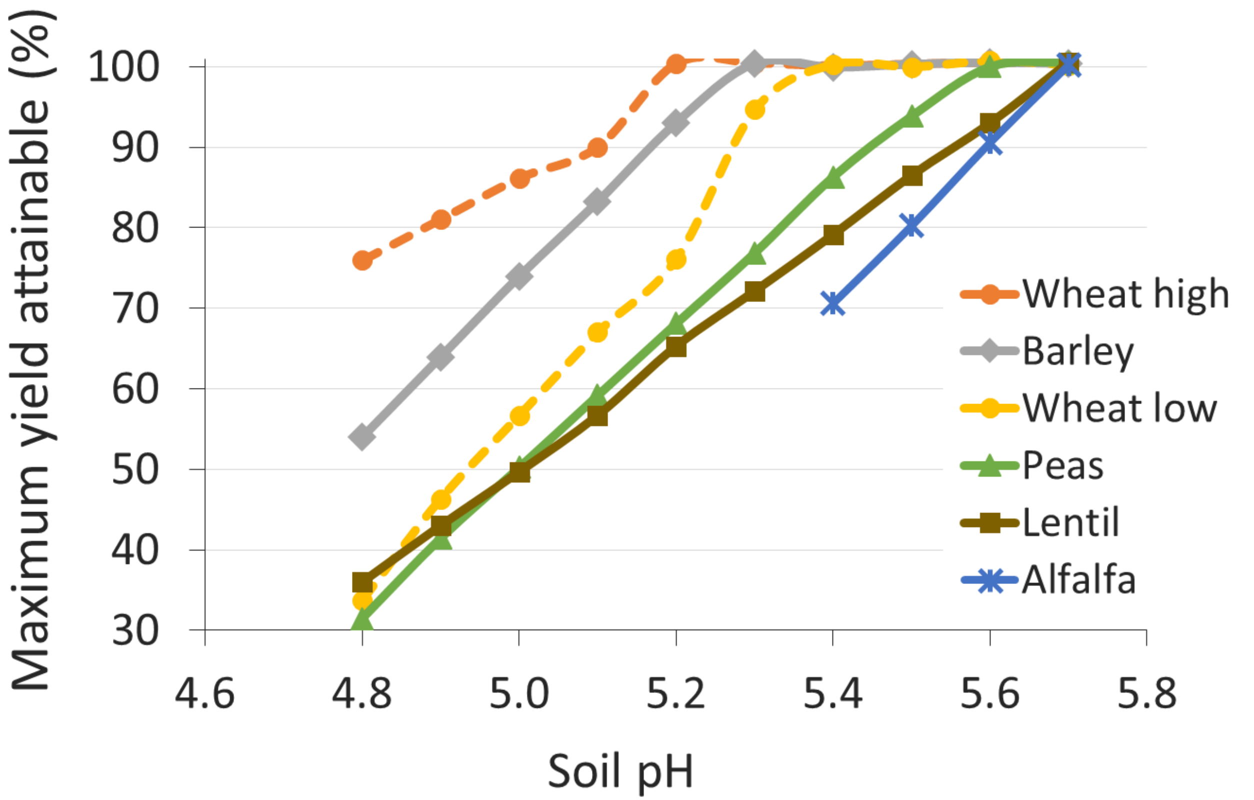
If consider the producer's cost of liming to remediate acidification, and/or lost yield, changing 'standard' practices may be economically reasonable.

Managing low pH: Adapt

- Plant Al-tolerant crops or varieties, MT variety trial results are available at http://landresources.montana.edu/soilfertility/acidif/index.html

- Fertilize after vulnerable seedling stage

- Seed deeper?



"Wheat high" are Al and acid tolerant varieties

McFarland et al., 2015

Seed-placed P_2O_5 a quick acting ‘band-aid’ to increase wheat yield even when (or only when?) P soil test is sufficient

0 P_2O_5

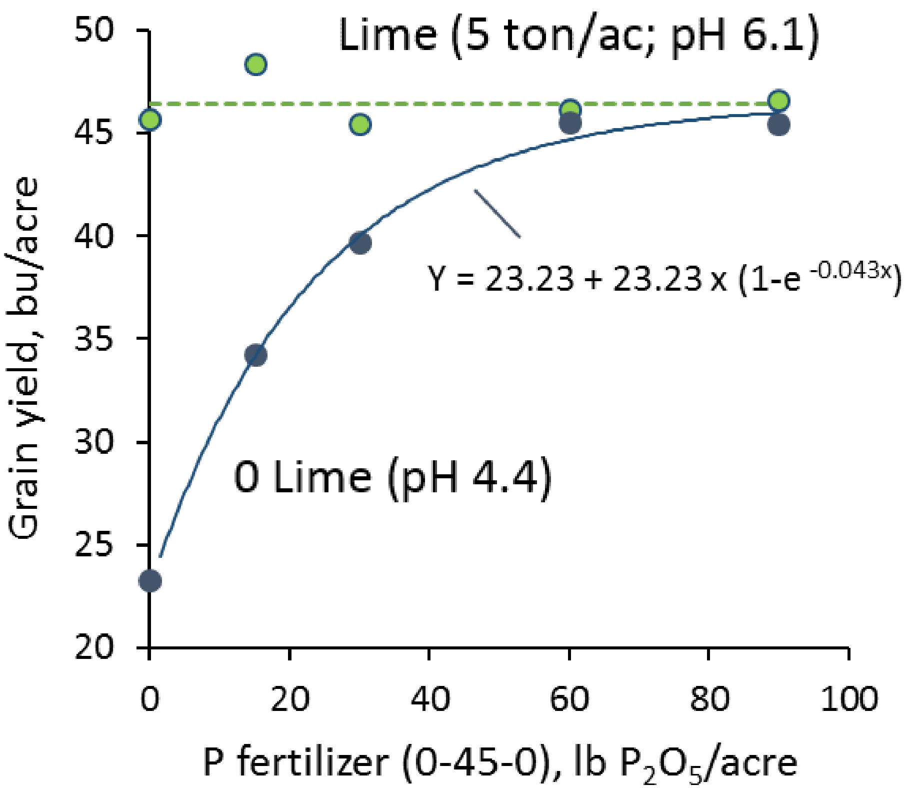
Engel unpub data

90 lb P_2O_5/acre

Soil pH 4.4, Olsen P = 48 ppm

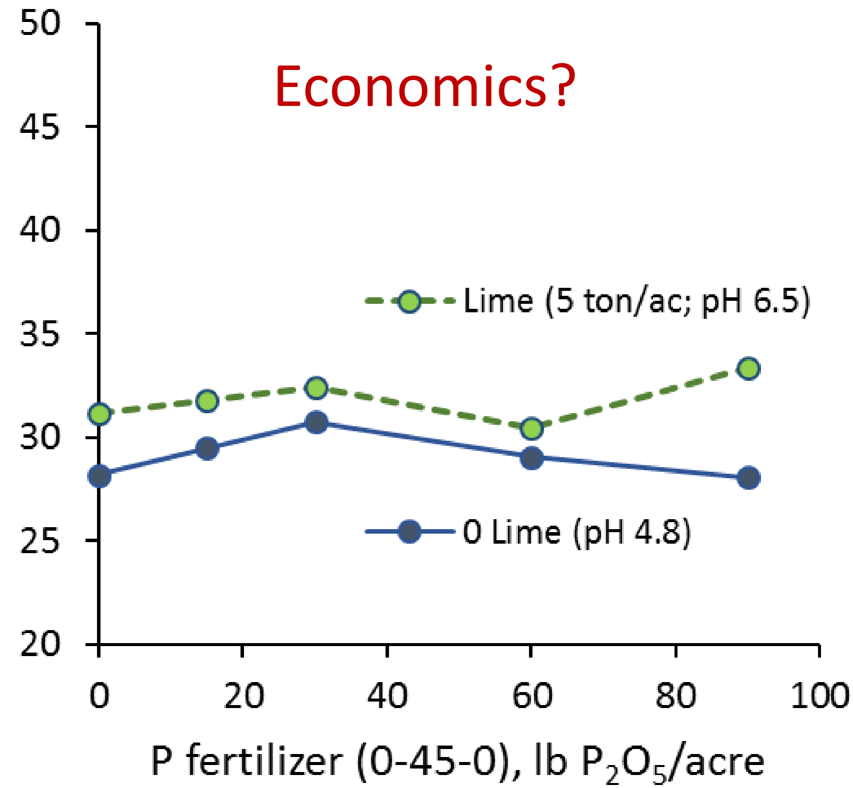
Seed-placed P_2O_5 or lime increased durum grain yield

at pH 4.4 site



Olsen P = 48 ppm

not at pH 4.8 site

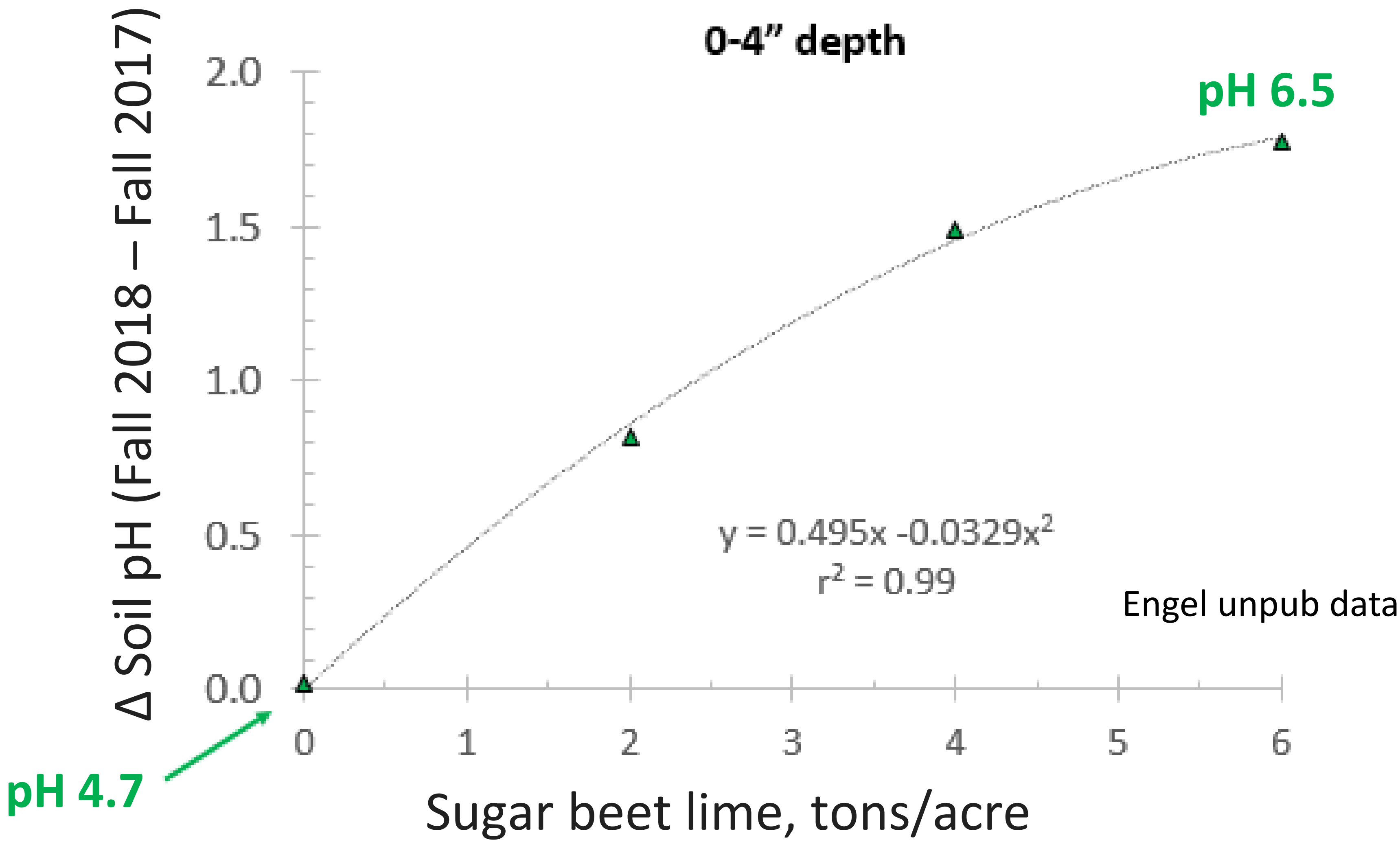


Olsen P = 53 ppm

Note at lower pH site, lime or seed-P increased yield by 22 bu/ac!

Engel unpub data

Managing low pH: Restore with lime

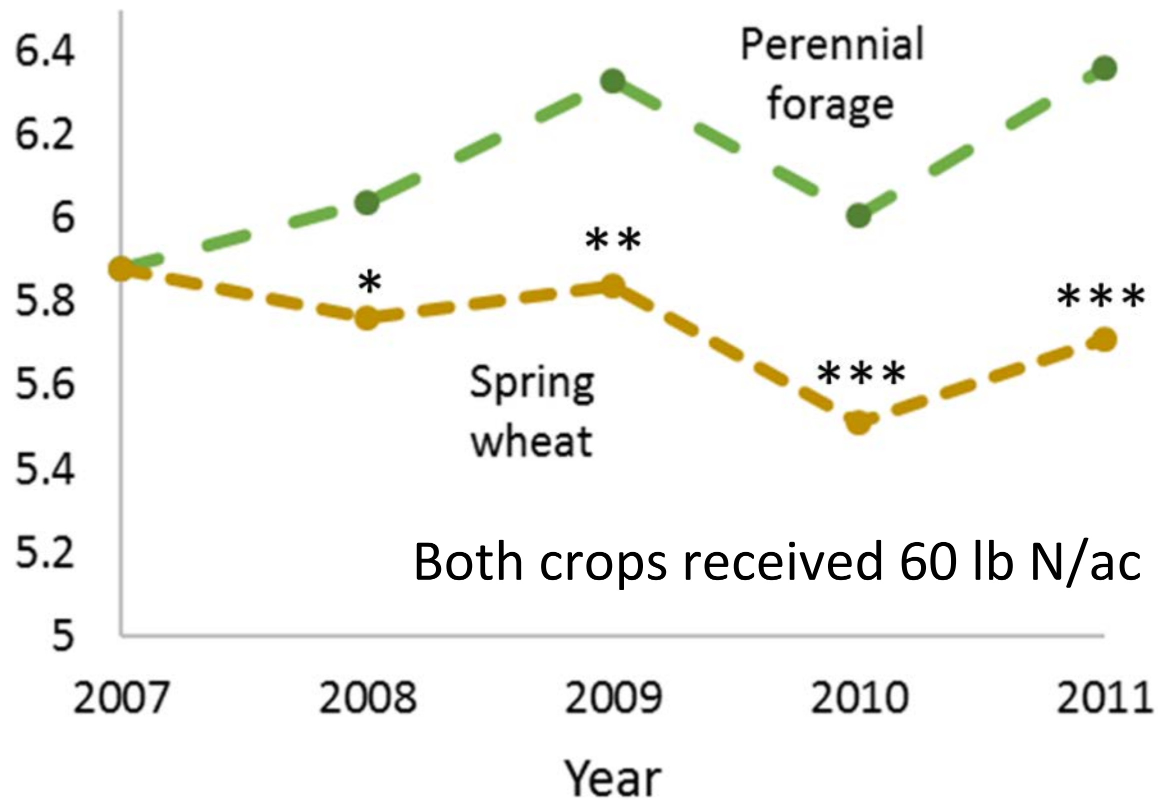


A lot of lime is required to impact soil pH

Managing low pH: Restore

Soil pH top 2”

- Plant acid- tolerant perennial crops



- Legume cover crop?

* > 90%, ** > 95%, *** > 99% confidence
Mandan, ND Liebig et al., 2018

- Tillage, may complicate liming, unless management changes to eliminate acidifiying causes

Good news

- MT has less acidic soil issues than other regions; catch and prevent now.
- MT's issue generally in upper 3", Palouse and SK have low pH at 3-6". Why important?
- Many MT cropland soils have calcareous parent material
- P and metal micronutrient availability better at low to neutral pH

Soil survey northern Idaho

Soil pH	% of fields in each category	
	1982-'84	2014-'15
>6.4	6	<1
6.0-6.4	11	4
5.8-5.9	16	3
5.6-5.8	22	7
5.4-5.5	18	9
5.2-5.3	11	25
5.0-5.1	10	26
<5.0	6	26

Schroeder, Univ of Idaho, unpub data

- **Opportunities for crop advisers**

Soil pH summary

- Cropland soils are becoming more acidic, largely due to N fertilization
- Acidification changes nutrient availability and Al toxicity
- Sound nutrient, crop, and residue management can slow or prevent soil acidification
- Management options are available to adapt to or restore acidic soils
- Crop advisers have an opportunity to help their clients minimize economic losses from this growing problem

Thank you!

Additional soil fertility information and this presentation are available at

http://landresources.montana.edu/soilfertility

- For more information on micronutrients, see Nutrient Management Module 7 (NMM 7)
- For plant nutrient functions and deficiency symptoms, see NMM 9

For information on soil acidification see

http://landresources.montana.edu/soilfertility/acidif/index.html

Questions?

Image by K Olson-Rutz